GEOLOGY OF WISCONSIN

VOLUME I.

1873-1879

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GEOLOGY

OF

WISCONSIN.

SURVEY OF 1873-1879.

VOLUME I.

PART I. GENERAL GEOLOGY.
II. NATURAL HISTORY.
III. INDUSTRIAL RESOURCES.

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To his Excellency, the Hon. JEREMIAH M. RUSK,

Governor of Wisconsin:

SIR — I have the honor of submitting herewith Volume I of the final report of the Geological Survey of Wisconsin.

Most respectfully, your obedient servant,

T. C. CHAMBERLIN,

Chief Geologist.

BELOIT, June 30, 1882.

PREFACE.

The leading purpose of this volume was determined by the following enactment, being section 1, chapter 121, of the Laws of 1876:

"*The people of the State of Wisconsin, represented in Senate and Assembly, do enact as follows:* Section 1. That in the preparation of his final report, the chief geologist be, and he is hereby authorized to collate the general geology and the leading facts and principles relating to the material resources of the State, together with practical suggestions as to the methods of detecting and utilizing the same, so as to constitute the material for a volume suited to the wants of explorers, miners, land owners, and manufacturers, who use crude native products, and to the needs of the schools of the State, and the masses of intelligent people who are not familiar with the principles of geology; said volume to be written in clear, plain language, with explanations of technical terms, and to be properly illustrated with maps and diagrams, and to be so arranged as to constitute a key to the more perfect understanding of the whole report."

To subserve the purposes thus legally defined, the volume will be found to consist of three distinct portions; Part I, embracing the General Geology of the State, with explanatory matter; Part II, consisting of lists of the minerals, rocks and life-products of the State, with descriptions and auxiliary discussions; and Part III, embracing industrial descriptions and practical suggestions with reference to the leading natural resources of the State.

In Part I, an attempt has been made to meet the somewhat difficult requirement imposed by "the needs of the schools of the State, and the masses of intelligent people who are not familiar with the principles of geology." The method chosen as seemingly best adapted to accomplish this was that of a simple narration of the geological growth of the State. In tracing the processes of that growth, nearly all the essential principles of geological science fall under consideration, and may be studied in their vital connection with geological history. To avoid the narrowness which a strict limitation to the confines of the State would involve, the selection and presentation of matter has been made with constant reference to its broader relations, and the deficiencies of the Wisconsin series have been supplied by reference to the geological development of other regions, so that it is hoped that the whole, while especially adapted to a limited region only, will be found to present a fair synopsis of geological history. There is perhaps even some advantage, as regards definiteness and precision, in tracing the growth of a single typical area, especially one so admirably adapted to the purpose as our own, rather than attempting a sketch of universal or even continental geology, since at present our knowledge of large portions of these wider fields is too incomplete to admit of a detailed tracing of the stages of growth, and too complicated to be easily described and readily conceived.

In the execution of the plan, regard has been had to the convenience of the general reader, as well as to the class-room student. The latter will possibly miss the customary artificial form of a text-book, but it is hoped he will not regret it. It is possible to destroy the vitality of a subject by dismembering it, and reducing it to formal definitions. Worse than this, it is possible to convey an artificial and even a false impression of the subject, rather than the true and natural one, by enforced system and rigid formalism in its presentation.

In the endeavor to make the current of thought clear, the attempt has been, not so much to shallow the stream, as to clarify the waters; with what success, the reader must judge.

Those portions of the subject which relate to the origin and peculiarities of the geographical features of the State, are commended to teachers as furnishing subject-matter for oral instruction auxiliary to the text-book study of State geography.

Part II is intended as a measurable contribution to studies in Natural History, in the broad sense of that term, embracing minerals and rocks, as well as plants and animals. The catalogues will serve as convenient check and reference lists for students and collectors, while they represent, in greater or less fullness, the amplitude of Wisconsin's native productions. It is not presumed that any of the lists are entirely complete. It is quite impossible to make them so at once. But an almost necessary step in that direction is the publication and wide distribution of such catalogues, which may serve as bases for additions by numerous local observers and collectors, by whose aid some approach to completeness may, in time, be secured.

The preparation of such lists, being an incidental, rather than a specific, function of the Survey, has been largely the gratuitous contribution of the authors, and merits a hearty recognition of their generosity. Beside the value of the lists as such, the descriptions and economic suggestions and discussions which accompany them, and in some cases form the main contribution, possess an intrinsic value of their own.

Part III is designed to furnish, in a convenient and compact form, such immediately practical information as may be serviceable in detecting and utilizing native resources. The intelligent public has learned from the remarkable developments that have in recent years sprung from what were at first regarded as purely scientific facts and principles, without so-called practical utility, that the highest real value often inheres in a full and exact development of truth, regardless of immediate apparent value, for the deeper values cannot usually be foreseen. Yet this does not remove the need for information more directly and immediately relating to the utilization of native products. The chapters of this part are to be taken in connection with the ampler descriptions of the resources to which they relate in the body of the report.

The typical fossils of Wisconsin formations are quite largely illustrated by newly prepared figures, the originals of which are mostly to be accredited to Prof. Whitfield, who is not, however, responsible for the reproductions. In illustrating the life of eras not represented in Wisconsin formations, but essential to a connected sketch of geological progress, a considerable number of figures have been reproduced from the excellent works of Dana and Le Conte, to whom acknowledgments are due. A few have been chosen from other accredited sources. The figures of birds, introduced to illustrate the types of the several families, are mainly from the admirable work of Baird, Brewer and Ridgway. The mechanical execution of the above is to be accredited to the Levytype Co. of Chicago.

The table of contents and index have been prepared by Mr. R. D. Salisbury, who has also rendered much other assistance in the preparation of the report.

The excellent mechanical appearance of the work stands to the credit of the printer and lithographers whose signatures appear on a preceding page.

The hearty thanks of the members of the Survey are again tendered to all — and their name is legion — who have so kindly and generously assisted in numberless ways in the prosecution of the work.

There arises here, also, a sad remembrance of losses. Four names are sorrowfully recalled and again recorded in deferential regard — Lapham, Eaton, Strong and Nicodemus.

And now, as with this first which has become last, I lay down, with inexpressible relief, the burden of this work, which has, notwithstanding, been largely a labor of love, I have greatly to regret its imperfections, of which no one can be more painfully conscious than myself. Such as it is, it is presented to the magnanimity of a generous people.

T. C. C.

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PART I.

GENERAL GEOLOGY.

I. CHEMICAL GEOLOGY.
II. LITHOLOGICAL GEOLOGY.
III. HISTORICAL GEOLOGY.

BY T. C. CHAMBERLIN.

CHAPTER I.

CHEMICAL GEOLOGY.

The law of publication directs that in the preparation of this volume such explanation of the technical terms and elementary principles of the science shall be made, as will conduce to the more perfect understanding of the whole report, and thus adapt it to the use of students. It is the purpose of this chapter to conform to this requirement in respect to the chemistry of geology. The law manifestly does not contemplate a systematic discussion of chemical geology, but only such a selection and brief treatment of topics as will be helpful to intelligent readers who have no technical knowledge of the subject.

I. Chemical Nomenclature

We are unfortunate in living in an age of transition from one system of chemical philosophy and of naming, to another. In nearly or quite all our schools, the new system is in use, so that recent students and professional chemists are more familiar with its terms than with those of the old system, while on the other hand, the great majority of citizens who have some knowledge of the science, as well as many scientists devoted to other departments, whose knowledge of chemistry was acquired some years since, are more accustomed to the terms of the old philosophy. The differences between the two systems, however, are not such as to make it difficult for those schooled in the one to understand the terms of the other, so far as there is occasion to use them in general geology. It being the purpose of these reports simply to convey geological information, and not to foster any chemical theory, those terms are used which, on the whole, seem best, without much regard to any rigid system of chemical names, new or old. In some cases even, the new and the old names are used alternately, or indifferently, in the same discussion, implying in passing, the equivalency of the terms, and the leading difference in the style of naming. In some cases, terms are used, for the sake of easy understanding, that do not strictly belong to either system, as in speaking of *carbonate of lime* (old system), the term *lime carbonate* is used, whereas, in strictness, the term under the new system should be *calcium carbonate* or *calcic carbonate.*

The most apparent difference between the old and the new methods of naming may be indicated by citing a simple example, as for instance, *carbonate of soda* of the old system becomes *sodium carbonate*, or *sodic carbonate*, in the new. It would be quite superficial to suppose that this constitutes any essential part of the real difference between the old and the new chemical philosophy, but it is about the extent to which it affects geological discussions, as the ultimate chemical theories do not affect geological reasoning. Below is given a comparative list of the leading terms used in these reports, which will obviate the necessity of further explanation.

OXIDES.

New System.	*Old System.*
Ferrous oxide	Protoxide of iron.
Ferric oxide	Peroxide of iron. Sesquioxide of iron.
Dicupric oxide Cuprous oxide	Suboxide of copper.
Cupric oxide Copper oxide	Oxide of copper.
Zincic oxide Zinc oxide	Oxide of zinc.
Plumbic oxide Lead oxide	Oxide of lead. Protoxide of lead.
Plumbic dioxide Lead dioxide	Peroxide of lead.
Silicic oxide Silicon oxide	Silica.
Aluminic oxide	Alumina.
Potassic oxide	Potassa.
Sodic oxide	Soda.
Magnesic oxide	Magnesia.
Calcic oxide	Lime. Calcica.
Etc	Etc.

SULPHIDES.

Dihydric sulphide Hydrogen sulphide	Sulphide of hydrogen. Sulphuretted hydrogen.
Ferric disulphide Iron disulphide	Sulphide of iron.
Plumbic sulphide Lead sulphide	Sulphide of lead.
Cupric sulphide Copper sulphide	Sulphide of copper.
Argentic sulphide Silver sulphide	Sulphide of silver.
Etc	Etc.

CHLORIDES.

Hydric chloride Hydrogen chloride	Hydrochloric acid.
Calcic chloride Calcium chloride	Chloride of calcium.
Etc	Etc.

SULPHATES.

New System.	*Old System,*
Dihydric sulphate	Sulphuric acid.
Ferrous sulphate	Protosulphate of iron.
Ferric sulphate	Sesquisulphate of iron.
Cupric sulphate Copper sulphate	Sulphate of copper.
Plumbic sulphate Lead sulphate	Sulphate of lead.
Magnesic sulphate Magnesium sulphate	Sulphate of magnesia.
Baric sulphate Barium sulphate	Sulphate of baryta.
Etc	Etc.

CARBONATES.

Calcic carbonate Calcium carbonate	Carbonate of lime.
Magnesic carbonate Magnesium carbonate	Carbonate of magnesia.
Zincic carbonate Zinc carbonate	Carbonate of zinc.
Plumbic carbonate Lead carbonate	Carbonate of lead.
Sodic carbonate Sodium carbonate	Carbonate of soda.
Etc	Etc.

SILICATES.

Ferrous silicate Iron silicate	Silicate of iron.
Aluminic silicate Aluminum silicate	Silicate of alumina.
Sodic silicate Sodium silicate	Silicate of soda.
Magnesic silicate Magnesium silicate	Silicate of magnesia.
Calcic silicate Calcium silicate	Silicate of lime.
Cupric silicate Copper silicate	Silicate of copper.
Etc	Etc

PHOSPHATES.

Calcic phosphate Calcium phosphate	Phosphate of lime.
Magnesic phosphate Magnesium phosphate	Phosphate of magnesia.
Etc	Etc.

II. Chemical Constitution of the Earth's Crust. (Chemical Geognosy.)

Only a very few chemical elements play important parts in rock formation, and the student and general reader will find it an easy task to acquire such a knowledge of the leading characters and affinities of these, as will be very helpful, without attempting to master the intricacies and obscurities which more profound study involves.

Chemical Elements of Rocks. The following elements constitute nearly the entire rock substance of the State, and, indeed, of the earth's crust: Oxygen, silicon, aluminum, calcium, magnesium, iron, carbon, sodium, potassium, hydrogen and sulphur. To these are to be added, more because of their value than their abundance, lead, zinc, copper, manganese, gold, silver, chlorine, iodine, bromine, lithium and titanium. A number of others occur in small quantities. Probably nearly or quite all of the remaining known elements occur in infinitesimal amounts.

Native Elements. Only a few of these substances occur in the simple elementary state.

Carbon, native copper, silver, gold and sulphur occur in the State, but, however interesting on account of their valuable properties, they make up a very insignificant portion of the earth's crust. It is mainly in the form of compounds that chemical substances enter into the earth's constitution. It will, therefore, be more serviceable to consider these compounds than to dwell upon the character of the elements as such.

Simple Compounds. By the union of elements, simple compounds are formed. Thus any of the above elements, united with oxygen, constitutes an *oxide*, and is named according to the element so uniting. Thus sodium, uniting with oxygen, forms *sodium oxide (oxide of sodium or soda*, old style). A similar combination with sulphur constitutes a *sulphide*, as lead, uniting with sulphur, forms *lead sulphide*, which is the common lead ore, *galena*. Of the simple compounds, the oxides are by far the most important. Among them, the geologically leading ones are *silicic oxide*, or *silica; aluminic oxide*, or *alumina; calcic oxide*, or *lime; magnesic oxide*, or *magnesia; iron (ferric* or *ferrous) oxide*, *potassic oxide*, or *potash*, *sodic oxide*, or *soda*, *carbonic dioxide* or *carbonic acid.*[1]

Of these, *silica* is familiar in the form of quartz, and common quartzose sand, and does not need further discussion here, than to remark that chemically it is an acid, though lacking the sensible acid properties. *Alumina* is the essential constituent of *corundum*, *sapphire*, *ruby* and *emery*. It is better known to us as the basic ingredient of clay, in which it is united with silica, forming *aluminum silicate*. *Lime* (calcium oxide) is familiarly known as common quick-lime, though in reality the quick-lime used in Wisconsin, with very few exceptions, is a combination of lime and magnesia, being

[1] In the strictest sense this is not regarded as an acid except in combination with water.

usually made up of about one part of *calcium oxide* to one of *magnesium oxide*, and so illustrates at once the character of both oxides. *Ferric oxide* is even more familiar in the form of iron rust, in which it is usually combined with water. *Soda* and *potash* are familiar in name, but the substances so-called are usually compounds of the oxides with carbonic acid. *Caustic potash* and *soda* are compounds of the simple oxides of potassium and sodium, with water. *Carbonic acid* is the common product of combustion and of animal respiration.

Of the foregoing oxides, a portion are chemically *acidic*, and the remainder *basic.* To the former class belong silica and carbonic acid, to the latter, potash, soda, lime, magnesia, alumina, and the iron oxides. Potash and soda are well known *alkalies* and are the most basic of the list. Lime and magnesia being somewhat alkaline, and at the same time earthy, are styled *alkaline earths.* Alumina and the iron oxides lack sensible alkaline properties, but are chemically basic, i. e., they unite with acids. Silica is found in nature united with all these bases, and carbonic acid with all except alumina.

Complex Compounds. Keeping in mind the simple chemical law that acids and bases unite when brought in contact under suitable conditions, it is easy to see how more complex compounds arise from these.

Carbonates. Carbonic acid unites with the several bases to form a group of *carbonates.* Thus carbonic acid, uniting with lime, forms *calcium carbonate (lime carbonate* by license); with magnesium oxide forms *magnesium carbonate;* with potassium oxide, *potassium carbonate;* with sodium oxide, *sodium carbonate;* with iron oxide, *iron carbonate.* The iron, sodium, and potassium carbonates form but very small ingredients in Wisconsin rocks, but the calcium and magnesium carbonates are very important, constituting the mass of our limestone series.

Silicates. In a similar way, silica unites with the basic oxides to form *silicates.* It may do this in a simple way, as in the case of carbonic acid combining with potassium oxide, to form a *potassium silicate*, as in the manufacture of common glass; or with sodium oxide, to form a *sodium silicate,* as in soda glass; or with lime, to form *calcium silicate*, as in the mineral wollastonite; or with magnesia, to form *magnesium silicate*, as in enstatite; or with alumina, to form *aluminum silicate,* as in andalusite.

But, unfortunately for simplicity, silica has the habit of combining with two or more of these bases jointly. Thus it unites with alumina and potash together to form an *aluminum-potassium sili-*

cate, as in orthoclase feldspar: with alumina, soda and lime, to form a *soda-lime feldspar*, as oligoclase; with alumina, lime, magnesia and iron, conjointly, to form an *alumina-lime-magnesia-iron silicate*, as in the mineral augite, and so on through a very complex series of silicates. The details are many and confusing, but it is not difficult to understand the general method of formation, which is the combination of silica with the several bases in varying numbers and ratios, and this general notion will be helpful.

Rocks classified chemically.— Gathering up these facts, it appears that the great mass of the rocks of the state fall easily into three classes.

1st. *The simple oxides.* Of these, silica in the form of quartz and quartzose sand is the great example. Under this head also fall most of the iron ores.

2d. *The carbonates.* These are either carbonates of lime simply, or of lime and magnesia combined. Our limestones and dolomites are familiar examples.

3d. *The silicates.* These are formed by the (usually complex) union of silica with lime, magnesia, potash, soda, iron, alumina and other bases. Some other acid occasionally replaces a part of the silica.

The Sulphides. While the above form a very large percentage of the earth's material, a few subordinate classes need mention. Just as oxygen unites with various elements to form oxides, so sulphur combines with certain of them to form *sulphides*, of which *lead sulphide*, or common galena, *zinc sulphide*, or zinc blende, *iron (bi-)-sulphide*, or iron pyrites, and *copper-iron sulphide*, or copper pyrites, are common examples. In these cases the compound is formed simply by the union of the metal and sulphur, atom to atom, except in the bi-sulphides, where there are two atoms of sulphur to one of the metal.

Sulphates and phosphates. Again, just as carbonic acid and silicic acid (silica) combine with the alkalies and alkaline earths, to form carbonates and silicates, so *sulphuric* and *phosphoric* acids may unite with the same to form *sulphates* and *phosphates*. Of the former, we have examples in gypsum *(lime sulphate)* and heavy spar *(barium sulphate)*, and of the latter in the *lime phosphate* of certain fossils.

III. Chemical Activities. (Chemical Geogony.)

The foregoing relates to the chemical *constitution* of the earth's material (chemical geognosy). But if we inquire into the chemical activities (chemical geogony) that have taken part in the history of its formation, we enter upon a wider and more difficult field, one which embraces the known domain of chemistry, and stretches on into the unknown region beyond. A full or systematic discussion is here manifestly impracticable, but it has seemed b est to gather together brief statements of the principal known processes. Some of these may be of service to the general reader; others will have interest for more advanced students only.

Oxidation. Of the chemical activities that have entered into geological history, one of the leading is oxidation. Throughout the whole range of known time, the free oxygen of the atmosphere, penetrating the pores and fissures of the earth, or carried down into them by atmospheric waters, has been continuously uniting with the earth's substance, giving it a higher state of oxidation. Among the results of this process are the change of blue limestones to buff, and of dark igneous and other iron-bearing rocks to a rusty color, by the higher oxidation of the iron compounds contained in them, which constituted their chief coloring matter. It also effects the change of some dark rocks to lighter ones, by the oxygenation of their organic coloring matter, also the change of metallic sulphides to sulphates, from which they usually pass into oxides or carbonates, as, for example, the change of iron pyrites (iron sulphide) to limonite (hydrous iron oxide), of sphalerite (zinc sulphide) to smithsonite (zinc carbonate), of galena (lead sulphide) to cerussite (lead carbonate), and of copper pyrites to azurite or malachite (copper carbonate).

The physical effect of oxidation is a change of texture, usually of the nature of disintegration. This is usually accompanied by and gives rise to other chemical activities, presently to be mentioned, which greatly magnify its results. Considering this process alone, the atmosphere is losing oxygen, and the earth gaining it. There are compensating processes, but it is doubtful whether they wholly counteract the action.

Hydration. The water of the atmosphere and of the surface of the earth continually penetrates the crust, and enters into combination with its substance by the process of hydration. Thus an iron ore, or a ferruginous ingredient of a rock, in the form of hematite or magnetite, may take up water and be transformed into limonite. So also in the disintegration of crystalline rocks into clays, water is an essential agency, and enters in large percentage into the product. In many of the less familiar changes which minerals undergo, hydration plays an important part.

Solution. A much more important agency of water, as a geological instrumentality, is found in its action as a solvent. No rock substance is absolutely insoluble in natural water, though the degree of solubility may be extremely small. This incessant and universal, though slow process of solution, has wrought, directly and indirectly, results without which the whole course of geological history would have been changed. Not only is it effective in the transportation of material, but by bringing different ingredients in contact, it has given rise to chemical activities that would otherwise have been impossible.

Action of Carbonic Acid. The agents, oxygen and water, are accompanied, in their penetration of the earth, by carbonic acid, which, in connection with them, is an effective geological agency. Water containing carbonic acid transforms many of the simple carbonates into bicarbonates, at the same time taking them up into solution. It has been remarked that oxygen, attacking the metallic sulphides, changes them to sulphates. These being brought into contact with the alkaline and earthy bicarbonates, formed as just noted, exchange partners, resulting in metallic carbonates and earthy sulphates. In this way, probably, the carbonates of zinc, lead, copper, and other metals, as also sulphates of lime and magnesia, are produced. Carbonic acid likewise attacks many of the silicates, effecting their disintegration. The change of feldspars into kaolin is believed to be mainly due to this agency. The extensive disintegration of the silicates of crystalline rocks, which is so important a process in the degradation of the ancient formations, and in the production of material for later ones, was probably very largely due to the action of carbonic acid, associated with free oxygen in water. The microscope reveals the fact that nearly all the minerals that enter into the complex constitution of the crystalline rocks have suffered change, and the fact that carbonates — particularly calcium carbonate — are found in them, as a mineral of secondary formation, clearly points to carbonic acid as one of the agencies of change.

Action of Organic Substances. In the slow decay which animal and vegetable substances undergo through the agency of air and water, when under conditions not favorable to rapid decomposition, a series of complex organic acids are generated, which, as they are carried into the earth, act chemically upon it. The precise extent of this action is as yet undetermined. It is probably somewhat greater than has usually been supposed.

Vital Chemistry. Calcareous Products. The wonderful chemistry of organic life has played an important part in geological history. From the waters charged with mineral substances by the processes above indicated, plants and animals extract lime for the construction of their inorganic parts, and this they leave in the form of carbonate, phosphate, or fluoride of lime. The first of these is the great source of limestone accumulation.

Silicious Products. Some organisms extract and secrete notable quantities of silica. These subsequently take the form of flint nodules, and other silicious deposits.

Metallic Products. Marine plants appear to have extracted considerable quantities of metallic substances which became imbedded with the sediments, and were afterward concentrated, constituting one source of the lead, zinc, and copper deposits, found in sedimentary strata.

Carbon Products. Marine plants likewise extract carbonic acid from the atmosphere and from solution in the water, and organize it into complex carbon compounds, which on their death are left to suffer decomposition. Through this, for the most part, they return to their original state, and make no permanent geological contribution. But when buried beneath water or fine sediment, and prevented from speedy decomposition, slow processes of decay ensue, which give rise to extremely important permanent products, as coal and petroleum. Vegetable tissue, under these conditions, undergoes slow oxidation, passing into peat or lignite coal, and thence by further action into bituminous coal. Certain other remains of organic life, probably both vegetable and animal, undergo an analogous, but little understood process, by which mineral oil, of which petroleum is the great example, is produced.

The organic matter, while it is undergoing decomposition, probably produces more or less metallic deposition, by extracting oxygen from the minute quantities of metallic substances held in solution in sea-water, and by converting them into the insoluble form of sulphides. By their decomposition also, organic substances give rise to sulphuretted gases which, rising through the water, doubtless precipitate[1] as sulphides, such metallic substances as they may meet.

By means of plant action and its products, the iron of the soil is rendered soluble, and is carried away with the under-drainage, and,

[1] The term *precipitate* is the common chemical expression for an insoluble product formed from a solution by any chemical reagent. The insoluble matter so produced falls gradually to the bottom, and is hence termed a precipitate, but not in a sense implying that the action is precipitous.

on being exposed at length to oxidation in a marsh, lagoon, or other suitable situation, it takes the form of an insoluble iron oxide, and is deposited, giving rise to iron ore beds. This process, observed to be now transpiring, doubtless gave origin, in the past, to many, and probably to most of the important iron deposits. Thus from the chemistry of life, there arose important agencies in the chemistry of metallic deposition.

CHAPTER II.

LITHOLOGICAL GEOLOGY.

In the preceding chapter, it has been briefly explained that the chemical elements, by uniting in various ways, give origin to the different substances which constitute the rocks of the earth's crust. But the chemical forces are in themselves only competent to produce molecules. If the rock substance be pictured to the mind as left by these forces, it would consist merely of incoherent particles.

The Union of Molecules to form Minerals. If now simple cohesive force is brought to bear, the particles become bound together to form a more or less solid rock substance, and if the chemical substances are confusedly commingled, as is the habit of nature in the absence of an assorting agency, there would result a rock of mixed, unindividualized constitution. But if there be brought into play a special attraction of like particles for each other, and that special form of cohesion known as crystalline force, this material will be assorted, like particles will be gathered together, and will be organized into appropriate forms according to definite crystalline laws. Such definitely organized substances constitute *minerals* in the special sense of the term. All inorganic substances are in a sense regarded as mineral matter, but only definite aggregates, which are usually crystalline, are considered as minerals proper.

The Combination of Minerals to form Rocks. The next natural step, therefore, in considering the substances with which geology has to deal, is the study of the minerals which enter into the constitution of rocks, or in other words, to study the method by which nature organizes her material, under the influence of cohesion and crystalline forces.

The number of minerals which play important parts in the structure of the earth's crust is not large, though the number which enter in as subordinate or occasional ingredients is so great as to be quite beyond the knowledge of any but a professional mineralogist. A full list of the minerals thus far identified within the State, prepared by Professor Irving, will be found in Part II of this volume. Brief descriptions of the composition and characteristics of these minerals are there given, and to them reference is recommended as occasion may require.

The Leading Rock-forming Minerals. The great bulk of our rocks is made up of perhaps not more than a dozen minerals. These are *quartz*, the *feldspars* (mainly *orthoclase*, *oligoclase* and *labradorite)*, the *micas (muscovite* and *biotite)*, the *amphiboles (hornblende* and *actinolite)*, the *pyroxenes (augite* and *diallage)*, *calcite* and *dolomite*. The following additional minerals are frequent constituents of Wisconsin rocks, or, for special reasons, possess interest: *epidote*, *chrysolite* or *olivine*, *chlorite*, *graphite*, and *sericite*. The following possess special interest as metallic ores: 1, the iron ores, *magnetite*, *hematite*, *limonite*, *pyrite;* 2, the lead ore, *galenite;* 3, the zinc ores, *sphalerite* or "*blende*," *smithsonite* or "*dry bone;*" 4, the copper ores, *malachite*, *azurite* and *chalcopyrite*.

In addition to the descriptions of Dr. Irving's list, above referred to, special descriptions of these ores and of some of the foregoing minerals may be found in Vol. II, pp. 691 to 694 (Strong); Vol. III, pp. 600–611 (Wichmann), and Vol. IV, pp. 380–398 (Chamberlin), besides incidentally in the lithological descriptions of the several volumes.

The Constitution of Rocks. Aggregates of mineral substances, whatever their condition, constitute rock in the widest sense of that term, as used by geologists. In a general way, it may be said that the union of atoms constitutes chemical compounds, that the cohesion of chemical compounds produces minerals (crystalline or uncrystalline), and that the aggregation of minerals constitutes rocks. It is possible, however, to obtain an erroneous idea from this form of statement, true as it is. In the union of ingredients to form chemical compounds, and in the cohesion of these to form crystalline minerals, the constituents sustain to each other a definite ratio, and the combination is controlled by specific laws. But in the formation of rocks, the mineral constituents are aggregated in any manner which the circumstances of formation may determine. There is no definite law determining what ingredients shall constitute the rock, nor in what proportions they shall enter into it. Rocks, therefore, are not definite combinations of minerals in the same sense that minerals are combinations of chemical compounds.

Notwithstanding this fact, the circumstances of nature are such that certain associations of minerals are much more frequent than others, as the combination of quartz, feldspar and mica, which forms granite, or of augite and a triclinic feldspar, which forms dolerite, etc. Such combinations are sometimes termed lithological species, but this is an objectionable usage, since it implies a definiteness and uniformity of character that does not exist.

Undoubtedly the most important characteristics of rocks are derived from the minerals that compose them. But before considering the subject especially, it may be most convenient to give attention to other characteristics.

Rocks Considered with Reference to Their Origin.

Igneous Rocks. An important class of rocks arise from the cooling of molten material. It is highly probable that the great core of the earth and its primitive crust are of this class. It is certain that at various times throughout geological history, molten rock material has been forced from within to the surface, and by cooling has produced igneous rocks. Lavas and other volcanic rocks of recent times are familiar examples.

Aqueous Rocks. Another important class of rocks are formed through the medium of water. Its agency is two-fold; 1st, it deposits substances held in solution, as in the case of certain formations of lime, gypsum, salt, etc.; and 2d, it deposits matter held in suspension, or otherwise transported by it, as mud and sand, which are subsequently solidified, either by their own coherence, or by chemical deposits from the water.

Metamorphic Rocks. Still another important class of rocks were originally aqueous or otherwise in origin, but have since, through the agency of heat and pressure (it is maintained), been changed into a highly crystalline state, quite unlike their original condition. Because of this change, they are termed metamorphic. When the change has been extreme, the rock often so closely resembles the corresponding ones of the igneous class, that it is extremely difficult to distinguish them.

Aquo-igneous Rocks. It is held that there are cases in which rocks which were originally formed through the agency of water have been subjected to very great heat and pressure, and have thus become pasty or plastic to such a degree as to permit of their being forced into fissures in adjacent bodies of rock, and so become intrusive, without really being igneous in the usual sense of the term.

Pseudomorphic Rocks. Through the agency of the chemical and molecular changes continually in progress in the crust of the earth, as explained in the last chapter, various minerals have been extensively changed in their nature, while their form remains the same. These are termed *pseudomorphs* (false forms), because the mineral assumes the form of the one it replaces, instead of its own. When the minerals composing a rock have been extensively changed in this way, it comes to be quite a different rock from what it originally was, and may be said to have had a *pseudomorphic* origin. This term is not, however, commonly used, and the extent to which the process prevails is yet a subject of difference of opinion. The microscopical observations of Professor Irving, and others, have shown it to be more prevalent in our rocks than has been generally apprehended. An example of this is the formation of diorite from diabase or dolerite, by the change of the *augite* of the latter, into *hornblende*, or, more strictly, *uralite*.

Æolian Rocks. The winds drift sand and dust, and heap it up in sheltered spots, forming deposits which are sometimes quite extensive, as the *dunes* of sandy shores and plains. These accumulations on solidification give rise to a rock essentially like those of aqueous origin. Such rocks may be said to have an æolian origin, though the distinction is of little importance.

Organic Rocks. The remains of animal and vegetable life, accumulating and solidifying, give rise to an important class of rocks. Familiar examples of this class are *coal*, formed by the accumulation of vegetable matter, and *chalk*, formed from the minute calcareous shells of Rhizopods. Limestone is formed from the remains of animals, decomposed and ground up by the action of water, so that it is due to combined organic and aqueous agencies.

Classified, therefore, on the basis of their origin, rocks are:

Igneous, those formed from molten material.

Aqueous, those formed through the agency of water.

Metamorphic, those formed by the crystallization of sediments.

Aquo-igneous, those formed by combined action of heat and water.

Pseudomorphic, those arising from metasomatic changes of the constituent minerals.

Æolian, those formed from wind depositions.

Organic, those formed through the agency of animal and vegetable life.

Rocks Considered with Reference to the Physical Nature of Their Constituents.

Rocks are usually made up either of aggregates of crystals or of particles derived from pre-existing rocks by disintegration or wear. Those that are formed by cooling from the molten state, or by chemical deposition from a watery solution, or by metamorphic changes, usually assume a crystalline structure. Those derived from older rocks by decomposition and wear are merely a mass of detrital particles, and are termed *fragmental*, *detrital* or *clastic*. Rocks may be composed in part of crystalline, and in part of clastic material.

Crystalline Rocks. These may be classified according to the degree and character of crystallization.

1. Those in which crystallization is complete, and the individual crystals are distinctly visible, are termed *granular crystalline*, or *phanero-crystalline*, as granite, statuary marble, etc.

2. Those which, while crystalline in structure, yet present no visible crystals, as some quartzites, flints, volcanic glasses, etc., are termed *crypto-crystalline* (hidden crystals).

3. Those which consist of a crypto-crystalline base, through which are scattered distinct crystals, are termed *porphyritic* or *porphyries*.

Fragmental Rocks. As these arise chiefly from the decay and wear of previous rocks, the constituents may be reduced in various degrees. If the material consists of pebbles solidified, the rock is a *conglo merate*. If the component fragments are well rounded, the rock is sometimes termed *pudding stone*, though usually simply conglomerate. If they are but little worn, remaining still angular, the rock is termed a *breccia*, a term of very frequent use in these reports. If the material is further reduced, the rock becomes a *grit* or *sandstone*, or if the material is calcareous, it is sometimes termed a *sandrock*, and if still further reduced to an earth or clay, the resulting rock is a *shale*. *Clay*, *mud*, *silt*, *earth*, *alluvium* and *soil*, are familiar terms used to designate fine rock-substance in its unconsolidated state. *Gravel*, in a similar way, is an incoherent conglomerate. *Till* is a term coming into general use to designate a confused mixture of bowlder clay, gravel and sand, formed by glaciers, constituting their ground moraine. It embraces the greater portion of the bowlder clay so extensively spread over the eastern and northern portions of the State.

Rocks Considered with Reference to the Structure of Their Mass.

Rocks are distinguished with reference to the internal arrangement of material, as follows:

1. Those whose material coheres in great masses, without any definite internal arrangement, are termed *massive*.

2. Those whose material is arranged in planes or leaves, as it were, giving the rock a banded structure, are termed *schistose rocks*, or

schists. This structure is also termed *foliated.* These terms are usually confined in their use to crystalline rocks, as gneiss and mica schist.

3. Those in which the material (usually a clayey or earthy sediment) was laid down in thin sheets, giving a laminated structure to the rock, are termed *shaly rocks*, or *shales.*

4. Those in which the particles are so formed and arranged as to make the rock split in thin, regular sheets, are termed *slaty rocks*, or *slates*, of which roofing slate is an example.

The distinction between schists, shales, and slates, is usually troublesome to the learner, though rarely so to the practical geologist. They all possess a parallel or stratified arrangement of their material, but in the true *slates* this arrangement is brought about by compression, which flattens the particles and forces them into a parallel arrangement at right angles to the compressing force. The direction of the cleavage is hence usually not parallel to the bedding planes, but more or less transverse to them. Usually this character sharply distinguishes slates from shales and schists. But practically the character of the structure and cleavage is of itself usually decisive. The term slate, however, is not rigidly confined to rocks of this class, but is made to embrace a class of closely laminated, fissile rocks of similar regular cleavage, that have become such from the manner of their deposition, and not from compression. In *shales* and *schists* the parallel arrangement of particles is usually conformable to the bedding planes. But the term shale is usually confined to rocks formed by the deposition of clayey or earthy material, the parallel structure being due to the stratified or laminated nature of deposition, while the term schist is usually applied to metamorphic rocks, in which the structure is due to a parallel arrangement of the crystals, especially those that take the form of thin scales, as mica, hornblende, chlorite, etc.

Stratification. The foregoing distinctions relate to the texture of rocks, taken in small masses. If their structure be considered in a larger view, rocks will be found to constitute two classes:

1. Those which are arranged in layers or strata, and are hence termed *stratified rocks.*

2. Those which present no such arrangement, and are hence termed *unstratified rocks.*

Stratified rocks usually owe their bedded structure to the modifying action of water during their deposition, and are mainly aqueous rocks. A few owe their stratification to the action of winds, as in the case of dunes and other wind-drift accumulations. Volcanic ashes and scoria usually take a stratified arrangement. A stratified arrangement of igneous rocks is produced when the molten matter issues from fissures at intervals in great quantities, and spreads out in successive thin sheets over a large area. Such an accumulation presents a very definite stratified appearance, viewed as a whole, though of course each flow is in itself unstratified. The igneous rocks of Lake Superior are a remarkable example of this.

Unstratified rocks are produced when great masses of molten rock solidify. They are probably also produced by an extreme degree of metamorphism of what were originally stratified, sedimentary rocks. Metamorphism, as usually known, does not entirely destroy the bedded structure, though it may obliterate the finer laminations. But it is highly probable that it sometimes, and perhaps often, reaches a degree in which the main bedding lines are destroyed also. The massive granites of the older formations which lie at the base of the geological column may furnish examples of this.

Rocks Considered with Reference to Their Chemical Nature.

It is often important to designate in general terms, the chemical character of rocks. This is usually done by a class of adjective terms, of which the following are some of the more common :

Silicious, those (1) in which silica is the predominant ingredient, as meant when we say, a silicious rock; or (2) those in which it is a notable though not predominant ingredient, as meant in the expression, a silicious limestone, or a silicious ore.

Calcareous, those in which lime is (1) a predominant or (2) a characteristic ingredient.

Ferruginous, those in which iron (in the form of an oxide) is a characteristic ingredient.

Carbonaceous, those in which carbon is a more or less considerable constituent.

Argillaceous, those consisting of, or characterized by clayey material.

Another chemical distinction of growing importance is the discrimination of rocks as *acidic*, *neutral*, and *basic*. Most rocks are chemically of the nature of salts, i. e., they consist of a combination of an acid ingredient and a basic or alkaline one. If these two unite in such proportions as to satisfy mutually their chemical affinities, the resultant rock is chemically *neutral*. In case the acid ingredient predominates, the rock is termed *acidic*. In case the basic is in excess, it is termed *basic*.

The chief acid constituents of rocks are silica and carbonic acid. As the latter is a gas when free, it cannot of itself form a rock. Silica, however, forms of itself immense deposits, as quartz, quartzite, and quartzose sand, and hence there is a very large and important class of rocks that are purely, or highly, acidic, through the predominance of silica. The basic ingredients of rocks are mainly potash, soda, lime, magnesia, alumina, and iron oxide. Of these, only the last often forms an uncombined basic rock.

The more important use of the terms acidic, neutral, and basic, relates to that large class of rocks in which silica, as the acid ingredient, unites with potash, soda, lime, magnesia, iron, etc., as basic ingredients. When the silica exactly satisfies the chemical affinity of the basic ingredients, the rock is *neutral*, when it is in excess of that, *acidic*, and when it falls short, *basic*. For convenience, when the silica exceeds 60 per cent., the rock is commonly regarded as acidic, when it falls below that, basic, though the exact point of neutrality varies somewhat above and below 60 per cent., depending upon the constitution of the rock.

Rocks Considered with Reference to Their Mineralogical Composition.

By far the most important characteristics of rocks are dependent upon the minerals which compose them. Certain rocks are formed almost exclusively of a single mineral, as quartzite, and common quartzose sandstone, which are little more than quartz; as limestone, which is mainly made up of minute grains of calcite; or as magnesian limestone, composed of crystals of the mineral dolomite. A larger number of rocks, however, are composed of several mineral substances in association. These substances are sometimes in an undefined, unindividualized condition (*amorphous*, without form), but they are more commonly in the condition of distinct crystals. These are usually small and interspersed mutually throughout the rock. They are not to be conceived as perfect crystals packed together, but as imperfect ones, modified by mutual interference in their growth. As a rule they appear to have been formed in succession. The crystals of the first formed mineral are more nearly perfect than those of the later ones which conform to and embrace them.

As previously remarked, there is nothing in the nature of the minerals themselves to determine how or in what proportion they shall be associated. That is dependent wholly upon the material out of which they were formed, and the conditions of their production. Certain associations of minerals are, however, much more frequent than others, and to these special names are given. Originally, many of the special names given to these mixed rocks had no reference to their mineral composition, but by usage have come to be employed exclusively to designate particular mineral aggregates. Thus *granite* was originally, and indeed is yet popularly, used to indicate a *grained rock*, but it is now confined to a special aggregate of quartz, feldspar and mica. Some names have a partly mineralogical and a partly structural signification, such as *gneiss*,— a combination of quartz, feldspar and mica, having a schistose or banded structure. There are still other names which really signify physical properties, but which are only applied to rocks of certain mineral constitution, as *trachyte*, a name referring to the quality of roughness, but which is only applied to a certain feldspathic, igneous rock.

It is unfortunate that there is no series of names based simply on the mineral composition of rocks. The writer has proposed a system of naming to meet this want, and the growing needs of lithological science, an outline of which is given on pages 30–40. The existing system is, of course, used in these reports, but the proposed names have been added in parenthesis in this volume for their definitive and mnemonic value.

The Leading Classes of Rocks.

The list of rocks which follows is only intended to embrace the more important ones found in Wisconsin. The definitions are largely based on mineral composition, but not entirely so. A complete list of all the rocks found in the State, with remarks as to their character and occurrence, prepared by Prof. Irving, will be found in Part II of this volume, to which reference is recommended. Fuller descriptions of our native rocks, including many microscopic delineations, will be found in the several volumes of this series. As these embrace descriptions and notes by prominent experts of Europe, as well as this country, they possess value for those who desire to follow the subject out in its fullness.

Simple Rocks.

Limestone consists essentially of calcium carbonate, or calcite, which occurs usually in small crystalline grains, forming a semi-crystalline mass. It is frequently impure from the presence of silica and clayey material. It is mainly derived from the comminuted remains of marine life, as corals, crinoids, mollusks, etc. Several varieties are formed by chemical deposition from lime-bearing water, as (1) **calcareous tufa,** and the **petrified moss** of lime springs; (2) the **stalactites** formed like icicles in caves by deposit from dripping water, and **stalagmite** formed in a similar way on the floors of caves, and (3) **calcite** or the marble-like filling of fissures, as the marble of Richland county.

Marl, as the term is used in these reports, denotes a lime deposit derived from disintegrated fresh water shells, and is commonly found in the bottoms of marshes and lakes.

Magnesian Limestone differs from simple limestone in containing a greater or less quantity of magnesium carbonate, and embraces by far the greater portion of the limestones of our State. It was probably formed from simple limestone by the substitution of magnesium carbonate for a part of the calcium carbonate, while it was still a marine sediment. When this process has been carried so far that there is a molecule of magnesium carbonate for every molecule of calcium carbonate, the rock becomes a true dolomite, a "double carbonate of lime and magnesia," in the old phraseology. The process is known as *dolomization.* In such cases, analysis will show the calcium carbonate to constitute 54.35 per cent., and magnesium carbonate 45.65 per cent. of the rock, when strictly pure dolomite. The majority of the magnesian limestones or dolomites of Wisconsin give, on analysis, nearly this proportion, showing that they are essentially dolomites.

Hydraulic Limestone. This is not to be regarded as a rock of definite composition, but consists of a limestone, usually magnesian, containing a considerable percentage of silica and alumina. The percentages of the ingredients vary considerably. Those of the Milwaukee cement rock, which gives excellent results, are as follows:

Carbonate of lime	45.11
Carbonate of magnesia	30.89
Silica	16.61
Alumina	4.09
Oxide of iron, etc	3.25
	99.95

Clay Rocks. Argillites. Shales. Rocks formed by clay, more or less hardened, are sometimes termed *argillites,* though oftener *shales. Shales,* however, are not necessarily formed of argillaceous clay.

Pipestone is a rock consisting of clayey material, usually colored to a rich red hue by iron oxide, having a compact texture, but rather soft, so as to be easily carved. It has little importance as a rock, and is mainly interesting because of its beauty.

Ironstone. All ores, in the geological sense, are rocks. None of them, however, are found in sufficient quantity to attain importance as rock-masses, except the iron ores. These, in the form of magnetite, the several hematites, and limonite, constitute important members of the rock series. Their characters are fully described in the mineralogical list, and in the chapter on iron ores in this volume, and in the reports on the iron deposits in Vols. II, III, and IV of this series.

Sandstone. By the unmodified term sandstone, a rock composed of rounded quartz grains is usually understood. But besides the quartz, there are frequently present grains of other minerals, as feldspar, magnetite, augite, and scales of mica. If these form any considerable part, modifying terms are used by careful writers, as *micaceous* or *feldspathic* sandstone. Sometimes sandstones are composed almost wholly of feldspar and other silicates, as in the case of some of the Keweenawan sandstone. Sometimes a rock of sandy texture is made up of particles of calcite, or, more frequently, of dolomite, when the term *sandrock* is frequently used instead of sandstone, the rock being designated a *calcareous* or *dolomitic sandrock.* A notable instance of dolomitic sandrock is a granular dolomite found near Taycheedah, and used as cut-stone at Fond du Lac. Though locally called a sandstone, analysis shows it to be one of the purest dolomites on the continent.

Crystalline Rocks.

A. Granitic Group.

There is a large group of complex crystalline rocks formed by the association of three or more minerals, of which *granite* (fel-qua-mi) may be taken as a type. The minerals are usually (1) quartz, (2) feldspar, most frequently orthoclase, but sometimes oligoclase or some of the triclinic feldspars, and (3) a mica, or an amphibole (hornblende). With these are associated a considerable number of accessory minerals, which are often present in minor quantities, and which sometimes replace some of the principal ingredients. The group has an almost infinite number of varieties, and of gradations from one variety to another, but the subsequent list contains the principal types.

The granitic group may be said to branch off from the preceding through quartzite which only differs from sandstone in being metamorphosed, and is really a simple rock, but is connected with the granites by gradations through the introduction of feldspar and mica crystals, and by a similarity of origin.

Quartzite. This is a rock formed essentially of compact quartz, and has usually arisen from the metamorphism of silicious sandstone through the aid of heat and pressure. The quartzites of the Devils Lake region are typical examples of this class. They are there colored red, as is not uncommon, with a little iron oxide. Some quartzites are produced by aqueous agencies.

Jasper. A fine-grained, quartzose rock, deeply colored, (usually) red, by iron oxide, constitutes a jasper rock. It differs from quartzite in little more than in being of finer texture, containing some clay, and being more highly colored. It is often banded, or schistose in structure, and is frequently associated with iron ores, as in the Lake Superior region. Only specimens of exceptionally fine grain and color are valuable as precious stones.

Chert. Flint. Chert is the name given to an impure silicious rock of flinty nature, usually of an opaque, white, or yellowish color. It occurs abundantly in certain limestones in the form of nodular concretions. In the lead region, these are known as flints, and do not differ greatly in nature, and probable origin, from the true flints of the chalk deposits, except in being coarser and less pure. Chert is sometimes colored by iron oxide, when it closely approaches jasper in nature.

Granite *(Fel-qua-mi)*. This is a complex crystalline rock, composed of feldspar, quartz and mica. The ingredients usually occur in distinct crystalline grains. The *feldspar*, in the typical varieties, is orthoclase, which, by its red or white color, determines the hue of the granite. This mineral may be distinguished by its smooth cleavage in two directions, and the satin luster of its faces. The *quartz* is usually glassy, and without apparent cleavage. The *mica* usually takes the form of thin scales, which may be either silvery, black, or bronze in color.

This may be taken as the typical form of granite, and from this it grades away by variations in the relative quantity of its ingredients, and by the introduction of others, into a variety of allied rocks. If the quartz is very greatly increased, it graduates in the direction of quartzite. If the mica is wanting, it becomes **granulite** *(qua-fel)*, a rock consisting of quartz and feldspar. If the mica is replaced by hornblende, the rock becomes a **syenite** *(fel-qua-horn)*, as the term is usually used in America, but not in Europe, where the term syenite is usually applied to a rock consisting of orthoclase feldspar and hornblende *(ortho-horn)*. If the mica is increased so as to give a banded or foliated structure to the rock, it is termed a **gneiss** *(foliated fel-qua-mi* or *qua-fel-mi)*. If the mica is further increased so as to predominate, and give a decidedly schistose structure, the rock becomes a **mica schist** *(schistose mi-qua-fel* or *mi-fel-qua).* All these forms pass into each other by insensible gradations, and are only somewhat arbitrarily distinguished.

In like manner, *syenite,* when its hornblende takes the laminated form, and is so arranged as to give a banded structure, becomes a **syenitic,** or **hornblendic gneiss** *(foliated fel-qua-horn).* When the hornblende becomes very predominant and gives the rock a decidedly schistose structure, it becomes a **hornblende schist** *(horn-qua-fel).*

From these foliated forms there grades away a great series of crystalline schists and slates formed from the partial metamorphism of earthy and clayey sediments. They are usually illy defined in character and are commonly designated by descriptive phrases or the name of some characteristic ingredient, as *graphitic, sericitic, chloritic, magnetitic, hematitic,* and *hydromica schists.*

B. Basaltic Group.

There is another large group of crystalline rocks in which there are usually only two leading minerals, though almost always one or more important accessory ones. These are commonly a plagioclase feldspar [1] and a pyroxene. These rocks embrace most of the dark, rather fine-grained, non-schistose rocks, that occur in the crystalline region, and are abundantly scattered in bowlders over the glaciated area of the state and popularly known as "nigger heads."

Dolerite. Diabase *(Plagi-aug).* A rock composed of *plagioclase feldspar* and *augite.* The feldspar in the Wisconsin rocks is usually either labradorite, oligoclase, anorthite, or two of these associated. Orthoclase is not uncommonly present also. Magnetite is almost universally present. This rock is usually dark green, iron gray, or black, of medium or fine crystalline grain, and weathers to a rusty brown by the oxidation of the iron. It is heavy and tough, but not very hard. It shows most of the characteristics common to the other rocks of the group, so that it is a difficult rock to determine precisely. The name dolerite signifies deceptive, referring to its liability to be mistaken for diorite or other rocks of this group.

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[1] The term *plagioclase* is coming to be commonly used as a generic term to designate an undistinguished feldspar, which may be either an *anorthite,* a *labradorite,* an *an lesite,* an *oligoclase,* or an *albite.* The term is serviceable in general descriptions when the feldspars are intermingled or undeterminable, or mutually replace each other. The term does not designate a definite mineral species, as usually defined, and is objectionable to the extent that it conveys that impression.

The propriety of making a distinction between diabase and dolerite has been questioned. In their original state they were probably essentially alike, but the more ancient rocks have undergone metasomatic alteration, whereby chlorite, calcite, viridite, and other secondary products have been produced, which somewhat change the aspect of the rock. Diabase may, therefore, be regarded as a dolerite which has undergone a notable degree of metasomatic change. It has been the custom of some lithologists to regard rocks of this class *older than the Tertiary* as *diabases*, and those younger as *dolerites*. While it may be a fact that the rocks of the earlier period are generally changed, while those of the later are not, the distinction on the basis of age can scarcely be justified. Lithological distinctions should rest solely upon rock-characters.

Gabbro *(Labra-dial)*. The term gabbro has been unfortunate in being applied to several different rocks. As used in these reports the term is applied to a rock formed of a *plagioclase feldspar* and *diallage*. The feldspar is usually *labradorite*. The diallage is little more than a foliated *augite*. The more important accessory minerals are magnetite and olivine. It does not differ radically, it will be observed, from diabase, but the distinction is of some geological importance. As found in Wisconsin, it is usually much more coarsely crystalline than the diabase, and in such cases is readily distinguishable. The so-called *Duluth granite* is a typical example.

Melaphyr *(Plagi-augi-chrys)*. This term, like gabbro, has had a varied application. It is in these reports applied to a rock consisting of a *plagioclase feldspar*, *augite* and *chrysolite* (olivine), imbedded in an apparently structureless base, at least a base which, under the microscope, cannot be resolved into distinct minerals. It is, therefore, porphyritic in character, and might be classed with the following group, but its general constitution allies it very closely to the diabases and gabbros. Its physical appearance is closely similar to that of diabase, but in Wisconsin rocks it is distinguished by "spots $\frac{1}{16}$ to $\frac{3}{4}$ of an inch in diameter, each of which reflects the light with a satin-like sheen" (Pumpelly), though the included surface has a granular texture. Microscopical examination shows that the spot is due to the cleavage of a crystal of augite in which are inclosed many crystals of feldspar. These crystals resist weathering better than the intermediate material, and give the worn surface a characteristic knobbed appearance. This peculiarity is probably not to be regarded as a universal characteristic, but is very generally true of the Wisconsin rocks, and is a convenient means of distinction.

Diorite *(Plagi-horn).* Diorite is a dark gray-green or blackish crystalline rock, quite similar to dolerite, diabase, and melaphyr in physical appearance. It consists mainly of a *plagioclase feldspar* and *hornblende.* It differs from diabase, in the substitution of hornblende for augite. In some cases this substitution is probably a real alteration of augite into hornblende (more strictly uralite) (Irving). The accessory minerals are usually the same as in the case of diabase. There is no satisfactory means of distinguishing by the eye or ordinary means of inspection, diorite from diabase or dolerite. Only critical microscopical examination is competent to give a trustworthy discrimination.

Amygdaloidal Rocks. In those cases in which rocks are formed from overflows of lava, the vapors held within the fluid rock expand on relief of pressure, giving rise to bubble-like cavities within the rock. These are mainly near the surface of the flow and usually become filled in time by secondary minerals deposited from infiltrating waters. The structure so formed is termed amygdaloidal from the almond-like cavities. The original rock may be any one of the basaltic group. The name, therefore, does not represent mineral constitution, but physical structure.

Sometimes a similar structure in a basaltic rock is produced by a removal of the original rock at numerous points, scattered through the mass, and the substitution of secondary minerals, constituting a *false amygdaloidal* or *pseud-amygdaloidal rock.*

Semi-Crystalline Group.

There is a large class of rocks which consist in part of distinct crystalline grains, and in part of a vitreous uncrystallized base or matrix in which the crystals are imbedded. The majority of these have probably arisen from the partial crystallization of what was originally a fluid mass, though it is not safe to assume that all have. Such rocks may be said to have been arrested on the way to perfect crystallization. If cooled at an early stage, the unindividualized base constitutes a large portion of the rock-substance. If only arrested at a late stage, but a small portion of unindividualized base remains. This base is usually of a glassy character. The crystals formed in it, being unobstructed in their growth, usually take regular forms, and when they differ sharply in color from the ground-mass, give to the polished surface those beautiful angular mottlings for which porphyries are valued. The term **porphyry,** in its proper use, applies only to rocks of this class, though it is often loosely applied to other rocks presenting distinct angular crystals.

It will be perceived that the distinction is a physical and not a mineralogical one, and that porphyries may differ widely in their mineralogical constitution. When the crystallization has proceeded so far that the base is a relatively small component, and the mineralogical character of the rock pronounced, the better practice is to use the mineralogical term, modified by the adjective porphyritic, as *porphyritic diabase (porphyritic plagi-aug)*.

Felsite. The unindividualized base of porphyritic rocks may be of various natures. That which is most common in the porphyries of Wisconsin consists of an intimate mixture of material having essentially the constitution of orthoclase feldspar and of free quartz. To this the term *felsite* is applied.

Felsitic porphyry consists of a base of *felsite*, through which are scattered crystals of *feldspar*, usually orthoclase.

Quartz porphyry consists of a *felsitic base*, through which are dispersed crystals of *quartz* as well as those of *feldspar*.

Felsitic and quartz porphyries are regarded as corresponding to the granites of the crystalline group, and, theoretically, it is conceived that, if they were completely crystallized, they would be typical members of that group, while the more basic porphyries are regarded as partially developed members of the basaltic group.

Difficulty of Distinguishing Origin by Constitution. Of the foregoing crystalline and semi-crystalline rocks, it is impossible to determine, in many cases, from the constitution of the rock, what was its origin. Crystalline rocks which have a definitely foliated or schistose structure, may be pretty safely assumed to be metamorphosed sediments. Rocks which have a true amygdaloidal structure, or fluidal lines, indicating flowage, may pretty safely be assumed to be igneous. But of the thoroughly crystalline rocks, such as granite, syenite, diorite, possibly even dolerite and diabase, and some of the porphyries, the simple lithological character cannot be regarded as sufficient indication of origin. Certain microscopical characters have been held to be more or less decisive in this regard, but the trustworthiness of such criteria is yet to be demonstrated.

Microscopical Lithology. The microscopical study of rocks in slices ground so thin as to be transparent, and examined under polarized as well as ordinary light, has, in recent years, developed into an important, and, indeed, almost indispensable means of lithological investigation. Such studies have developed the existence of a class of microscopical minerals not recognized by the naked eye. These may be, in many cases, only crystals of well-known minerals in their incipient stages. But some forms are quite different from any known crystals. The general class are known as **microlites.** They are generally thin, cylindrical, or needle-like forms. Some are dark and hair-like, and take curved or twisted forms, and are termed **trichites** from their resemblance to hair. Pellucid grains, **globulites,** are also distinguished.

If these are products of incipient growth, there are, on the other hand, certain peculiar products of decomposition, as **opacite** — black opaque grains and scales whose composition is probably various; **ferrite** — yellowish, reddish or brownish substances, occurring commonly in iron-bearing rocks; **viridite** — green and transparent substances resulting from the decomposition of hornblende, augite, olivine, or other minerals. These, though named as if they were distinct minerals, probably are not so, but the terms are convenient in description.

APPENDIX TO LITHOLOGICAL GEOLOGY.

A Proposed System of Lithological Nomenclature.

Note.—At the meeting of the Wisconsin Academy of Science, in January, 1881, the writer presented a paper on the above subject, a portion of which is here incorporated for the purpose of explaining the system, so far as introduced in this report. The extent of the introduction consists in inclosing the new names in parentheses, after those in common use. As each name defines the mineralogical composition of the rock, it will serve as a definition, and, if familiarized, will assist in fixing in memory the rock constituents. T. C. C.

That our present system of lithological nomenclature is, in some important respects, unsatisfactory, it is needless to assert. It is *inadequate*, in that it falls far short of properly designating all the mineral aggregates that have now become subjects of description, and of not infrequent reference in geological literature. It is *ambiguous*, in that certain terms in common use are differently used by different writers. So common a term as *syenite*, and the not infrequent ones, *melaphyr* and *gabbro*, are striking examples. It is *inaccurate*, in that it groups under the same term, rocks whose ultimate chemical composition varies widely, or those whose origin is diverse. It is *mischievous*, in that the individuality of its naming inevitably implies hard and fast lines which do not exist in nature. It is *etymologically objectionable*, in that terms are wrested from their derivative sense, and forced into incongruous applications. Thus the term *granite* is driven from its popular, and as it happens in this case, proper application to a wide class of *grained* crystalline rocks, and restricted to a certain *mineralogical* aggregation.

That these objections are felt in greater or less degree, is shown (1) by the drift in the signification of terms, (2) by the efforts made to restrict and define old terms, (3) by the introduction of new terms, (4) *by the compounding of terms*, and (5) *by the use of mineralogical names as defining adjectives.* As examples of compounding may be cited such terms as quartz-syenite, oligoclase-trachyte, quartz-augite-andesite, labradorite-diorite, hornblende-andesite, diorite-gneiss, hornblendic-biotite-gneiss, and so on through the long list of complex terms that characterize the later and more precise lithological discussions.

The essential features of the proposed system lie in the direction of this manifest tendency, and consist, essentially, (1) in an effort to separate lithological terms into distinct classes, having reference to the several attitudes from which the character of rocks may be viewed, as physical, chemical, mineralogical, petrographical; and (2) the introduction of a series of contractions, and a system of compounding terms, which shall render lithological names at once specific, self-explanatory, and measurably quantitative. At the same time, the mischievous implications attached to prevalent terms, fashioned after those applied to definite mineralogical species, are avoided.

Lithological terms are either adjective or nominal in character, and a complete series of each would greatly facilitate expression.

The following classification of terms, embracing mainly those already in use, will make more clear the place and function f the changes and additions proposed:

Lithological Terms.

A. Adjective.

Class I. *Basis of Classification — The Physical Nature of the Constituents.*

1. Fragmental. (Detrital, Clastic.) { Conglomeratic. / Sandy or arenaceous. / Clayey or argillaceous. / Compact. / Etc.

2. Crystalline. { Granular or phanero-crystalline. / Crypto-crystalline. / Porphyritic (the above combined).

Class II. *Basis of Classification — The Structure of the Mass.*

Massive.
Schistose.
Shaly.
Slaty.
Laminated.
Etc.

Class III. *Basis of Classification — Coherence.*

Tenaceous, firm, compact, etc.
Incoherent, friable, uncompacted, etc.

Class IV. *Basis of Classification — Chemical Nature.*

Silicious.
Calcareous.
Ferruginous.
Carbonaceous.
Etc.

Class V. *Basis of Classification — Mineral Constitution.*

Quartzose.
Micaceous.
Pyritiferous.
Garnetiferous.
Staurolitic.
Chloritic.
Etc.

Class VI. *Basis of Classification — Lithological Character.*

Granitic.
Basaltic.
Porphyritic.
Trachytic.
Dioritic.
Etc.

Class VII. *Basis of Classification — Origin.*

Igneous.
Aqueous.
Metamorphic.
Pseudomorphic.
Æolian.
Etc.

B. Nominal.

Class. I. *Basis of Classification — Physical Form of the Constituents (mainly).*

Conglomerate. { Pudding stone. Gravel (incoherent conglomerate). Breccia.

Grit, grit-rock, sand, sandstone, sandrock, clay, mud, silt, earth, alluvium, soil.
Till.
Tufa.
Etc.

Or again.

Crystallites.
Clastites.
Aggregites.
Amorphites.

The terms of the last group may be defined as follows:

Crystallites, those rocks that are crystalline in structure;

Clastites, those which are fragmental or detrital in origin;

Aggregites, those which are simply accumulations of individualized particles of matter — coherent or incoherent — neither crystalline nor detrital in origin, as, infusorial earth, or chalk, so far as it is composed of uncomminuted rhizopod shells;

Amorphites, those in which there are no discernible, individualized constituents.

Class II. *Basis of Classification — Structure of the Mass.*

Schist.
Shale.
Slate.
Etc.

Or again.

Stratified.
Unstratified.

Class III. *Basis of Classification — The Crystalline Character of the Constituents.*

Granite (crystals distinct).
Granulite (crystals minute).
Aphanite (no visible crystals).
Porphyry (crystals in compact base).

It is proposed to restore the term *granite* to its proper etymological use, and apply it to rocks consisting of distinct, crystalline grains of medium or large size, and to deprive it of mineralogical signification, making it a term denoting simply a certain class of crystalline aggregates.

It is proposed to designate minutely granular crystalline rocks by the diminutive term *granulite*. *Aphanite* may then be more freely used to include all crypto-crystalline, or at least micro-crystalline rocks, while *porphyry* will embrace combinations of the last with the two former.

Class IV. *Basis of Classification — Physical Characters.*

Trachyte.
Rhyolite.
Pumice.
Scoria.
Phonolite.
Buhrstone.
Pearlstone.
Etc.

Class V. *Basis of Classification — Origin.*

Lava.
Trap.
Meta (——).
Igno (——).
Aquo (——).

There is a very prevalent, and for the most part just, prejudice against the use of the term *trap*, arising from the frequent misuse of the name, as though it conveyed a mineralogical signification, whereas the term really has none, and, in its proper application, includes rocks of various mineralogical and chemical constitution. But this abuse is only an aggravated instance of what is common, indeed, almost universal, under the present system of nomenclature. To merely specify that a rock is *granite*, may be to use that term as a "cloak of ignorance" in the same sense, though perhaps not to an equal degree, as to rest with the assertion that the rock is a "trap;" for the term granite embraces a scarcely less wide range of minerals, or of ultimate chemical constituents, and the wresting of the term from its primitive and proper application, is scarcely less violent. If, however, the term *trap* be stripped of all pretension to mineralogical signification, and confined to the simple designation of rocks formed of molten matter, that issued through fissures, either constituting dikes or spreading out into sheets, and so incidentally giving rise to step-like topography, as distinguished from lavas that have arisen from craters, and have flowed away in radial streams, with the attendant structural distinctions between the two, it will serve a convenient function in the literature of the subject, without being a "cloak of ignorance" in any other sense than *lava* is, or many other general and very convenient and necessary terms.

There will doubtless arise many cases in which it will be impossible to determine the method of issuance of a given rock, and neither the term *lava* nor *trap* could be used in the restricted sense here proposed, and there may be little fundamental distinction between the phenomena in the two cases. But both the distinction and the terms are serviceable in geological literature, when stripped of the pretentious clothing to which they have no title.

Prof. Dana has suggested that metamorphic rocks be designated by the prefix *meta-*. If this were generally adopted, it would doubtless be serviceable. But the limitations of knowledge being such as they are, it would seem almost necessary to introduce a corresponding prefix to indicate similar rocks of igneous, or aqueous origin. For if the simple name, as *diorite*, for example, be understood to imply an igneous origin, and the compound term, *meta-diorite*, a metamorphic one, it would be necessary, *in the very naming of the rock*, to assert an opinion as to its origin. But in many cases it is impossible to positively determine the origin of a rock whose other characteristics are very well known; and there would be no convenient term to express this knowledge, without implying knowledge not possessed. In respect to granite, for instance, it is contended, severally, by able geologists, that it may have an igneous, an aqueous, or a metamorphic origin, and yet, in many instances, the working geologist would not feel at liberty to assert that a given granite belonged to either class; and it would be a sore inconvenience to be obliged to make an implied assertion upon the subject, or else be shut out wholly from the use of the term granite.

If, therefore, the system of introducing prefixes to designate origin be adopted at all, it should be complete, and yet leave the working geologist at liberty to use the fundamental term, free from the added signification. It is hence suggested that the term *meta-* be used as a prefix when it is desired briefly and conveniently to assert a metamorphic origin; that the prefix *igno-* be used similarly, to assert an igneous origin; and *aquo-*, in like manner, to imply an aqueous origin; while the simple terms shall have merely their own mineralogical or other appropriate signification.

Class V will then embrace the terms *lava* and *trap*, used to designate rocks of certain special eruptive origins, and a long list of terms to which the prefixes *meta-*, *igno-* and *aquo-* are attached, to signify respectively metamorphic, igneous, and aqueous origin.

The foregoing terms furnish fair, though somewhat inadequate, facilities for the designation of the several classes of properties indicated under the headings.

There remains to be added a series of terms which shall express the mineralogical constitution of rocks, which is by far their most important characteristic. It is in respect to this that our present practice is weakest, and, from the fact that it attempts to impose fixed names upon indefinitely varying aggregations, must necessarily ever remain unsatisfactory. It is, therefore, proposed to escape this difficulty by the use of a system of flexible compound terms, which shall admit of variation to express varying composition, and roughly, the varying quantitative relations of the mineral ingredients. As above indicated, the growing tendency in lithological literature is toward the employment of compounds of mineralogical names. The advantage of this in clearness and precision, as well as in the convenience of the reader, is manifest. But it results in cumbersome terms, and if carried sufficiently far to overcome the defects of the present system, becomes burdensome. This, however, may be obviated by a series of contractions which shall retain a significant portion of the mineralogical name without the burden of its entirety. For the sake of euphonious combinations, these contractions may be varied somewhat in their several combinations. The following are suggested as available abbreviations for the names of the leading minerals that enter into the composition of our native rocks, and it will not be difficult to extend the list to other minerals that may, in the case of other rocks, become prominent lithological constituents:

Abbreviations of the Names of Minerals Constituting Our Native Rocks.

- Quartz — Qua., or qu.
- Feldspar — Fel.
  - Orthoclase — Orth., or ortho.
  - Microcline — Micr., or micro.
  - Oligoclase — Olig., or oligo.
  - Labradorite — Lab., labra., or labrad.
  - Albite — Al., alb., or albi.
  - Andesite — And., or andes.
- Mica — Mi.
  - Muscovite — Musc., or musco.
  - Biotite — Bio., or bi.
  - Hydromica — Hydrom., or hydromi.
- Amphibole — Amph., or amphi.
  - Hornblende — Horn., or 'orn.
  - Actinolite — Act., or actin.
  - Tremolite — Trem., or tremo.

Pyroxene — Pyr., pyro., or pyrox.
Augite — Aug., or augi.
Sahlite — Sahl.
Diallage — Dial.
Epidote — Ep., epi., or epid.
Garnet — Gar., garn., or garni.
Chrysolite — Chrys., or chryso.
Olivine — Oliv., or olivi.
Calcite — Calc., or calci.
Chlorite — Chlo., or chlor.
Pyrite — Pyri., or pyrit.
Magnetite — Mag., magn., or magne.
Hematite — Hem., or hema.
Menaccanite — Menac., or menacca.
Tourmaline — Tour., or tourma.
Graphite — Graph., or graphi.
Apatite — Ap., or apa.
Andalusite — Andal., or andalu.
Sericite — Seri., or Seric.

In the combination of these, it is suggested that the leading constituent stand first and that the others follow in the order of importance. In crystalline rocks, there will often be present minerals in small and varying quantities, which it will be neither convenient nor desirable to include in the compound name of the rock, but which should be regarded, as they now commonly are, as accessory minerals. There may be little philosophical basis for this distinction, since the rock is at best but an aggregate, and is what it is by virtue of the total aggregation, and not by virtue of any definite composition, as in the case of a mineral or chemical compound. Nevertheless these minor mineral constituents do not, in the main, represent any distinctive condition in the formation of the rock, but rather some of those accessory circumstances, common to a wide range of rock-formation. They are, therefore, geologically incidental, rather than essential conditions, and their products may, therefore, be omitted from the compound name, and classed as accessory minerals, and as such, receive attention in exhaustive descriptions, without burdening the more general discussions. It will, of course, be within the discretion of each writer, to decide in the case of a given rock, what are its essential, and what its trivial constituents.

In this system no uniform terminal syllable is proposed. It may be doubted whether lithologists will take kindly to this innovation, since it is at variance with the prevalent custom of terminating rock-names with an *ite* or an *yte*, after the fashion of mineralogical terms. A grave objection to the usage, however, arises out of the very fact of this imitation, since it implies something of the same definiteness of constitution that the mineral possesses; and this, I believe it is almost universally conceded, is a false and mischievous idea. It seems to the writer, therefore, best that the name should imitate the complex aggregation of the rock which it designates, rather than the individualized character of a mineral to which it has only the semblance, not the substance of a just claim.

The following series of proposed names will, therefore, consist of a bare aggregation of abbreviations of the names of the mineral constituents of the given rocks, in the order of their relative importance, thus both representing and defining the rock, without pretension to individualization. The oddness of the names may at first be taken for uncouthness, which indeed will be justly chargeable in some cases, but the quaint elegance of other instances will offer some, if not full, compensation. The uniformity — not to say monotony — given by the fashionable suffix, will be lost, but a vivacious variety will be gained.[1]

The application of the system may be illustrated by the familiar rock granite. Its composition is generally stated as quartz, feldspar, and mica. Assuming, for the moment, that no more precise statement is desired, and that the relative amounts of the ingredients are in the order given, its name under the proposed system will be *qua-fel-mi (quàfelmi)*. If, however, as is very frequently the case, feldspar is the leading ingredient, and quartz second in order of importance, the name will be *fel-qua-mi (fèlquami)*. Should mica stand second in importance, the formula would be *fel-mi-qua (fèlmiqua)*, and so on for other variations. In this case, mica rarely assumes the leading place without removing the rock from the present category of granites. But under the proposed system, the nomenclature will adhere strictly to the mineralogical constitution and the compound terms *mi-fel-qua (mìfelqua)*, and *mi-qua-fel*

[1] An alternative series of names was proposed in the original paper, more in harmony with the present habit, both in respect to uniformity of termination, and the order of arrangement of the constituents, which is that of the inverse order of importance, the most important mineral being last, and receiving the termination. The suggestion of Prof. Dana that the terminal syllable of the names of rocks should be *yte*, to distinguish them from minerals of the same name, ending in *ite*, would be important in this case, from the prevalence of the use of mineralogical names. It has not been adopted in this report in the use of old names.

(mìquafel), will represent the preponderance of mica in this mineral aggregation, and the structure will be represented by an appropriate adjective, as *foliated mìfelqua*, or *schistose mìquafel* or *mìquafel schist*, as the case may be.

But the mere indication that the granite is composed of quartz, feldspar, and mica, may be quite too general for precise discussion, since it does not indicate which feldspar, nor which mica, nor whether more than one of either or of both is present. The more precise of the text-book definitions of granite rarely go beyond the statement that it is composed of quartz, orthoclase and mica. If this is the degree of precision chosen to be asserted, the new terms will be, *qu'-orth-mi (quòrthmi)*, *or-tho-qua-mi (orthòquami)*, *mic-ortho-qua (micòrthoqua)*, *qua-mic-orth (quàmicorth)*, *ortho-mi-qua (orthòmiqua)*, or *mi-qu'orth (miquòrth)*, according as the relative proportions may be. But the mica, instead of being common *muscovite*, which would doubtless be understood by the general term, may be *biotite*. In this case the names will be, *qu'ortho-bio (quorthòbio)*, *ortho-qua-bio (orthoquàbio)*, *bi-ortho-qua (biòrthoqua)*, and so on, according to the relative proportions.

If, as is occasionally the case, there are four or more constituents, the names will assume uncomfortable complexity, but not more so than Nature's products which they represent, nor more so than some far less significant terms now in use. By modifications of the abbreviations which will not destroy their distinctive, representative character, difficult vocal combinations may, for the most part, be avoided, and euphonious terms secured.

The system, it will be observed, is quite analogous to that adopted by chemists, to meet the complexities of carbon compounds, but will rarely need to approach it in cumbersome combinations.

The foregoing perhaps sufficiently illustrate the method of the system, its extreme flexibility, and consequent adaptability to the variations of rock combination, the self-definitiveness of the terms, and their mnemonic advantages with students, as well as, on the other hand, something of the cumbersome complexity and quaintness which will sometimes arise where exact nomenclature is attempted.

In the following lists no attempt is made to exhibit the complete variations under the several rocks, but simply to give the names under the two systems, assuming, usually, that the common order of naming the ingredients is that of their relative abundance. The verbal combinations that would arise with other proportions and other rocks can be readily constructed.

Old Names.	*Proposed Names.*
Granite (general)	Fel-qua-mi, qua-fel-mi, etc.
Granite (specific)	Ortho-qua-musc, qu'ortho-musc, etc.
	Ortho-qua-bio, qu'ortho-bio, etc.
Granulite	Fel-qua or qua-fel.
Gneiss (general)	Foliated mi-qua-fel, fel-mi-qua, qua-mi-fel, etc.
Gneiss (specific)	Foliated musc-ortho-qua, ortho-mus-qua, qua-musc-orth, etc.
	Foliated bi-ortho-qua, Ortho-bio-qua, qua-bi-orth, etc.
Mica schist (general)	Schistose mi-fel-qua, mi-qua-fel, mi-qua, mi-fel, etc., or mi-fel schist, mi-qua schist, or simply mica schist.
Mica schist (specific)	Schistose musc-ortho-qua, bi-ortho-qua, etc.
Hydromica schist (general)	Schistose hydromi-qua-fel, hydromi-qua, hydromi-fel, etc.
Sericite schist (specific)	Sericite schist, schistose seri-qua, or seri-qua schist.
Protogine	Qu'orth-mi-chlor.
Greisen (general)	Granular qua-mi.
Felsite	Felsit.
Quartz-felsite (general)	Felsi-qua.
Kersantite (specific)	Bi-olig.
Syenite (general)	Fel-amph, or amphi-fel.
Syenite (specific)	Ortho-horn, or horn-orth.
Quartz syenite (general)	Fel-amphi-qua, amphi-fel-qua, etc.
Quartz syenite (specific)	Ortho-horn-qua, horn-ortho-qua, etc.
Syenite gneiss	Foliated ortho-horn, or horn-orth.
Diorite (general)	Plagi-amph or amphi-plag.
Diorite (specific)	Labra-horn, oligo-horn, anortho-horn, etc.
Quartz diorite (general)	Plagi-amphi-qua, amphi-plagi-qua, etc.
Quartz diorite (specific)	Labra-horn-qua, oligo-horn-qua, etc.
Andesite	Ande-horn or andesite.
Gabbro	Labra-dial or dial-lab.
Dolerite or diabase (general)	Plagi-pyr or pyro-plag.
Dolerite or diabase (specific)	Labrad-aug, olig-aug, anorth-aug, etc.

In pronunciation, the accent should be placed upon such syllables as will best preserve the original sounds of the abbreviations, so far as convenience of utterance will permit.

Since a gradual transition, advantageous at all stages, is to be preferred to a sudden revolution, it is suggested that the new terms may be introduced in lithological discussions in parentheses after the common names. The new terms will thereby not only serve as definitions of the old, as used, but as succinct statements of the composition of the special rocks described, which is often but vaguely indicated by the common names. This will often permit a shortening of descriptions, and will certainly foster precision of observation and statement, while (if a brief explanation of the system and a list of abbreviations are given until they become well known) it will greatly serve the convenience of students, semi-scientific readers, and not a few geologists who may not be specialists in lithology, and not freshly familiar with its drifting terms. The system would thus have opportunity to perfect itself while growing into general use.

APPENDIX—DEFINITIONS.

An attempt has been made to render most of the terms employed in the body of this volume intelligible to non-professional readers by the connection in which they are used, deeming this the most convenient and serviceable method of definition. It may be helpful to students, however, to introduce here a few definitions of the more important special terms used.

Metamorphism *(Change of form).* This term, in its widest sense, is applicable to any *change of form* which a rock undergoes subsequent to its original formation. It is usually, however, confined to the change of ordinary sedimentary rock into the corresponding crystalline rock, as the change of common limestone into statuary marble, of sandstone into quartzite, of clayey sandstone and sandy shales into gneisses, mica schist, etc., of the more basic clays into hornblendic and allied rocks, and similar changes in other varieties of sedimentary deposits. These changes when they affect large areas are held to be the result of the combined action of (1) heat, (2) pressure, and (3) water, more or less mineralized with earthy and alkaline salts. Of these, *pressure* may be regarded as the determining circumstance, since water is universally present in the strata, and heat is generated by pressure, so that, given the necessary pressure, the remaining conditions would everywhere be found present.

The degree of metamorphic change varies greatly in different instances and in that way exhibits all stages of the process. In some instances the granules, pebbles, ripple marks, lamination and fossils of the original sedimentary beds remain undestroyed, and there is no room for doubt as to the previous character of the formation. In other instances these have been obliterated by the more complete crystallization which has taken place, but the main bedding lines and the coarser features of the original stratification still remain to indicate its previous character. In some instances a foliated or slaty structure has been produced by the pressure, and this, instead of the original sedimentary lines, determines the cleavage of the rock. In a still higher degree of metamorphism, the original bedding which sediments naturally take has entirely disappeared, but each great stratum of rock remains distinct from the adjacent ones. In the last degree of metamorphism the whole of the original sedimentary structure is destroyed, and the mass of the rock is changed into a homogeneous crystalline formation, such as the massive granites, syenites, etc., some, at least, of which are probably of metamorphic origin.

Local metamorphism, producing results very similar to general metamorphism, is sometimes observed adjacent to intruded masses of igneous rock, and is undoubtedly due to heat derived from the intrusion and is apparently not due to any exceptional pressure. At great depths metamorphism may perhaps take place through the agency of intense heat aided by the gravity-pressure of the overlying rock. This has even been maintained to be the explanation of general metamorphism, a view in which we do not coincide, since general metamorphism is almost universally associated with independent evidences of horizontal pressure manifesting itself in the folding, crumpling and compacting of the strata.

Metasomatosis *(Change of body).* There is another class of metamorphic changes to which, however, the unmodified term is not usually applied, and for which no special term is in common use. The terms "metasomatosis" and "methylosis," signifying *change of body* and *change of substance*, in distinction from metamorphosis, signifying change of form, have been proposed, and to a limited extent used. The changes embraced under these terms are those in which the substance of the rock is affected, with or without the change of its form. Familiar instances of metasomatic changes are found in the "petrifaction" of wood, or the "silicification" of fossils, where the original substance is removed particle by particle and a new substance deposited in its place. In this way there may be an entire change of composition, while the form remains unaltered. In other and more common instances partial changes of substance only take place. The complex silicated rocks have almost universally been modified in some degree by water, bearing free oxygen, carbonic acid and various substances in solution. These are for the greater part slow changes that have been constantly in progress from the earliest ages and are still in activity. A special case under this head is **Pseudomorphism.** This term is applied to those cases in which a *false form* is produced by the change of one mineral into another, or the replacement of one by another, particle by particle, without in either case destroying the original form. This term is strictly applicable to minerals rather than to rocks, but where a large mass of a formation is changed in this way, it amounts to a pseudomorphism of the rock.

Terrane. It is often convenient to speak of a continuous series of rocks of a region in a general compendious way, especially in the case of igneous and complex metamorphic rocks, or confused intermixtures of these, and the term *terrane* is sometimes used to designate such a series.

Dikes. Rocks are sometimes fractured and pushed apart by molten rock forced up from below, which on cooling forms vertical sheets intersecting the strata and known as *dikes.* In brief, they may be said to be *the igneous filling of fissures.* These are usually only a few feet in thickness, but are sometimes a hundred feet or more.

Veins. When fissures are either entirely or partially filled by material deposited by infiltrating waters or from a vaporous state, such formations are termed *veins.* The term is, however, somewhat loosely applied to any belt of rock that is specially mineralized, particularly if it is metalliferous. *Gangue* is the name applied to the spars and other rock-like constituents of a vein in which ore is deposited.

Beach Structure. The varying strength and constantly shifting action of waves on exposed beaches gives rise to very uneven deposits, consisting of irregularly alternating layers of material, of various degrees of coarseness, stratified in various oblique directions. The deposits are often partially worn away, after being made, by the changes in the strength and direction of the waves, and so the layers are frequently cut off and new ones laid against them in different attitudes, forming *cross* or *discordant lamination.* Some special forms, as the *ebb and flow structure,* produced by tides, and the *flow and plunge structure,* produced by violent wave action, are distinguished.

Ripple Marks are the little ridgelets formed in sand or mud by the action of waves on beaches and shallow bottoms. They are, therefore, proof of the sedimentary origin of the rocks on which they occur, not only, but show also that the deposition took place in comparatively shallow water.

Rill Marks. Rills, especially those following outgoing tides, furrow the sand or mud, particularly in flowing over a pebble, shell or other obstruction. Such grooves where preserved constitute *rill marks.*

Mud Cracks. Rocks made of clayey or earthy material sometimes show markings precisely similar to cracks in common mud, save that the cracks are filled. They indicate that the deposit took place as a mud flat, at times exposed to drying and again buried. They were probably usually estuary bottoms alternately covered and exposed by the tides.

Dip. Strata are rarely exactly horizontal. The degree in which they slope in any direction is termed their *dip*.

Strike. The trend of strata, i. e. the direction of their horizontal edges, or of a horizontal line in them, is termed the *strike*. It is always at right angles with the line of dip.

Anticlines. Synclines. If strata are folded upwards so as to *dip in opposite directions*, an *anticlinal axis* or *anticline* is formed. Similarly, a downward fold, causing the beds to *dip toward each other*, gives rise to a *synclinal axis* or *syncline*.

Unconformity. If strata, after being formed, are tilted and exposed so that a portion is worn away, and, subsequently, other beds are laid down upon or against them, the latter usually have a different dip and are said to be *unconformable*.

Faults. Strata are sometimes deeply fractured and one side is depressed or raised, so that different beds lie opposite each other. Such displacements are called *faults*.

HISTORICAL GEOLOGY.

CHAPTER III.

PRE-LAURENTIAN HISTORY.

The Foundation. The natural masonry of Wisconsin is laid on a granitic foundation. The lowest accessible rocks constitute the "fundamental gneiss" of the older geologists. Upon this hard and firm foundation, the other known rock series of the State are piled. Layer upon layer the rocky architecture of the State was built upon it. Our task is the narration of its building.

The Oldest Known Rocks. In stricter geological terms, this "fundamental gneiss" consists of an immense series of granites, gneisses, syenites, and hornblendic, micaceous, chloritic and allied crystalline rocks. It is not "fundamental" in the sense of being primitive; for these rocks bear within themselves decisive evidence that they were once sediments, derived from the wear of earlier rocks. But concerning these earlier rocks, observation has, as yet, given us no positive knowledge. Nowhere are they known to be exposed at the surface. Whether they belong to the supposed original crust of the earth, or whether they were themselves derived by waste and wear from still older rocks, is at present wholly unknown. But we confidently reason, that, tracing the series backward, whether through one or more stages, we should at length arrive at the primitive surface of the great earth-mass. For, while it may not be strictly demonstrable, yet it is the current belief of geologists and physicists, that the entire rock-substance of the earth was once in a molten condition, and that on cooling, it solidified, giving rise to a primitive rock from which the greater portion of the sediments of all subsequent geological formations was derived, through the simple and familiar agencies of atmospheric disintegration, and the wash, wear and solvent action of water.

There is no trustworthy evidence that any accessible portion of the earth's present surface belongs to this primitive crust, and the failure of continued exploration to discover it leaves only a waning hope that it will ever be found. Could we but place ourselves upon it, and sketch thence geological growth through the ages, we might well content ourselves with so firm and rational a beginning, and leave the earlier history of the globe to the astronomer and physicist.

Hypothetical Early History. But the insatiable spirit of human inquiry is forever pushing thought beyond the clear and safe realm of known truth into the mists and uncertainties of a doubtful antiquity. We may yield to this prompting so far as to briefly sketch, for the young student, the more rational views concerning those earlier stages of the earth's history, which, confessedly, lie beyond the domain of strict science. Let it, therefore, not be forgotten that it is a sketch of belief, rather than of knowledge.

Facts Significant of the Earth's Origin. But rational belief as much demands evidence as knowledge does demonstration. Any theory worthy of acceptance, even as a theory, must be justified by the facts the earth presents. Now our globe offers a series of facts so significant that it does not leave belief much room to wander. The oblateness of the sphere; its internal heat and volcanic phenomena; the upheaval of mountain ranges and continents; the subsidence of ocean basins; the breaking, faulting, folding, compacting, crushing and metamorphism of strata, all must be embraced, potentially, in the supposed condition of the early earth. Even the familiar facts of rotation and revolution, which, at first thought, because they are so familiar and so primal to our usual conceptions of things, may not seem to teach anything concerning the original condition of the earth, are yet, if critically questioned, able to render us instructive answers.

Significance of Rotation. It is now quite generally believed that the rotation of the earth has not been uniform in rate throughout the earth's history, because there is found to be an agency in constant operation tending to reduce its rate. The friction of the tides, raised by the moon and sun, acts as a brake upon the rotating earth, and, while the effect of this in any limited measure of time is small, the accumulated effects, in the vast lapse of the earth's duration, are very important. Mr. Geo. H. Darwin has recently computed that the earth once rotated in from two to four hours. While it may yet be too early, in the progress of this new line of investigation, to accept with much confidence specific results, the general fact of more rapid rotation at a former time is worthy of belief.

But whence came this once more rapid rotation? An assignable cause is found in the earth's contraction, since the shrinking of a rotating mass hastens its speed. That contraction has actually taken place seems to be clearly indicated by geological evidence. Immense subsidences of the crust, measured by tens of thousands of feet, have occurred. Certain belts have been folded into immense wrinkles,—the mountain ranges of the earth. Gentle movements of the earth's crust have been almost constantly in progress throughout geological history. These, and attendant phenomena, are thought to be evidences of a contracting sphere. But the effect of the earth's contraction in recent geological ages is computed to be less in accelerating its rotation, than that of the tides in retarding it, and hence if the former more rapid rotation were due to contraction, it must have been relatively more efficient in those days. This would be true if the earth were then shrinking from a much hotter, and more expanded condition, especially if at that time the moon were, as supposed, a part of the earth, when of course the retarding lunar tides would be wanting. To account in full for the extraordinarily rapid rotation which these recent investigations make probable, it would appear necessary to suppose that, in a still earlier period, the matter of the earth was in a highly expanded and diffused condition. Thus we are led back along one of several lines of thought to views which postulate a highly dispersed state of matter in the early ages.

Conjectured Early Condition of the Earth's Matter. Pushing this line of thought onward, it has been conjectured that the matter of the earth and the solar system, and perhaps of the known material universe, was, at an early stage, in an elementary, gaseous condition. But modern thought is not content to rest even here. Several investigators, notably Prof. Lockyer, have recently assigned definite reasons for believing that the so-called elements, as now known, are not really atomic in the ultimate sense, but are compounds of matter still more elementary.[1] This suggests the still more extreme view that the matter of our system may once have existed in a state even more elementary than any substance now known to us. We are thus led back by scientific speculation to a supposed primeval state of matter quite as formless and void as the chaos of oriental cosmogonies.

The Testimony of the Heavens. But this is not simple speculation. If we turn to the heavens, we may find light in their light. The heavenly bodies differ in the color and character of their radiance. In the light of the whitest, and, therefore, probably hottest stars, the spectroscope reveals mainly hydrogen, the rarest, and seemingly the most elementary of all known substances. In the less brilliant,

[1] Comptes Rendus, Dec., 1873, and Hunt, Am. Jour. Sci. Feb., 1882, p. 123.

and, therefore, probably cooler stars, there are indications of the presence of the more stable metals, as magnesium, calcium, sodium and iron. Still cooler ones are thought to be indicated by the appearance of other metals and metalloids and compounds, while in the red stars there are indications that the metallic vapors have entered into combination. The stars, therefore, seem to present a progressive chemical complexity, corresponding to their temperatures.

In other respects also celestial bodies offer suggestive analogies. Certain of the nebulæ are vast attenuated masses of glowing gas. Others have a condensed center, surrounded by a gaseous envelope of vast extent. Still others have less envelope and more nucleus, leading on to the class in which the nucleus becomes greatly predominant, and the envelope less important. Our own sun may be named here as an example of a great mass of matter concentrated in the orb itself, but with a vast glowing atmosphere still surrounding it.

Recent observations indicate that Jupiter and Saturn represent a further stage of condensation, in that they consist of a hot central mass surrounded by an extensive, vaporous, hot, but not incandescent atmosphere.[1] In the Earth and Mars we have examples of cool, solid globes, surrounded by cool, gaseous atmospheres. The moon represents a still more extreme stage of condensation, in which the entire visible mass is solid, and, if it ever had any sensible atmosphere, it has entered into combination with its substance or been absorbed into its interior. In brief, the heavens present bodies in all stages of concentration, from solid spheres to vast irregular masses of attenuated gas, and seem to afford examples of forming worlds in all essential stages of development.

So far as the spectroscope reveals the chemical constitution of these bodies, they contain the same elements as are found in the earth, with perhaps rare exceptions, and this fact favors the view of their unity of origin.

Even from the solar system itself a remarkable array of facts may be gathered from the size, position, densities and movements of the bodies composing it — notably the rings of Saturn and the peculiarities of the satellites and asteroids — pointing to an evolution from a common mother-mass. But we cannot enter upon the wide field of details which here opens.

Evidence from Meteorites. Along still another line of thought we are likewise led to a belief in the growth of the earth from disseminated celestial matter. We are familiar with the fall of "shooting

[1] This want of incandescence is only to be understood of the external portion.

stars," little particles of celestial matter, that, in their fall, strike the atmosphere of the earth with such velocity that they ignite, and are dissipated in its upper regions. But their dust at length settles to the ground. The earth daily gathers in several millions of these little particles. Occasionally a larger mass is encountered which descends bodily to the earth and tells us something of the matter circulating in space. Among all that have been examined no element has yet been found which does not exist in the earth, and, what is more interesting and significant, several of these elements are compounded into minerals like those of the earth, such as augite, anorthite, olivine, magnetite, pyrrhotite, enstatite, and chromite. Some, however, differ from any known terrestial compounds.

It is to be noticed that these are minerals which commonly enter into the constitution of our igneous rocks, and such as are supposed to abound in the original crust of the earth. The existence of metallic iron alloyed with nickel, was once supposed to distinguish meteorites from all combinations native to the earth. But nickeliferous iron, associated with magnetite, olivine, augite and feldspar, as in meteorites, has recently been found in the igneous rocks of Ovifak, on the island of Disko, off Greenland.[1] A large specimen of this, brought away by Nordenskjold, may be seen at the National Museum, Washington.

Metallic iron in microscopic particles has also been found in the basalts of the British Isles.

While there are a few compounds in meteorites not yet found among terrestial rocks, yet their general similarity to the more profound volcanic ejections is very striking and suggestive.

Now, as already stated, counting great and small, the earth is gathering in daily several millions of these celestial particles,— the "star dust" of space. It is more than probable that it has done so in all past ages, and in progressively increasing quantity, for with every sweep of the heavens fewer remain, and hence fewer can thereafter be gathered; so that, while the present growth from this source is exceedingly small, it was doubtless much greater in the past. This has even been conceived to be the main mode by which the planet has gathered in its substance.[2] This view, like the preceding, points to an original condition of highly scattered, if not extremely attenuated matter, for the meteorites must be supposed to have gathered in a similar way, from more widely disseminated matter, and, ultimately, from the gaseous state.

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[1] Judd: International Scientific Series; Volcanoes, pp. 318, 319.

[2] Proctor, Tribune extra, 18. Also "Other Worlds than Ours."

Without dwelling longer upon the several lines of evidence, the adequate discussion of which would vastly transcend our limits, we may assume as highly probable, the conditions to which they all seem to point,—that the matter of our solar system was, at a remote period, in an extremely rarefied condition. We will make this the starting point of the conjectural portion of our history.

Nebulous Stage.

Conceive all the matter of the present solar system to be expanded into its extreme gaseous condition, and to swell thereby into a mass of gas, stretching far beyond its present outermost limits, and you have the favorite conception of the primal condition of our planetary system. Beyond this there may have been an ultra-elemental or even ultra-luminous stage. But, if there were sufficient ground for conjecturing this, which perhaps there is not at present, it would not satisfy the insatiable questionings of the mind, which would still ask, What was anterior to that? To this, from the standpoint of material philosophy, whatever belief may spring from other considerations, we give no answer, not even a conjecture. We have already gone to the very extreme of hypothesis. Indeed, we have trod far beyond the safe ground of well supported theory.

Origin of Rotation. By combination and the radiation of heat into space, this nebulous mass must needs contract. Now, if it were originally stationary, and a perfect sphere, absolutely uniform in structure and density throughout, and were entirely unaffected by external influences, or if these influences were precisely alike and uniform on every side, then the mass might simply shrink without any tendency to turn. But if there were the slightest unbalanced inequality in any of these conditions, a corresponding tendency to rotation in some direction would be the result. The probabilities are so infinitely great as to make it well-nigh certain that this would happen. When once rotation is started, further contraction would tend to increase it, according to well-known physical principles, and the mass must have gone on rotating more and more rapidly as the cooling and shrinking progressed. The origin of rotation is thus accounted for under the Nebular Hypothesis, commonly attributed to the celebrated mathematician Laplace, though previously suggested in cruder form, by others.

If, however, it is deemed more rational to conceive of the earlier stage as that of "star dust" rather than "fire mist," or, in other terms, if we imagine all the matter of our system to have been in a state similar to the fine particles which the earth nightly and daily gathers in as "shooting stars," and even if we suppose this matter to have been without definite rotation and revolution, to have been, indeed, quite chaotic — still, unless it were scattered with absolute uniformity throughout space, under conditions of perfect equilibrium, its attractive forces must, sooner or later, have caused it to collect, and unless the lines of convergence were absolutely balanced, the collecting mass must have turned upon its center, and rotation have been inaugurated. The further the ingathering proceeded, the more rapid would the rotation become. Thus, as in the previous case, rotation seems to be the almost necessary result of the concentration of matter under the varied conditions that characterized the early stages of our universe.

Formation of Planets. But it is maintained under the Nebular Hypothesis, that when the increase in the rate of rotation reached a certain stage, the centrifugal force of the outer equatorial portion would become greater than its gravitating force, when it would necessarily separate from the remainder of the mass. This separated portion, whether in the form of a ring, as Laplace supposed, or otherwise, is assumed to have condensed, like the original body, and for a like reason to have become a rotating sphere, i. e., a planet. The original mass meanwhile continued to contract, and to discharge at intervals other masses from its exterior, which, in turn, condensed into planets. Some of the planets thus formed threw off (it is supposed) from themselves masses, which became their satellites. The residual portion of the original whole is supposed to be found in our sun, still hot and condensing. The meteorites and the comets of the solar system may be conceived to be miniature planets, or portions separated from the original mass, not yet ingathered, in the process of accretion. Some wandering masses may have been derived from regions beyond the limits of the original solar system, as, perhaps, certain comets.

The essential features of the above outline seem to be largely true, whether the process of formation be mainly a condensation from a gaseous condition, as set forth by the Nebular Hypothesis, or whether it be a growth by accretion from disseminated meteoric matter, or whether (a view to which we incline) a combination of the two processes. Under either hypothesis, the newly formed earth must have been hot. If formed by the condensation of hot gases, it is believed to have been at first a glowing sun, with an intensely heated core, surrounded by an immense, incandescent atmosphere. As cooling and condensation progressed, the core increased and the atmosphere diminished, until there developed an earth and an atmosphere analogous to that we now know.

In so far as the growth was accomplished by the accretion of meteoric matter, the heat generated by the ingathering masses would raise the temperature of the whole. Just as the impact of every little meteorite now arriving fires it into a "shooting star," and just as every aerolite comes to the earth a glowing ball, and just as in the great meteoric showers the heavens are ablaze with darts of fire, so in the immensely greater meteoric ingathering, which, according to the accretion hypothesis, constituted the early growth of the planet, there must have been a still more fiery display, resulting in a heated earth. Combine the two processes, nebular condensation and meteoric accretion, and picture their joint fiery results, and you have the conception which best satisfies the rational imagination, as we view it. It may long remain impossible to determine the relative parts performed by gaseous condensation and mechanical accretion, and it is more than likely that our best views of both combined fall far short of an adequate conception of the real history of the earth's growth.

Liquid Stage.

But, pursuing either course of thought, we emerge somewhat from the mists of uncertainty when we picture the earth as a molten mass, surrounded by an immense heated atmosphere, and attempt to trace its consolidation into the more stable stage in which we now find it. This may be said to constitute the second great stage of its history.

Condition of the Earth's Interior. It was formerly very widely believed that in the progress of cooling a crust formed over the molten globe, which thickened as solidification proceeded, leaving a molten interior, which was believed yet to exist, and to give origin to volcanic ejections and the other evidences of internal heat of the present day. But physicists and astronomers, attacking the problem from their appropriate fields, have greatly weakened the confidence formerly reposed in this seemingly rational hypothesis. They have insisted, that, to satisfy the conditions of astronomical and physical phenomena, the earth must possess a rigidity greater than is compatible with such a structure, and that, further, owing to the intense pressure to which the interior was subjected, it must have been reduced to a solid condition, notwithstanding its high temperature.

Furthermore, geologists, by a more critical examination of volcanic ejections, have arrived at conclusions adverse to their origin from a liquid interior. At the first flash of thought, the two or three hundred large, active volcanoes, and the thousands of extinct ones, scattered over the face of the earth, seem to point quite explicitly to a molten interior. But when, on critical examination, it is found that they eject different kinds of matter at different stages, that adjacent volcanoes may, at the same time, be giving forth very different material, and especially that the liquid matter, in neighboring vents, may stand at heights differing by hundreds, and even by thousands of feet, it seems an almost necessary conclusion that volcanoes do not have their origin in a common liquid reservoir. Other evidences may be deduced in support of the same conclusion.[1]

Restraining ourselves to these mere hints as to the lines of argument, we may pass the subject with the statement that the recent tendency of scientific opinion has been toward the theory of an essentially solid interior.

It is quite likely that the true view is not correctly represented either by the notion of a solid or of a molten mass, as those terms are commonly understood, but rather by the peculiar state of a solid under great pressure. It is a well known fact that solid bodies, under great pressure, yield, by flowing like a liquid or plastic body. A familiar instance is found in the punching of holes in steel plates. A part of the steel flows laterally and only a part is punched out, the amount of steel in the core never equaling that displaced by the punch. That the interior of the earth is yielding and plastic, the phenomena of geology seem to quite clearly indicate, but the plasticity may be of the nature of a solid under pressure, rather than that of a liquid due to temperature.

None of these views, however, militate against the theory of the former molten condition of the earth, or of its igneous, and ultimately, nebulous origin.

Character of the Primitive Crust. It is a question of some theoretical interest and importance to determine what was the nature of the primitive crust of the earth, using that term, as is commonly done, for convenience, to express the original outer layer, without

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[1] The student will find valuable discussions of this and kindred themes in the Geological Exploration of the Fortieth Parallel, Vol. I, by Clarence King; in the Geology of the High Plateaus, by C. E. Dutton; in Richthofen's Memoir on The Natural System of Volcanic Rocks; in Volcanoes (International Scientific Series), by J. W. Judd, and in Dana's Manual, pp. 716, 808.

regard to whether the interior is in a liquid, solid, or pressure-plastic condition.

As already stated there is no sufficient reason for believing that any portion of the present surface of the earth, that has been geologically investigated, belongs to this primitive crust, and there is but faint hope that any such portion will ever be found, or at least, if found, can be demonstrated to be such. We are, therefore, limited to theoretical considerations, and can now only hope, at best, to arrive at probable, not demonstrative conclusions. The question may be approached along four lines of argument, but as these necessarily involve knowledge in advance of our discussion, they are thrown into smaller type and may be passed over.

1. *Arrangement of the Material in the Molten Sphere.* First, and perhaps weakest, we may speculate as to the arrangement of material that would naturally be assumed in a molten earth-sphere. The earth has been weighed, so to speak, by different processes, and found to be, on the average, five and one half times as heavy as water. But the surface rocks have an average weight only about two and one half or three times that of water, and hence it appears that the exterior of the earth is only about one half as heavy as the average of the whole. It is hence very much lighter than the densest central portion. A part of the increase of specific gravity in the interior is doubtless due to the density produced by the enormous pressure to which it is subjected by the weight of the overlying rocks. But it is scarcely credible that the whole of it is to be attributed to this cause. There are independent reasons, and some little direct evidence, for believing that the interior is composed of different, and inherently heavier materials than the crust. In the earth's supposed condensation from a nebulous condition, and in its passage through the molten state, it is rational to assume that the heavier materials would collect at the center, while the lighter would be arranged, in the order of specific gravity, around them, and hence that the superficial crust would be formed of the lightest class of material then forming the molten sphere.

Since among volcanic rocks the lightest are the acidic, or highly silicious class, it has been suggested, with seeming plausibility, that the outer original shell would consist of such material, and the heavier basic rocks would be arranged below, while the deeper interior parts were perhaps largely metallic.[1]

But it is by no means certain or even probable that the volcanic rocks have all been derived from the primitive crust, and it may be doubted whether, in the original condition, acidic rock-substance would be formed in the presence of so much basic material as the high specific gravity of the earth seems to imply, and as the alkalies and alkaline earths of the sedimentary series more surely indicate.

2. *Igneous Ejections.* In appealing to the character of volcanic rocks, however, we enter upon the second line of approach to the problem. It might, at first thought, seem that igneous ejections would throw clear light on the question. It has been suggested that the ejections, which took place while the crust was yet thin, would reveal the character of the superficial portion, and that the later ejections, springing from deeper sources, would disclose the nature of the lower

[1] Durocher; Haughton's Manual of Geology.

layers. This view was quite plausible under the former theory of a continually thickening crust over a liquid interior, from which the ejections were supposed to arise. But according to the later views of the local origin of lavas from the liquefaction of rock within the superficial crust, such conclusions lose much of their apparent force. The testimony of critical investigation, particularly observations on the source of the earthquake tremors preceding eruptions, indicates that volcanic action is not very deep-seated.

"Mr. Mallet has shown that by the careful study of the effects produced at the surface by earthquake-vibrations, we may determine with considerable accuracy the point at which the shock or concussion occurred which gave rise to the vibration. Now, it is a most remarkable fact that such calculations have led to the conclusion that, so far as is at present known, earthquake shocks never originate at greater depths than thirty miles from the surface, and that in some cases, the focus from which the waves of elastic compression, producing an earthquake, proceed, is only at a depth of seven or eight miles. As we have already seen, there can be no doubt that, in the great majority of instances, the forces originating earthquake-vibrations and volcanic outbursts are the same, and independent lines of reasoning have conducted us to the conclusion that these forces operate at very moderate distances from the earth's surface."[1]

Source of Volcanic Material. Now the question whether the liquefaction, which is assumed to furnish the material of volcanic ejection, will take place within the original crust, or in the sedimentary beds above, or in both, is not easily determined. The assumption that the earlier ejections are most likely to represent any certain portion of the original mass, while the later represent a different horizon, is by no means sustained on critical examination. For if the local liquefaction is a function of depth, or the source of eruption otherwise dependent on depth, the thickness of sedimentary beds overlying the original crust will be an important factor in the problem. If it is dependent on pressure or its relief, the same will be true, for the radial pressure due to simple gravitation will depend largely upon the accumulation of sediments, and tangential pressure, supposed to be due to shrinking as the result of secular cooling, has, throughout geological history, shown a disposition to manifest itself most powerfully at the points of thickest sedimentation. It is, therefore, apparent that the special stratigraphical situation of any igneous eruption must be studied to determine its probable source, and that the simple fact of age is no trustworthy guide.

Earliest Intrusive Rocks. Now the earliest intrusive rocks of which we have any knowledge are those that invaded the great Laurentian formation. It is quite certain that some of these were forced through the Laurentian series after it was compressed and folded into essentially its present form, for the dikes traverse the folds directly, and have not suffered distortion with them, as would necessarily have been the case if they had been injected before the Laurentian revolution. No demonstrably igneous rocks of earlier date can now be appealed to. The intrusions of the Laurentian period are partly of the granitic, i. e., acidic class, and partly of the basaltic or basic order, with intermediate grades; but until discrimination between metamorphic and igneous rocks shall be more successfully made, and until the Laurentian areas are more thoroughly and critically studied in the interest of such discriminations, it will be impossible to arrive at any trustworthy estimate of the relative prevalence of the two classes.

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[1] J. W. Judd, Volcanoes.

But these ejections occurred when the original crust was overlain by the Laurentian series, and such other sedimentary accumulations as may lie beneath, the amount of which is wholly unknown. The Canadian geologists have estimated the known portion of the Laurentian series at 30,000 feet, with an unmeasured portion below; but a part of this is probably Huronian. In our own region the extreme folding and distortion of the beds prevent trustworthy measurements, but the full Canadian estimate seems a moderate one. But the stratigraphical thickness by no means represents the vertical depth, in the compacted and folded condition of the strata, for it is the *height of the vertical folds*, rather than the thickness of the stratum, that determines the vertical depth.

Now it is quite certain that, at the close of the Laurentian revolution, the folds were of gigantic dimensions, and hence the underlying crust was surmounted by an enormous mass of rock; for it is to be borne in mind that the present Laurentian areas are those in which this primitive compacting and folding took place, and we nowhere have access to the undisturbed, horizontal beds. If the height of the folds were three times the thickness of the folded strata, the vertical depth of the sedimentary aggregation would probably exceed the greatest depth from which volcanic tremors are known to originate. Now it is apparent, upon a moment's consideration, that the earliest eruptions that followed the Laurentian revolution penetrated a greater thickness of overlying rocks than any subsquent ones *in that region*, for denudation has been ceaselessly engaged since that time in cutting them away, and thicknesses to be estimated in miles have been removed.

If, for illustration, it be supposed that eruptions take place from a uniform depth, then it is manifest that an eruption taking place to-day, within the Laurentian area, would spring from a horizon many thousands of feet lower than the eruptions of the Archæan ages, and hence it is more probable that the early extrusions of Archæan areas arose from melted sediments, than the later ones. In other regions quite different results might be reached from a consideration of the special circumstances of eruption, but it is doubtful whether, in any instance, eruptions could be more plausibly attributed to melted sediments than those which followed the Laurentian upheaval. It seems quite possible to suppose, therefore, that from Laurentian times onward, igneous rocks may have arisen from the melting of sediments, and that the presumption of such an origin is quite as defensible in earlier as in later periods.

Tertiary and Mesozoic Eruptive Rocks. If we consider volcanic products in another aspect, however, grave objections will arise to the belief that they have sprung from the original crust of the earth. In the primitive molten mass the material was probably essentially homogeneous except so far as arranged in layers by gravity. It, therefore, follows that any remelted portion, unless the liquefaction had a very considerable vertical extent, would be homogeneous. But observation has shown that in areas of great volcanic action, the successive ejections are widely diverse. In the case of the great Tertiary eruptions, Richthofen, King, Dutton and others[1] have shown a most remarkable law of succession, which is, in brief, that the earliest eruptions were of a character intermediate between the pronounced acidic and basic types, while those of the middle stage were acidic, and those of the last, basic. But in the earliest great

[1] Richthofen, Memoir on the Natural System of Volcanic Rocks; King, Geological Explorations of the Fortieth Parallel; Dutton, Geology of the High Plateaus.

consecutive series of eruptions with which we are familiar, viz.: that of Lake Superior, we find acidic rocks intercalated at intervals between immense basic flows, while the intermediate class of lavas are distributed in a similar irregular manner. (Irving.) Taken as a whole, however, the basic rocks immensely predominate.

The Mesozoic eruptions of the Atlantic border are perhaps the nearest approach to a homogeneous product exhibited upon the American continent, presenting as they do a remarkable uniformity of character. These are diabases very similar to the prevalent rock of the Lake Superior series.

Comparing these great series of eruptions, and assuming that they originated at equal distances below the surface, it is probable that the Mesozoic traps of the Atlantic border came from a lower geological horizon than the much earlier eruptions of Lake Superior; for in the latter instance, there lay over the original crust not only the Laurentian series and such sedimentary beds as may lie beneath, but the Huronian series, and the rocks of the intermediate interval, minus only the denudation of Archæan time; while in the Atlantic border region the gneissoid series, through which the eruptions in large part took place, is probably Laurentian, and had suffered in addition to the denudation of Archæan times, that of the whole Palæozoic age, and that of the earlier Mesozoic. The immense thickness of the Palæozoic sediments of the Appalachian system indicates that the denudation was very great, and hence the surface was presumably cut down nearer to the original crust.

Comparing the Mesozoic with the western Tertiary eruptions, it is to be observed, that, while the loss of Archæan sediments in the latter region might have been equal to that of the former, there had been added the Mesozoic and earlier Tertiary accumulations.

The phenomena of these great eruptive series may be satisfied by supposing that the Mesozoic traps of the Atlantic border came from the original crust of the earth, and that, by reason of its uniformity of composition, no essential difference is to be observed between the successive ejections, nor between those situated hundreds of miles apart. The Keweenawan eruptions of Lake Superior may be assumed to have come from the uppermost portion of the original crust, and to have involved at intervals the overlying silicious sediments, the whole resulting in an enormous series of basaltic outpourings, with a few intercalated flows of acidic and neutral matter, while the Tertiary series of the west may have been derived from the earliest metamorphic sediments, whose composition varies, as illustrated by the Laurentian group, but is predominantly acidic. From this material might be derived the vast acidic lava-flows of the west, with the somewhat less abundant neutral and basic ejections, described by King and Dutton. The hypothesis of the latter seems competent to account for the order of ejection.

The conclusion derived from this uncertain line of reasoning is, that the crust was most probably formed of basic material, of a type not far removed from the Archæan and Mesozoic diabases. It is manifest that this line of reasoning has many points of weakness, and that the conclusion to which it leads is entitled to but little weight.

3. *Composition of Sedimentary Series.* The third line of approach to the problem is through a study of the chemical composition of the sedimentary series. Since the entire body of sediments has been derived from the original crust of the earth (unless it be maintained that volcanic eruptions arise from beneath the crust, which would not, however, vitiate the results arrived at),

their average chemical composition must represent the average constitution of the original crust. The determination of the one would demonstrate the other. The only weakness encountered on this line of investigation is the imperfection of data. It is impossible at present to arrive at anything like a trustworthy estimate of the average composition of the entire mass of sediments of the globe, based on direct observation, because of the limitations of geological exploration. But over certain large areas an approximate computation of some value may be made. The interior continental basin of North America is such an area, and as it probably lost but little sediment by transportation elsewhere, and gained but little by importation, and as it has had a consecutive, undisturbed history of erosion and sedimentation from the earliest ages, it may fairly be assumed to be a representative area.

After a somewhat extensive gathering of facts and computation of their bearing upon the question, it became manifest that anything like a fair presentation and discussion would transcend the limits of this report, and so the mass of material was regretfully laid aside, and a few general statements here substituted without the data on which they are based.

1. It appears quite clear from such a study that the original material from which the secondary rocks were derived was not granite nor any rock of its chemical class, for its decomposition would not give the right *proportions* of derived material. For example, to decompose a sufficient amount of granite to furnish the lime or magnesia of the sedimentary series would result in a quantity of sand and clay vastly greater than that observed to exist. If, therefore, the original crust be supposed to be of the granitic class, it would seem that it must be assumed either to have been very thin, so as soon to be extensively worn away, exposing large areas of some underlying stratum of more basic character, that, added to the superficial crust, could give the right proportion of derived material, or else, that eruptions from such deeper basic rocks brought up a sufficient quantity, both of which assumptions are open to objections.

2. On the other hand, such a study of the sedimentary rocks seems to show that the original material could not have been of the very basic class represented by basalt, dolerite, or diabase, for the decomposition of these would give too little silicious matter in proportion to the lime, magnesia and iron.

3. The right proportions could apparently be derived from the *neutral* class of rocks, somewhat such as are found to be the first products of eruption among Tertiary igneous rocks.

Or, reversing the order of thought, if all known rocks and the mineral matter held in solution in the ocean were fused together, they probably would produce such a neutral product.

4. *Argument from Meteorites.* A fourth argument may be drawn from meteorites. These were doubtless derived, directly or remotely, in common with other celestial bodies, from the original mother-mass of disseminated matter. As the number of these little planets that have been examined is large, and as they have come from various quarters of the heavens, and at varying velocities, it would seem that the common testimony which they give must represent some general fact. Now they all contain a preponderance of basic material. This strengthens the belief already expressed, that this is also true of the earth. In none of these meteorites is free quartz or an acidic silicate a constituent. This supports the conviction already indicated, that originally all of the silica of the earth must have been united to saturation with the basic material, and hence that no such rock as granite, in which free quartz is an important element,

could have been abundant. Neutral and basic rocks alone could have prevailed, if this reasoning be valid. Of these, the neutral and relatively non-ferruginous rocks would, on the whole, be the lightest, and hence take a superficial position. This is precisely the class of rocks that satisfies the demands of the sedimentary series; as indicated under the third argument.

Conclusion. On the whole, therefore, the most acceptable view seems to be that the original crust was of the intermediate or neutral class.

Formation of the Ocean. If the earth were once in a molten condition, or heated to a temperature at all approaching it, it is manifest that essentially all the water which now constitutes the ocean, together with that held in the pores, fissures, and caverns of the earth, and much or all of that chemically compounded with its substance, must have existed in the state of vapor, giving rise to an atmosphere of vast extent. Mingled with this there would be not only the present atmosphere, but so much of the atmospheric ingredients as has since entered into combination with the material of the earth. This embraces large quantities of oxygen, some nitrogen, and the enormous quantity of carbonic acid that is now combined with lime and magnesia in limestone strata, and that which is represented by the coals, oils, graphites, and disseminated carbonaceous material of the sedimentary rocks. Dr. Sterry Hunt is authority for the statement that the carbonic acid of the limestones would give a volume of that gas whose pressure would equal that of 200 atmospheres.[1]

These large estimates, both of water and of gases, are, however, to be diminished by such unknown quantities as might have been then occluded in the molten material, under the great atmospheric pressure, and also such amounts as may have been since derived from celestial sources. Meteorites contain all the atmospheric constituents, and gases may have been gathered in, independently of solid meteoric matter. The amount of the additions from such sources is wholly unknown, but may be quite large.

In addition to the water and carbonic acid of the earth's primitive atmosphere, there were also doubtless added other substances which would be volatile at so high a temperature. The gases issuing from volcanic vents perhaps furnish the best known data for judging what these would be. The chief volcanic gases are hydrochloric, sulphurous, sulphydric, carbonic, and boracic acids, and with these are associated hydrogen, nitrogen, the volatile metals, arsenic, antimony, mercury, and some other substances. The earth at this period, there-

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[1] Am. Jour. Sci., Feb., 1882, p. 133. Dr. Hunt, however, maintains that this must have been mainly derived from extra-terrestrial sources.

fore, may be pictured as a molten, or at least extremely hot, sphere, surrounded by an immense, vaporous, acid atmosphere.

As cooling progressed, the earth solidified, and at length reached a temperature at which these substances could be condensed. It would not be necessary for the temperature to sink to 212° F. before the water would begin to be deposited, for the enormous pressure of so great an atmosphere would permit its condensation at a very high temperature. These condensing waters would form the early ocean, and since the crust had recently solidified from the molten state, it has generally been assumed that it was comparatively smooth, and, therefore, that the primal ocean spread nearly or quite uniformly over the surface of the earth. It is highly probable, however, that the shrinking of the earth, even at this early stage, had been sufficient to produce inequalities of the surface. If so, the waters first settling upon the earth necessarily gathered in the shallow depressions, forming local lakes. These, with the increasing condensation, grew to oceans, and at length probably prevailed over the entire surface, coalescing in a shoreless sea. The sway of this universal ocean has been a favorite theme of graphic delineation, but we will not enter on this poetic field.

With the progress of cooling the ocean grew and the atmosphere diminished by the gradual condensation of vapor, and this process may be said to have continued to the present day.

The early ocean was, therefore, both hot and acid, since the condensed aqueous vapor would absorb acidic ingredients from the atmosphere, and was thus armed for most efficient attack upon the solid material of the earth's crust. This it disintegrated, absorbing into itself the soluble portions, and leaving the remainder, the first of residual clays.[1]

While the ocean covered the whole face of the land, this could take place to only a limited extent except by the penetration of water into the crust, and over this there would soon be formed a protecting bed of residual material. But as the cooling of the earth progressed, greater inequalities of surface arose from contraction, whereby certain portions sank, and drew away the waters into the

[1] In this heated state the acidity of the waters was — so far as we may reason from known laws under present natural and artificial conditions, to the somewhat extraordinary circumstances of that early age — mainly dependent upon the acids derived from compounds of chlorine, sulphur and similar substances, rather than upon carbonic acid, which is but slightly absorbed by hot water. The extreme pressure, however, probably caused the latter to permeate the waters, and to give them an enforced acidity. As the waters cooled, the absorption of carbonic acid increased, and became the main permanent source of acidity.

basins so formed, while other portions were relatively elevated, causing them to ascend from the retiring waters.[1]

Thus the waters gathered together and the dry land appeared.

Erosion. Then began the long battle between land and sea, the former struggling to rise from beneath the ocean, the latter striving incessantly to recover its lost dominion. The efforts of the former were more or less vacillating and intermittent, those of the latter unceasing. The ocean continually lashed and chafed its shores, both wearing and dissolving them backward and recovering to itself its lost territory. No protecting sediment could save the shore line. As soon as formed, it was washed away. The debris itself was made an instrument of attack, for the waves, beating it against the shore-rocks, wore them down with increased rapidity. Nor was the conflict confined to the shore line. Copious rains descended over the whole surface of the land, and flowing thence into the sea, carried down with them fine sand and silt and soluble material, and rolled along beneath their rills and floods the sand and pebbles they could not carry. Thus the whole surface as well as circumference of the land was being continually eaten away by the active waters, whose work was to cut down the land and fill up the ocean beds, tending to restore the earth to its primitive uniform surface.

Location of the Primitive Land. Precisely what was the location of the primitive land we do not know, for there is as yet no clear proof that the earliest sediments which we have studied were the earliest formed, while it is almost certain that the earliest lands which we can map did not constitute the primitive continent. But it is highly probable that the earliest known sediments were near those actually first formed, and hence near the first land. The tenor of geological evidence is to the effect that the land has been essentially constant in position from the beginning, and it is a well known fact that the greater part of oceanic sediments accumulate near the land whence the material is derived.

Earliest Known Land. Now the earliest known land in our quarter of the globe consists of a great V-shaped or U-shaped area occupying the northern part of our present continent, embracing Hudson's Bay between its great arms, and resting its point on

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[1] Since the earth was contracting as a whole, some cases of apparent elevation may be only a relatively slower contraction. The most elevated portions of the present crust surface are estimated to be many miles below the position of the original crust. Mallet has estimated the contraction of the earth's diameter to be miles, so that the primitive surface may be conceived as passing miles over our heads.

the great lake region. From the latter, one broad belt stretches northwesterly to the Arctic sea, and another northeasterly to the coast of Labrador. South of Lake Superior there arose an island which will become to us an object of especial interest, since around it gathered the formations which at length produced the sub-structure of our State.[1]

There probably existed at the same time a long island parallel and adjacent to the present Atlantic coast, which became the basis of growth in the Appalachian region. Although our knowledge of the Archæan geology of the mountain belt of the west is limited, sufficient is known to warrant the statement that there were elongated areas or lines of islands along its axis, that became the germs of growth of the western border lands.

Within these greater ranges, scattered islands or archipelagoes seem to have appeared, the remnants of which are now found in Missouri, Arkansas, Kansas, Indian Territory, Texas, and the Adirondack region of New York. The last, however, may have been a peninsula. All these areas were doubtless really more extensive than the present mapping, based on their worn remnants, indicates. Some of them may, however, be due to subsequent elevation.

In a generalized view it may be said that there was a V-shaped area in the northern part of the continent, flanked on the southeast and southwest at moderate distances by linear belts, parallel respectively to the arms of the V, leaving between them a Y-shaped sea.

Now if these early lands were derived by sedimentation from still more primitive lands lying adjacent to them, as must needs be, the simplest supposition is that the earlier land occupied the Y-shaped area between these lands, and that the growth of the continent was outward from this. On this supposition, the material which accumulated within the fork of the Y on its northern side formed the great Laurentian V-shaped series, while the sediments on the southeastern side formed the earlier Atlantic crystalline belt, and those on the west gave origin to the Cordilleran series. But, of course, this is all hypothetical. The critical investigations that will mark the more perfect development of geological knowledge in the future, may teach us something more definite concerning the primitive lands. Meanwhile the above, or some similar hypothesis, will serve to give us the necessary conception of the order and method of development of the subsequent formations concerning which we have definite knowl-

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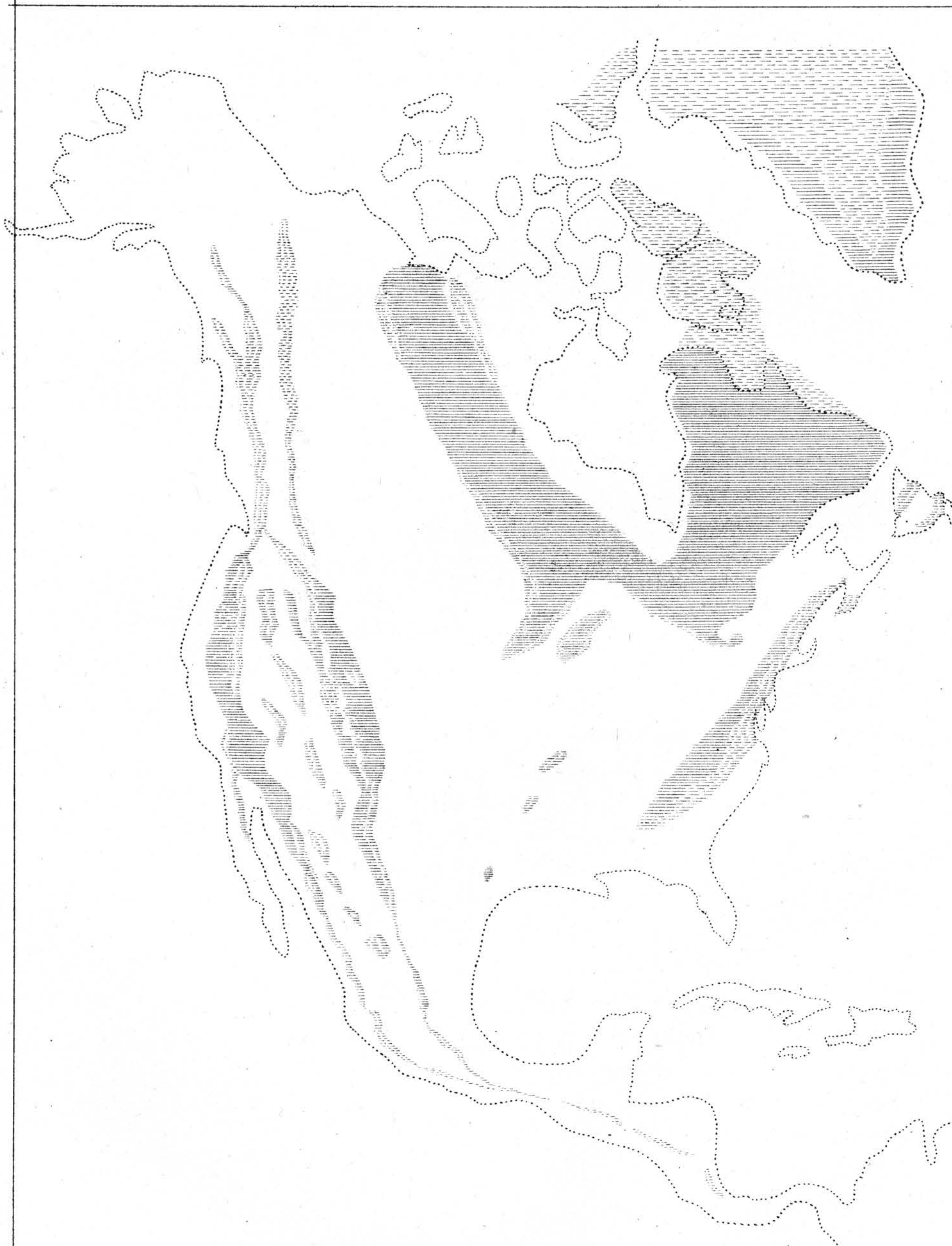
[1] Present data make this a Laurentian *island*, but probably at the stage of maximum Laurentian elevation, it was connected with the adjacent land.

PLATE Nº 1

APPROXIMATE MAP OF LAURENTIAN LAND
IN NORTH AMERICA

Doubtful areas in dotted lines



edge, for the earliest series that falls within our actual survey is manifestly derived, and not original.

This may be said to close the doubtful portion of our geological history. Over the preceding ages, the mists of antiquity hang heavily. But from this point onward the general outlines of progress are clear and sure. There are obscure and absent intervals and doubtful details, but the grander march of events is legibly impressed upon the rock-record, and, fortunately for us, the earliest authentic history is as clearly and simply written in the formations of our state as in any known portion of the globe. We pass, therefore, from the most ancient and doubtful history of the continent and the earth as a whole, to the special development of our State

ARCHÆAN (EOZOIC) ERA.

CHAPTER IV.

LAURENTIAN AGE.

FIG. 1.

GENERAL SECTION OF THE FORMATIONS OF WISCONSIN. The inclination of the unflexed beds is exaggerated. *L.* Laurentian. *H.* Huronian. *P.* Potsdam sandstone. *L. Mg.* Lower Magnesian limestone. *St. P.* St. Peters sandstone. *T.* Trenton limestone. *G.* Galena limestone. *H. R.* Hudson River (Cincinnati) shales. *N.* Niagara limestone. *Hr.* Lower Helderberg limestone. *Hm.* Hamilton limestone (cement rock).

Synoptical Notes on Laurentian Formation. Name derived from Laurentide Hills of Canada. Rocks of metamorphic class, mainly gneisses. Thickness undetermined, but great. Strata much folded and contorted. Occupies a large area in Northern Wisconsin.

For details see Vol. II, pp. 248–9 (Chamberlin), 461–501 (Irving); Vol. III, pp. 5–6, 92–99 (Irving), 224 (Julien), 248–50 and 300 (Wright), 399–400 (Strong), 434 and 661 (Brooks); Vol. IV, p. 109 (Wooster), 585–601 (King), 617–715 (Irving).

Location of Early Wisconsin Land. That part of the earliest known formation which falls under our special study formed an island, or group of closely associated islands, lying immediately south of the present Lake Superior, and occupied portions of Northern Wisconsin and the upper peninsula of Michigan.[1]

General Character of the Rocks. We have already referred to this as the granitic foundation upon which the rock structure of our State is builded. The rocks, as we now find them, consist of a series of granites *(qua-fel-mi)*, gneisses *(foliated fel-mi-qua)*, syenites *(fel-qua-horn)*, hornblendic, micaceous and chloritic schists, and allied rocks. With these are associated igneous diabases *(plagi-aug)*, and similar rocks, together with diorites *(plagi-horn)* of undetermined origin. Among these rocks, the gneissoid granites vastly predominate, so that the whole series in a general view is conveniently termed granitic.

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[1] It is not improbable that this was at one stage united with the adjacent mainland on the west and north.

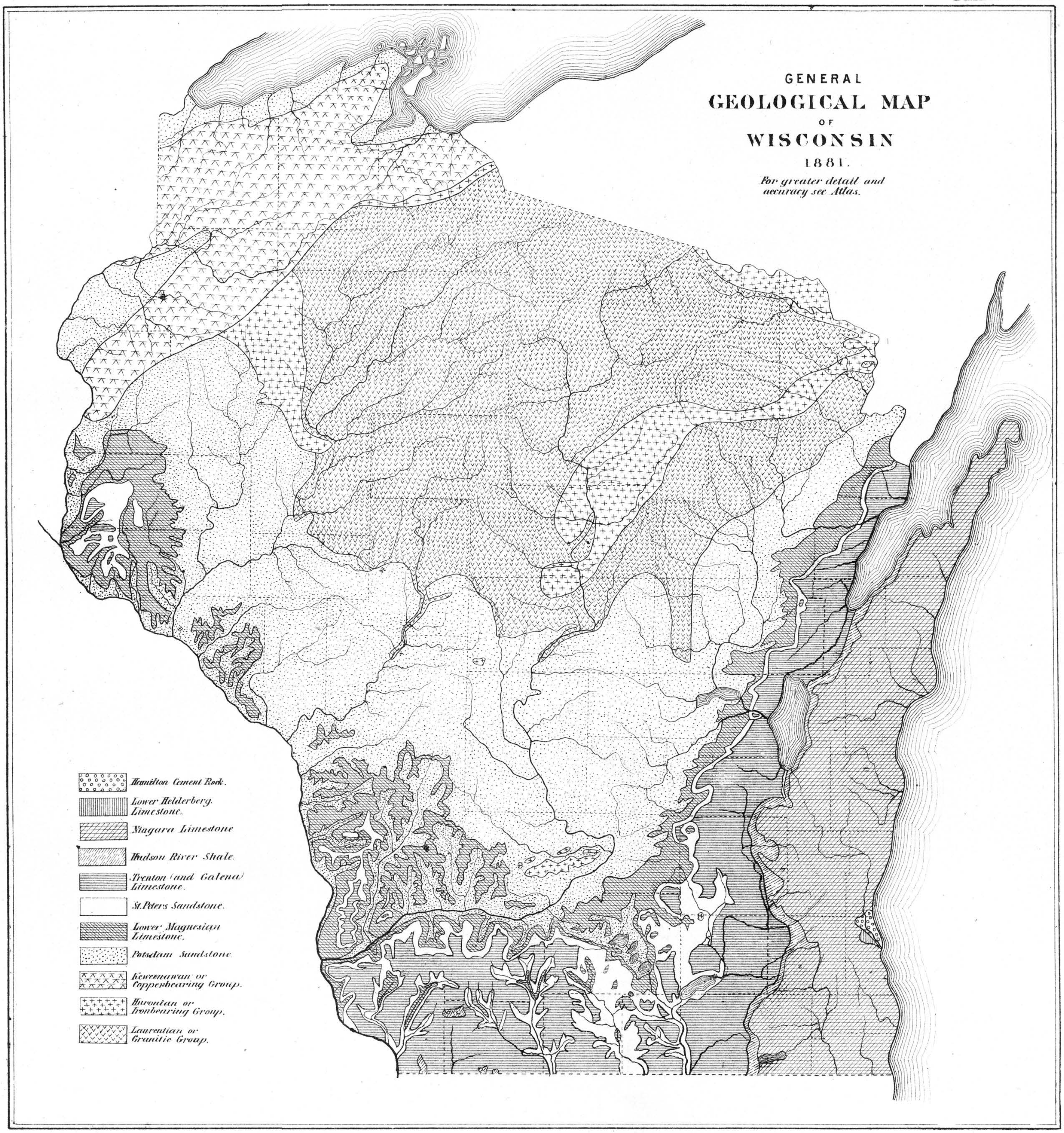
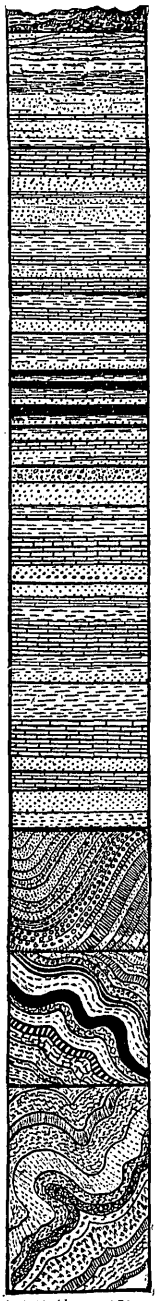

GENERAL
GEOLOGICAL MAP
OF
WISCONSIN
1881.
For greater detail and
accuracy see Atlas.
Hamilton Cement Rock.
Lower Helderberg. Limestone.
Niagara Limestone
Hudson River Shale.
Trenton (and Galena) Limestone.
St. Peters Sandstone.
Lower Magnesian Limestone.
Potsdam Sandstone.
Keweenawan or Copperbearing Group.
Huronian or Ironbearing Group.
Laurentian or Granitic Group.

FIG. 2.



IDEAL GEOLOGICAL COLUMN

	Eras.	Ages.	Periods.	Epochs.
ZOIC.	PSYCHOZOIC	*Human Age...*	Industrial .	Agricultural.
		Quaternary. Age of ice...	Glacial	Champlain. Terrace. Second Glacial. Interglacial. First Glacial.
	CENOZOIC ..	*Tertiary. Age of Mammals.*	Pliocene...	Wyoming Cong. Niobrara. Humboldt. North Park. Truckee.
			Miocene ...	White River.
			Eocene	Bridger. Uinta. Green River. Vermillion Creek.
	MESOZOIC ..	*Reptilian Age.*	Cretaceous	Laramie. Fox Hill. Colorado. Dakota.
			Jurassic ...	Wahsatch. Nevada.
			Triassic ...	Star Peak. Koipato.
			Permian...	
	PALÆOZOIC.	*Carboniferous. Age of coal plants.*	Carboniferous......	Upper Coal Measures. Lower Coal Measures.
			Sub-Carboniferous	Millstone Grit. Catskill.
		Devonian. Age of Fishes....	Corniferous (Hamilton)	Chemung. Portage. Hamilton. Corniferous. Cauda-Galli or Schoharie.
			Helderberg	Oriskany. Lower Helderberg.
		Upper Silurian. Age of Mollusks	Niagara ...	Salina (in part). Guelph. Niagara. Clinton. Medina.
		Lower Silurian. Age of Mollusks.	Trenton ...	Hudson River. Trenton. Chazy.
		Interval.....	Interval.	
		Cambrian. Age of Trilobites	Potsdam...	Calciferous. Potsdam. Acadian.
		Interval.....	Interval.	
	EOZOIC (ARCHÆAN).	*Huronian. Age of earlier invertebrates and plants?*	Keweenawan	Undetermined.
			Interval.	
			Huronian..	Undetermined.
		Interval.....	Interval.	
		Laurentian. .. Age of Zoöphytes?	Undetermined ...	Undetermined.

	Era.	Ages.	Periods.	Epochs.
AZOIC.	AZOIC..........	*Solid* .... *Molten* .... *Nebulous*	Undetermined.......	Undetermined.

Sedimentary Origin. But throughout the series, evidences of sedimentary accumulation abound, (1) in the foliations and stratification; (2) in the alternating bands of varying chemical constitution; (3) in the verging of one kind of rock into another laterally; and (4) in kinds of rock not known to be produced by igneous agencies. The whole series has been distorted, folded, and crumpled in a most intricate manner, and the rocks, as the above names imply, are in a highly crystalline condition. It is manifest that the series was not so formed originally.

Derivation of the Material. Disintegration. To recount the stages of its formation, let us return to the conditions sketched in the last chapter. Picture to the mind a portion of the supposed earlier lands lying adjacent to the area under consideration, while the latter was still beneath the ocean. If you choose, let that earlier land be assumed to be a portion of the original crust,[1] and, if we further agree, let its rock material be of the neutral igneous type, i. e., a rock composed of complex silicates of alumina, lime, magnesia, iron, soda and potash, with a variety of lesser ingredients. Picture also the supposed surrounding conditions; an immense, vaporous atmosphere, still warm, still burdened with carbonic and perhaps other acid gases, still heavily laden with dense, universal clouds that formed the swaddling bands of the young earth, enveloping it in darkness, and maintaining universal and nearly uniform conditions of heat and moisture over the land, conditions favorable in the highest degree for the disintegration and reproduction of rocks The warm, moist, and acid atmosphere attacked the complex silicates under the most favorable conditions. The result was the

[1] It is not maintained that the Laurentian material was derived from the primitive crust, though it may have been, but the assumption gives a connected view of the consecutive processes of the earth's growth and the derivation of its material, and in the general conception of this it is immaterial whether there was or was not an earlier stage of sedimentation. The opinion is not infrequently expressed by geologists that the material of the crust has been worked over and over repeatedly. While this is undoubtedly true of the later sediments, the character of the Laurentian material, if we may judge from present identifications, affords some reason for thinking that it had not suffered repeated disintegration and deposition. Each working over tended to separate the material into distinct classes, both physical and chemical, and to the formation of separate beds of sand, clay, conglomerates, etc. The Huronian beds that were derived from the Laurentian show this in a marked degree, as will be seen later, but the Laurentian beds are far less differentiated, and to that extent support the view that they stand near the head of the long series of derivations by which the successive formations have been produced. The correctness of Prof. Selwyn's classification of the Canadian Huronian and Laurentian is here assumed, something in support of which will be said subsequently.

formation of carbonates of lime, magnesia, potash, soda and other bases, and possibly also chlorides, sulphates and other compounds. If hydrochloric acid still remained in the atmosphere, common salt and other common chlorine compounds were formed. If sulphur gases were not yet exhausted, sulphates were produced. These substances, being soluble, would be borne by the drainage waters down to the sea, and thus contribute to its saline character. If these more vigorous agencies and favorable conditions had passed away at an earlier date, the process was essentially the same through ordinary atmospheric agencies, though the action was less rapid.

Transportation. But these atmospheric agencies removed only a part of the rock. The silica, the alumina, and a portion of the iron, remained as an earthy residue of the disintegration. This likewise the drainage gradually carried down to the sea. The rains of so humid a period were possibly copious to an extraordinary degree; but, whether hastened by torrential floods, or more slowly washed by lighter rains, the inevitable final result was the removal of the disintegrated rock from the face of the land to the bed of the sea. There it accumulated in stratified beds of sediment, whose character varied with the circumstances of accumulation. That which was lightest was doubtless carried farthest out to sea, and settled in the deeper, quiet waters, as a fine, clayey mud. That which was coarser and heavier sank sooner in shallower water, and nearer shore. That which was coarsest, and had been rolled down, rather than borne by the streams, accumulated nearest the river mouths, and constituted the coarser delta deposits.

Corrasion. Another phase of the same agency must not be overlooked. The streams were erosive agents, as well as vehicles of transportation. The silt which they carried and the sand which they rolled wore the sides and bottoms of their channels, and the resulting detritus was borne to the sea. Though the work of each little particle was infinitesimal, their ceaseless activity in the lapse of ages effected a momentous work. Torrential floods, carrying larger masses with greater power, accomplished more striking, but perhaps on the whole, less important results.

Differences in the Sediments. The material thus *worn* away from the primitive rock, and carried mechanically to the sea without undergoing decomposition, formed a deposit differing in chemical, as well as physical character, from the clays and earths formed by *decay*, and hence there arose an important distinction between sediments derived from the same rock, at the same time, and deposited simultaneously in the same sea. That which was formed by purley mechanical action was of essentially the same nature as the rock from which it was derived — in the present case supposed to be of the neutral silicate type. That which was derived by chemical decomposition, besides being in the main in a more finely comminuted condition, contained less of the alkalies and alkaline earths, and relatively more of silica and alumina. In other words, the material would have passed from the hypothetical neutral, to the acid type, and hence from a supposed neutral rock there arose a sediment which, on recrystallization, gave an acid rock. This we deem a consideration of some importance in following geological history, whose main function is the narration of the ceaseless decay and growth of rock.

Coast Erosion. In addition to the solution and disintegration constantly, however slowly, in progress over the whole face of the land, and in addition to the mechanical action of streams, the ocean itself was constantly gnawing at the edges of the land. The ever active waves were continually wearing the shore, and carrying the derived material back into the deeper water, where it was added to the accumulating sediments. Wave action, in that ancient time, as now, ground some of the shore rock to fine flour. Other portions were only reduced to sand or pebbles, while the massive blocks of the cliffs, which it undermined and threw down, were sometimes only rounded before they were buried beneath the sands of the shore. Shore action, therefore, produced at once the material for shale, sandstone and conglomerate. Chemically, so far as the material was decomposed, it became like that from the general surface of the land, more silicious than the parent rock. The coarser material, which was merely mechanically worn, remained, for the most part, like the ledges and cliffs from which it was derived.

Method of Deposition. But the waves were garnerers as well as destroyers. They assorted and laid away the material gathered, for future hardening into rock. By their more violent action near the shore, they washed out the finer sediment, and left little but the coarser — the sand and pebbles and bowlder-masses from the cliffs. The sands were driven hither and thither by wind-waves and tide, and arranged in layers whose attitude changed with every changing phase of the current, and there resulted oblique and discordant stratification. Ripple and rill marks were formed and buried as witnesses of the work. The finer material, winnowed from the coarser grains, was borne back by the waves to greater depths and to gentler waters, and spread over the bottom in laminated layers of progressively finer and finer material, as the distance and depth increased.

Thus, from a supposed uniform parent rock, by the simple agencies of atmosphere and water, there were produced sediments differing widely in chemical constitution and physical character. We have sketched the process in detail, because it is a typical and constant geological method, whose activities have never ceased, from the early day in which they were inaugurated, to the present hour. It therefore enters into all subsequent eras, and having been once clearly conceived, will thereafter demand mention, rather than description.

Whether the formation from which the Laurentian sediments were derived was actually a portion of the original crust cannot be safely asserted. But that the sediments were derived in a manner similar to that we have sketched, and from some more primitive rock, is put beyond question by the constitution of the formation. The derived material was of the nature we have indicated, i. e., mainly clays and sands, rich in silica and alumina, poor in lime and magnesia, but with a notable quantity of potash. That this last ingredient, usually so soluble, should have remained in the sediment under the conditions indicated, is somewhat remarkable, but is in harmony with the "well-known power of argillaceous sediments to abstract from water the potash salts which it holds in solution,"[1] and with the property of earths of absorbing and retaining it.

Thickness. The thickness to which these sediments accumulated was something enormous. In their present crystalline state, the current estimate of 30,000 feet is probably not too great for the exposed portion, though the original Canadian measurement on which it is based included beds now referred to the Huronian series. How much may lie below is not known, since the base is not exposed. So great an accumulation could only have taken place on a subsiding bottom.

Cause of Subsidence. It has been suggested that the occasion of such subsidence may be found in the weight of the accumulating sediments themselves, and as subsidences accompany nearly or quite all great accumulations, the explanation derives some force from the ease and simplicity with which it explains a constantly recurring phenomenon. The adequacy of the agency, however, seems, at first thought, more than questionable. But it may appear otherwise when it is considered that the crust of the earth is under constant horizontal pressure from the contraction attending secular cooling, and that every portion is balanced between tendencies to bow upward or bend downward to relieve the lateral stress, and accommodate

[1] Hunt's Chemical and Geological Essays, pp. 22 and 95.

itself to the contracting core. Now a very moderate loading *over a wide area*, accompanied by a corresponding unloading of an adjacent region, may be quite sufficient *to determine* that the burdened area shall bend downward and the lightened area upward under the tangential strain. The sediments are thus conceived to be the *deciding agency* rather than the effective cause of the flexure.

Correlative Difficulties. This view explains a correlative difficulty often overlooked. There are several instances where essentially conformable series have a thickness of from 40,000 to 60,000 feet. Now it is quite clear, upon consideration, that no such enormous subsidences affected the whole continent, for either (1) it must have been previously elevated to an altogether incredible height, or else, (2) it would have been submerged long before the accumulation was complete, and further fragmental sedimentation would have been prevented for want of a source. An equally grave problem is encountered in attempting to find an adequate source for the enormous amount of material required for such a series. If the present Appalachian mountain range were cut down to the ocean level and strewn over an equal area of the adjacent Atlantic bed, it would make but a relatively trivial formation. If the entire continent of North America were worn to the sea level, it would not give more than about twice the material of the Paleozoic sediments of the Appalachian region, according to standard estimates. To furnish the requisite material for the whole Paleozoic series of the continent, from the contracted areas then exposed, would require a most extraordinary elevation on any hypothesis of general continental subsidence.

If, however, the land be gradually elevated as it is unburdened by wear, while the adjacent sea bottom correspondingly sinks under its accumulations, these difficulties vanish, since the source of material is continually renewed. The generalized conception is that of the sea bottom and adjacent land surface tending to rotate about an axis near the shore line, the former descending and the latter ascending. This conception is supported by stratigraphical evidence throughout geological history, subject, however, to occasional profound intercurrent general revolutions.

Was there Life? The interesting question arises, Was the earth graced, during this era, with either animal or vegetable life? So far as the formation in Wisconsin has thus far been questioned, it has returned no direct answer. Not only have no fossil remains been found, but no organic products such as limestone and graphite, which are thought to indicate the presence of life. But this evidence is only negative. More searching investigation in the future may reveal evidences of organic beings.

It has been maintained that in the contemporaneous formations of Canada, extensive beds of limestone and of carbonaceous matter occur, and that these may be regarded as a safe indication of the abundant presence of life at the time of their formation. It has even been claimed that the remains of a Foraminifer, to which the name *Eozoon Canadense* has been given, occur in the serpentinous limestone of the formation. But the correctness of the identification has been contested. While able geologists have stoutly affirmed its organic character, others have as stoutly denied it. Leaving this question to be settled by further collections and future investigations, it may yet be fairly claimed that the calcareous and carbonaceous beds indicate the presence of life, since such formations are clearly shown to have originated through the agency of life throughout subsequent geological ages, and are not known to have arisen in any other manner.

But a serious doubt arises as to whether those portions of the Canadian series containing calcareous and carbonaceous beds are the equivalent of the Laurentian series under discussion, although they have heretofore been generally referred to this era, and have been described as such in the standard text-books of the science. The present director of the Canadian survey maintains that all these beds belong to a later (Huronian) age, and that they are, therefore, the equivalents of the next great series which we shall have occasion to consider. All the facts thus far disclosed in Wisconsin support this view, which, pending the results of investigations which must yet occupy some years, we shall assume to be the correct one. The Archæan limestones and iron ore beds of New York are likewise considered to be Huronian.

This, however, does not settle in the negative the question of the existence of life. It merely sets aside the main evidence upon which its existence has heretofore been predicated. Certain theoretical considerations incline most geologists of the present day toward an affirmative belief.

At most no more than 25,000 or 30,000 feet of sedimentary rock are as yet known to lie between this formation and the Primordial zone, and not more than half of this has as yet been generally accepted as demonstrably lying within the interval. But the Primordial zone presents an array of life representing the vegetable kingdom, and all the great subdivisions of the animal kingdom except the vertebrates. To reach so ample a display of life at that age, those geologists who believe in the doctrine of slow derivation or evolution of species, and those who, without regard to such hypotheses, believe in a gradual, systematic introduction of life-forms, must needs maintain the existence of life during an immense anterior period. Unless the intervals between the series were of incredible duration (they certainly were long), it seems necessary to carry the beginning of life well down into the Laurentian series, and even then the views of the "American School" of evolutionists, that there were periods of exceptionally rapid development of life (in opposition to the view of extremely slow and uniform evolution), would seem to be best supported.

Again, the suggestion made above, that the large ingredient of potash found in the Laurentian rocks was due to the power of argillaceous sediment to absorb that alkali, while it undoubtedly has force, does not carry the conviction that it is a complete or adequate explanation, and the question may fairly be raised whether a notable portion of the potash may not have arisen from imbedded marine vegetation. Algæ at the present time extract large quantities of potash from the ocean, and by their death and burial imbed it in the sediments now accumulating. That they did so in past ages seems clearly implied by the potash present in unleached rocks, rich in fucoidal remains. There is some ground, therefore, for supposing that the primitive vegetation made large contributions of potash to the deposits, and that, when the sediments were of an earthy or clayey nature, as seems to have been largely the case in the Laurentian era, large quantities were preserved and retained. It seems quite necessary, too, to suppose that there was an important era of vegetable life, or at least of life performing the functions of vegetation—that of transforming inorganic matter into organic,—before the introduction of the true animal type which depends upon organic matter for its food. Many of the earliest known forms of animal life were fixed in position, and dependent for their support on the food which the water brought to them, and hence the sea must have been essentially saturated with organic matter. We, therefore, venture the suggestion (it is nothing more), that the relatively large ingredient of potash in the Laurentian series may in part be the residue of vegetative life.

Period of Laurentian Upheaval.

Distortion of the Beds. The long period of Laurentian subsidence and sedimentation at length drew to a close, and the accumulated material underwent a most extraordinary transformation. The sands and clays lay originally in essentially horizontal beds. But at present we neither find horizontal beds, nor sands nor clays. The strata are crumpled and folded in the most intricate manner. Not only have the great series of beds been arched and compactly folded upon themselves, but even the thin laminations have been contorted and crumpled in the most remarkable manner. The axes of the folds, in the region of Northern Wisconsin, run mainly northeast and southwest, varying several points in either direction. On the southwestern margin, however, there is a tendency to a more westerly and northwesterly trend, somewhat parallel to that margin of the area.

Nature of the Disturbing Force and the Direction of its Action. Now if we consider attentively the dynamical problem which this folding presents, it will soon become evident that no force acting directly from beneath was competent to produce the effects observed. Such a force might be conceived to lift the strata into conical points or perhaps even ridges, but is altogether incompetent to produce long folds, closely packed side by side against each other, and compressed by a force which it is difficult adequately to conceive. In some of the folds, not only have the sides been forcibly pressed against each other, but the folds themselves have been pushed over to one side, so as to lean at a very considerable angle,—a phenomenon quite unaccountable on the supposition of a force acting directly from below. Furthermore, some of the beds present specific evidence of the direction in which the force acted. Certain classes of shaly material, when subjected to great pressure, assume a slaty structure, the cleavage planes of which stand at right angles to the compacting force. This phenomenon has been repeatedly imitated artificially. To some extent, in the formation in question, and more signally in other formations of the region that have suffered similar changes, the direction of cleavage planes in the slaty material shows that the compressing force acted horizontally. The entire assemblage of phenomena attending the disturbance agrees with this.

To apprehend the accepted view, conceive an immense force to push the strata edgewise from the southeast, while it is resisted from the opposite direction. The strata in resisting this force would be compacted, and at length, in yielding to it, would be wrinkled in the manner described. That the force acted with exceeding slowness, as well as immense power, is attested by the fact that the strata are compressed, thickened, and bent, rather than crushed or riven. Rock substance, however seemingly brittle, yields somewhat as a plastic body to a powerful force applied with sufficient slowness.

This property is greatly increased by heat and moisture, both of which would be present, the latter as the residue of submarine accumulation, the former as the necessary result of the compression of such a mass of strata. It is perhaps not too much to assume that, at certain points of exceptional stress, the rock may have become so far plastic as to be intruded into the surrounding or overlying strata after the fashion — but not exactly in the condition — of molten rock.

Attending Metamorphism. The crystallization of the material is strikingly in harmony with this hypothesis of its heated condition. The sediments, while still in their horizontal position, doubtless became solidified into somewhat firm rock (1) by their own weight, (2) by their tendency to cohere, and (3) by the agency of cementing infiltrations. But there is no reason to suppose that this induced any notable degree of chemical or crystalline change. But in their present metamorphosed condition, instead of compacted sand and clay, we find thoroughly crystallized rock, in the form of granites, gneisses, syenites, hornblendic, chloritic and micaceous schists. These show that a profound chemical change has taken place, wherein the matter assumed new combinations. At the same time, compounds of like kinds collected together, under the control of crystalline forces, and assumed the form of definitely crystallized minerals. Sediments that may originally have been a sandy clay, composed of silica, alumina and potash mainly, formed granites, gneisses, or mica schists. The potash, alumina and quartz united in part to form orthoclase feldspar, or, in different proportions, together with magnesia, to form a mica, while the excess of silica took the form of crystalline quartz. The minor incidental constituents of the sediments entered into these minerals as replacement elements, or as impurities, or formed distinct accessory minerals. When, as in some cases was true, there was a larger proportion of the basic material, as lime, iron, etc., hornblende and allied minerals were formed, giving rise to syenitic rocks. Where these basic elements existed in still larger proportions, and the silica was relatively less abundant, hornblendic and allied rocks were formed, and in similar ways other variations in the constitution of the sediments gave rise to other variations in the crystalline results.

These changes were not carried so far, in most cases, as to destroy all traces of the original bedding of the sediment, or to mix the material of adjacent layers in any notable measure. There are certain massive portions, however, in which nearly all distinct traces of original sedimentation are obliterated.

To conceive in detail of the exact method by which these remarkable transformations took place, lays a heavy tax upon the scientific imagination, and certainly transcends the limits of demonstrable science. In general terms, however, the metamorphism may quite safely be said to be due to combined chemical and molecular forces, acting under the conditions of (1) pressure, (2) heat, and (3) moisture. Beyond reasonable doubt the strata in question presented these conditions, while undergoing the distortions already described.

Cause of the Horizontal Force. It remains to find an assignable cause for the horizontal force which produced these results.

Recalling that the earth was a cooling and consequently contracting sphere, it is clear that the external layers must have soon become too large for the shrinking core. This would result in a tendency of the latter to withdraw its support from beneath. But the great weight of the upper layers, together with the extremely low arch which the curvature of so large a sphere gives, would force the strata to accommodate themselves to the contracting core. The effort of each portion of the crust to settle down would cause a lateral crowding of the beds, the cumulative effects of which, for a large segment of the crust, would be exceedingly great, and would constitute a force generally regarded as competent to compass the observed results.[1]

The first effect of the attempt of the outer shell to settle down upon the interior would be to powerfully compress the beds. But when the limit of their compressibility under the existent conditions was reached, further contraction could only be accomplished by the wrinkling of the layers themselves, whereby the greater portion of the crust was permitted to sink down with the contracting core, while certain belts were forced up into folds. The portion which would yield was not necessarily that which was thinnest and inherently weakest, but may have been that portion whose *attitude* placed it in a position unfavorable for resistance. For instance, if the strata had been previously bent downward by sedimentary accumulations upon them, or bent upward by any pre-existent cir-

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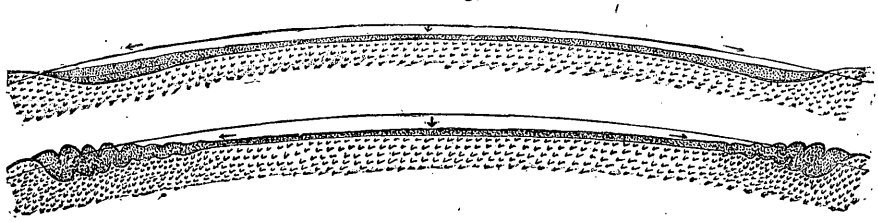
[1] While holding with some confidence to the generally accepted view that these results are due to the contraction incident to cooling, it is due the reader and certain able scientists to remark that this view is not universally accepted. This non-concurrence has found its most pronounced and definite expression in a recent work entitled "Physics of the Earth's Crust," by the Rev. O. Fisher, in which it is maintained that contraction is not an *adequate* cause. It is not clear, however, that the data upon which his computation is based are trustworthy, and there are presumable sources of contraction incidental to cooling that seem not to have been considered.

cumstance, such portions would be most liable to yield and relieve the strain, though they might perhaps be even thicker than other portions which remained unflexed because more favorably situated for resistance.

It seems to be a law of geological history, that the greatest foldings took place where there had been previously the greatest sedimentation. This may be attributed to the *downward curvature* of the beds of that region, which threw them into an unfavorable posture for resisting horizontal force. This suggests a probable reason why the thick Laurentian sediments of our region suffered such exceptional folding.[1] The great thickness to which they accumulated, near the ancient shore, may be supposed to have caused a gradual downward curving of their floor, and, at length, also of the lower beds themselves. Their great thickness makes this essentially certain. When this depression reached such a degree as to throw the beds notably out of, or across, the lines of greatest strain, their power of resistance was reduced, and they gave way and suffered wrinkling and compacting. Their yielding permitted an extensive adjacent area to settle down undisturbed upon the shrinking interior, or, more accurately speaking, the subsidence of the adjacent area determined the folding at this, the weakest point.

We may even determine with much probability the adjacent segment of the crust that did the work. If a line be drawn at right angles to the Laurentian folds — the direction in which the force acted — it will encounter a similar series of folds in the Atlantic

FIG. 3.



IDEAL PROFILES OF A SEGMENT OF THE EARTH'S CRUST, intended to illustrate the accompanying theory of subsidence and upheaval. In the upper profile, the dotted portion illustrates the fact of greater accumulation of sediment near the shore than in the central portions of the ocean. The difference is really much greater than the figure represents. It at the same time illustrates the depression of the crust that accompanies the accumulation of the sediment. The lower profile is intended to show the horizontal action, and consequent folding of the sediments and subjacent rock, produced by the settling of the arch.

[1] It is manifest that the whole crust could not have been folded to an equal degree, for the beds in question were compacted so as to cover a very much less area than before — probably less than one half. It is of course incredible that the whole crust, or any considerable part of it, was reduced to any such an extent.

border region.[1] Between these regions, the ancient crystalline rocks had settled down to considerable depths. But, owing to the sphericity of the earth, they still had the form of a low, broad arch, and probably have even to this day, notwithstanding all subsequent subsidence. The accompanying cross section will make the situation more clear. It is evident that, as the interior contracts, and tends to leave this broad low arch unsupported, its weight must exert an enormous lateral pressure at its feet. The pressure so produced would be exceedingly slow in operation since the producing cause came slowly into action.

It is quite possible that the agencies above sketched are only a part of the forces engaged in the stupendous work of crumpling the crust and metamorphosing its material.

Amount of Elevation. At the beginning of this great era of disturbance, the formation under consideration lay beneath the ocean that formed it. But under the action of the great forces that thickened and folded the strata, it was forced up from the sea, and became a new area of land. The height which it reached can be only vaguely estimated from the remnants of the folds that still exist, and from the immensity of the sediments that have been derived therefrom. Judging from these, the total amount of elevation was prodigious, but it was a slow process, contemporaneous in part with the sedimentation, and hence probably suffered much denudation while being elevated, so that the actual height attained is uncertain, but it is quite probable that the Archæan mountains successfully rivaled those of later times. The elevation of the surface was probably due in part to the thickening of the strata, resulting from lateral compression, and partly to their folding.

When first elevated, doubtless that portion which now lies in Wisconsin was united with the larger area lying to the north, and the whole extended beyond the limits now revealed to observation.

Igneous Phenomena of the Laurentian. The Laurentian rocks are frequently traversed by dykes, veins, or irregular masses of intruded rock. These are most commonly composed of granite, but are sometimes of the darker basic classes. It has not been determined how far the phenomena may be due to true igneous penetration from below, and how far to the rendering of the rock of certain portions of the series sufficiently plastic by heat and moisture to be forced into the cracks and fissures of adjacent portions. In either

[1] The Archæan folds on the eastern margin of the belt, and not the Palæozoic ones, are, of course, here referred to.

case the essential nature of the action was the same, the difference being in degree of liquefaction and the source of material. We incline to refer the granite intrusions mostly to the latter class, regarding them as but softened portions of Laurentian gneiss pressed into adjacent fractures of the rock. Some support for this view is thought to be found in the similarity of composition between the intruded granites, and the gneisses and bedded granites of the series, and also in the irregular, sprangled form of the intruded masses, and in their local extent. When it is considered that the rocks now exposed originally lay many thousand feet below the surface, and were subjected to enormous pressure, which, as the yielding strata changed their attitude relative to the compressing force, must at some points have been brought to bear with extreme power, and have been subsequently relieved, in part, as the beds took a new position, it is not surprising that local plasticity should have been induced and the softened rock forced to invade neighboring portions of the series. That there were instances of typical igneous invasion from below is not, however, to be doubted. Some apparently intrusive sheets may be due to aqueous deposition, and are, therefore, veins in the stricter sense of the term.

Interval Between Laurentian Elevation and Huronian Sedimentation.

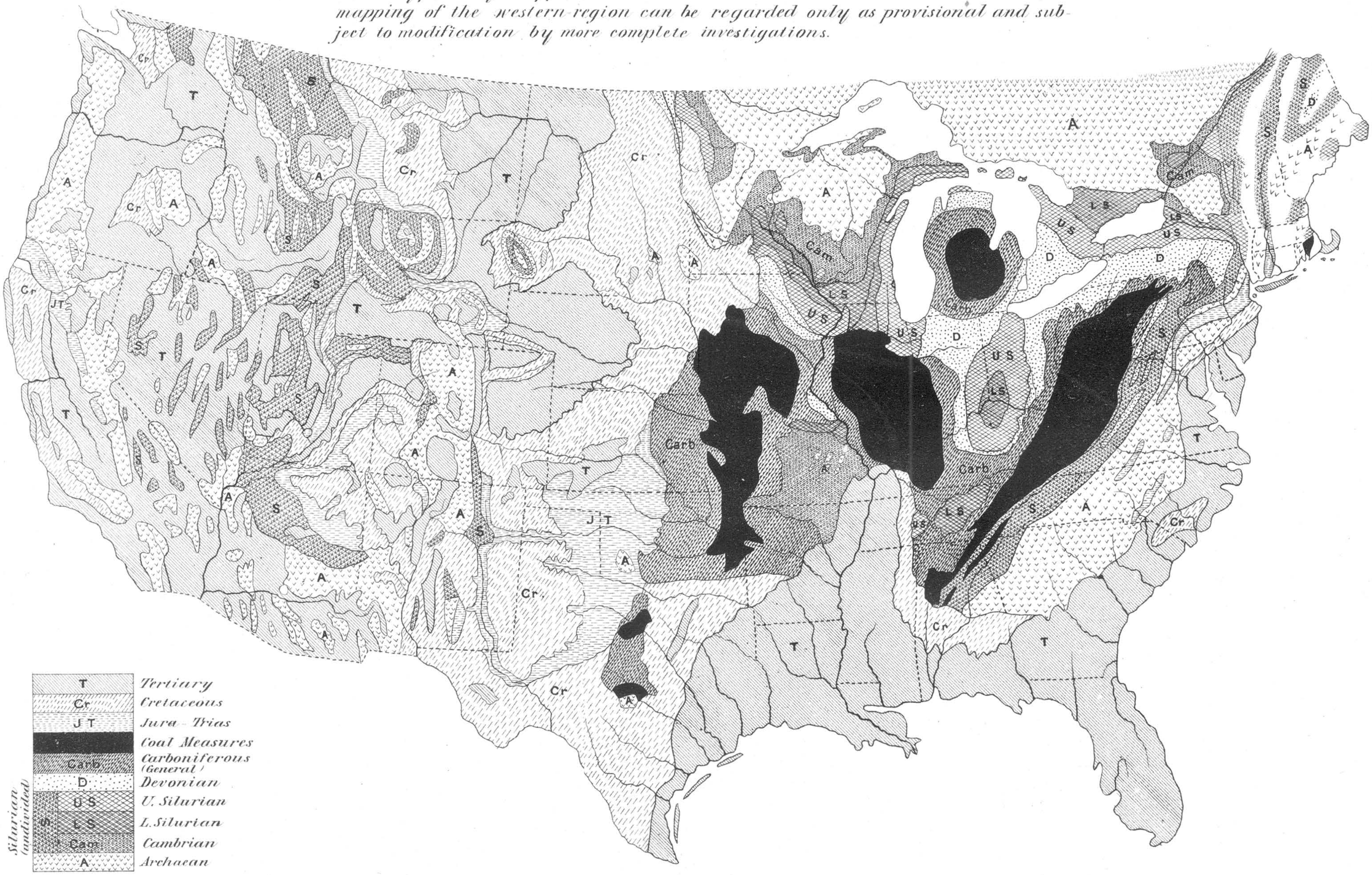
We have said that Laurentian sedimentation drew to a close, but it was only because the elevatory forces just described forced the beds up from the ocean, and prevented further accumulation upon them. But sedimentation elsewhere did not cease. The wash of the land, the wear of the waves and the settling of silts beneath the sea, continued ceaselessly. Even while the great elevation was in progress, the land was being worn and beds were accumulating in the adjacent sea, and as soon as it reached its loftiest height, it began at once to be cut down and carried back to the sea, by the agency of the great leveler, water.

Of the sediments formed during the elevation and immediately after — for a time whose limits are yet unknown — we know nothing. They are deeply buried from sight in our region, and, if their equivalents elsewhere have been seen, they have not yet been determined to be such. So far, therefore, as the details of its history are concerned, it is an unrevealed chapter. The record is not destroyed, as are certain pages of human history, but it has not yet been reached and read. In this interval there may have been disturbances interrupting and modifying the steady progress of land wear and ocean

GEOLOGICAL MAP OF THE UNITED STATES

Compiled from various official Sources.

Note.—A considerable portion of the geology of New England, being still in dispute, has been only partially mapped and the boundaries left indefinite. Much of the mapping of the western region can be regarded only as provisional and subject to modification by more complete investigations.



deposit, but of this there is no present trustworthy evidence, and it seems most in harmony with the general tenor of the testimony of our region, as well as most prudent and judicious, to regard the unrevealed interval as embracing only a long period of wash and wear, and slow lowering of the mountainous land, without prejudice, however, to the acceptance of an intervening disturbance, should adequate evidence of it arise from future investigation.

American Distribution. The areas occupied by the Laurentian formation on this continent will be best seen by reference to the map of earliest land, Plate 1, and the general geological maps of Wisconsin and the United States, Plates II and III. These last map the areas as now exposed, which differ from the areas exposed at the close of the Laurentian upheaval, for some portions of the latter have been since covered, and some not then exposed may have since been uncovered.

Foreign Equivalents. When the whole surface of the globe shall have been carefully studied, Laurentian areas will doubtless be found to form numerous centers of growth on all the continents. At present, outside of Europe little is known. The formation is well developed in northwest Scotland and the Hebrides. Some limited areas are held to occur in Wales and Ireland. The Scandinavian peninsula presents a large development, which reaches into northwestern Russia. It also occurs in northeastern Russia and in the Urals, also in Bavaria and Bohemia, and forms the nucleus of the Alps and Carpathians. In the Himalayas and in the peninsula of India, there are large areas of gneissic rocks, a portion of which are probably Laurentian.

CHAPTER V.

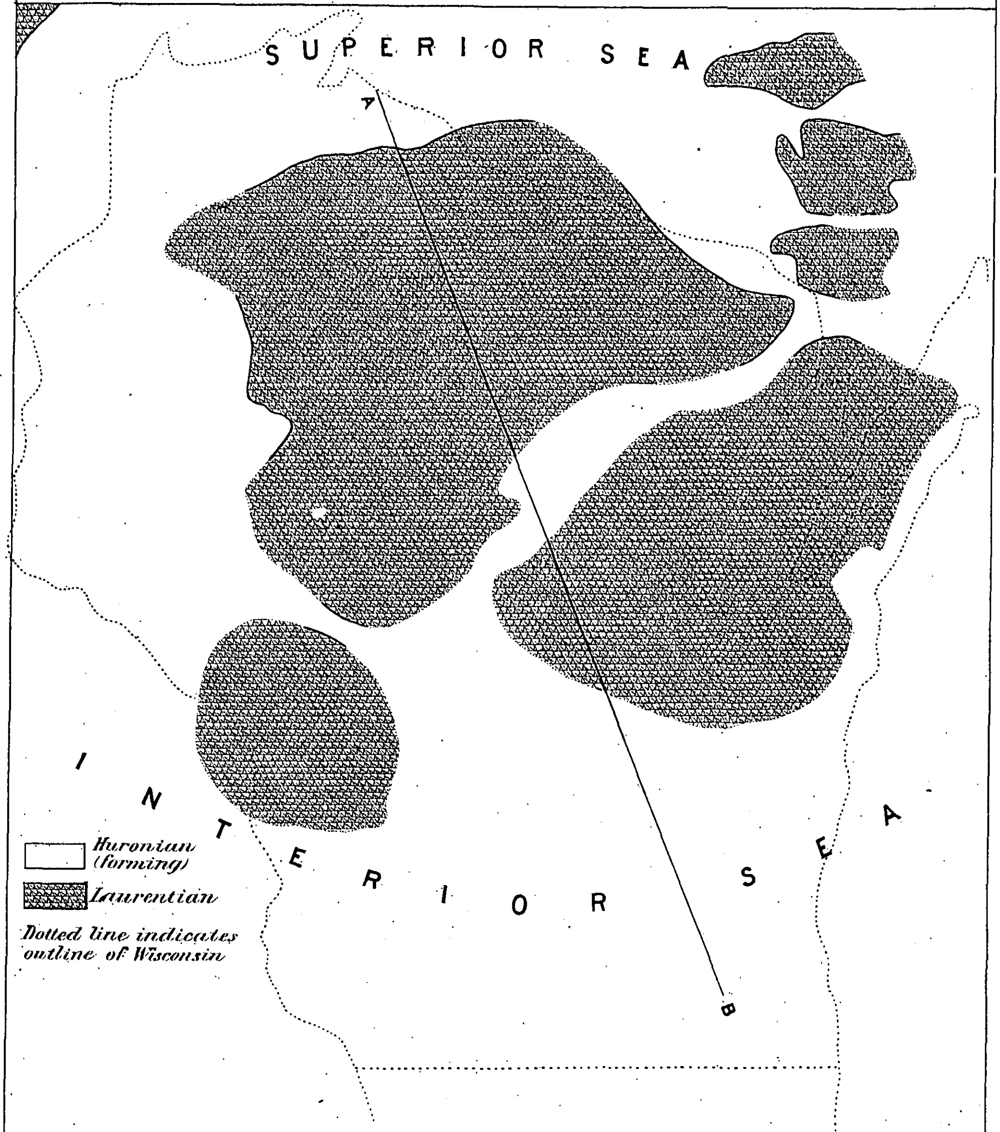
HURONIAN AGE.

Synoptical Notes on Huronian Formation. Name derived from Lake Huron, on the north side of which the formation is well developed. Known in Wisconsin and Michigan as the Iron-bearing formation. Probably embraces also the great iron deposits of Missouri, New York, and Canada. Consists of a variety of variously metamorphosed sediments, embracing quartzites, limestones, clay slates, micaceous, hornblendic, carbonaceous, and magnetic schists, and diorites and porphyries of doubtful origin. Thickness 13,000 feet, more or less. Strata arched, and sometimes folded, but not usually closely crumpled and compacted like the Laurentian. Constitutes the Penokee, Menominee, and Black river iron ranges, the quartzite and porphyry outliers of central Wisconsin, and the quartzites of Barron and Chippewa, and probably of Marathon and Oconto counties. Existence of life probable.

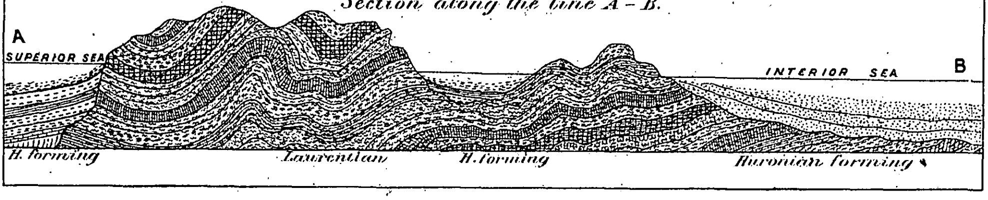
For details, see Vol. II, pp. 249–256 (Chamberlin), 484–5, 493–9, 504–24 (Irving); Vol. III, pp. 6–7, 100–166 (Irving), 225–33 (Julien), 250–301 (Wright), 334–6 (Sweet), 437–599 (Brooks), 600–656 (Wichmann), 667–734 (Wright); Vol. IV, 573–581 (Chamberlin), 617–715 (Irving).

Huronian Geography. At length the unrevealed interval gave place to a known era. In the progress of erosion and subsidence the sea advanced upon the Laurentian lands, and separated from them a large island within our northern boundaries, and two or three smaller ones, as it would seem, in the adjacent territory of Michigan. To the former, for convenience, the name *Isle Wisconsin* may be assigned, since it became the nucleus about which gathered the later formations of our State, and to the latter, that of *Michigan Islands.* The approximate location and boundaries of these, so far as discernible, are indicated upon the following sketch map, which exhibits the general features of the geography of the region during the period of Huronian sedimentation. The boundaries are approximately those which limit the Laurentian rocks as now exposed by denudation. In some portions, this is known to represent very closely the actual outline in the ancient period named. In others, it may be less approximate, but it is thought best to give a correct idea of its present stratigraphic geography, based on definite evidence, even if it depart in unessential particulars from the actual ancient outline, since the mapping which it is desirable to retain permanently in mind, is that of the present area of the formation.

HYPOTHETICAL MAP OF THE LAND IN THE HURONIAN AGE



Section along the line A – B.



These islands appear to have been at one time lofty and mountainous. The girdling seas gnawed away at their shores and spread the erosion-product over the bottom about them, building up a new formation by the degradation of the old. A glance at the map will show that their shores were not equally exposed to the violence of the waves of the great ocean. There were open seaward coasts exposed to oceanic violence, and protected straits and basins where more quiet conditions prevailed. The deposits bear witness to this. On the southern and western coasts, exposed, as they were, to the full force of the ocean waves, coarse sand and pebbles were all that could lie on the shallow sea bottom, except some finer material infiltrated between the coarse particles, or occasionally forming interstratified layers. But within the straits and protected basins among and behind the islands, much finer and much more varied deposits took place. We, therefore, turn from the general sketch of the formation to the more marked local peculiarities.

Local Characteristics. Penokee Region. Along the Penokee range the Huronian beds are found abutting against a wall of Laurentian rock which formed the ancient shore line, and definitely marked the southern limit of the primitive *Superior Sea.*[1] Here we find a series of Huronian beds nearly 13,000 feet in thickness. These are now upturned and metamorphosed, but the history of their formation remains for the most part legible.

THE PENOKEE SERIES. 1. *Limestone.* The lowest member exposed to view is a crystalline, magnesian limestone, 130 feet in thickness,—the earliest limestone known in our series. Its bedding, and its association with aqueous sediment, show that it was deposited beneath water as a calcareous sediment. The source of its material deserves special consideration. The student will perceive, on a moment's reflection, that neither the simple decay, nor the wear, of the adjacent Laurentian rocks would give a material made up almost wholly of lime and magnesia, for the Laurentian rocks contain these ingredients only in very subordinate quantity, and, furthermore, these are among the ingredients *removed*—not left—by decay. The ordinary sediments resulting from decay and wear are clays and sands, not limestone.

In later ages there is the clearest evidence that the great limestone formations were made from the calcareous remains of marine

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[1] This was not then a vertical wall as it now appears, because it has since been disturbed in common with the Huronian strata. But if the latter be depressed to their original position, the Laurentian slope where observed would be about 30°, which may be taken as the declivity of the Laurentian shore.

life, in ways that will appear more clearly as we proceed. It is probable that the ancient bed of limestone under consideration was formed in a similar way, although no distinct traces of fossils have yet been discovered in it. It is highly magnesian and is a dolomite, rather than a limestone proper. It is also impure from the presence of silicious and aluminous material.

Detrital Beds. Overlying this formation at some points is a bed of white granular quartzite, which indicates that the deposition of calcareous sediment was followed by an accumulation of quartz sand.

Upon this lie beds of quartz schist, and argillaceous mica schist, having together a thickness of about 400 feet. These were probably originally a deposit of sand, and sandy, calcareous and magnesian clay, derived mainly by ordinary wear and decomposition from the adjacent land.

Above these is a thick series of beds of iron-bearing and silicious schists and quartzites, which now form the crest of Penokee Iron Range. These have together a known thickness of about 800 feet. They appear to have consisted originally of beds of fine impure sand, with lenticular layers of iron ore thickly sandwiched through the mass.

Origin of the Iron Ore. The origin of the silicious material can be confidently referred to the atmospheric decomposition, and the wearing and assorting work of streams and waves, acting upon the granitic and other silicious rock of the adjacent Laurentian land. To account for the iron ore is less easy. It occurs (1) in thin layers, or (2) more frequently in lenticular masses a few inches in thickness, inserted irregularly among the laminations of the schist, and (3) in scattered particles disseminated through the rock. In its present form it is largely magnetic ore, though the specular variety is present. In some places both these forms have been reduced to hematite and limonite by subsequent changes.

The manner in which the iron is associated with quartzose material bears a somewhat close resemblance to the way in which magnetic iron sands are distributed through the quartz sand of certain beaches, as may be seen at many points on the shore of Lake Michigan,[1] at the present time, and as is reported to be the case on the coast of Labrador, where the ocean is now acting upon the same formation that the ancient Huronian sea did, in its day, in the Penokee region. This similarity suggests a like derivation — an ex-

[1] Vol. II, p. 239.

planation applicable to many of the features of the deposit, but it does not very satisfactorily account for other characteristics. It certainly seems inapplicable to some of the great iron deposits that occur in the Huronian series.

The most probable explanation of the massive iron ore beds, in general, refers their origin to organic agencies. Meteoric waters charged with decomposable organic matter, percolating through the soil and surface rock, change its iron ingredient from the insoluble to the soluble form, and bear it onward and at length out into some adjacent body of water, into which the drainage is discharged. Here it is reoxidized by free contact with the atmosphere, and precipitated in the insoluble form, and thus accumulates in beds. Bog ore is now being deposited in this manner, and the ores of the Clinton and Coal periods are generally attributed to similar action. Little hesitancy would be felt in referring the Huronian deposits to the same agency, if there were any independent evidence of the prevalence of land vegetation. There is, as we shall see, independent evidence of life, but it has not usually been thought to have been terrestrial. Lowland or marsh vegetation would probably furnish the requisite conditions, and there is no reason for doubting its existence except the want of direct evidence of it in this and the succeeding formations. Notwithstanding this doubt, no equally satisfactory explanation of the origin of the massive iron ores has been proposed.

Slates, Schists and Diorites. Upon the magnetic schists there repose a series of black, mica-bearing slates, alternating with diorites *(plagi-horn)* and schistose quartzites, including several horizons which are concealed by superficial material, and whose character is, therefore, unknown. Among these there appear to be included those horizons which, in the Marquette region, bear the rich iron ores. They are here doubtless concealed because of their softness, owing to which they have been more deeply eroded by denuding agencies. Whether these horizons are iron-bearing here, remains to be determined by actual removal of the drift. The mica slates were originally clay beds, probably containing some carbonaceous matter. The schistose quartzites were silicious sandstones or quartzose clays. What the diorites were originally is yet an open question, it being maintained, on the one hand, that they are metamorphosed basic clays, and, on the other, that they are ancient lava flows, modified by long continued chemical action. This series reaches a total thickness of about 3,500 feet.

Mica Schists. Above this is found a still thicker series of mica schists which were probably once mixed clayey sediments. This series now measures nearly 8,000 feet in thickness, making the entire group of the region embrace, as above stated, about 13,000 feet of strata.

It will be observed, in glancing over the whole, that the great mass of the series was formed from the ordinary sediments arising from rock disintegration, and that they were unquestionably derived from the adjacent Laurentian land. The exceptions to this statement are found, (1) in the limestone, probably derived from the remains of marine life, (2) in the iron ores, a portion, at least, of which probably arose through organic action, and (3) possibly the diorites, which may have had an igneous origin.

Huronian of the Menominee Region. Waiving for the present the subject of the tilting and transformation of these beds, let us pass to a comparison with the deposits that took place in the Menominee region, where the accumulations gathered in what seems to have been a strait, or bay, even more protected from violent action than the Penokee region, as will be observed by glancing at the map. The deposits here, while corresponding in general with those of the Penokee region, differ from them in precisely those respects which might be anticipated in view of the above conditions. There were (1) larger ingredients of fine detrital material, as indicated by the great clay beds, slates, and fine textured schists, (2) a larger proportion of calcareous and magnesian deposits, (3) a larger proportion also of iron ore, so far as present developments show,[1] and (4) more particularly, a vast increase of carbonaceous material.

The Iron Ores. The iron ores are here associated with clay-slates and carbonaceous schists, as well as with the quartzite, and exist in beds of great thickness and richness. Industrially considered, they constitute much the most important element of the formation, and have recently given rise to a settlement and development of the district quite extraordinary. A region that five years ago was an almost unbroken wilderness is now dotted with thriving towns, and resounds with the scarcely interrupted rumble of passing trains. Ore shipments that began in 1877 reached in 1880, 592,288 tons, or nearly half as much as the famous Marquette district itself.[2]

The ore occurs in definitely stratified beds, which show a pro-

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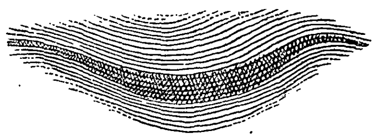
[1] The supposed equivalents of the higher iron-bearing horizons of the Marquette and Menominee districts are concealed in the Penokee region, and have not yet been uncovered, and, therefore, the limitation of this statement to *present development* is not to be overlooked.

[2] Report of the Commissioner of Mineral Statistics for Michigan (C. E. Wright). This statement embraces the production of the Menominee range in Michigan as well as in Wisconsin.

nounced tendency to assume lenticular forms, swelling out at points to a thickness of one, two, three or four score feet, and then soon "pinching up" to a narrow seam. There are two varieties of lenticular aggregation. In one, the rich ore-lenses appear to be transformed portions of leaner silicious ores, from which the silica has been removed by solution, and iron ore concentrated in its stead. In this case, the original bedding lines may be traced through the ore mass parallel to each other. In the other, the lenticular masses are original deposits, and the beds above and below bend around them, as illustrated in the accompanying figure.

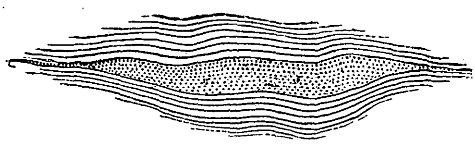
FIG. 4.



LENTICULAR ORE BED, formed by the transformation of ferruginous schist.

The ores belong mainly to the hematitic class, several varieties of which are represented. A peculiar, soft, granular, blue-black, specular variety is the prevailing type east of the Menominee river. It is apparently the result of secondary action through the agency of water, whereby a magnetic flag-ore has been freed from silica and enriched in ore, attended by a change of magnetite to specular hematite (martite). Unchanged magnetite still occurs in the rock belt which incloses the ores. On the west side of the Menominee, at the Commonwealth mine, soft, specular, and sometimes velvety ores occur, together with red hematite. At the Florence mine, soft, red hematite and brown limonitic ores prevail, associated with some slaty specular ore.

FIG. 5.



LENTICULAR ORE BED, formed between the layers of adjacent rock.

At other Wisconsin localities, less developed, red and specular hematites are the principal ores, with sometimes magnetite on the one hand and limonite on the other.

Besides the rich ore aggregated in lenses, pockets, or beds, in sufficient richness to repay mining, it is to be understood that there are very much greater quantities disseminated more or less richly through great groups of strata, constituting lean ores, approaching with varying, and often tantalizing, degrees of closeness the marketable ores. It is within these wider ferruginous belts, that the richer masses are found.[1]

[1] For details, see Vol. III, pp. 429–734.

Carbonaceous Shale. One of the most geologically striking characteristics of this formation consists of large deposits of black carbonaceous shale, in which the carbon sometimes forms as much as 40 per cent. of the whole. If this carbon were concentrated in a bed in the form of anthracite, free from earthy material, it would form a deposit rivaling, if it did not surpass, the greatest coal seams of the continent. Unfortunately, however, it is disseminated through a great thickness of earthy sediment and is in a semi-graphitic condition, vitiating its combustibility. These carbonaceous deposits undoubtedly arose from vegetation buried with the accumulating sediments, but whether it was marine or terrestrial, present evidence does not decide.

Limestone. As regards the calcareous and magnesian elements, not only is the limestone formation massive and important, but calcareous and magnesian material enters somewhat largely into the schistose rocks of the series.

Diorite. This region is also characterized by extensive developments of diorite *(plagi-horn)* whose origin is yet in doubt,[1] and of diabases *(plagi-aug)* and gabbros *(plagi-dial)* and allied rocks which are doubtless eruptive.

Deposits on the South Side of the Laurentian Island. The south side of the Laurentian island, exposed to the open ocean, suffered its full violence. The forcible sweep of the waves sifted out the fine material from the detritus brought down from the land, and that eroded from the shores, and carried it far back into the depths of the ocean, leaving along the shore and on the bottom of the adjacent shallow sea, only the coarser material,—the sand and pebbles. If we consider the origin of this material, it will be clear how it arose. The rock of the neighboring land was composed mainly of crystals of quartz, feldspar, mica and hornblende. The last three are prone to decompose under the action of atmospheric agencies, resulting in clay-like substances, while the quartz remains essentially unaffected. The streams, therefore, carried down clayey material and angular pieces of quartz. On reaching the sea, the former was borne away by the waves, while the latter was rolled

[1] From the fact that sheets of diorite occur frequently interstratified with slates (whose lamination, however, is due to bedding and not to pressure), and schists which are only moderately metamorphosed, it seems most probable that these diorites are eruptive, being perhaps overflows analogous to those so prevalent in the succeeding Keweenawan period; otherwise it is not clear how the diorites could have undergone such complete crystallization and consolidation, without involving similar changes in the adjoining rock.

continuously to and fro along the shore and on the shallow sea-bottom, and rounded into sand and quartz pebbles.

Baraboo Quartzites. The accumulations of this material were simply enormous, and were probably never surpassed in geological history. A portion of these are now displayed, in their metamorphosed form, in the Baraboo quartzite ranges.

Quartz-Porphyries. Overlying these quartzites, in Central Wisconsin, there is a massive series of quartz-porphyries, the origin of which is yet in doubt. If they are metamorphosed sediments, they must have been deposited upon the immense sand-bed above described, as a great thickness of silicious sediment, probably in the condition of a fine silt, carrying some alumina and potash. They may, however, be of eruptive origin, in which case they must have constituted immense overflows of molten rock, closely allied to rhyolite in chemical composition.

Deposits on the West Side of the Laurentian Island. Pipestone. On the western side of the Laurentian island a like immense accumulation of sand took place, with, so far as known, only a very slight admixture of foreign material, except that, at one or more horizons within it, there gathered a deposit of very fine, aluminous clay, impregnated with sufficient iron to give it a rich red color. This was subsequently transformed into "pipestone." The Catlinite of Barron county is the best known Wisconsin example. The pipestones of Minnesota are believed to belong to the same horizon.[1]

Iron-Bearing Series of Black River Falls. In the vicinity of Black River Falls there is an iron-bearing series, embracing magnesian, hematitic, and quartz schists, closely resembling the iron-bearing series of the more northern region, and probably belonging to the same horizon. These may have been gathered in the lee of a Laurentian island lying south of them, for the deep wells in that direction penetrate granite, which most probably represents a Laurentian area lying in that direction.[2]

General Considerations. Bringing together into a summary review the Huronian deposits that gathered about the Laurentian Isle Wisconsin, the salient features of the principles of sedimentation are beautifully illustrated. On the sides exposed to the grand sweep of the ocean, great accumulations occurred, but only of the coarser and more resistant material. In the more protected Superior sea, large accumulations of finer sediments, with relatively less of the coarser, were laid down, with frequent alternations, and much admixture of

[1] For details see Vol. IV, pp. 578, 580.
[2] For details see Vol. II, pp. 493, 501.

coarser and finer material. In addition to the ordinary sediments derived from rock-disintegration, there were the special accumulations of limestone, carbonaceous material, and the iron ores that have rendered the region famous,—all probably directly or indirectly the contribution of organic life.

Acidic Character. It is worthy of remark that the acidic element predominates in the sedimentary portion of the series, and apparently sustains a larger ratio to the whole than in the Laurentian. We have already assigned causes which operated to render the Laurentian sediments more silicious than their parent rock. The same agencies operating upon the Laurentian series produced a still higher degree of acidity in the Huronian deposits derived from them.

Check on Acidic Tendencies. We observe, however, in the Huronian series, the introduction of agencies tending to antagonize this extraction of the basic element and consequent concentration of the acidic. The limestones constitute a deposit almost purely basic in character, leaving out of consideration the carbonic acid, which is derived from the atmosphere. The great iron deposits are a like example. Probably also some of the magnesian and calcareous schists owe a part of their constituents to the new agencies, tending to produce basic depositions. These new counteracting agencies we believe to have been incidental to the introduction of life, and from this time forward, throughout geological history, they assume increased importance, and become, in a sense, coequal with the inorganic agencies, so that the tendency of the latter to extract the basic elements (lime, magnesia, iron, etc.)—thereby leaving an acid (silicious) residue—is counteracted by the former, which re-extract from the waters the bases and restore them to the solid condition.

Alumina and Soda. Two prominent ingredients, however, fail for the most part to enter into the reaction. Alumina is little affected by the inorganic agencies of solution, and remains with the silica among the undissolved sediments, thus acting with the silicious portion. On the other hand, soda is readily dissolved with the other basic ingredients, but for the most part escapes reprecipitation, and remains as the leading saline ingredient of the ocean.

Agency of Atmospheric Constituents. It is interesting to observe, further, that the whole rotating process is dependent upon the action of the atmospheric ingredients, carbonic acid and oxygen, which play a double part, (1) by their direct action upon the rock, producing disintegration, and (2) by their support of the reactive agencies of life, leading to redeposition.

Maximum Acidity in the Huronian. We may, perhaps, be justified in suggesting the broad generalization that the sediments increased in silicious character until the Huronian era, when they reached their maximum, beyond which they remained in equilibrium or declined.

Canadian Formations. In Canada and adjacent regions of the east, there exist extensive deposits of limestone, iron ores, and carbonaceous shales, which were formerly classed with the Laurentian, but which Dr. Selwyn, the present director of the Canadian survey, identifies with the Huronian. He refers to the Laurentian only the great series of gneisses and allied highly crystalline rocks. It will be observed that this view brings into striking harmony the Canadian and Wisconsin series, and this concordance lends support to Mr. Selwyn's views. For while mechanical sediments might vary materially within the space of a few hundred miles, it is far less likely that a profound change should be suffered by an immense system of rocks, involving (besides a great variety of mechanical sediments) limestones, carbonaceous deposits, and iron ores. We, therefore, adopt with much confidence this classification.

Life of the Era. No identifiable fossils have yet been found in the Huronian series of Wisconsin. Some obscure organic remains are thought to have been found in the adjacent region of Michigan,[1] and in the supposed equivalent in Canada, as before mentioned, the *Eozoon Canadense* has been found. Some additional supposed organic remains are reported from the same series.[2] But none of these seem in themselves to be absolutely indisputable. Notwithstanding this meagerness of direct evidence, the existence of great deposits of limestone, carbonaceous material and iron ore, leaves little room for rational doubt of the existence of life. Probably the limestones of the age were derived, like those of subsequent times, from the calcareous remains of marine animals. The carbonaceous deposits probably arose from plant accumulations. It seems most probable also, as already indicated, that the iron ores were, in the main, concentrated through the agency of organic matter. Taken together these present a strong case of "circumstantial evidence."

Period of Huronian Upheaval.

Succeeding the period of Huronian sedimentation, whether immediately or somewhat delayed, there was an era of upheaval and metamorphism, analogous to that which occurred at the close of the Laurentian era. It produced analogous, but less extreme effects.

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1 Geol. Surv. Mich., Vol. II, p. 5.

2 Geol. Surv. Wis., Vol. III, p. 561.

Metamorphism. None of the original deposits now remain precisely in their primitive condition, though only a portion of them have been so transformed that the original state is not clearly discernible. The limestone was somewhat compacted and rendered more crystalline, and scattered crystals of tremolite were formed by the union of lime and magnesia with silica, — in other words, were generated from a somewhat silicious portion of the limestone. The great sand deposits were transformed into quartzite, but, for the most part, the original grains and pebbles still remain unobliterated, while in some instances fine laminations, and beautiful ripple and rill marks are excellently preserved, bearing the most unequivocal testimony to their aqueous origin. The iron ores associated with the quartzites and silicious schists are now found largely in the form of magnetite or derivations from it. If they did not originally exist in that state (and they probably did not), they were doubtless transformed into it at this time of general metamorphism. Probably some of the more massive iron deposits in association with clay and carbonaceous schists, as those of the Commonwealth and Florence mines, were only compacted and dehydrated. Certain substances that accumulated incidentally with the sand of the series now constitute accessory minerals scattered through the quartzite, as pyrolusite, novaculite, mica and others. The various finer silts, clays and mixed sediments, were changed to slates and schists. In short, the whole series was hardened, compacted, and in some measure chemically transformed and crystallized. The changes in these respects, however, were rarely equal to those of the preceding Laurentian revolution.

Disturbance of Beds. In respect to attitude, great changes took place. Beds which lamination, ripple marks, and other characteristics show to have been essentially horizontal when formed, are now found arched and tilted at high angles. In the Penokee region, the strata stand at angles varying from 20° to upwards of 80°. In the Menominee region they were warped and folded in a still more striking manner, and stand at various angles, according to situation. In Central Wisconsin, instead of close folds, immense arches were formed. The Baraboo quartzite ranges are but the insignificant remnant of the north side of an arch of gigantic dimensions, which swept upward to an altitude approaching, if not surpassing, the highest existing elevations.[1] Similar broad arches were formed on the western side of the Laurentian island.

[1] For fig., see Vol. II, p. 506.

Direction of Axes of the Folds. The axes of the folds of these several regions vary somewhat in direction, but usually trend in general accordance with the folds produced by the earlier Laurentian revolution. In the Penokee region, the strike is north of east and south of west, parallel to the adjacent Laurentian border. In the Menominee region, the trend is north of west and south of east, likewise parallel to the adjacent earlier formation. In central Wisconsin, the trend is generally parallel to that of the Penokee region, viz.: north of east and south of west. The same is true of the western region, where it is to be noted that the position of the fold-axes conforms to the general system, and not to the adjacent Laurentian border. The long Huronian tongue of north-central Wisconsin thrust in from the northeast has a like bearing.

Gathering these observations together, it appears that the axes of the folds have a general trend from north of east to south of west, and with this, the strikes of the series in the adjacent regions of Michigan, Canada and Minnesota generally agree.

Direction of Disturbing Force. According to the law of folding and upheaval already indicated, the disturbing force is to be sought along lines at right angles to these axes, either to the east of south or to the west of north. In the latter direction, however, we encounter the great Laurentian belt that stretches northwestward to the Arctic sea, from which an active force could hardly be expected, because of its previous solidification, and the fact that it was undergoing denudation. In the opposite direction was an extensive sea, whose bottom constituted a broad flat arch. On this, near the land, there had accumulated heavy sediments, causing it to sag, and hence to assume an attitude unfavorable for resistance, notwithstanding the thickness of the accumulations whose uncompacted condition would give them little resistant power. The settling of the arch, to accommodate itself to the shrinking earth, presumably caused it to exert a powerful lateral pressure, and the sagged portion yielded and was compressed and crumpled. Such at least is our theoretical conception of the cause and method of upheaval. It is certain that the condition named — deep sedimentation on the border of a wide ocean — is the common condition of orographical disturbances. It is also a well ascertained law that the active force comes from the adjacent ocean.

In support of these theoretical conclusions, there is direct evidence that the strata were bent by being pushed from a southeasterly direction. Interstratified with the quartzite of the Baraboo region, are schistose layers, which, under the action of the disturbing force, assumed a foliated structure analogous to slaty cleavage. The direction of this cleavage indicates a movement from the south south-eastward.[1]

If such a force be conceived as pushing the strata edgewise against the Laurentian land already formed, and thereby folding and crumpling them and compacting their material, and at the same time causing the crystallization of their substance by the aid of the heat generated by the pressure, and the moisture that permeated them, the accepted view of the metamorphism of the strata will be gained.

Slowness of the Action. The time occupied in these great changes must have been long. A force great enough to disturb the strata, if it acted rapidly, would have crushed and broken them, rather than have bent them into such grand and beautiful arches as they assumed. Only an inconceivably great force acting with extreme slowness seems competent to have produced the known results. If the force owed its origin, as we suppose, to the settling of the adjacent ocean bed, under the combined influence of its slowly accumulating load of sediment and the contraction of the crust, due to the extremely slow loss of heat from the earth, the result would be just such an exceedingly slow, and, at the same time, inconceivably powerful force.

Upheaval Not All Accomplished in the Interval Between Huronian and Keweenawan Periods of Sedimentation. We have, for convenience, spoken of the disturbance of the Huronian strata as though it all occurred in this period. But speaking more strictly, a portion of the results was probably accomplished during and at the close of the next, the Keweenawan period, or, in other words, the period of Huronian upheaval embraced that of Keweenawan eruption and sedimentation. It is furthermore to be observed that the great forces of this period also affected the Laurentian rocks, adding to the contortions they had suffered in the previous era of stratigraphical revolution. Whether or not this induced further chemical transformation and crystallization in the Laurentian rocks is not determined,—perhaps is not determinable, though attention may well be directed to it.

Geographical Changes. The Huronian upheaval thrust up sedimentary formations around the borders of pre-existing land-areas, and very notably increased their extent. The Wisconsin and Michigan islands appear to have been again joined to the mainland.

Igneous Action During the Huronian Era. Among the Huronian

[1] For details see paper by the writer on "Some Evidences of the Method of Upheaval of the Baraboo Quartzites." Trans. Wis. Acad. Sci., Vol. II.

strata we find gabbros, diabases and diorites, the igneous origin of some of which seems scarcely open to question, while the origin of others is still a subject of debate, with the probabilities in favor of their ultimate determination as igneous rocks. It has not yet been proven whether those maintained to be igneous sheets were forced in between the inclosing beds after they were formed, or whether they were out-poured upon their surface while they were accumulating, i. e., whether they were Huronian in age, as in the latter case, or whether they were subsequent, as in the former, or whether they were partly of one age and partly of another. In addition to these interstratified beds, there occur dikes which cut across the strata, and which were therefore obviously of later origin than the strata they traverse, but not necessarily later than the whole series. In the case of contemporaneous outflows, of course the beds below must be cut across by the erupted material. Where dikes cut straight across contorted beds, it is safe to assume that they were later than the era of flexure, otherwise they would have suffered contortion in common with the strata.

Wisconsin is barren of decisive evidence bearing upon the question, but in the adjacent states of Michigan and Minnesota, numerous dikes cut the Huronian strata in various attitudes toward the bedding, and in seeming disregard of the folds and flexures of the strata. Some of these are demonstrably later than the Huronian period, for they traverse the later Keweenawan beds. These are of the diabase and gabbro class. Dr. Rominger is authority for the statement that this class cut diorite dikes, which are thus proven to be older. He further remarks that "the dioritic dikes seem to be restricted to the lower horizons of the Huronian group, if we are not inclined to consider the large belts of diorite which protrude in the central part of the synclinal rock-basin from the midst of the upper Huronian strata, as analogous eruptive masses coeval with the smaller transverse belts."[1] Major Brooks, in speaking of the dike-like sheet of diorite near Taylor mine, in the Marquette district, remarks as follows: "Whether it actually cuts the series of clay and ferruginous slates and schists at an acute angle, was not determined, but in places it certainly has that appearance. If it does so, it is the only case that has come under my observation, in which the Huronian diorites (often termed greenstones and traps) do not conform with the schistose and slaty strata with which they are associated."[2]

[1] Geol. of Mich., Vol. IV, p. 145.
[2] Geol. of Mich., Vol. I, Part I, p. 156.

The most probable view seems to be that successive dioritic eruptions occurred during the sedimentation of the Huronian period, traversing the beds below, and spreading out in sheets on the surface, conformably to the sediments, and so appearing as members of the stratigraphical series, like the later Keweenawan overflows. The fragmental material derived from these, as an incident of their eruption and exposure to wave action, would furnish the material for the dioritic schists, and those other gradational rocks that render so difficult a satisfactory discrimination between igneous and allied metamorphic beds, after all have been subjected to metamorphic influence. It seems quite incredible that intruded diorites should conform to contorted strata in the striking manner shown by Major Brooks' maps and sections;[1] and, on the other hand, as previously remarked, it is difficult to imagine circumstances which should have produced such close, uniform, and nonfoliated texture and crystallization as the diorites present, while adjacent beds of not very unlike composition are but moderately metamorphosed. There seems, therefore, to be reasonable ground for entertaining the opinion that at intervals, during the progress of Huronian sedimentation, overflows of lava took place, and became incorporated in the series, and that, subsequent to the completion and distortion of the series, diabase lavas traversed the whole.

In the Penokee region, according to Prof. Irving, and in the Menominee, according to Major Brooks, there are intrusive granites cutting the upper Huronian strata, and constituting masses and veins occupying a higher horizon.[2] In addition to these clearer cases of igneous action, there exists, in Central Wisconsin, a great series of quartz-prophyries, whose origin is not yet satisfactorily determined. These were folded in common with the Huronian series, and if they were of eruptive origin, which is not asserted, they must have constituted great silicious lava-flows.

Interval Between Huronian Sedimentation and Keweenawan Eruption.

Between the Huronian and Keweenawan periods an interval of moderate extent appears to be indicated by the fact that the beds of

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[1] Atlas accompanying Vol. I, Geol. of Mich.

[2] The area south of the Pine river, mapped by Messrs. Brooks and Wright, as Huronian granite, will be found on the general geological map colored as Laurentian, and so sketched in this report. The opinion of Messrs. Brooks and Wright, who have carefully studied the formation, and have had large experience in the investigation of the equivalent series elsewhere, is entitled to much weight, but the writer feels under obligation to express his doubt as to the Huronian age of the rocks in question, and is inclined to regard them as Laurentian.

the latter repose unconformably upon those of the former. The amount of this unconformity is, in Wisconsin, but slight, though it appears to be more considerable elsewhere.[1] This interval was probably entirely occupied by the disturbance and metamorphism of the Huronian strata above described. Indeed there is reason to think that this was only partially accomplished when the Keweenawan eruptions began. Sedimentary deposits must, however, have been in progress while the slow upheaval was taking place. If we could reach these deposits, we should doubtless find them in no very essential respect different from those which preceded and followed. Prof. Selwyn, director of the Canadian Geological Survey, as the result of his studies upon the equivalent formation at the east, does not recognize any interval between the two series, and it may be that what is but a moderate break in Wisconsin, is bridged by what seems to be an essentially continuous series in the eastern region.

Distribution. This formation has not been sufficiently distinguished from the Laurentian to admit of a statement of its separate distribution either in America or Europe.

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[1] Fuller data than is given in the Wisconsin reports, relating to the unconformity of the Huronian and Keweenawan series, may be found in the forthcoming monograph of Prof. Irving, on the Keweenawan or Copper-bearing series, issued under the auspices of the U. S. survey. See also the earlier paper of Major Brooks; Am. Jour. Sci., Vol. XI, 1876.

CHAPTER VI.

KEWEENAWAN PERIOD.

Synoptical Notes on the Keweenawan Formation. Name derived from Keweenaw Point. Formation also called Copper-bearing, or Cupriferous series. Rocks consist of interstratified igneous and sedimentary beds, the former mainly diabases, with some gabbros, melaphyrs and porphyries, the latter of conglomerates, sandstones and shales, derived mainly from the igneous rocks. Beds tilted, but not contorted or metamorphosed. Maximum thickness about 45,000 feet, of which about 15,000 feet is sedimentary. Period characterized by a long succession of lava-flows, with intervals of repose and sedimentation, followed by a long period of sedimentation. Existence of life probable.

For details, see Vol. III, pp. 7–15 (Irving), 29–49 (Pumpelly), 167–206 (Irving), 216–223 (Whittlesey), 233–238 (Julien), 298–301 (Wright), 336–350 (Sweet), 391–395 (Chamberlin), 339–428 (Strong).

The Great Epoch of Eruption. We now reach a period in which ejections of molten rock occurred on a scale of great magnitude. In the Lake Superior region, the strata were broken, and there welled forth from the interior great flows of lava, which spread out in successive horizontal sheets, covering an area scarcely less than 300 miles in length and 100 miles in width. These flows of fiery rock followed each other at first in relatively quick succession, and afterward at longer intervals, heaping up layer upon layer until the whole attained an enormous thickness.

Sedimentation. In the longer intervals of repose between successive flows, seams and beds, and even considerable depths of sandstones, conglomerate and shale were accumulated on the surface of the igneous sheets, showing that water covered them, eroding their surfaces, and depositing over them silt, sand and pebbles, derived from them, as well as from the adjacent land.

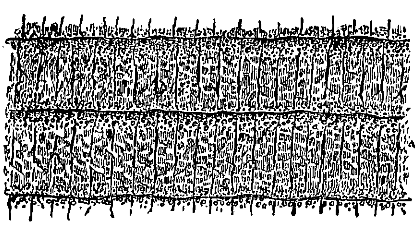
Subsidence. The fact that these detrital beds occur again and again in the accumulating series, separated from each other by thousands of feet, clearly indicates a third action in progress, viz.: the gradual subsidence of the region, for such conglomerates and sandstones could only be formed in shallow water, within the reach of the forcible action of the waves. Each bed of conglomerate and coarse sandstone, therefore, marks approximately the surface of the sea, at the time of its accumulation. It is manifest, therefore, that the bottom of the Lake Superior basin was gradually subsiding at a rate almost exactly equal to that of the accumulation of the beds above. It was as though the crust settled down to take the place of the material ejected from below.

Thickness. The maximum thickness of the combined accumulation seems to have been not less than 40,000 feet or 45,000 feet. Of this probably three-fourths is igneous material.

Succession and Distinction of Flows. In the earlier portion of the period, the molten outwellings generally followed each other in relatively rapid succession, for sheet lies upon sheet without any intervening sediment, such as would have occurred had the beds been long submerged between successive flows, and, on the other hand, without notable surface erosion, such as would have taken place if the beds had been long exposed to atmospheric agencies.

Each individual flow betrays its limits by the peculiarities of its upper and under portions. The base is marked by a thin layer of fine-textured, amygdaloidal rock, which means that vapor vescicles confined within the molten mass were included in an undercrust quickly formed by rapid cooling. The upper surface is marked by a deeper layer of more highly amygdaloidal rock, the result of the more abundant inclusion of vescicles in the superficial portion, where the slight pressure favored their formation. The interior of the flow, cooling more slowly, because kept warm by the non-conducting upper and under crusts, crystallized more completely, and formed a more compact and solid rock, which frequently manifests a tendency to columnar structure.

FIG. 6.



SECTION OF KEWEENAWAN IGNEOUS BEDS, illustrating the relations of the superficial amygdaloidal portions to the more solid, and sometimes columnar central portions. The basal amygdaloidal layer is shown relatively too thick.

Kinds of Rocks. The successive flows now appear as great sheets of diabase, gabbro, melaphyr, quartz-porphyry, and felsite. The first three of these, which vastly predominate, are of the basic type (silica 45 to 52 per cent.), while the last two represent the less abundant development of the acidic class (silica, 60 to 78 per cent.).[1] Prof. Irving has recently recognized an intermediate class of some importance (silica, 52 to 60 per cent.).[2]

[1] Intrusive granites occur in the series in Ashland county, but it is not certain that they belong to the Keweenawan epoch of eruption.

[2] Vol. V, Monographic Series of Publications of the United States Geological Survey, 1882, by R. D. Irving.

The Clastic Beds. The sedimentary rocks of the period consist of sandstones, conglomerates and shales. Unlike the great Huronian sandstone, and conglomerate deposits, which were almost purely quartzose, those of this period were largely composed of granular particles derived from the disintegration of the igneous rocks of the series itself. This, independently of the evidence above given, indicates that the surface of the formation oscillated near the water level, suffering disintegration from exposure at some points, while at others it was being buried beneath shallow water deposits. The conglomerates are sometimes exceedingly coarse, containing pebbles, if they may be called such, reaching one to two feet in diameter. These are more frequently composed of felsitic and quartz-porphyry than of any other rock, but the diabases of the series are also represented, and, in some localities, quartzite. A single stratum of coarse conglomerate on the Montreal river attains a thickness of 1,200 feet, though it thins out rapidly to the westward.

Source of Porphyry Pebbles. The abundance of porphyry pebbles among these conglomerates, taken in connection with the relative rarity of outcropping porphyry, has been the source of some surprise to investigators. If the observed distribution of porphyries is assumed to represent the full extent of their occurrence, the only tenable view seems to be, that the Lake Superior basin was gradually sinking in the center, while the edges of the strata were being tilted upwards and were thus exposed to denudation. In this way, pebbles and bowlders, as well as finer clastic material, were derived from the upturned edges of the strata, and borne backward into the basin, forming the conglomerate beds. The porphyry being harder, lighter, and less subject to disintegration, would better resist wearing action than the diabases and allied rocks, which would, in large measure, be reduced to sands and clays. Hence, although the porphyries form but a fraction of the rock, they might still yield a large proportion of the conglomeratic material. The existence of quartzite, presumed to have been derived from the adjacent Huronian series, perhaps illustrates the same selective action. The softer constituents of that series are scarcely, if at all, represented among the coarser material. This explanation has the merit of confining itself to known facts and principles, with the exception that the settling of the center, and the upturning of the edges of the basin, has not been independently demonstrated to be contemporaneous with the formation of the detrital beds, although there are sufficient reasons for thinking that it was so. It is not improbable, however, that the porphyries had a larger surface distribution than is clearly indicated by the present outcrops. If the granite intrusions of the Penokee and other regions rose to the surface, they would then probably take the form of porphyries, instead of granites, according to the accepted doctrine that igneous granitoid rocks are formed under pressure, and hence usually at considerable depths, the same material, under the less pressure at the surface, taking the form of rhyolite, porphyry, trachyte, and similar imperfectly crystalline forms. Porphyries, so formed, might, by their complete degradation, yield the required amount of detrital material.

The Shales. The shales of the formation are only the finer product of the wear of the beds that lay around the margin of the basin. The character of the shales indicates that, like the sandstones and conglomerates, they were quite largely derived from the igneous rocks of the series. Certain probable circumstances of eruption may have greatly facilitated their formation. It is clear that the lava sheets were frequently submerged between periods of eruption. In instances in which they were thus covered at the time of the succeeding outflow, the sheet of molten matter spreading out beneath the water would suffer sudden cooling at the surface from contact with the water, resulting in the shattering of the external portion into fragments, so that the surface would be covered by material favorably disposed for effective action and further reduction by the waves. The surface of the lava-flows seems to indicate that this was not a uniform circumstance, but may have been a not uncommon one.

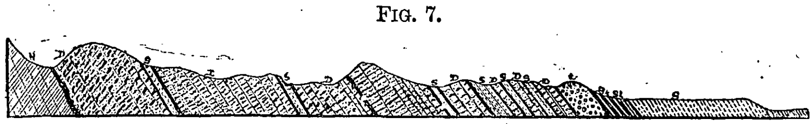
The formation of volcanic ash and scoria in the vicinity of fissures of eruption, even though not distinctly of the crater type, may have been an additional source of ready-formed fragmental material.

Composite Action of the Period. The age was, therefore, one in which igneous and aqueous agencies united with nicely adjusted conditions of exposure, subsidence, and submergence, to produce a series of beds, which, in massiveness and rapidity of accumulation, have rarely been equaled in geological history. At first the fiery element held sway, and flow after flow welled forth and spread out over the great area of the basin, while the never-ceasing, but less obtrusive, as well as less impulsive, action of aqueous agencies cast in here and there its contribution of detrital material. But, in time, the outpourings of lava slackened, the intervals of eruption became more distant, and their products less massive, while erosion and sedimentation relatively increased, and sandstones, shales, and conglomerates became more frequent and thicker. At length, the eruptions ceased, and over the whole, in Wisconsin, at least, and to some extent beyond, there was formed the great conglomerate, after which shales and sandstones were piled upon the settling series, until a maximum thickness of perhaps 15,000 feet of sediment was attained.

The series in the Montreal region, where best exposed, presents at the base thousands of feet (estimated at 35,000) of igneous diabases, melaphyrs, gabbros and porphyries, followed by an alternating series of igneous and sedimentary beds of about 1,200 feet thickness,[1] the whole overlain by perhaps 15,000 feet of detrital strata.[2]

In adjoining regions, the sedimentary beds appear lower in the series, and scatter more freely through it, while the great upper sandstone accumulations are less displayed, probably because they have been more deeply eroded, and concealed by the lake. The following section will show the relations of these members to each other in the tilted attitude in which they now stand.

FIG. 7.



GENERALIZED SECTION OF THE KEWEENAWAN SERIES, from south shore of Lake Superior. *H.* Upper member of the Huronian series. *D. D. D.* Diabase and allied igneous rocks of the Keweenawan series. *S. S. S.* Sandstone and associated detrital beds. *C.* The great conglomerate. *Bk. Sh.* Black shale. The detrital beds in the lower part of the section are based on their occurrence in Keweenaw Point. None have yet been found so low down in Wisconsin.

Comparative Chemical Character. In a comprehensive study of igneous phenomena, much interest attaches to chemical, mineralogical, and textural constitution. Of these, the chemical composition is much the most fundamental and important, since the mineralogical organization and textural nature, in so far as they are not dependent on it, represent little more than conditions of solidification, while the chemical composition is significant of the source of the material and the necessary conditions of fusion and eruption, however imperfectly that significance can, at present, be determined. Practically, however, when means of investigation are not ample, microscopical inspection of the constituent mineral is more available than chemical analysis, since, besides revealing whatever crystalline character can tell, it indicates the approximate chemical character, and many microscopical examinations may be made in lieu of each chemical analysis. Under its limitations, the dependence of the survey has been mainly upon the new microscopical methods. The descriptions of Professors Pumpelly, Irving and Julien, taken in connection with the field notes of Irving, Sweet and Strong, furnish data for detailed study.

The most salient chemical characteristic is that to which attention has already been called, viz.: that the eruptive rocks belong to diverse classes, the great mass to the basic group, others to the intermediate and acidic. The two analyses of Mr. Sweet show the diabases of the Keweenawan series to be somewhat less basic than those of the similar outflows of the Mesozoic era, in the Atlantic border regions, and more notably less than the basalts proper. These are too few to be taken as a fair representation of the series, and are not to be trusted as indicating that the original flows were not of the extreme basic class, though near that extremity of the igneous scale. On the other hand, some of the por-

[1] This alternating portion of the series is much greater in other regions.

[2] Details, Vol. III, pp. 11–13 (Irving), 336–340 (Sweet), 400–428 (Strong).

phyries lie near the acidic end of the scale. The greater mass lies near the "normal pyroxenic type" of Bunsen, and the lesser part near his "normal trachytic type." The intermediate sub-basic and sub-acid types, represented in the west by propylites, andesites and the less acid trachytes, to which the Huronian diorites are perhaps the nearest equivalents found in the Lake Superior region, are subordinate in the Keweenawan series, though shown by the recent investigations of Prof. Irving to be less rare than formerly supposed.

The place of our rocks in the volcanic scale may perhaps be most conveniently seen by the following comparison:

Richthofen's Natural System.[1]	Western Tertiary Series. Dutton.[2]	Lake Superior. Keweenawan Series. Irving.[3]	Atlantic Border. Mesozoic Series.
I. Rhyolite. 1. Granitic rhyolite. (Nevadite.) 2. Porphyritic rhyolite. (Liparite.) 3. Hyaline rhyolite. (Rhyolite proper.)	Liparite. Rhyolite.	Augite granite. Granitic porphyry. Quartz-porphyry. Felsite.	
II. Trachyte. 1. Sanidin-trachyte. 2. Oligoclase-trachyte. *Hornblende-plagioclase-trachyte.* (King.)[4] *Augite-trachyte.* (King.)	Granitoid trachyte. Porphyritic trachyte. Argilloid trachyte. Hyaline trachyte. Hornblendic trachyte. Augitic trachyte. Phonolite trachyte. Trachytic obsidian.	Augite syenite. Quartzless porphyry.	
III. Propylite. 1. Quartzose propylite. 2. Hornblendic propylite. 3. Augitic propylite.	Quartz-propylite. Hornblendic propylite. Augitic propylite.	Orthoclase gabbro. Diabase-porphyrite.	
IV. Andesite. *Quartz Andesite.* (King.) 1. Hornblendic andesite. 2. Augitic andesite.	Quartz-andesite. Hornblende-andesite. Augite-andesite.		
V. Basalt. 1. Dolerite. 2. Basalt. 3. Leucitophyre.	Dolerite. Nephelin dolerite. Basalt proper. Leucite basalt. Nephelin basalt. Tachylite.	Diabase. Melaphyr. Olivine gabbro.	Diabase. (Dolerite)

[1] Richthofen's Natural System of Volcanic Rocks.
[2] Dutton, Geol. of the High Plateaus, p. 112.
[3] Irving, Copper-Bearing Rocks of Lake Superior, U. S. Geol. Surv., 1882.
[4] King, Geol. Explorations of the Fortieth Parallel.

Life of the Keweenawan Period.

No direct and positive evidence of the existence of life during this period has been found in Wisconsin. Obscure forms supposed to be of organic origin occasionally occur in the sedimentary beds, but the validity of this identification is not entirely beyond doubt.[1] Overlying the great conglomerate in the Penokee and Porcupine mountain regions, there is a black shale that closely simulates that of later ages formed in association with life, and the existence within it of disseminated silver, copper and iron — in part united with sulphur,— lends support to the view that organic life was present during its accumulation.

Theoretically there is little room to doubt the existence of life throughout the period. The igneous eruptions, while in their full activity, perhaps gave rise to conditions incompatible with fixed forms of life in this immediate vicinity, but in the intervals of repose, and in the long age of sedimentation after the lava-flows ceased, conditions congenial to life may be supposed to have been presented. The absence of fossils, therefore, is to be referred to the want of suitable conditions for their preservation.

The Keweenawan Flexure.

We have already alluded to the evidence that during the accumulation of the great igneous and detrital series, the center of the Lake Superior basin was slowly settling down, while the margins were being tilted upward. This process continued until the whole series assumed the form of a great, deep trough, the axis of which lies between Isle Royale and Keweenaw Point, and extends southwestward across Ashland, Bayfield and Burnett counties in Wisconsin, to the borders of Minnesota. The first determination of the westward extension of the Lake Superior synclinal into Ashland and Bayfield counties, Wisconsin, seems to have been made by Prof. Irving in 1873. The upper portion of the St. Croix river lies near the axis of this synclinal valley. On the south margin, the strata are tilted at various high angles, apparently reaching their greatest inclination in Ashland county, where they are nearly vertical. From this region, as traced both to the east and west, they decline, being quite flat both on the eastern shore of Lake Superior and on

[1] In Geol. Surv. of Wis., Iowa and Minn., Table I. D., Dr. Owen figures "Impressions of plants (?) in the red sandstones of the northwest shore of Lake Superior," which probably belong to the Keweenawan system. In his "Sketches of Creation," Prof. A. Winchell figures a supposed seaweed, *Palæophycus arthrophycus* "from the Lake Superior sandstone, north flank of Porcupine mountains," which probably is to be referred to this series.

the western Wisconsin border. On the opposite side of the trough, the beds slope more gently, according to the testimony of various observers. To the southwest this trough shoals and tapers to a point in the vicinity of the St. Croix river a short distance above the Falls, while in the opposite direction it seems to curve upon itself concentric with the outline of Keweenaw Point (Irving), and to occupy the eastern bed of the lake where it is mainly concealed, and its extent or limitation in that direction unknown.

The combined subsidence and uplifting which produced this synclinal trough, was manifestly a quiet, progressive, long-continued action. It did not induce any noteworthy metamorphic changes in the strata involved, notwithstanding the fact that their material was such as to peculiarly fit them for transformation, being a commingling of contrasted acidic and basic substances. The shales, sandstones, and conglomerates remain such, without notable evidence of compression or chemical combination. Even the cellular, amygdaloidal portions of the lava-flow were not compressed so as to produce any conspicuous flattening of the spherules. The tilting and flexure of a rock series miles in thickness, from a horizontal to a nearly vertical position, attended by so slight effects upon the character of the rock, is an instructive illustration of great stratigraphical tilting attended by little metamorphic change. The fact that this is one of the greatest eruptive series of geological history adds impressiveness to the illustration. It teaches caution in attributing great metamorphic results either to simple tilting, great depth of accumulation, or associated igneous action.

Character of the Action. However well it might accord with popular predilections and satisfy the thirst of a sensational imagination to picture this as an era of great convulsions and of violent upheavals, the cold facts of even so igneous a period give little ground for it. Its great movements were of the quiet, gigantic character, fitter subjects for our admiration than destructive convulsions. Even its igneous eruptions were of a quiet sort, and came welling up through great fissures in the crust, and flowed away in broad molten sheets. The conflicts between these fiery flows and the water of the basin doubtless gave rise to a vaporous display of truly magnificent proportions. The opening of the fissures through which the outflow took place was probably attended by earthquake tremors, which may have sometimes been locally violent, but were trivial circumstances in a comprehensive earth-study.

Hypothetical Agencies of Igneous Eruption. No theory of the hidden nature and causes of volcanic eruptions has yet been proposed which has met with general acceptance. The elucidation of this extremely difficult problem will doubtless only be wrought out by very extended and exact observations, and by a more thorough-going and critical analysis of the phenomena than has yet been made, or is indeed possible with the data now at command. It may, however, be only a proper yielding to a commendable spirit of inquiry among general readers, to state in brief propositions, what seems to the writer, at the present stage of investigation, most likely to ultimately prove true, advising, however, that they be held very lightly. The hypothetical postulates are as follows:

1st. That the source from which the eruptions spring is relatively superficial.

2d. That the material erupted is not the remnant of a supposed primordial liquid, either constituting a liquid interior, or local molten lakes, but is formed from the melting of the rock of the earth's crust.

3d. That such melted portions are extremely local, so that neighboring vents connect with independent reservoirs.

4th. That the melted rock has sometimes been derived from the primitive crust, but perhaps more frequently from melted sediments.

5th. That the fusion is due to a combination of causes, the most essential of which consist of great pressure, resulting in high temperature (the fusion point being necessarily elevated also), followed by a reduction of pressure, and consequently a lowering of the fusion point, resulting in liquefaction *before the temperature has been correspondingly reduced.*

6th. This succession of high and low pressure (and consequent changes of temperature and fusion point) are possibly due, we venture to suggest, to the *changing attitudes* of strata, under the tangential pressure of a shrinking globe.

7th. That the ejective force is the resultant of the combined action of (1) tangential pressure, (2) the weight of superincumbent rock, (3) the expansive force of included vapors, and (4) the effect of heat upon the specific gravity of the liquefied rock.

8th. That the relative order of eruption is due to the relative order of liquefaction, modified by specific gravity and the relations to the eruptive force, very much as maintained by Dutton.[1]

The only point in these propositions that is at all novel — and that may not be — is that which refers liquefaction to the varying relation of temperature and fusing point, due to changing attitudes of the strata while yielding to lateral compression. Beds in being forced from their original horizontal position, into the variously folded, crumpled and crushed states which they at length assume, must necessarily sustain different postures toward the compressing force, and hence be affected by it in a correspondingly *unequal* manner. This will become more and more evident as the conception is carried into detail. The stratified portion of the crust is composed of layers of unequal compressibility and rigidity. The more resistant layers will necessarily bear the greater strain, and the greatest compressing force will, therefore, be exerted within their planes. As they are bent at any point out of the horizon of this plane, the pressure upon them will be in part relieved at that point, and correspondingly transferred to other layers that now fall within it. The phenomena of rupture, igneous intrusion, and faulting, afford direct evidence both of difference and of change of strain.

If the fundamental cause of eruption be found in the varying stress of tangential pressure, it is not strange that eruptive phenomena should be manifested mainly near coast lines, since the crust, balanced under tangential stress, is

[1] Geology of the High Plateaus of Utah.

being increasingly burdened off shore by the accumulation of sediments, and continually lightened landward by denudation. This transferred material might reasonably be thought not to be of itself a very potential element, but by being brought to bear on the extremely low arch of the crust already under horizontal stress to the initial point of yielding, it may become the *decisive* factor in determining the point of bending, and consequent throwing of given beds previously under compression out of the planes of maximum stress. The general suggestion of the transfer of eroded material, as a potential element, is due, I believe, to Clarence King, though his conception of its agency is different from that here suggested.

Recurring to what has been said on a previous page respecting the depression produced by sediments adjacent to the shore-line, it may be conceived that, at some distance off the mainland, along the outer border of the heavier accumulations, there will be another line of yielding — the outer margin of the sag — where flexure and crumpling may take place. To this cause may perhaps be due volcanic islands off the coast of mainlands.

Faulting. There is some reason to believe there were a few cases of faulting of some magnitude. Prof. Irving has determined the existence of a displacement of the Huronian beds of 1,700 feet at Penokee Gap. It has not been proven whether this involves the Keweenawan strata or not. It, of course, occurred after the close of Huronian sedimentation.

Parallel to the southwestern projection of Lake Superior, in Douglas and Bayfield counties, there runs a cliff formed by the upturned edges of igneous, southward-dipping beds, against which a later-formed horizontal sandstone (Potsdam) abuts, showing that it stood as a sea-cliff in the Potsdam seas. Keweenaw Point presents a similar phenomenon of more striking character, its beds dipping northwestward, and exposing in the opposite direction a mural face against which abuts a similar horizontal sandstone.[1] This may all possibly be the work of erosion in the great interval otherwise demonstrated to exist between the Keweenawan period and the Potsdam, but the extent and the regularity of the cliff-faces lends support to the hypothesis that the phenomenon is due to displacement afterwards modified by erosion. If these cliffs were produced by faulting, the displacement was doubtless attended by the nearest approach to a great convulsion that the period witnessed. At best, this might amount to the settling down of a small bit of the globe's crust to a depth perhaps one ten-thousandth part of its distance from the earth's

[1] This has been recently disputed by Dr. M. E. Wadsworth in a paper entitled "Notes on the Geology of the Iron and Copper Districts of Lake Superior, Bulletin of the Museum of Comparative Zoology of Harvard College," but more recent observations under the direction of Prof. Irving have shown the groundlessness of his contention.

center, a local phenomenon of great importance to be sure, but relative to the whole globe, only trivial.

Huronian Strata Involved. The underlying Huronian strata partook of the Keweenawan subsidence, and so appear to-day tilted in a manner nearly conformable to the Keweenaw series. It hence appears that a portion at least of the Huronian disturbance transpired during the Keweenawan period, and a still further portion after the close of its sedimentation. We incline, therefore, to the view that the Huronian folding began before the Keweenawan period, extended throughout it, and only reached its completion at a later period. The eruptions that were the great event of the earlier Keweenawan epoch may have had an intimate connection with the disturbing force, while the flexing of the same series entered as an important factor into the later disturbances. Under this view the connection of the Huronian and Keweenawan series is intimate, and the latter furnishes an illustration of igneous and sedimentary accumulations forming contemporaneously with an orographic disturbance, in which they themselves were measurably involved.

Distinctness of Huronian from Keweenawan Period. The metamorphism of the Huronian sediments, however, appears to have been mainly accomplished before the recognized Keweenawan period began, for the rocks of the latter contain metamorphic pebbles, apparently from the former, while they were not themselves metamorphosed. This, together with the interval between the two periods and the diversity in their predominant characteristics and their great individual development, is held to be sufficient ground for their distinct designation. The names Keweenian, proposed by Hunt, and Keweenawian, by Brooks, have been practically accepted, slightly modified orthographically. Not much can be said for the euphony of any of the three, but Keweenaw Point is so unquestionably entitled, under geological usage, to give its name to the formation, that we must accept its uncouthness and strength, in lieu of the smoothness and elegance that is certainly to be desired in a term so often repeated as the name of a formation.

What may be the precise taxonomic value of the distinction in the somewhat unequal scale of discriminations that characterize the commonly accepted geological series, it is difficult to determine, before the formation shall have been worked out in other regions. Judging from the area under consideration, its value appears to be greater than that of the distinctions characterizing Palæozoic periods, possibly greater than those of the Palæozoic ages, though of course the organic basis for distinction is lacking. It is certainly much less than the distinction between the Laurentian and Huronian eras. The conviction may be here expressed that the taxonomic value of the Archæan eras has been usually greatly under-estimated.

Chemical Metamorphism. Metasomatism. While the mechanical disturbance of the system was attended by but trivial metamorphic changes, a series of chemical transformations of an interesting nature ensued, but were probably not immediately dependent on the disturbance.

Formation of Amygdules. It has been remarked that the upper, and, to a less extent, the lower faces of each of the lava-flows, was marked by vapor vescicles, doubtless due mainly to steam inclosed in the molten rock. These, at first, were empty cavities, but are now found filled with a variety of secondary minerals, such as calcite, quartz, laumontite, chlorite, epidote, datolite, prehnite, orthoclase, analcite, and, most interesting of all, native copper and silver. Sometimes a cavity is filled with a single mineral, but quite often two or more occupy the same vescicle, lining it with concentric layers, sometimes completely filling it, and at others, leaving a miniature geode in the center.

Pseud-Amygdules. But the process was not wholly one of filling and reconstruction. The walls of the cavities were sometimes enlarged, occasionally uniting vescicles, and sometimes even considerable masses of the rock were removed and replaced by minerals of secondary formation. Still further, in portions of the rock where vapor vescicles seem not to have been originally present, the primitive rock-material was removed, and a secondary mineral — often a chlorite — substituted, forming a false amygdaloid (pseud-amygdaloid).

Metasomatic Changes. But the igneous rocks did not escape with even these changes. The original material was largely triclinic feldspar and augite. These have undergone more or less change, and, by critical microscopical examination of a series of specimens in which the process is still incomplete, the various stages of progress may be seen, which is nearly equivalent to seeing the actual transformation. The result of these changes has been the production of chlorite, uralite, viridite, and other secondary products throughout the rock, while a portion of the substance has been carried out into the amygdaloidal cavities, and the cracks and fissures of the rock, to form the filling of amygdules and veins. The details of these interesting changes may be found in Vol. III of this report, in Prof. Pumpelly's paper upon Metasomatic Development of the Copper-bearing Rocks of Lake Superior,[1] and in the forthcoming memoir of Prof. Irving.

[1] Proc. Amer. Acad. Arts and Sciences, Vol. XIII, p. 253 et seq.

Metallic Contents. While the extraordinary display of igneous and aqueous agencies lends deep scientific interest to the formation, its metallic contents attract, by even a stronger fascination, the industrial world. The richest known copper mine in the world is located within it. The formation has long been known as the copper-bearing, or cupriferous series, and the latter term would doubtless stand as its permanent name, but for the fact that it might be misleading when applied to the equivalents of the series elsewhere.

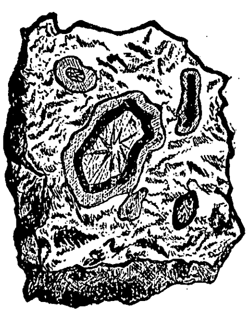
The Copper. *Conglomerate Deposits.* The copper of the formation occurs partly in the igneous rock, and partly in the sedimentary. In the latter case, the metal usually occurs scattered through the conglomerates, sandstones and shales, in nuggets, flakes, leaves, and fine particles. In some instances, pebbles of the conglomerate have been gradually removed and copper substituted in their stead, so that there is now a pebble of metal, where there was formerly one of stone — a clear demonstration that copper was introduced by a process of replacement, after the formation of the conglomerate. In other instances, little seams in the sandstone or shale have been filled with the metal, constituting miniature metallic veinlets. A specimen in my possession shows such a seam across a ripple-marked surface, indicating the following historical stages: first, the arrangement of the sediment by the rippling action of the waves; second, its hardening and subsequent cracking; and third, the filling of the little crevices with metallic copper.

In the great Calumet and Hecla mine of Michigan — the greatest of the world — the copper is so abundant as to act as a cementing matrix for the conglomerate, enwrapping and binding the whole into a mass of extraordinary richness. The so-called vein in this mine is really a bed of conglomerate from 8 to 12 feet thick, lying between massive sheets of trap. This may be taken as a type, though exceptionally rich, of the deposits in sedimentary portions of the formation.

Amygdaloidal Deposits. In the igneous portions of the series, the richer copper deposits are mainly found in the amygdaloidal portions of the flows. The simplest form of deposit of this class consists in the filling of the vapor vescicles of the lava-flows with metallic copper. Occasionally a portion of such rock occurs thoroughly shotted with copper, so deposited. The deposit, however, is rarely so simple as this. It is often complicated by the deposition of other minerals in the same vescicles, sometimes preceding the copper, and sometimes following it, while in still other cases, their deposition was contemporaneous with it, so that copper is but one, and often the least of many occupants of these cavities. A peculiar and complex succession is unequivocally indicated by the relations which copper sustains in numerous cases to the associated minerals.

The cavities themselves did not usually remain intact. They were often greatly enlarged, and sometimes, by the removal of their walls, were made to coalesce. In exceptional instances large portions of the amygdaloidal rock were removed, and copper and associated minerals substituted.

FIG. 3.



FRAGMENT OF AN AMYGDALOID, showing filled cavities. *Ch.* Chlorite. *C.* Calcite. The black of the fillings represents copper.

Thus were formed those great masses of copper which have been the wonder of the world. Not infrequently the irregular cracks and crannies of the rock are filled with sheets, leaves, or irregular masses of native copper.

In addition to these richer concentrations in the amygdaloidal portions of the lava-flows, copper particles are disseminated through the more massive portions, sometimes plentifully, but oftener quite sparingly. These leaner inocculations are scattered widely throughout the formation, and may be said to be essentially coextensive with it, indicating that the source of the copper was such as to infuse the formation widely with the metal.

Vein Deposits. The copper deposits present still another and quite distinct phase — that of fissure veins. The igneous rocks were, in some instances, extensively and deeply fractured, and the crevices so formed were subsequently filled by minerals formed in successive layers upon their walls. Among the minerals so deposited, native copper is found, and some mining, in Michigan, has been prosecuted on such deposits. The position and regularity of these fissure veins is such as to make it highly probable that they were formed after the upheaval of the formation, which closed the era under discussion.

Relation of Copper to Associated Minerals. The manner in which copper is associated with its fellow minerals is interesting and significant. Its relations to calcite may be taken as an illustration. The copper sometimes lies upon the calcite, sometimes is overlain by it, and sometimes the two are interleaved or intermingled.[1] In some instances, the copper appears to have penetrated the cleavage cracks of the calcite after the latter was fully formed. The two

[1] See Geol. Surv. Mich., Vol. I, Part II, pp. 232–35.

were, therefore, mutually successive, as well as partially contemporaneous in origin, and must have been deposited under conditions compatible with the formation of both. Similar facts are true, in some measure, of the relation of copper to other associated minerals.

Origin of the Copper. Igneous Theories. Taking all the foregoing facts into consideration — especially in the fullness of their details, not here admissible — it is quite clear that the copper was not deposited by being injected in a molten state into the positions in which it is now found. The manner in which it is associated with calcite and other minerals, its scattered condition in many instances, the extremely attenuated, leaf-like forms which it often assumes, its existence in the midst of fissure-veins formed much later than the igneous period, its replacement of pebbles, together with other significant circumstances of occurrence, seem conclusive upon this point. If these leave any doubt, the occurrence of native copper and silver together, in the same lump *and yet not alloyed*, ought, it would seem, to dispel it.

Deposition from Aqueous Solution. It may be maintained with confidence that the copper was deposited in its present situation from aqueous solution by chemical agencies. It has been plausibly suggested that iron protoxide compounds may have been the chief agency of precipitation, by deoxidizing the copper solutions.[1] Organic solutions penetrating from the surface may perhaps have acted as reducing agencies.

Source of the Copper. 1. *Theory of Derivation from Underlying Ore Beds by Ascending Melted Matter.* This still leaves to be answered the ulterior question of the source of the copper solution. It has been maintained that the molten rock, as it rose to the surface, traversed beds containing copper ores, which were reduced by the heat, and borne upward, mingling with the liquid rock from which they were subsequently extracted and concentrated by thermo-aqueous and chemical agencies.[2] Several objections stand against this hypothesis.

1. The underlying strata, so far as determinable by their outcroppings around the margin of the basin, give no warrant for the supposition that they contain such ore deposits.[3] The existence of the supposed ore beds must, therefore, be gratuitously assumed.

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[1] Pumpelly, Geol. Surv. of Mich. Vol. I, Part II, pp. 44 and 46.

[2] Dana's Manual, p. 186.

[3] The copper-bearing series, described in the older Canadian reports, and apparently assumed to underlie the series under discussion, is thought to be its eastern equivalent. There certainly is no evidence of the existence of any such series on the south shore of Lake Superior, nor, if the writer is correctly informed, upon the opposite side.

2. In the second place, they must be assumed to be of enormous magnitude and richness, for it is incredible that dikes crossing them should have melted more than that portion of the metal which lay immediately adjacent to the passing lava; or, in other words, only a small fraction of the entire deposit. But the amount of copper in the series under consideration is something extraordinary in itself. To suppose the enormous wealth of the Calumet and Hecla mine to be derived from such portions of an ore bed below as could be melted and brought up by the flows overlying and underlying that extraordinary mine, is to lay a severe tax upon belief, without the support of any adequate evidence. If it be assumed that the traversing dikes followed the copper-bearing beds for some distance, the force of this objection will be somewhat mitigated, but by no means removed.

3. Each successive flow would traverse relatively more and more exhausted ground, and hence would be correspondingly less enriched. The earliest flows should, therefore, have been most metalliferous, especially as they were most massive and followed each other in quickest succession. As a matter of fact, however, the copper deposits lie more largely in the later portions of the series, and, what is especially significant, *in the alternating igneous and sedimentary portions*, which bear upon their face the evidence of being moderate ejections separated by long intervals of repose — circumstances little favorable to the extensive heating and reducing action which the theory presupposes. This, besides strengthening the second objection, constitutes in itself an independent one, in the fact that the metal does not occur where the hypothesis demands.

4. A further objection arises from the want of evidence that the penetrating molten rock produced any profound effects upon the adjacent rock. Observations upon the rock lying next the dikes, now exposed by denudation, indicate that the walls were but little affected by the passing material. A little baking or hardening, or slight local metamorphism, is the extent of observed effects. The inclosing walls are clearly and sharply defined, and not fused and commingled with the trap, as might be expected if the molten rock were superheated to such an extent as to reduce copper ores. These observations are in harmony with theoretical considerations, for the eruptive rock is not a heat-generator, but merely a heated mass. It cannot impart heat without corresponding loss to itself, and cannot suffer much reduction of temperature without solidifying. At the point of its origin, it cannot be supposed to be sensibly heated above the point of fusion, for any excess of heat would be consumed in

the liquefaction of adjacent rock. In rising through the strata its fusion point would sink, because of relief of pressure. This would tend to give it a temperature above that necessary to maintain its liquid condition, but it would, on the other hand, lose heat, (1) from expansion both of the molten rock and the contained gases, and also (2) from contact with the walls of the fissure through which it passed, and from the conversion into steam of the moisture contained in them. The evidences of rapid cooling which the walls of dikes almost universally present, show that these are important considerations, and justify the belief that the surrounding rock has a more manifest effect in congealing the molten rock, than the latter has in fusing it. The hypothesis that the copper was melted from ore beds traversed by rising lava, seems, therefore, untenable.

Theory of Oceanic Precipitation. It has been suggested that the copper was derived from oceanic waters through the extractive agency of organic matter, and the precipitants generated by its decomposition, and that the metallic sediment so formed was afterward taken up in solution, and deposited as now found, being reduced to the metallic state by iron protoxide compounds or other reducing agencies.

This view encounters difficulties in requiring the assumption of the existence of organic life beyond what evidence justifies or theoretical presumption warrants. In circumscribed basins, repeatedly overwhelmed by great eruptions, life would quite certainly be less abundant than under the average conditions of the adjacent undisturbed sea, and hence to that extent, this region should be supposed to be lean, rather than rich, in the metallic precipitants to which life gives origin. Unless, therefore, reasons can be assigned why this area of the ocean was exceptionally enriched by metallic solution, this hypothesis lacks probability. Now, if any exceptional enrichment took place in this basin, it would seem that it must have had its origin from the igneous ejections themselves, for we have already alluded to the evidence that the sediments of the period were mainly derived from the erosion of the margins of the earlier lava-flows, and hence, even pursuing this line of hypothesis, we are led to seek the origin of the copper in the eruptions themselves.

Another difficulty encountered by this hypothesis arises from the copper deposits that lie in or between the igneous sheets, and in no ascertainable way associated with sedimentary deposits.

Oceanic precipitation would seem, therefore, to be an exceedingly improbable source, considered in relation to the great massive deposits in question, although it may have been a subordinate and secondary agency.

Theory Here Accepted. From the consideration of all the phenomena involved, we are led to seek the proximate source of the copper in the igneous rocks themselves, and the more distant source in the rocks from whose melting these arose. A metallic ingredient from such a source would be widely — though probably not uniformly — distributed throughout the igneous rock, and in this it accords with observation.

It would, however, only become observable and industrially available where concentrated by subsequent agencies, and therefore, practically, the method of concentration is one of the most important phases of the problem.

Method of Concentration. Concentration is believed to have been accomplished through the agency of permeating atmospheric waters. These, penetrating the fissures and capillary crevices of the rock, bore in oxygen, and carbonic and organic acids which attacked the disseminated ores of some portions of the rock substance, as abundantly shown by microscopic inspection. The solutions so formed would be borne onward with the capillary moisture in the direction of internal drainage. This would be toward the more open portions of the formation, whether they were the vesicular amygdaloidal bands, the interstratified conglomerates and sandstones, or gaping fissures, for these are the great avenues of internal drainage. The waters, permeating different portions of the rock, doubtless bore away somewhat different solutions according to the special conditions encountered by them.

On entering the more porous belts, they would commingle with waters that had descended more directly from the surface, and were differently charged with accessory ingredients. There were thus continually brought together (1) solutions formed by waters percolating through the rock, meeting (2) those differently charged, because they had passed through different rocks or under different conditions, and (3) waters descending more directly through the porous avenues of drainage, possibly charged with reducing organic agencies. The precise character of the chemical reactions that would take place under these conditions is quite hypothetical. Several probable reactions may be assigned which would involve the deposition of copper, among them the reducing action of the proto-salts of iron, as suggested by Pumpelly.[1] It is probable that an elabo-

[1] Geol. Mich., Vol. I, Part II, pp. 41 to 44; also Am. Jour. Science, 3rd series, II, 1871, p. 353.

rate study of the order and relations of the complex groups of minerals with which copper is associated, such as that so well begun by Professor Pumpelly, supplemented by special chemical researches, will at length satisfactorily determine the precise reactions. But this is a labor of the future. There is much yet to learn concerning the complicated chemistry that is ever being wrought in the interior of complex rocks of the type under consideration. That they are thoroughly pervaded by the effects of chemical changes is unequivocally attested by critical investigation, especially by the recent microscopical methods. Allusion has already been made to some of these, and the special reports give ampler details.

The concentration of copper is regarded as but one of the many results of slow chemical activities, inaugurated and sustained by permeating waters — begun when first the rocks were formed, continued throughout the lapse of the vast succeeding ages, and still in progress. The greatness of the copper concentration ceases to be so surprising when regarded as the accumulated result of the action of millions of years.

Ores in Detrital Beds Not Associated With Igneous Rocks. One class of deposits, however, to which little allusion has as yet been made, seems to require special explanation under this hypothesis, though they are so far subordinate in richness as not yet to have proved remunerative to mining, viz.: the occurrence of copper and silver in detrital beds that lie entirely above the igneous sheets. The silver-bearing horizon of the Ontanagon (Iron river) region, which has been traced into Wisconsin, may be taken as a special illustration of this, since it is the highest, best known, and best defined of such deposits. It may be called to mind that the metallic deposit is distributed along a definite bedding horizon, and that this lies in the dark shale, immediately above the great conglomerate, separated by some hundreds of feet from the uppermost igneous sheets. The further fact that a part of the ore, especially of the copper, is in the form of the sulphide is to be noted.

In accounting for this peculiar deposit, the conditions prevalent when the stratum was formed are to be considered. We rejected the theory of marine origin for the main deposits of the series for the reasons already assigned, mainly the want of evidence of the existence of abundant life, and the absence of conditions making its existence probable in this eruptive region. But, accepting the above hypothesis, that the lavas were infused with copper and silver, and that the sedimentary beds, which contain the deposits now under consideration, were derived from these by disintegration, there is a manifest source whence the waters of this nearly inclosed basin might be exceptionally enriched, and, now that the eruptions had long since ceased, organic life might have flourished undisturbed. The association of the deposit with the black shale lends support to this presumption, though, so far as known, it has not been shown that its dark color is due to organic agencies. There are, therefore, good reasons for thinking that this deposit may have been due to marine deposition, through the extractive agencies of life and the sulphuretted gases attending the decomposition of its remains. The metals so precipitated would undoubtedly be in the form of disseminated sulphides, and would have need to be taken up by percolating waters and concentrated as indicated above.

These considerations may perhaps have an application beyond this immediate region. The waters so enriched, drifting away to the eastward through the open mouth of the basin, might furnish an essential condition of metallic deposition in that region, and may account for the cupriferous enrichment of the sedimentary strata there, so far as not attributable to similiar igneous sources indigenous to that area. It is a well known fact that cupriferous rocks prevail to the eastward in Canada. It remains to be proven, however, that they belong to this particular horizon, though the present evidence favors this view.

The essential features of the view here maintained are, therefore, these: (1) That the metals, copper and silver, were primitively constituents of the rocks that were melted to produce the lavas that formed the trappean sheets of the formation, and (2) that they were brought up, and spread out, commingled with the molten rock-material, (3) that they were chemically extracted thence by percolating waters and concentrated in the porous belts or fissures of the formation, giving rise to the exceptionally rich deposits for which the formation is famous, and (4) that the surface disintegration of portions exposed in the latter part of the period yielded metallic ingredients to the adjacent sea, from whence they were extracted by organic agencies, giving rise to impregnated sediments, which in turn, through subsequent concentrations, gave rise to other copper and silver deposits, among which are to be reckoned the later metallic horizons of the Lake Superior region, and possibly some elsewhere.[1]

[1] For a detailed discussion of the methods of metallic precipitation from oceanic water and of subsequent concentration, reference may be made to a discussion of the *Ore Deposits of Southwestern Wisconsin*, in Volume IV, which, with some modifications, is applicable to other metals and formations than those there considered.

Geography at the Close of the Keweenawan Period.

At the close of the Laurentian elevation the land had gained and the sea lost large areas in our northern region. During the period of Huronian sedimentation the land was reduced both by wear and subsidence of its border. Its outline, in part, at the close may be recalled by reference to plate IV.

The prolonged Huronian and Keweenawan elevation forced the sea to again retire, and the land again extended itself. How far the waters receded cannot now be determined with even moderate approximation. It is not improbable that the entire area of the State was lifted above the ocean level, and became a part of the Huronian continent, which probably had a form and outline similar to that of the earlier Laurentian land, but was broader and more confluent in outline.

Interval Between Keweenawan Elevation and Potsdam Sedimentation.

As soon as the foregoing elevation had lifted the region from the sea, arching it upward into lofty land, a fresh impetus was given to the old-time, never-ending process of land-wearing and sea-filling. The rains, and the agencies which they called into action, softened, dissolved, and abraded the surface, and bore the resulting material down to the sea to fill its bed, and, to that extent, to lift its surface. The sea on its part ground away at the borders of the land, wearing back the shore line little by little through the lapse of the ages. These general facts are certain, but for a long period following the Keweenawan elevation, during which the sea was slowly readvancing from the distance to which it had retired, and before it again reached our borders, there is, in the interior, no definite record of geological events, for the deposits are concealed. What were the special details of that long history we may never know from any evidence found in the interior of our continent. On the Atlantic border of New England and the Provinces, the formation known as Acadian represents a part at least of the work of the interval—how great a part has not yet been determined. Quite possibly the lower Cambrian formations of Great Britain and Bohemia bridge the entire interval.

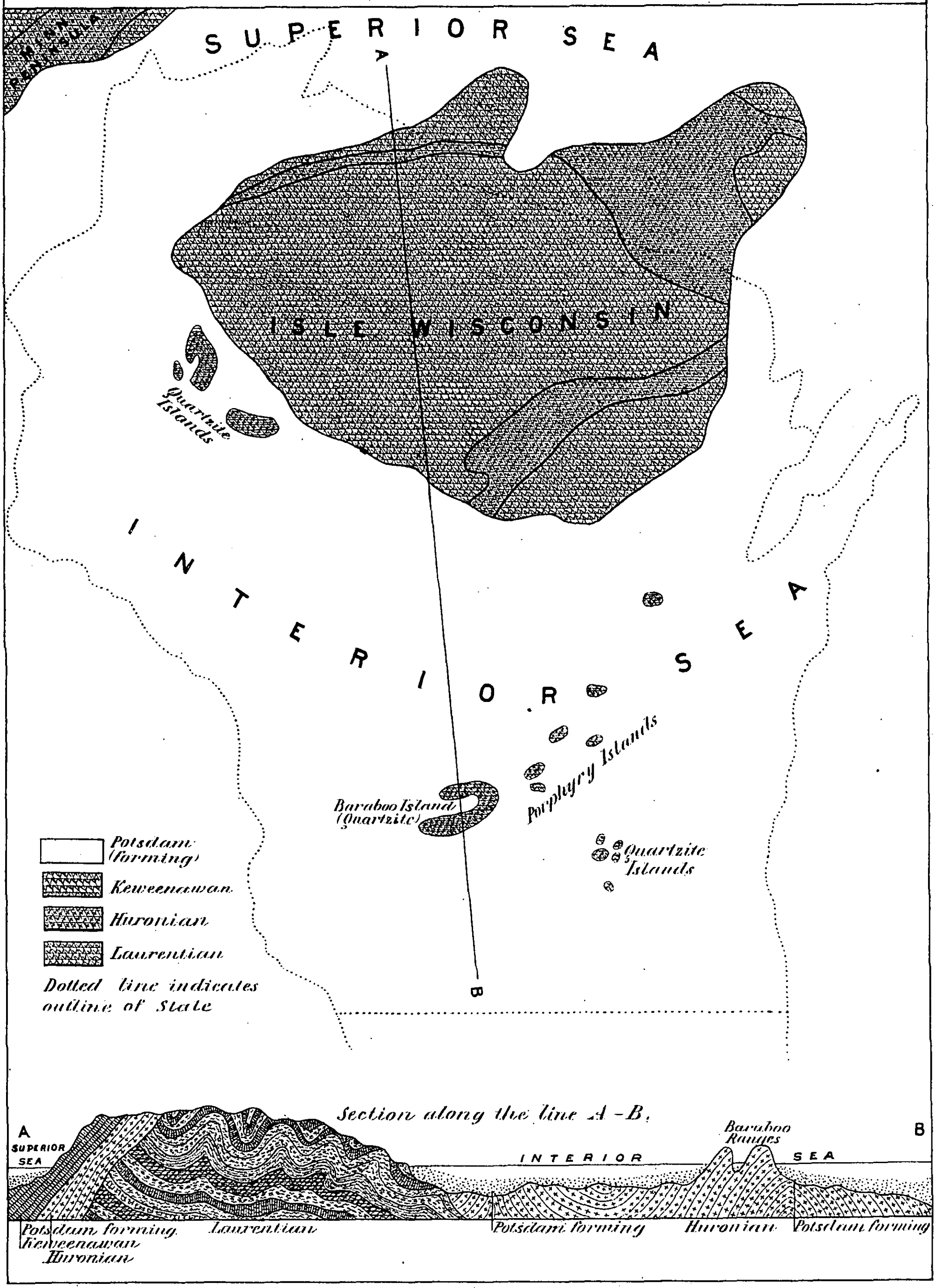
In these foreign formations appear the first well-preserved and undisputed organic forms. Reasons have been given for believing that abundant life existed earlier, but, leaving out of consideration the contested *Eozoon Canadense* and some other problematical remains, its forms are not definitely known to us. While the sea was withdrawn from our shores after the Keweenawan elevation, a somewhat abundant and interesting group of plants and animals were living, dying, and being buried and fossilized on the Atlantic border, and in the foreign localities named, as well as elsewhere, indeed in all probability quite generally throughout the ocean's borders, though the deposits have not been revealed to us. As these life forms do not differ in those general features which alone can be considered here, from those which first appeared in our own region, they will only be considered in connection with them.

The introduction of these distinctly preserved forms of ancient life marks the dawn of the Palæozoic era. It was the opening of a new and easier and fuller chapter of geological history. Not only are the physical and chemical records better preserved, but the life-remains add their testimony and tell of the progress of biological events. We shall be able to read the lithographed story with greater ease and interest.

This greater fullness and legibility of the record will naturally lead to a more detailed study. In standard works on geology, it is customary to dismiss all that precedes this era with a few pages devoted to the Laurentian and Huronian *periods*. In some, indeed, the latter age is not even separately recognized. Where best considered, these divisions are ranked as *periods*, and thus placed in the category of formations that often measure fewer hundreds of feet than these do thousands. Even in the more extended views presented in this sketch, relative injustice is done the earlier eras. In discussing the Laurentian, measuring as it does accumulations many thousands of feet in thickness, we only considered it as a whole, making no attempt at even an enumeration of the subordinate periods of deposition that marked its history. Even in describing the Huronian system, we barely enumerated the successive thick deposits, though they embrace rich and varied accumulations of ore, carbon, and lime, besides common detritus. Were these unmodified members of the later systems, they would doubtless be ranked as important periods, and the whole Huronian system would be graded as the equivalent of the Devonian age, or, perhaps, of the Mesozoic era. Our justification, in common with others, is the obscurity and complexity which the contortion and metamorphism of the series have produced, and the consequent imperfection of our knowledge of details. But while this justifies meagerness and generality of description, it does not sanction a bedwarfing of the extent and importance of these early eras. They embrace, in our estimation, more than one-half of the sedimentation of geological history, and, as we shall have occasion to remark presently, at least half of the life-history of the globe, if measured by the physiological results attained.

The reader seeking a just comparative estimate of the enactments of the ages, will do well to bear these suggestions in mind, as we descend more into detail in following the progress of events, and thereby seem to relatively magnify the importance of formations whose rich organic contents make them relatively more interesting to us.

HYPOTHETICAL MAP OF THE LAND IN THE POTSDAM PERIOD



PALÆOZOIC ERA.

CHAPTER VII.

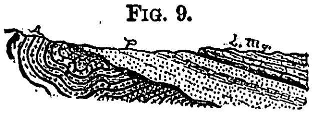
CAMBRIAN AGE—POTSDAM PERIOD.

The Potsdam period of Wisconsin embraces the epoch of the Potsdam sandstone, and of the Lower Magnesian limestone. It perhaps should also include the St. Peters sandstone, which may have been formed, in part at least, by the retiring seas of the Potsdam period. The group would then stand:

Potsdam Period. { St. Peters Epoch (in part).
Lower Magnesian Epoch.
Potsdam Epoch. }

Potsdam Epoch.

FIG. 9.



SECTION illustrating the relations of the Potsdam sandstone (*P.*) to the underlying Archæan formations (*A.*), and the overlying Lower Magnesian Limestone (*L. Mg.*).

Synopsis of Characters. Name derived from Potsdam, New York. Epoch one of sandstone accumulation. Rocks mainly light-colored sandstone in Central and Southern Wisconsin, and red sandstone in the Lake Superior region, but embrace some beds of limestone and shale. Maximum known thickness about 1,000 feet. Contains many fossil Trilobites and Linguloid Brachiopods, with some other forms.

For details, see Vol. II, pp. 257–267 (Chamberlin), 525–547 and 563–607 (Irving), 668–671 (Strong); Vol. III, pp. 15–25 and 207–210 (Irving), 340–347 and 350–352 (Sweet), 395–397 (Chamberlin), 415–419 and 427–428 (Strong); Vol. IV, pp. 38–64 (Strong), 109–123 (Wooster), 169–193 and 341–345 (Fossils, Whitfield), 518–520 (Chamberlin). For area occupied by Potsdam sandstone, see atlas.

Geography. To picture the geographical circumstances that attended the commencement of the Potsdam formation, the earliest Wisconsin member of the Palæozoic series, conceive the whole or the greater portion of our State to be above the sea, and to be attached to the Archæan continent lying to the northward, forming one of its southward-projecting promontories. The sea lay to the southward, and during the period gradually advanced upon the land. At a very early stage it crept up through the basin of the lower peninsula of Michigan, and entered the depression of Lake Superior. At the same time it appears to have advanced through the stratigraphical basin lying beneath Iowa and southern Minnesota, and reached well to the northward on that side, partially surrounding the Archæan heights of Northern Wisconsin, forming a peninsula, connected with the mainland only by an isthmus in the upper St. Croix region. This stage was apparently reached at about the middle of the period. During the later part, the sea continued its advance, reducing the peninsula and narrowing the isthmus. It is a matter of some difference of opinion whether or not by the close of the period the neck of land was entirely severed, making the peninsula an island. In the judgment of the writer, the sea crossed the neck, cutting off the Archæan heights, and reproducing the *Island of Wisconsin.* If this view be correct, the water swept entirely around the old granite highlands, submerging three-fourths or more of the State, but leaving reefs and islets formed of resistant portions of the Huronian rocks, lying off the southern shore of the main island in Central Wisconsin.

Character of the Deposit. The Potsdam epoch was characterized by great sandstone accumulation. Remembering that the rocks of the adjacent land were quartzites, gneisses *(foliated fel-qua-mi)*, granites *(fel-qua-mi)*, syenites *(fel-qua-horn)*, and crystalline schists, this appears but a natural result. The quartzites could yield little but quartzose detritus. The granites, gneisses, mica schists and syenites, by the disintegration of their feldspar, mica, hornblende and similar silicates, yielded mainly a clayey product, while their hard quartz particles were left as angular sand. The waves assorted these products, washing out and carrying back into the stiller depths the fine material, while the sand was strewn along the shore and over the wide, shallow sea-bottom adjoining. The angular quartz grains were rolled to and fro, and rounded in various degrees, until at length they found rest in burial in the accumulating beds.

If this sand be examined under the microscope, its grains will not appear as the little spheres we are wont to think them, but as irregular, angular particles of quartz, more or less rounded by wear. Their angularity is due to the fact that in the crystallization of the parent granitic rock, the feldspar and mica mainly took form first, while the quartz was left to fill the interspaces between them, and was thus forced to assume varying, irregular, angular outlines. Occasionally, where greater freedom of formation was afforded, the quartz assumed its own proper crystalline form, so that some of the sand particles present the appropriate outline of quartz crystals. But this is the exception, rather than the rule.[1]

[1] Secondary crystals of quartz and crystalline attachments and envelopments of grains were afterwards sometimes formed in the sandstone. See note of Rev. A. A. Young, of New Lisbon, in Am. Jour. Sci., April, 1882; also fuller article in July No.

In addition to the quartz grains, some of feldspar, hornblende and other minerals are occasionally present, having escaped the complete reduction which those minerals usually suffered. Scales of mica and other foliated minerals frequently occur. These accessories are more common near what was the ancient shore line, where they were buried before their complete destruction was effected by the action of the waves.

Irregular Wear, Formation of Islands. The advancing sea met with unequal resistance. The hard quartzites and quartz-porphyries opposed it with some success, while the softer schists, and decomposable granites, yielded more easily. The result was, first, irregularities of coast outline, then islands, and, at length, submerged reefs. Some of the quartzites and quartz-porphyries of Central Wisconsin resisted to the close of the period, and stood as islands in the Potsdam seas. Among these were the quartzite domes of the Baraboo and Portland regions, the quartz-porphyry knob — Pine Bluff — in Green Lake county, and probably others of the isolated Archæan peaks of Central Wisconsin. Against these islands the ocean waves beat with great violence, undermining and throwing down from the cliffs fragments, and sometimes even large masses of rock, which were then rolled by the breakers and ground by the sand into bowlders and pebbles, and at length buried, forming the belts of coarse conglomerate that encircle these islands.

Succession of Beds. On the southern side of the Archæan island, the lower part of the formation usually consists of coarse quartzose sand, of an exceedingly open, porous nature, with but little aluminous, or ferruginous, and almost no calcareous matter. Higher in the series, the sandstone becomes finer-grained and the accessory substances named more abundant. Somewhat above the middle of the series a stratum of shale occurs, attaining a known thickness of 80 feet. This is not everywhere present, and seems to be mainly developed at some distance from the ancient shore-line. It appears to indicate that for a time there was a deepening of the waters, admitting of the accumulation of fine sediment, except near the shore, where the deposit of sand continued. Above the shale, sandstone, reaching a thickness of 150 feet, is again found. This is medium or coarse-grained, and slightly calcareous. It, in turn, is overlain by a deposit of associated shale and limestone *(the Mendota limestone)*, which attains a thickness of 35 feet in the vicinity of the lake from which it derives its name. These beds indicate a modification of the conditions of deposition, such as to permit not only the settling of fine sediment, but the accumulation of calcareous mud as well.

The latter was doubtless derived from the calcareous remains of life, since the sea then swarmed with living organisms whose shells and skeletons are found entombed in the strata. The frequency of broken and worn fragments implies that the greater portion were ground to powder, forming the calcareous flour that subsequently hardened into limestone. These beds appear to point quite surely to a moderate deepening of the waters.

Overlying this impure limestone is a third and thinner bed of sandstone *(the Madison)* with which the Potsdam series closes. This, on the whole, is finer-grained than that below, and is bound more firmly together by cementing material, which is mainly a calcareous and ferruginous infiltration. The thickness of this bed is about 30 feet.

The foregoing may be taken as a fair type of the succession of the Potsdam series, as developed on the southern side of the Archæan area. (That on the north, in the Lake Superior basin, is reserved for separate consideration a little later.) In some regions there are local modifications arising from the absence of some of these beds or from the introduction of additional shaly or calcareous layers, or from the substitution of one kind of rock for another. The variations are particularly characteristic of the upper Mississippi and St. Croix regions. There, also, in addition to the variations mentioned, greensand *(glauconite)* abounds in certain horizons. It also occurs elsewhere, but less abundantly.

Lake Superior Sandstone. The sandstones on the southern side of the Archæan island are light-colored, being mainly yellow or white, varying locally to pink, brown and green. They are nowhere bodily dark. An easy explanation of this is found in the fact that they were derived from the light-colored quartzose and granitic rocks of the southern face of the land. But passing around to the Lake Superior basin on the northern side of the island, where erosion preyed upon the iron-bearing members of the Huronian series, and more especially upon the traps, sandstones and shales of the copper-bearing series, the resulting beds are not only reddish brown in color, but contain a notable ingredient of iron and of shaly material derived from those formations. Indeed the deposit bears a very close external resemblance to the sandstones of the Keweenawan series, and the two have been considered as identical by able geologists.

Concerning the distinctness of the two formations, we entertain no doubtful opinion. The Potsdam sandstone is habitually horizontal, while the Keweenawan is tilted, indicating that the latter partook of a general stratigraphical movement, which did not affect the former, which, considering the attendant circumstances, is equivalent to saying that the horizontal sandstones were not then in existence. The observations of Mr. Sweet in Douglas county are further proof of this.[1] The Potsdam sandstone there abuts unconformably against the Keweenawan traps, and contains pebbles derived from them, showing not only that they were earlier formed, but that they were tilted and extensively eroded at the time the horizontal sandstones were formed. The local disturbance of the latter does not vitiate the force of the evidence when critically considered. Similar phenomena are presented along the southeastern face of the promontory of Keweenaw Point.[2]

Beside these stratigraphical evidences of distinctness, the microscopical observations of Prof. Irving, and the chemical analyses of Mr. Sweet, show an important constitutional distinction between them.[3] Whereas the Keweenawan sandstones are largely non-quartzose, the horizontal beds are highly quartziferous.

As the latter are traced eastward along the south shore of Lake Superior, they are found, according to Dr. Rominger, to be interstratified with, and graduated into, the light-colored sandstones which prevail in the eastern portion of the upper peninsula of Michigan, and which are traceable into direct continuity with the light-colored sandstones of Wisconsin. The same geologist (as also Foster and Whitney) is authority for the statement that in the Keweenaw valley, Silurian limestone overlies this sandstone.

The southern light-colored sandstones, like their northern equivalents, abut unconformably against eroded cliffs of Keweenawan rock. At St. Croix Falls, light-colored Potsdam sandstone containing characteristic fossils reposes unconformably upon and against Keweenawan cliffs, and occupies depressions and valleys formed through its erosion. Conglomerates derived from it mark the junction of the two formations, and contain Potsdam fossils. Hand specimens may be obtained, having Keweenawan rock for one side and Potsdam sandstone containing shells of *Lingulepis pinnaformis*, for the other. The phenomena absolutely forbid any explanation based on faulting or intrusion.

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[1] Geol. Surv. Wis., Vol. III, pp. 340–347; also 350–352.

[2] This has recently been denied by Dr. M. E. Wadsworth, but more recent examination by experienced observers shows his discussion of the subject to be more pronunciative than trustworthy. Bulletin of the Museum of Comparative Zoology, at Harvard College, Geol. Series, Vol. I. The facts in detail as determined by the later observations will be found in Prof. Irving's forthcoming report on the Copper-bearing series.

[3] Vol. III, pp. 15 and 350, and microscopical plate XIX A.

North of St. Croix Falls, the same strata, sustaining a like stratigraphical relationship (though not seen in actual unconformable contact), may be traced more than half way across the Keweenawan series. Passing the remainder of the interval to Lake Superior, the horizontal red sandstones are found abutting, in similar unconformable contact, against the eroded Keweenawan series, as above

FIG. 10.

SECTION FROM ST. CROIX FALLS TO LAKE SUPERIOR, illustrating the relations of the Potsdam sandstone to the Keweenawan igneous and detrital beds. *P. P. P.* Potsdam sandstone. *K. K.* Keweenawan series. *L. S.* Lake Superior.

stated. The accompanying section illustrates the general relationship, but only a careful study of the details can make clear the full force of the evidence.

When to these considerations there are added others less susceptible of brief statement — to which we are here confined — it appears that the distinctness of the horizontal Lake Superior sandstone from that of the Keweenawan system, and the correctness of its reference to the Potsdam series, is sustained by a weight of evidence that would not be seriously questioned, but for complications with what we deem the misinterpretations of other geological features of the Lake Superior region. The modifications which the formation assumes in that region are precisely those which its method of derivation demands.

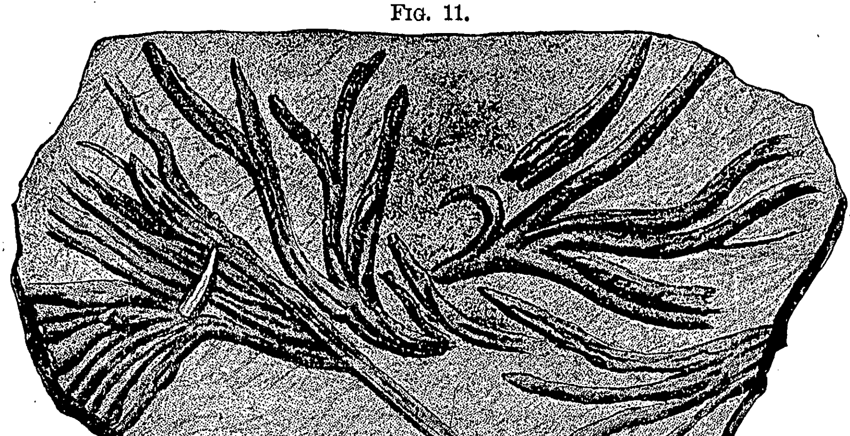
Life of the Epoch. The Potsdam epoch marks the introduction of an interesting phase of the geology of the interior. While in the earlier strata the presence of carbonaceous beds, limestone, and ore deposits, furnishes sufficient indirect evidence of the existence of life to warrant a rational *belief* in its presence, and while theoretical considerations, arising from prevalent views of the development of life-history, point to the same presumption, and while, further, strata that are somewhat older than those under consideration contain well-preserved fossils, yet, in the interior region, the Potsdam beds are the first that have yet been found to contain distinct and well-preserved relics of ancient life. In this sense, the Potsdam epoch introduces us to the life-history of the interior basin, and almost to the known life-history of the globe, since the few earlier known forms were mainly of essentially the same types. The characteristics of these primordial forms of life become, therefore, a subject of peculiar interest.

Plants. The fossils give evidence of the presence of both animal and vegetable life. Of the former, the only determinable forms are regarded as seaweeds. No remains of higher or lower forms are found. It is reasonable enough to suppose that other kinds may have existed, since succulent, perishable plants would be little likely to leave permanent traces of their existence. From theoretical considerations, it is quite generally believed that such unrecorded types existed, representing the lower forms of vegetable life. It is not impossible that there were higher forms, but of this there is less inherent probability, since the higher vegetable species usually possess firmer tissue, and hence are better subjects for preservation.

There is no direct evidence of land plants. It may not be safe to assert their absence, however. The great iron-ore beds find their easiest explanation in the supposition of land vegetation, and the carbonaceous shales, from their analogy to later coal deposits, naturally suggest marsh vegetation.

If the land of the earlier periods was bare, or scantily clothed with vegetation, this circumstance must be considered in estimating the character and rate of denudation. It is manifest that the absence of vegetation would greatly facilitate the washing away of disintegrated superficial material, and would swell the torrential effects, since a function of the vegetable clothing is both to protect the soil

FIG. 11.



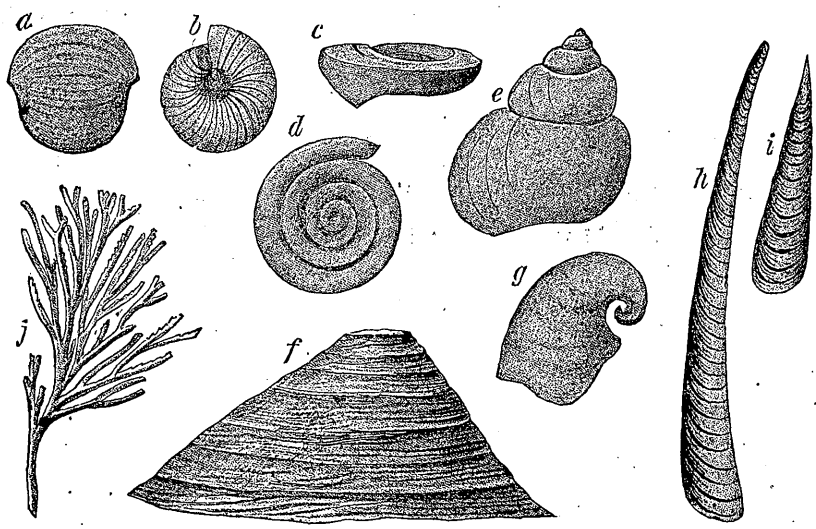
PALÆOPHYCUS PLUMOSUS, a supposed marine plant.

and to retard violent drainage. The nakedness of the land promoted its degradation, and correspondingly hastened deposition in the sea.

Special Plant Forms. The supposed fossil plants consist of an undetermined species of *Palæocordia*, one of *Cruziana*, four determined species of *Palæophycus*, viz.: *P. duplex*, *P. plumosus*, *P. simplex*, and *P. tubularis*, with one undetermined species. These consist mainly of obscure cylindrical casts that indicate very little of the character of their originals, and even their reference to plants has been questioned. In placing them here we have adopted what seems to be the best sustained view.

Special Forms of Animal Life. "*Radiates.*" That strange group of plant-like animal forms, the *graptolites*, was represented by *Dendograptus Hallianus*. Of corals, so abundant in the following ages, we have found in Wisconsin no representatives, which is perhaps not strange in view of the prevailing sandiness of the sea-bottom. Crinoids, the "stone lilies" of the sea, have not been found within our State, but the fact that their stems occur at La Grange, Minnesota, leads to the hope that they may yet be found within our borders.

FIG 12.

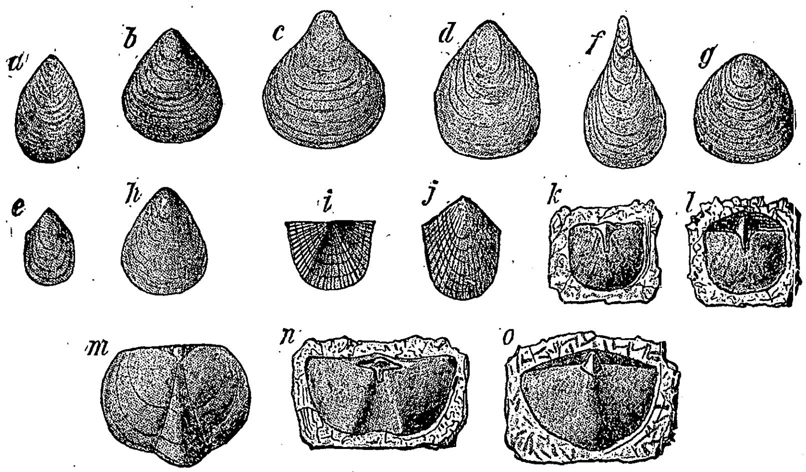


POTSDAM FOSSILS. *a* and *b*. Bellerophon antiquatus — Whitf. *c* and *d*. Ophileta primordialis — Winchell. *e*. Holopea Sweeti — Whitf. *f*. Palæacmæa Irvingi — Whitf. *g*. Platyceras primordialis — Hall. *h*. Serpulites Murchisoni — Hall. *i*. Theca primordialis — Hall. *j*. Dendograptus Hallianus — Prout.

Mollusks. The univalve type of Mollusks was fairly represented by the following Gasteropods: *Palæacmæa Irvingi*, *Platyceras primordialis*, *Euomphalus vaticinus*, *Ophileta primordialis*, *Holopea Sweeti*, and *Pleurotomaria advena;* by the Heteropod, *Bellerophon antiquatus*; and by the Pteropod, *Hyolithes primordialis*. These show that this group, though it has not left very abundant remains, was represented even in that early age by quite divergent forms.

Brachiopods. Of the true bivalve Mollusks, the Lamellibranchs, no remains have yet been found in this region, but the Brachiopods, which closely resemble them as fossils, though they are structurally allied to the worms, are abundantly represented by *Lingula ampla*, *L. Mosia*, *L. Winona*, *Lingulella aurora*, *L. Stoneana*, *Lingulepis pinnaformis*, *Discina inutilis*, *Obolella polita*, *Orthis Pepina*, *Leptæna Barabuensis*, and *Triplesia primordialis*. The linguloid shells of the group were phosphatic, a circumstance which favored their preservation, while shells of simple lime carbonate, as those of the

Fig. 13.



Potsdam Brachiopods. *a.* Lingulella Stoneana—Whitf. *b.* Lingula antiqua—Conrad. *c.* Lingulella aurora—H. *d.* L. ampla—Hall. *e.* L. Mosia—Hall. *f.* Lingulepis pinnaformis—Owen. *g.* Shorter valve of same. *h.* Obolella polita—Hall. *i.* Dorsal valve of Orthis Pepina—Hall. *j.* Ventral valve of same. *k.* Inner cast of dorsal valve of same. *l.* Inner cast of ventral valve of same. *m.* Triplesia primordialis—Whitf. *n.* Inner cast of dorsal valve of Leptæna Barabuensis—Winchell. *o.* Inner cast of ventral valve of same.

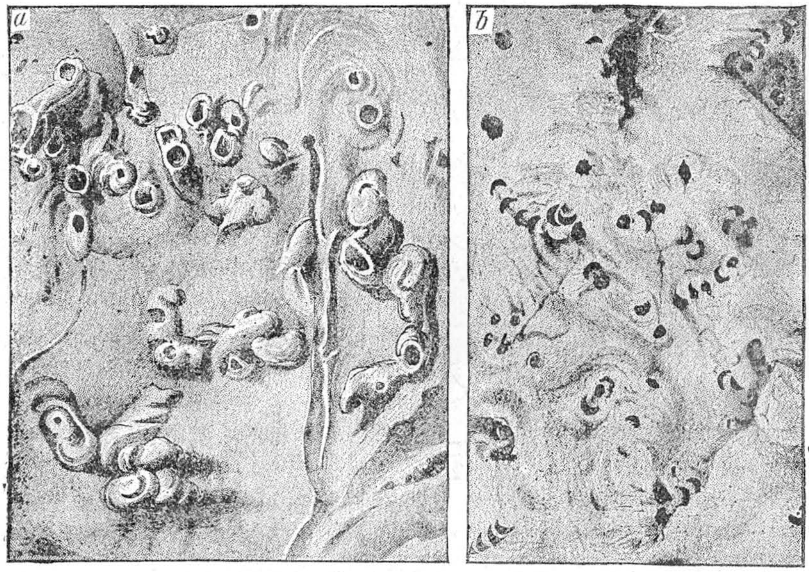
Orthidæ, were dissolved away, and only their casts remain. The genera *Lingula* and *Discina* have representatives in the present seas, having lived through all the vicissitudes of the Post-Potsdam ages. They stand as remarkable instances of organic stability amid the prevalent mutations that mark the life-history of subsequent eras.

Cephalopods. Of the Cephalopod type which attained such importance in the Trenton period closely following, no representatives have been found *in our State*, though two species are reported from the Potsdam of Canada, indicating that the type had its representatives in the primordial seas.

Annelids. Worms of the Annelid class were abundant in numbers, though the known species are few. The vertical borings, commonly called *Scolithus*, but now referred by Prof. Whitfield to

Arenicolites, occur plentifully in various parts of the formation.[1] Some doubt as to the true nature of these has heretofore existed, but Mr. J. W. Wood, of Baraboo, has been fortunate enough to find specimens which, in the hands of Prof. Whitfield, have thrown much light upon their character, and satisfactorily demonstrated that the tubes were formed by marine worms.

FIG. 14.



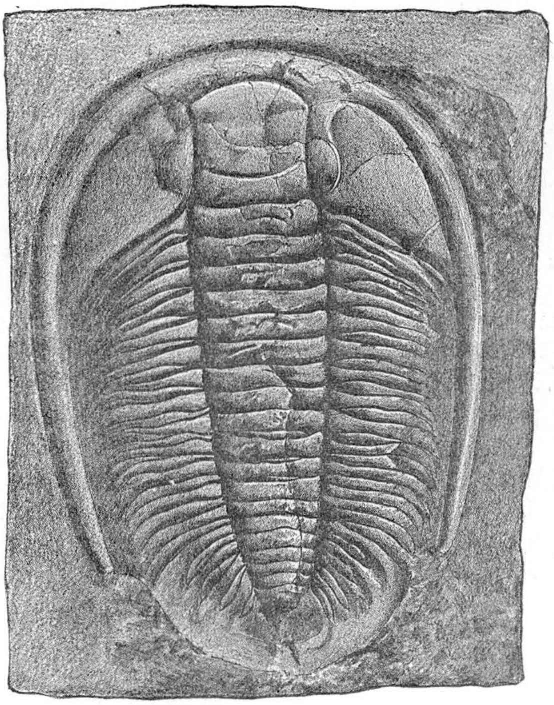
ANNELIDAN BORINGS. *a*. Block of Potsdam sandstone presenting a natural surface, showing the borings, hillocks, and horizontal grooves of the annelid, *Arenicolites Woodi*. *b*. Block of Potsdam sandstone showing the circular perforations of *Arenicolites Woodi*, also the semi-lunar perforations formed by the crowding in of one side of abandoned borings in forming new adjacent ones.

Trilobites. But by far the most numerous and interesting life-forms of the period were the Trilobites. Fifty species have been identified, and obscure fragmentary representatives of others found. No other State has furnished an equal number of these interesting fossils. This is about half the entire number known from American rocks, indicating an exceptional richness in these remarkable forms. These Trilobites, being articulated animals, usually suffered disjointing before final burial and fossilization, so that complete specimens are extremely rare in our formations, the fossils usually consisting of the disjointed and often broken members. The accompanying

[1] In Vol. II, the generic name *Scolithus* is used in accordance with prevalent usage, but now that the annelidan character of the fossil is determined, the reference to *Arenicolites* is preferable.

figures represent the least fragmentary condition in which they are commonly found. Mr. R. E. Stone, of Prairie du Sac, has, however, recently been fortunate enough to find nearly complete specimens of the largest and leading genus, *Dicellocephalus.*

FIG. 15.

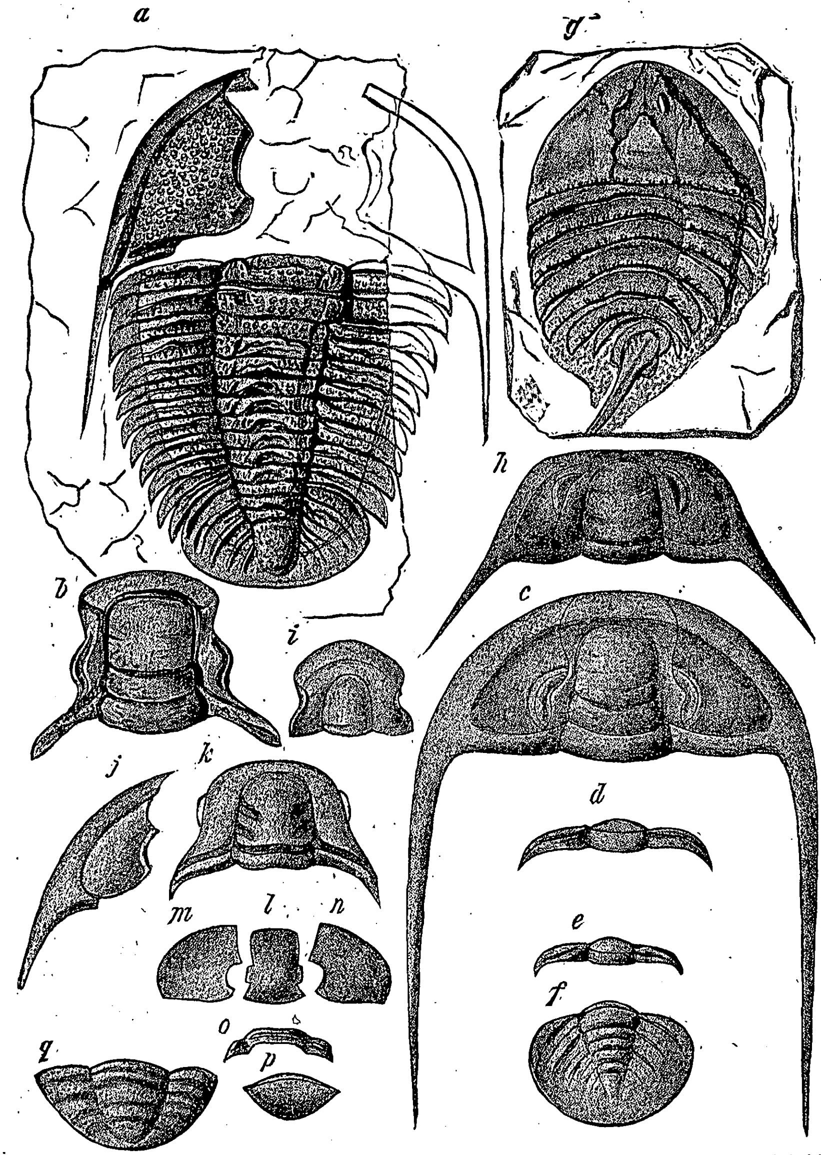


DICELLOCEPHALUS. A common and characteristic Potsdam Trilobite.

Figure 15 is a representative of one of these (lateral spines restored and somewhat too large in figure), which will serve at once to represent the form of the animal and the articulate parts of which it is composed, and into which it is usually separated before fossilization. The head portion (cephalic shield) is usually disjointed into three members, the central piece (the glabella and fixed cheeks), and two side pieces (the movable cheeks). The body consisted of twelve thoracic segments which are usually separated from each other in fossilization. This portion best shows the three-lobed character of the animal which gives it its name. The posterior portion of the animal consisted of a single solid piece (the caudal shield or pygidium), which is one of the commoner parts preserved. These parts represent the back of the Trilobite.

The under parts are rarely found, even in formations much more favorable to preservation than the one under consideration. The character of their organs of locomotion has long been a subject of

FIG. 16.



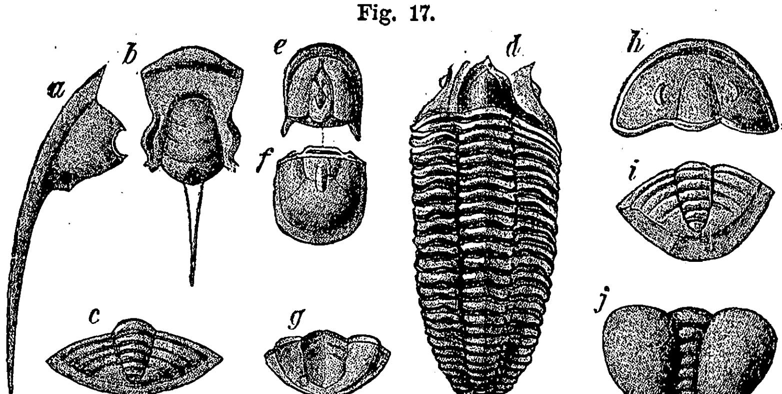
POTSDAM TRILOBITES. *a*. Dicellocephalus Lodensis—Whitf. *b*. Glabella and fixed cheeks of same. *c*. D. Pepinensis—Hall; restored head from actual specimens. *d*. and *e*. Thoracic segments of same species, from different parts of the body. *f*. Pygidium of same species. *g*. Aglaspis Eatoni—Whitf. *h*. Chariocephalus Whitfieldi—Hall; restored head from actual specimens of cheeks and glabella. *i*. Pygidium of Arionellus convexus—Whitf. *j*. Movable cheek of Ptychaspis minuta—Whitf. *k*. Glabella and fixed cheeks of same species. *l*. Glabella of Illænurus quadratus—Hall. *m*. and *n*. Cheeks of different individuals of same species. *o*. Thoracic segment of same species. *p*. Pygidium of same species. *q*. Pygidium of Crepicephalus Gibbsi—Whitf.

diversity of opinion. The recent investigations of Mr. C. D. Walcott, of New York, have shown that they at least possessed delicate articulated cephalic limbs and spiral branchiæ, and he maintains that they had a set of articulated limbs on either side, corresponding to the body segments.

The eyes of our Potsdam species are not usually well preserved. But other ancient specimens show that some of the order possessed highly organized, compound eyes. In some species, however, no eyes are discernible.

Among the special forms, the *Dicellocephalus* (shovel-head) is notable for its large size, the head of the dominant species, *D. Minnesotensis*, being sometimes four or five inches wide. *Conocephalus* leads in the number of known Wisconsin species, there being eighteen of this genus alone, but the forms are smaller and less conspicuous than those of *Dicellocephalus.* Of *Ptychaspis* there are six species, of *Agnostus* three, of *Crepicephalus* two, *Arionellus* three, *Agraulos* two, and of *Pemphigaspis*, *Ellipsocephalus*, *Chariocephalus*, *Triarthrella* and *Illænurus* one each. The unique form *Aglaspis*, a close ally of the Trilobites, is represented by two species, *A. Barrandi* and *A. Eatoni.*

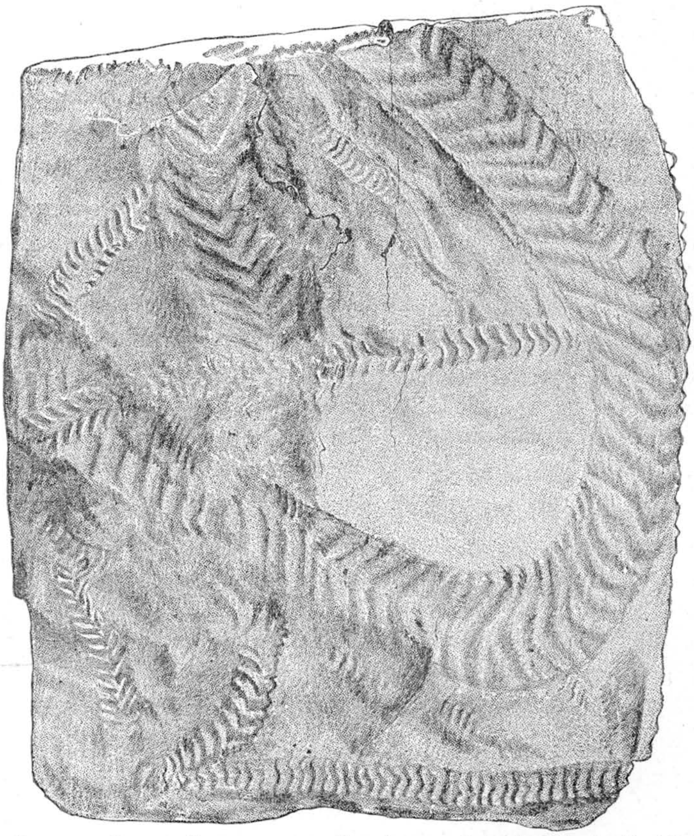
Fig. 17.



POTSDAM TRILOBITES. *a.* Movable cheek of Conocephalites Wisconsensis — Owen. *b.* Head and movable cheeks of same with spine restored in outline. *c.* Pygidium of same. *d.* Conocephalites calymenoides — Whitf. *e.* Head of Agnostus Josepha — Hall — showing the short spines at the postero-lateral angles. *f.* Pygidium of the same species. *g.* Pygidium of Ellipsocephalus curtus — Whitf. *h.* Head of Agraulos Woosteri — Whitf. *i.* Pygidium of same. *j.* Pemphigaspis bullata — Hall.

Fossil Tracks. In the vicinity of New Lisbon, there occur large fossil tracks that probably exceed in definiteness of detail and complication of impression, any similar relics of the primordial period. Figure 18 imperfectly represents some of the leading features, which consist of a consecutive series of V-shaped ripple-like ridges and depressions, forming a track varying in width from 2 to 5 inches. The V-shaped form of these ridges is the habitual, but not by any means universal one. The organs which produced the ridges were evidently flexible, for the ridges are frequently curved in different ways, especially where the course of the animal was curving.

FIG. 18.



FOSSIL TRACKS ON POTSDAM SANDSTONE FROM NEW LISBON. Natural width of widest 4½ inches. It is proposed to call the larger variety *Climactichnites Youngi*, and the smaller one at the base *Climactichnites Fosteri*. (The figure does not make clear the distinction between the latter and the smaller varieties of the former.)

The ridges on either side of the track usually meet in the center, as implied by their comparison with a V, but occasionally they alternate as though the steps or strokes of the locomotive organs were alternate instead of simultaneous. Where the course of the track curves the number of strokes upon the outer side of the curve is usually greater than upon the inner. This indicates independent action of the organs.

Over these coarser ridges there are a number of finer markings, sometimes appearing as though appendages of the animal had been dragged over the ridges after they were formed. In other cases these finer markings are wavy, as though formed by filaments in motion, acting upon the coarser ridges subsequent to their formation. On the outer margin these lines frequently incline backward and inward, or, in other words, are transverse to the larger ridges, the apices of which point in the direction of the animal's movement. In one instance there are three consecutive conical impressions near one side of the track, which appear to have been molded by an organ concave below, which was not rigidly attached to the locomotive organs and did not usually impress itself upon the sand, as these are the only impressions of it observed.

From the depth of the impressions and their smoothness, which implies considerable compacting force, it is inferred that the weight of the animal was considerable.

In a second smaller variety, the ridges are flattened so as to present a long, low, anterior slope, and an abrupt posterior one. In this variety too, the ridges pass more directly across the track, and the minor markings are absent or inconspicuous.

The character of the animal that produced these ridges is problematical. Similar markings, as the *Climactichnites* of the Canadian Reports, have been ascribed to Trilobites. But it is difficult to see how the tracks above described could have been made by a Trilobite, since the flexibility and independence of action of the organs producing the main ridge-like impressions, forbid the supposition that they could have been produced by any rigid part of the Trilobite's undercrust, while their breadth and depth, and the compactness and smoothness of their surface, seem equally to forbid their reference to filamentous appendages, especially as the subordinate markings appear to represent the impressions of such organs. Furthermore, the investigations of Mr. Walcott, render it highly probable, if not demonstrative, that the Trilobite's method of progression was by slender limbs, rather than by broad organs constantly in contact with the surface, as would seem to be necessary to the formation of the tracks in question. We are led, therefore, to reject the view that these are Trilobite tracks, but we are unable to offer any satisfactory suggestion concerning the animal which produced them. We have designated the larger kind *Climactichnites Youngi*, and the smaller *C. Fosteri.*[1]

[1] I am indebted to Rev. A. A. Young, of New Lisbon, for the first information concerning these interesting tracks, and for much assistance in procuring a suite. About half a ton of slabs are now in the museum of Beloit College, procured through his kindness. He has also supplied the University of Wisconsin and Dartmouth College with specimens.

Rhizopods. The greensand that abounds at certain horizons "suggests the probable presence of Rhizopods, since the shells of these Protozoans have been found to be connected with the origin of this material in the Silurian rocks of Europe, as well as in those of the Cretaceous in Europe and America" (Dana).

General Remarks. Gathering together mentally the foregoing types of life, and adding to them such other forms as appeared elsewhere in the same general period, it appears that thus early — almost at the beginning of the earth's known life-history — all the great types of living organisms except the vertebrates were represented. Upon thoughtful consideration it will appear that much more than half the differentiation of the animal kingdom had already been accomplished. Not only were the great types (except the vertebrates) established, but the divergence of the leading branches within each was not conspicuously less than now.

The lower Protozoan types of life were, for obvious reasons, imperfectly preserved, but the presence of Sponges and Rhizopods in the closely following periods, if not in this, indicate great divergence of forms, and under any hypothesis of genetic derivation implies that the organization of the leading structural types of this class had been attained.

Among the types commonly known as Radiates, Echinoderms were represented by Crinoids, and Star-fishes are found in the closely following Trenton period. Acalephs were represented by Graptolites, and the Polyp branch, though its remains have not been found in the Potsdam sands, yet appears in great abundance and in highly divergent forms in the succeeding Trenton. The presence or absence of the soft types, as the Holothurians, cannot be determined, since they could not be expected to leave fossil remains. It appears, therefore, that not only were the "Radiates," as a great group, organized, but the leading branches had (at least by the Trenton period) assumed something like their present diversity, so far as fundamental structure is concerned.

Turning to the Molluscan group, the presence of Bryozoans Brachiopods, Cephalates and Cephalopods, and of abundant Acephals in the Trenton, show that this branch had attained the essentials of its present divergence. The Brachiopods are so far removed from the common type as to lead eminent zoölogists to follow Prof. Morse in separating them entirely from the Molluscan group.

Among articulates, so divergent forms as Trilobites, Phyllopods, and Annelids, indicate a wide differentiation of this type.

Without, therefore, drawing upon that much-abused resource, "the imperfection of the geological record," further than to presume the existence of some forms which are preserved in the rocks of the immediately following period in highly diverse forms, we are justified in the assertion that the structural types, below the vertebrates, were already organized in a wider and deeper sense than is implied by the simple statement that the lower sub-kingdoms were all present. They were not only present, but they themselves embraced widely divaricate subdivisions. The later additions consist largely of interstitial forms and of unessential modifications, rather than of profound departures from fundamental type-structures. The appearance of Insects is the greatest innovation of later ages among these classes, and even this may be more apparent than real, for when they appear in the middle Palæozoic, a geologically not distant period, they present a completeness of organization and a diversity of character quite surprising, so much so that many modern zoölogists would probably maintain, on theoretical grounds, that this class also must have been introduced very much earlier, though not appearing in the record for want of preservation.

It would appear to be not too much to assert that the only really great development of organized structure that has taken place since the primordial ages is embraced in the vertebrate type. Even this, physiologically (not psychologically) considered, was a much less wide departure from primordial structures than these latter were from the lowest known forms of life, and immeasurably less, as we conceive it, than that of the latter from unorganized matter; for, in the Potsdam forms, all the great physiological systems were well organized. There was not only that most mysterious and perhaps greatest of vital functions, the undetermined and almost undefinable agency that builds up the animal structure, but the muscular, skeletal, digestive, respiratory, circulatory, excretory, secretory, and nervous systems existed, and were displayed in great variety and in some degree of complexity. The highest of these, the nervous system, seems even then to have embraced all its present functions except the higher intellectual ones. Otherwise certain animals could not have exercised the functions with which they were unquestionably endowed. The eyes and the free life of the Trilobites necessarily imply the possession of some, if not all the senses, and of other intellectual faculties.

The organic developments of Post-Potsdam ages may, therefore, be summed up as (1) modifications and improvements — very marked to be sure but not fundamental — in the arrangements and adjustments of the physiological systems, and (2) the immeasurable addition of the higher intellectual functions. The development of the Pre-

Potsdam ages embraced, (1) the origination of organic structures, (2) the creation of the great physiological systems, and (3) the development of all but one of the great anatomical types.

The momentous question of the origin of life-structure, in its great physiological essentials, appears, therefore, to reach back for its direct geological data beyond the definite life-record into the obscurities of the early ages. The importance which these ages, therefore, possess in geological history cannot easily be over-estimated, however difficult, or perhaps impossible of solution, the problems they present. Impressed with this thought we have departed somewhat from common usage and dwelt at unusual length upon them.

Life-contribution to Rock-formation. The abundant life of the Potsdam period yielded its remains to the accumulating sediments, and the sands became the great cemetery of its dead. Though the contribution of each little being was small, the myriads which the waters brought forth, collectively yielded a notable contribution of calcareous matter to the formation.

Geographical Distribution. The formation gathered about the Archæan nucleus of the State and thence stretched away in all directions, underlying all the later formations of the State. As now exposed, after the denudation of ages, it occupies, at the surface, a crescentic area, having its greatest width in Central Wisconsin, between Portage and Stevens Point, and its limbs stretching, the one northeasterly to the Michigan border, and the other northwesterly to Minnesota. South of this main area, the streams have frequently cut down into and exposed it along their channels. In the Lake Superior basin it now appears only as a narrow bordering belt at the foot of the highlands and next to the lake.

Undisturbed Condition of the Beds. It will be understood from the preceding discussions that the strata of this formation lie in a nearly horizontal position, and repose unconformably on the worn surface of the crystalline rocks. The close of the period was not marked by any great upheaval; there was no crumpling nor metamorphism of the strata, and they have remained to the present day very much as they were deposited, save a slight arching upward in the central portion of the State. The beds have been somewhat compacted by the pressure of superincumbent strata, and solidified by the cementing action of calcareous and ferruginous waters, and by their own coherence; but the original character of the formation as a great sand-bed has not been obliterated. It still bears the ripple-marks, cross-lamination, worm-burrows and similar markings, that characterize a sandy beach.

Thickness. The thickness of the formation varies widely because of the unevenness of its Archæan floor, but perhaps averages 700 feet, or 800 feet, and reaches a maximum of at least 1,000 feet.

Climate of the Period. Theoretical considerations lead us to suppose that the climate of the period was uniform, moist and warm. Several considerations point to this conclusion. First, and probably least, the heat of the interior of the earth may yet have been sufficient to have affected the surface in some slight degree more than in later ages. But the amount of this was probably trivial. In the second place, the ratio of water to land was apparently very much greater than at present, and this wide prevalence of the ocean facilitated the absorption, retention, and uniform distribution of heat through oceanic circulation. In the third place, the atmosphere probably was more extensive (a part of it since having entered into combination with the crust of the earth), and more moisture-laden, because of the prevalence of the ocean, and other circumstances, so that the earth was wrapped in a more retentive atmospheric blanket than in subsequent ages. Fourth, somewhat more heat was probably received from the sun, if current views in regard to the secular cooling of that orb be trustworthy.

American Distribution. Ideally the Postdam beds should everywhere be found skirting the Archæan areas, and this they probably do, but are often concealed by later formations that overlap them. Tracing the formation eastward it is found to skirt the south shore of Lake Superior to the Straits, beyond which it is concealed, but its margin probably stretches southeastward along the edge of the Archæan area, passing under Georgian Bay and across Canada to the St. Lawrence, just below Lake Ontario, where it reappears on the flank of the Archæan neck that joins the Adirondacks with the great Archæan area of Canada. It also appears on the opposite side of this neck, and skirts the base of the Adirondacks. Rocks of essentially equivalent age occur as far northeastward as Newfoundland, and the adjacent Labrador shore. They occur also in the Green Mountains of Vermont, and along the Appalachian range from southern New York to Alabama.

Tracing westward, the belt becomes buried in Minnesota. Ideally it should stretch northwestward along the base of the Archæan range to the Arctic ocean, and probably does do so, but is concealed by the overlapping of the later Silurian limestones. The Potsdam formation occurs in the Black Hills, where its fossils are strikingly similar to those of Wisconsin, and at several points among the western mountains, where complete explorations will probably disclose considerable areas. There is also a small area in Texas

Lower Magnesian Limestone.

Fig. 19.

Section illustrating the relations of the Lower Magnesian limestone (*L. Mg.*) to the Potsdam sandstone (*P.*) beneath, and to the St. Peters sandstone (*St. P.*) above.

Synopsis of Characters. Formation named by Owen "Magnesian," from its dolomitic composition, and "Lower," to distinguish it from the Galena and Niagara formations which were then styled the Upper Magnesian limestone. It is the equivalent of the Calciferous sandrock of New York. Both names are objectionable. The term Calciferous sandrock is inapplicable to the western formation, while Lower Magnesian is even more inapplicable to the eastern. The formation has perhaps a sufficiently wide extent to justify the introduction of a new name, that will conform to good usage and be everywhere applicable; but in a report of this kind, it has been thought best to accept the name already in general use. Formation, a cherty magnesian limestone, from 65 to 250 feet thick, underlain by Potsdam sandstone, and overlain by St. Peters sandstone. Contains few fossils.

For details, see Vol. II, pp. 268–285 (Chamberlin), 547–555, and 577–607 (Irving), 671–675 (Strong); Vol. III, pp. 397–8 (Chamberlin); Vol. IV, pp. 64–81 (Strong), 123–129 (Wooster), 194–204, 248–9 (Fossils, Whitfield), 511–518 (Chamberlin).

Peculiarities of Stratification. During the previous epoch, the accumulation of sandstone gave place for a time to the formation of limestone (the Mendota). At the close of the epoch, without any very marked disturbance of existing conditions, the formation of limestone was resumed and progressed, with some interruption, till a thickness varying from 65 feet to 250 feet was attained. This variation in thickness is mainly due to irregularities of the upper surface of the formation, which is undulatory, and, indeed, in some localities may appropriately be termed billowy, the surface rising and falling like the swells of a subsiding sea. In the localities where these phenomena are best developed, these petrous billows vary in height from a gentle swell to elliptical domes rising a hundred feet above their bases; while their length ranges from a few rods to a quarter of a mile or more, and their width from one third to one half their length. The symmetry of outline here indicated is frequent and typical, though not universal. It finds its best observed expression in Green Lake and Winnebago counties, where the axes of the domes lie in an east-westerly direction much more commonly than otherwise, or, in other words, are at right angles to the trend of the formation. While not equally conspicuous everywhere, this undulatory surface is prevalent throughout the State and beyond.[1]

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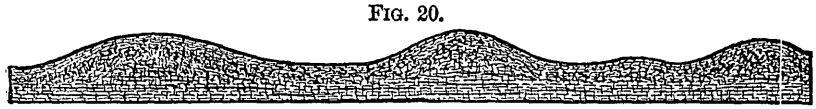
[1] This has been recognized in Central Wisconsin by Irving, Vol. II, pp. 551 and 553, in Southwestern Wisconsin by Strong, ibid., p. 673, and Vol. IV, p. 68, and in Northwestern Wisconsin by Wooster, Vol. IV, p. 124, fig.

The phenomena cited by Winchell, Rep. Nat. Hist. Minn., 1873, is probably identical, as also that cited much earlier by Hall, Geol. of Iowa, Vol. I, p. 336, The internal structure of these rock-billows is interesting. In the more typical ones at least, and perhaps universally, the superficial strata dip in every direction from the center, most rapidly at the sides (the dip sometimes reaching 30°), and less so at the extremities; or, in other terms, the beds are generally concentric with the surface. The rock of this superficial portion is as homogeneous and even-grained a dolomitic limestone as is common to the formation, and presents no unusual evidence of fracture or disturbance. Indeed the rock gives the impression of having been laid down as a mantle of calcareous sediment over an irregular surface.

FIG. 20.



PROFILE illustrating the accompanying view of the structure of the Lower Magnesian limestone.

Where erosion has exposed the interior, however, a very different structure is exhibited. The core of the dome appears to be composed of a brecciated mass formed of limestone fragments bound together by calcareous material that seems to have been a mud derived from the wear of the rocks themselves. Although the base of the formation has never been seen immediately beneath one of these prominences, yet from all that can be ascertained from the study of the lower beds in the vicinity, it is probable that the basal strata are homogeneous and horizontal, and unaffected by the peculiarities that lie above.

If we interpret these facts aright, they indicate a somewhat peculiar history for a limestone formation. We conceive that in the earlier stages of the period the limestone accumulated to a considerable thickness, after which the depositing waters retired, leaving the surface exposed to drainage erosion, whereby it was carved, in some measure, into the usual irregularities of corraded surfaces. After this had taken place, the sea advanced, eroding still further and breaking up and grinding the superficial beds, heaping the broken and comminuted material into shoals, bars and reefs.

As the sea advanced, these accumulations became more deeply covered with water so as to be at length beyond the forcible action of the waves, and they then became covered with a deposit of cal-

and in the Wisconsin report, though it is not apparent from the descriptions of these last two writers that it is a prevalent feature, or that it bears the characteristics first definitely determined in Eastern Wisconsin.

careous detritus, borne backward from the still advancing beach. This calcareous deposit covered the irregularities of the bottom like an undulatory blanket, forming the homogeneous, superficial layers above described. The effect of this last deposit would be to subdue the roughnesses and irregularities left by beach action, and give the prominences the flowing, billowy contour which they are observed to possess.

If this be the true interpretation, there is here presented a peculiar species of unconformity within what has been recognized as a simple formation, seeming to mark a subordinate epoch in geological history. It is not quite clear, however, that this epoch of erosion may not mark a more considerable and important interval. Were fossils more generally present, this question might be set at rest. But their rarity leaves it yet undecided, and the attention of observers and collectors is invited to it. In the northeastern part of the State the cast of an *Ophileta*, and two obscure, undetermined *Raphistomæ* have been observed in the over-arching superficial layers. The beautiful *Euomphalus Strongi* also occupies this horizon in the Lead region.

Other Characteristics. In addition to the foregoing peculiarities of stratification, the unity of the formation in Eastern Wisconsin is interrupted by a shaly stratum in its sub-central portion, and in Northwestern Wisconsin by a sandstone layer of very irregular thickness, sometimes merely consisting of a layer of lenticular, or pocket-like deposits. Locally there are seams of sand and shale intercalated in the series, particularly in the basal portion.

The bedding of the rock is usually uneven and heavy, and its texture is coarse, rough and irregular, though exceptionally it becomes uniform in bedding and grain, forming a beautiful and serviceable rock.

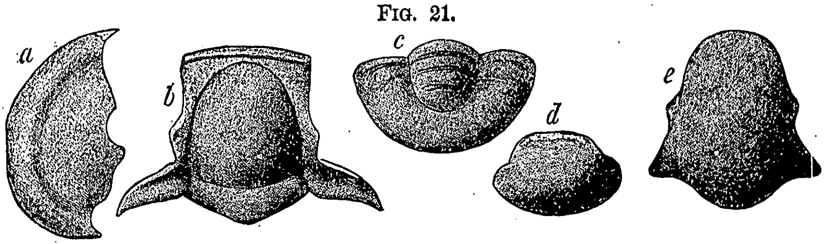
In composition it is, in the main, a magnesian limestone, or, more technically, a dolomite. But it contains, in addition, much silicious material, most commonly in the form of flint or chert nodules, but sometimes in disseminated sand grains, and not infrequently as an oölite, in which the center of the spherules is a grain of sand, about which concentric layers of calcareous material are gathered. Silica also often constitutes a crystalline lining of cavities, forming beautiful little geodes lined with variously colored quartz. A varying amount of aluminous impurity is also present throughout the rock.

A notable feature of the formation is the occurrence, at various heights, of brecciated layers interstratified with others more homogeneous. These are composed of fragments of limestone in a matrix of finer material, derived from the same source. They seem to indicate that the formation, during its deposition, suffered successive variations of conditions, from comparative quiet to forcible wave action, probably due to slight oscillations of level. The comparative absence of fossils under such circumstances is not surprising. There seems little doubt, however, that the material of the formation was derived mainly from the calcareous remains of life.

Metallic Contents. In addition to the more common constituents, there were deposited, in certain localities, metallic compounds, among which, copper, lead and iron are the most noteworthy. These were, in our view, originally disseminated through certain portions of the accumulating sediments, where their presence is thought to have been due to the agency of organic life. Seaweeds are known to absorb these metals from solution in the oceanic waters, and must afterward give them up to the sediments on decay. Precipitating agencies, especially sulphuretted gases, are also generated by the decay of animal and vegetable matter, and by these, ores may have been extracted from the sea water.[1] The amount of such metallic accumulation has not yet been shown to be very great, and yet quite noteworthy in the southwestern quarter of the State. The concentration of this in the form in which it is now found is the work of much later ages.

Life of the Epoch. As previously remarked, distinct remains of life are very meager. Some seaweeds, a few Mollusks, an occasional fragment of a Trilobite, and a few other obscure forms, make up the meager list of fossils, except in a single favored locality of peculiar and somewhat doubtful relations, where an ampler fauna is

FIG. 21.



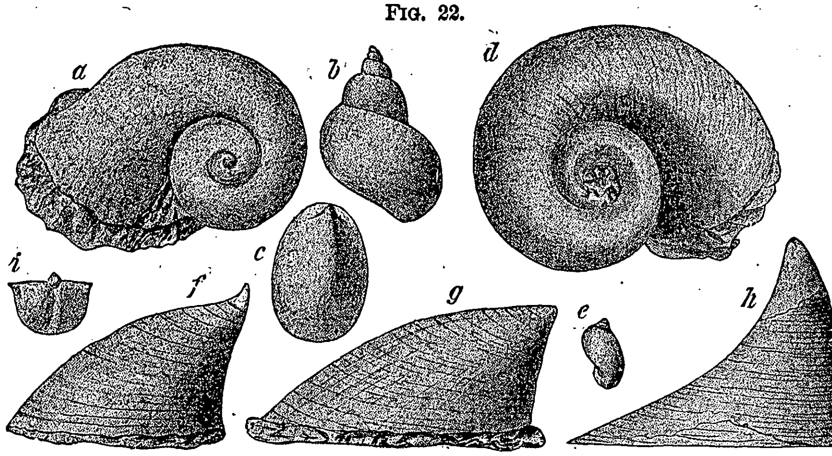
FRAGMENTS OF TRILOBITES from Eikey's quarry, near Baraboo, referred by Prof. Whitfield to the Lower Magnesian limestone. *a.* Movable cheek of Dicellocephalus Barabuensis — Whitf. *b.* Glabella and fixed cheeks of same. *c.* Pygidium of same. *d.* Pygidium of Illænurus convexus — Whitf. *e.* Glabella of same.

[1] For a full discussion of this class of metallic deposits, see *Ore Deposits of Southwestern Wisconsin,* Vol. IV, pp. 365–553.

found. The general list embraces *Fucoids*, and undetermined *Stromatopora*, *Strophomena*, *Ophileta*, *Salterella*, *Straparollus*, *Buçania*, *Leperditia*, and *Euomphalus Strongi*.

At Eikey's quarry, east of Baraboo, in what must have been a protected bay between the quartzite ranges, a peculiar and interesting group of fossils occurs, embracing the following species: of Trilobites, *Dicellocephalus Barabuensis*, *D. Eatoni*, and *Illænurus convexus*; of Heteropods, *Scævogyra elongata*, *S. obliqua*, and *S. Swezeyi*; of Gasteropods, *Metoptoma Barabuensis*, *M. recurva*, *M. retrorsa*, and *M. similis*; and of Brachiopods, *Leptæna Barabuensis*,— all of which except the last are new species.

FIG. 22.



FOSSILS from Eikey's quarry near Baraboo, referred by Prof. Whitfield to the Lower Magnesian limestone. *a.* Scævogyra Swezeyi — Whitf. *b.* S. elevata — Whitf. *c.* S. obliqua — Whitf. *d.* Euomphalus Strongi — Whitf. *e.* Metoptoma similis — Whitf. *f.* M. retrorsa — Whitf. *g.* M. Barabuensis — Whitf. *h.* M. recurva — Whitf. *i.* Leptæna Barabuensis — Whitf.

The stratigraphical relations of the beds containing these fossils are quite peculiar, as described in Vol. III,[1] and render doubtful the precise horizon to which they should be referred, further than that they belong to the upper portion of the Cambrian series. The general aspect of the fauna is Cambrian, with modifications verging toward succeeding formations.

Distribution. As now seen, after the erosion of subsequent ages, this formation occupies, at the surface, an irregular belt skirting the Potsdam area. Originally, it probably swept entirely around the Archæan island, for we now trace it nearly across the eastern portion of the upper peninsula of Michigan to the neighborhood of

[1] Irving, pp. 537 and 593.

Lake Superior, and a remnant portion of it occurs in the valley extending inland from Keweenaw Bay, while upon the western side we find it reaching up the valley of the St. Croix as far as Osceola Mills. When its position and relations are considered, it seems probable that the original formation entirely encircled the Archæan heights.

American Distribution. The surface area of this formation should theoretically be found skirting that of the Potsdam strata previously described. This is does westward into Minnesota, where it disappears, being buried by later formations, and also eastward through the Upper Peninsula of Michigan as far as St. Marie Straits, and also in the Adirondack and St. Lawrence regions, and along the Appalachians. In some other regions, in the east, and in the western mountains, it has not been clearly distinguished from contiguous formations. It occurs in southeast Missouri, surrounding the Archæan protuberances.

General Observations on the Cambrian Age.

The foregoing Potsdam and Lower Magnesian formations (taken together with the St. Peters sandstone perhaps) represent, so far as it is developed in the interior, what has been termed the Primordial group. The term Primordial, however, is unfortunate, in so far as it seems to imply that this was a primitive period, either in the history of life, or of rock-formation. It is primordial only in the sense of embracing the earliest group of well-defined fossils. In the Eastern Border region, in Massachusetts, New Brunswick, Nova Scotia, and elsewhere, there are earlier, though not distantly separated, fossiliferous beds—the Acadian group—which are also included in the Primordial system. In English nomenclature, which is gradually extending itself, the supposed equivalents of these rocks are termed Cambrian. Those which we have had under special consideration constitute the upper members of this system as it is usually limited. The general introduction of this term into American geology would be serviceable. It the other volumes of the report (published before this one) we have adhered to the Murchisonian classification and designated these, in common with those above them, Silurian, because, at that stage of investigation, we were unprepared to express an independent opinion as to the classification best suited to the formations under consideration. That adopted in this volume expresses our present judgment.

But whatever the naming and classification, these formations represent a distinct series, separated from the preceding by a great interval, as demonstrated by the enormous erosion that intervened, and separated likewise from the succeeding formations by a briefer interval.

Foreign Distribution of Cambrian. This series is especially well developed in North Wales (Cambria), from whence it takes its name, and occurs in Scotland, Ireland, Scandinavia, and notably in Bohemia, where the remarkable researches of Barrande have developed an extraordinarily rich fauna. This is probably but a small part of its real distribution, as the earlier geological formations are imperfectly determined even on the continents most studied. The difficulties of identification increase with the antiquity of the formation.

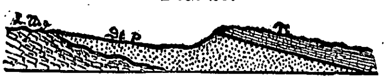
CHAPTER VIII.

LOWER SILURIAN, CAMBRO-SILURIAN, OR ORDOVICIAN AGE.

Subdivisions. (1) Epoch of advance of sea, *St. Peters sandstone.* (2) Epoch of maximum invasion of sea and consequent greatest depth, *Trenton limestone.* (3) Epoch of incipient shoaling, *Galena limestone.* (4) Epoch of pronounced shoaling, and oceanic retreat, *Hudson River or Cincinnati Shales.*

EPOCH OF THE ST. PETERS SANDSTONE.

FIG. 23.



SECTION illustrating the relations of the St. Peters sandstone (*St. P.*) to the Lower Magnesian limestone (*L. Mg.*) below, and the Trenton (*Tr.*) above.

Synoptical Notes. Name of the formation derived from the St. Peters (now Minnesota) river, at the mouth of which it is well displayed. Rock a friable, white, or yellow sandstone, underlain by Lower Magnesian limestone, and overlain by Trenton limestone. Thickness varies from 212 feet down to a fraction of one foot. Average, probably between 80 and 100 feet. Fossils *very* rare.

For details, see Vol. II, pp. 285–290 (Chamberlin), 555–558, 559, 600, 603 (Irving), 675–680 (Strong); Vol. IV, pp. 81–87 (Strong), 129 (Wooster), 415–417, 509–511 (Chamberlin). For area occupied by the formation, see atlas.

Lithological Character. Reposing upon the billowy surface of the Lower Magnesian limestone, filling up its depressions, and, for the most part surmounting its prominences, lies a singularly pure quartzose sandstone. Next the underlying limestone, to be sure, there is found some shaly material derived from its wear, and against the sides of the few Archæan prominences that still stood as islands or reefs in the depositing seas, there are conglomerates which the breakers formed by beating fragments from the cliffs, and rolling, rounding and burying them in the sands encircling the parent ledges. But aside from these occasional variations, manifestly due to special local circumstances, the formation is notable for the uniformity of its material.

The sand consists of quartzose grains of medium coarseness, comparatively free from that admixture of coarser and finer material which is common in sandstone. It is also mainly free from intermingled silt, and from the calcareous and ferruginous cements that so frequently bind sand deposits into coherent rock. The result is that this formation, though one of the most ancient of its class, and though once buried at some points by an estimated thickness of at least 1,000 feet of strata, remains to-day, in large part, little more than an incoherent sand-bed. It is scarcely compacted enough to be handled without crumbling to a sand, so that it is quite frequently used for mortar-sand, but very rarely for building stone.

White, yellow and gray are the prevalent colors, though red, brown, pink and green are not uncommon. In exceptional instances the rock is beautifully variegated by an irregular disposal of colors, or is banded in a disjointed and irregular way, producing an interesting and unique effect. These irregularities of coloration are chiefly due to a dyeing of the sand by the infiltration of solutions carrying coloring matter, apparently iron and manganese compounds, for the most part.

The formation shows oblique and discordant lines of stratification, due to the shifting action of the waves during its deposition. At some points the arrangement is exactly typical of ebb-and-flow structure. At a single locality, Mr. Strong found ripple-marks. In the upper part of the formation, infiltrations and concretions of iron-ore not infrequently occur. The latter, on weathering, present a dark-brown glazed surface, which has led to the popular impression that they are of volcanic or meteoric origin.

A somewhat prevalent departure from the general characteristics is found in the northeastern part of the State, where considerable white argillaceous material is introduced, interlaminated with the sand in thin seams, or mingled with it, giving a somewhat schistose structure, and a greater firmness and endurance than elsewhere. At some points in the southwestern part of the State, the sandstone is exceptionally impregnated with iron, and hardened by its cementing property, and seemingly also by exceptional pressure brought to bear at these points.[1] The "Red Rock" below Darlington is the most conspicuous example of this kind.

Thickness. Owing to the unevenness of its bottom, the deposit varies greatly in thickness. The greatest yet observed is 212 feet, while on the other hand, the prominences of the Lower Magnesian limestone occasionally rise entirely through it. Its average thickness is estimated at less than 100 feet, probably about 80 feet.

Life of the Period. Until recently no organic remains had ever been found in the formation, and the traces now known are very

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[1] Vol. IV, pp. 484–5.

meager, though sufficient to show the existence of marine life. Tubes of *Arenicolites (Scolithus)* occur in the formation in Southern Wisconsin at several points in the upper horizons, and in one instance, in beds referred to the base of the formation. Fucoidal impressions also occur in the upper layers. In Minnesota, Prof. N. H. Winchell has found a small Linguloid shell *(Lingulepis Morsensis)*, likewise in the upper layers of the formation. The organic remains so far found occur exclusively where the sandstone was compacted by some cementing material, which sanctions the belief that the rarity of fossils is to be ascribed to the porous nature of the rock, which is unfavorable to their preservation.

Method of Formation. The origin of the formation has been the subject of some diversity of opinion, but the remains of marine life demonstrate that the inclosing portions, at least, are submarine deposits, while the character of the grains, the ebb-and-flow structure, the ripple-marks, the shaly laminations and conglomeratic portions, as well as its relations to adjacent formations, confirm the conviction that it belongs to the common class of oceanic sand deposits.

As the character of the constituent grains has been occasionally appealed to in support of quite different views, it may not be improper to refer again to the usual method of formation of our sandstones, which explains precisely the characters they bear. They are derived, in the main, from the granitoid and schistose rocks of the northern Archæan area. These are composed of particles of quartz intermixed with a variety of other softer and more decomposable crystalline minerals. In the metamorphism that gave origin to these minerals, quartz was usually last in crystallization and occupied the angular interstitial spaces between the crystals that had already taken shape, and hence, while crystalline in internal structure, it molded itself about the crystals of the previously formed minerals. It was thus angular, but not in its own appropriate crystalline form.

Now, upon decomposition, the associated minerals were mainly reduced to earths and clays, while the undecomposable quartz remained in angular grains. By the action of streams in carrying these down to the sea, and by the agency of the waves in distributing them, these grains were sifted, assorted, rolled, rounded and finally deposited in the forms in which we now find them. It is manifest that while the majority of these might be worn into somewhat spherical grains, others, less acted upon, might remain quite angular. This angularity, however, is not that characteristic of freely-forming quartz crystals. That the form of the grains composing the great mass of the formation is in harmony with this explanation of its origin, abundant observation has shown. In the original crystalline rock, occasional cracks and cavities occur filled with secondary quartz, which, in such situations, assumes its own crystalline form. Such crystals are also quite common in the Lower Magnesian limestone, which was somewhat eroded in the formation of the St. Peters sandstone. The degradation of the rock inclosing these would give points and fragments of true crystals of quartz, which might not be so far worn as to lose their characteristic form. Furthermore, in the sandstone itself, secondary crystals may be formed after deposition, just as they are in adjacent limestone beds where their secondary origin is unquestionable. The occurrence of true crystalline points and facets in the St. Peters sandstone is, however, relatively rare. The angularity of the grains, which is sometimes noticeable, is not appropriate to quartz, but to the circumstances under which it was formed, as above explained.

History. Looking at the foregoing characteristics of the formation from the historical standpoint, they seem to teach the following succession of events. After the completion of the Lower Magnesian limestone, with its peculiar undulatory surface, there was perhaps an interval unrepresented by deposit in the Wisconsin series. But this is not certain. The surface of the Lower Magnesian limestone is eroded, but it is not clear that this might not have been accomplished while the sandstone was being deposited, for the observed erosion is upon the sides of the mounds. However this may have been, in the St. Peters epoch a shallow sea spread over the uneven floor of limestone, and reached northward to the source whence the sand was derived. This may have been the Archæan nucleus at the north, or the Potsdam sandstone which girt it about, and whose encircling edge may at this period have been lifted to the surface, or, at least, within reach of the waves. The sand from either or both these sources, as the case may have been, was borne backward by the waves and ocean currents, leveling up, first, the inequalities of the floor, and, at length, spreading a stratum of sand over the whole, except in the northeastern part of the State where the Lower Magnesian prominences in some instances still kept their crests above the burying sands, and excepting also scattered Archæan knobs which still stood as islands, or reefs, disposed as a little archipelago in the south-central portion of the State.

The remoteness of the source of the sand suggests an explanation of its uniformity of size and character. Only so hard a material as quartz could successfully resist the wear of so great transportation in the to-and-fro method of sand drift. At the same time, exceptional opportunities were offered for the sifting of the material. That which was coarsest was, because of its weight, left near the original shore, while that which was lightest was borne far out beyond the shallow wave-swept depths, leaving the winnowed grains of medium size over the intermediate shallows. These are the portions now exposed to observation.[1]

A modification of these conditions prevailed in the northeastern part of the State, where the accumulation was thin and mingled with finer material, perhaps derived from the Lower Magnesian limestone, whose prominences frequently protruded through it. This thinning out is progressive toward the northeast, in which direction the formation is last seen on the Peshtigo river, within about four miles of the State line. Beyond that, in the Upper Peninsula of Michigan, the present geologist of that State does not recognize its presence. It, however, very likely maintains an interrupted existence for some distance beyond, but may be nowhere exposed.

The formation is not known at the east, being peculiarly a western deposit. The Chazy limestone has usually been considered its eastern equivalent. To the westward it is apparently thicker and more uniform in depth and character, and the same appears to be true as it is traced backward from its margin toward the south and southeast, as indicated by borings for artesian wells.

State Distribution. As now exposed, the St. Peters sandstone occupies a narrow area fringing that of the Lower Magnesian limestone on the south, and stretching in an irregular course from the Lower Menominee river on our northeast border, to the mouth of the Wisconsin on the southwest. North of the Wisconsin river (Crawford and Vernon counties), and in the Lower St. Croix region (St. Croix and Pierce counties), there are isolated areas dissevered by the erosion of later ages from the main body of the formation. South of its main line of outcrop, especially in Southwestern Wisconsin, the streams have cut their way down through the overlying formations into it, and exposed it along their courses in the peculiar branching areas shown on the atlas maps. This formation, in common with those immediately above and below, dips gently to the southeast on the eastern side of the State, and to the southwest on

[1] There are about equally good reasons for thinking that the retiring Cambrian sea carried back with it from the Archæan region the material of the St. Peters sandstone. If so, the upper portion was probably re-wrought by the advancing Silurian sea, for the sandstone shows no signs of erosion, and is perfectly conformable to the overlying Trenton.

the west side. The maps and cross-sections of the report show in detail its distribution and relations.

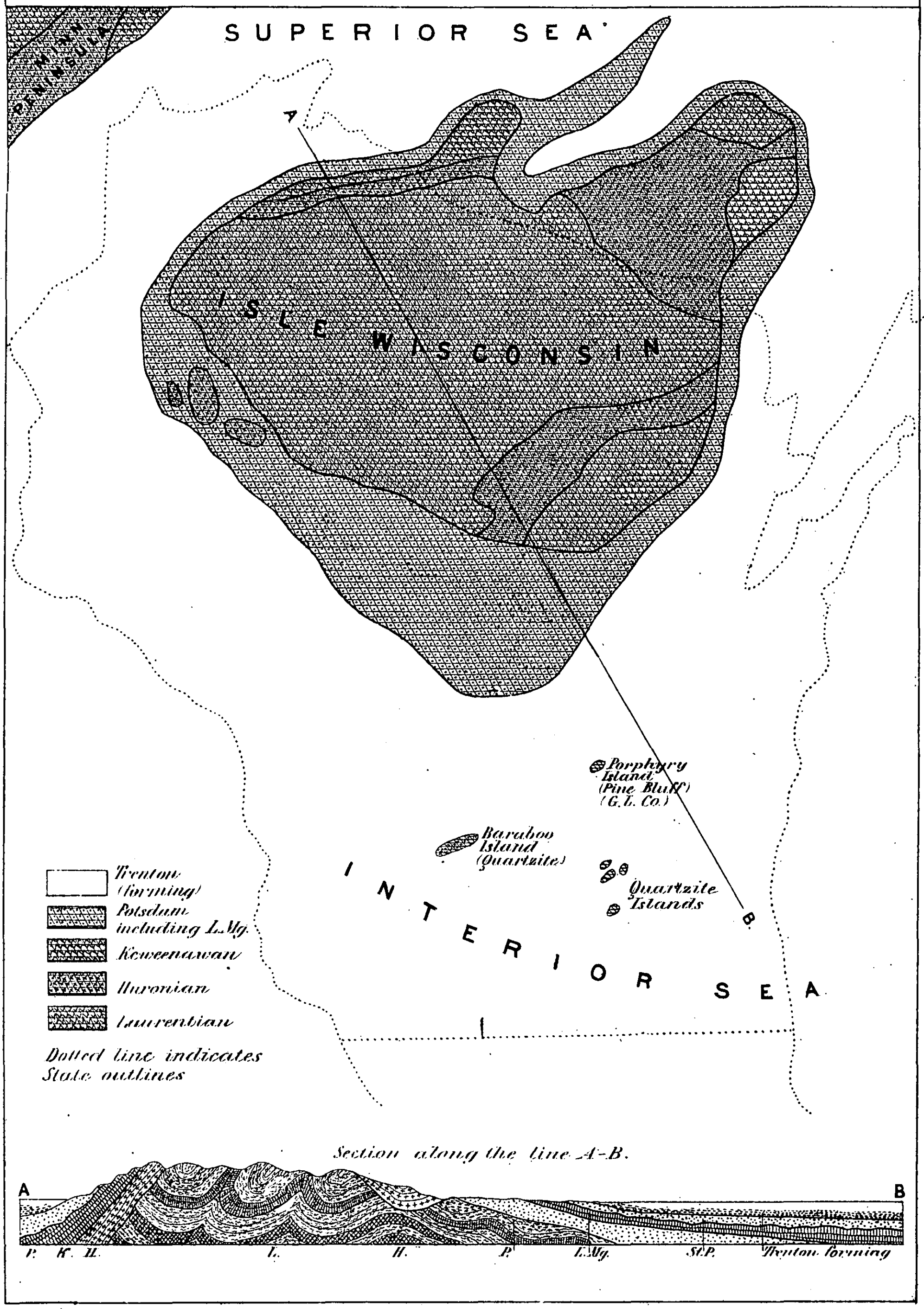
American Distribution. In its typical character, this formation is confined to this immediate region. The present State Geologist of Michigan, Dr. Rominger, has not recognized its presence in that State. As, in Northeastern Wisconsin, it is frequently interrupted by the formations above and below coming together, it probably has but a limited extent in that direction. It occurs in northeastern Iowa and eastern Minnesota, but is unknown beyond. In Illinois it occurs at Oregon on the Rock river, and at La Salle on the Illinois, where it is brought to the surface by an arch in the strata. In Missouri, the Saccharoidal sandstone is probably its equivalent. Beyond this Upper Mississippi region, it has not been recognized. The Chazy limestone of New York has been regarded as its equivalent, as it occupies the same interval in the series, and where the one is present, the other is absent. The interval, however, includes the horizon of the Quebec series, and perhaps the upper portion of the Calciferous, so that the reference to the Chazy epoch, on stratigraphical grounds, does not carry much weight. We have felt somewhat inclined to refer its main deposition to the closing Calciferous or early Quebec, and to suppose that it was re-wrought by the advancing sea in the Chazy or early Trenton epoch, the remainder of the interval between the Calciferous and Trenton being unrepresented in our series, because the waters had retired.

Trenton Period.

The Trenton period embraces three, and perhaps four epochs, viz.: that of (1) Trenton limestone, (2) Galena limestone, and (3) Hudson River shales. Perhaps the St. Peters sandstone is also to be here included. It was probably at least modified and rearranged on the surface by the advancing seas that deposited the Trenton and Galena limestones. It seems not improbable that the St. Peters sandstone was formed by the retiring seas of the previous period, and was rearranged by the advancing sea of the Trenton period, and so, in a certain sense, belongs to both. If it be included here, it fills up the ideal group of a period, viz.: sandstone at the base, limestone in the center, and shale at the top, thus:

	Epochs.
Trenton Period.	Hudson River shales.
	Galena limestone.
	Trenton limestone.
	St. Peters sandstone.

HYPOTHETICAL MAP OF THE LAND IN THE TRENTON PERIOD



TRENTON EPOCH.

FIG. 24.

SECTION illustrating the relations of the Trenton limestone (*Tr.*) to the St. Peters sandstone (*St. P.*) below, and to the Galena limestone, (*Ga.*) above.

Synoptical Notes. Name of the formation derived from Trenton Falls, N. Y., where it is finely displayed. Rock in part a simple, and in part a magnesian limestone, with clayey leaves and partings. Beds usually thin and undisturbed. Fossils abundant. Formation usually shows distinct subdivisions, which, in the Lead region, are known as Buff limestone or "Quarry rock," and Blue limestone, embracing the "Glass rock." To these are perhaps to be added the "Brown rock" and "Green rock" which form the transition beds to the Galena limestone above. In the Rock river valley the subdivisions are, Lower Buff limestone (equivalent to Buff above), the Lower Blue limestone (equivalent to Blue above), the Upper Buff limestone, and Upper Blue limestone (probably the equivalents of the "Brown rock" and "Green rock" above). Total thickness about 115 feet, often considerably less. Yields large quantities of zinc, with considerable lead and copper, in the southwestern part of the State.

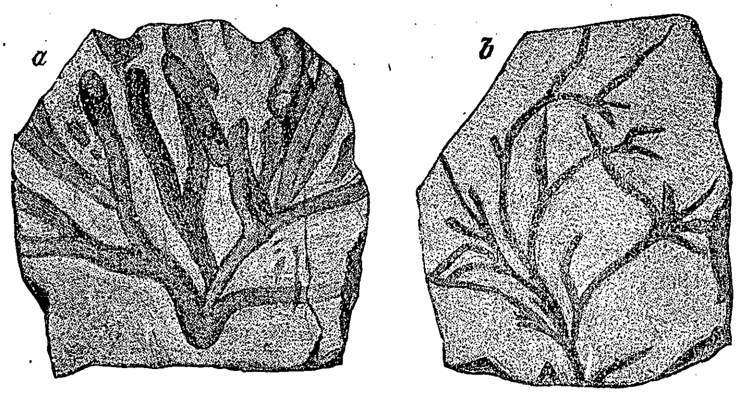
For details, see Vol. II, pp. 290–305 (Chamberlin), 558–562 and 600–607 (Irving), 680–683 (Strong); Vol. IV, pp. 88–90 (Strong), 129–130 (Wooster), 205–238 and 345 (Fossils, Whitfield), 404, 412–415 (Chamberlin).

A change of oceanic conditions caused the deposition of sandstone that had marked the St. Peters epoch to give place to the formation of limestone which characterized the Trenton epoch. The change was measurably abrupt, though necessarily not without a slight admixture of the two formations. Over the greater portion of the area exposed to observation in Wisconsin, the transition was accomplished within a depth of scarcely more than a foot, neither the sand being notably mingled above, nor the limestone penetrating below that. In the lower Rock river valley, there is a slight alternation, consisting of about four feet of impure sandy limestone, followed by from one to two feet of sandstone, above which follows the limestone proper. The upper surface of the sandstone nowhere shows erosion, or gives other evidence of an interval between the two formations. It is manifest that so erodable a formation as the St. Peters sandstone could not long suffer exposure, without a notable channeling of its surface, unless it had remained practically at the sea level.

With the return to limestone formation there was a return of conditions favorable not only for the abundant existence of life, but also for the preservation of its remains. Indeed, we should state the conditions in the reverse order, viz.: there was a return of conditions congenial to life, and, as a result of its abundance, limestone was formed. Life was, therefore, the important circumstance of the age. Countless numbers of its lower forms lived in the seas, and left their remains to be comminuted and consolidated into limestone. Following the dynamical order, this life first demands our attention.

Life. The fauna of the epoch was ample, and, with the exception of the Vertebrates, embraced representatives of all the greater divisions of the animal kingdom; and not only were these greater divisions represented, but they embraced, even at this early period, the larger number of their leading sub-branches. Of course nothing is positively known of such as had a soft structure and were, therefore, unsuited for preservation.

FIG. 25.

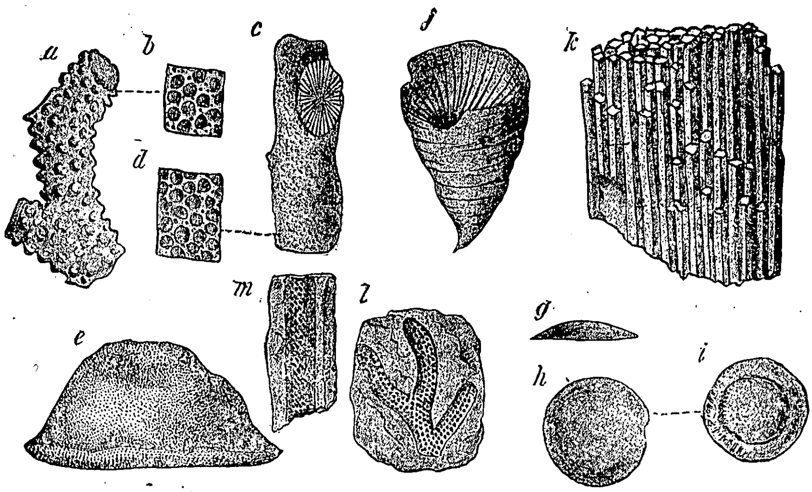


TRENTON MARINE PLANTS. *a.* Buthotrephis succulens — Hall. *b.* B. gracilis — Hall.

Plants. The flora, if flora it may be called, where no flowers existed, has left a much more meager record. The only remains thus far found are impressions of sea-weeds, and these are but obscure cylindrical imprints which teach us little of the real nature of the plants which produced them, beyond what is inferred from their resemblance to living forms. To the genera noted as occurring in the Potsdam period, *Buthotrephis* and *Phytopsis* were added. *Buthotrephis gracilis*, and *B. succulens* were the most abundant species. Their general characteristics are illustrated in the accompanying figures.

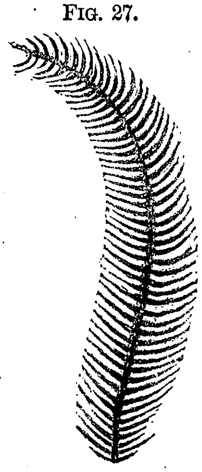
Animals Corals. The most notable addition to the previous fauna was the presence of both branches of corals. The minutely-celled Chætetoid Corals, with their various branch-like, button and puff-ball forms, were represented by five species. The "Honey comb" or "Wasp's nest" Coral, *Columnaria alveolata*, and a related Favositoid form are occasionally found. The "Cup-corals" *(Cyathophylloid)* perhaps surpassed all other forms in their numbers — the "Calf's horn" Coral, *Streptelasma (Petraia) corniculum*, being the most abundant of the period. These sometimes grew in colonies, forming a thickly planted patch on the ocean bed, rivaling in profusion, and possibly in color, those of to-day, often fitly compared, in their living state, to a bed of asters.

FIG. 26.



TRENTON CORALS. *a.* Monticulipora Dalei — Ed. and H. *b.* Surface of same enlarged. *c.* Chætetes pulchellus — Nich = Monticulipora fibrosa — Goldf. *d.* Surface of same enlarged. *e.* C. (Monticulipora) lycoperdon — Say. *g.* Profile view of C. (Monticulipora) discoideus — James. *h.* Same seen from above. *i.* Concave under-surface of same. *j.* Streptelasma (Petraia) corniculum — Hall. *k.* Columnaria alveolata — Goldf. *l.* Stictopora elegantula — Hall. *m.* Ptilodictya recta — Hall.

FIG. 27.

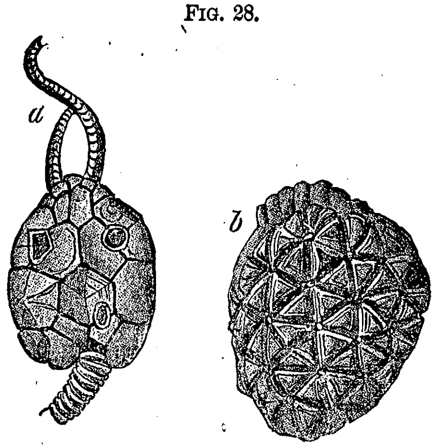


BUTHOGRAPTUS laxus — Hall, — a Trenton Graptolite.

Peculiar Lower Forms. Those singular animals, the *Graptolites*, were represented by three or more species. A form referred doubtfully to the peculiar genus *Oldhamia* has been found. Still lower in the scale, an obscure form of *Sponge* indicates that even this plant-like animal then lived, and suggests that the border line between the great life kingdoms was occupied then, as now.

Crinoids. The *Crinoids*, the "stone lilies" of the ancient seas, presented several species, though only fragments have usually escaped destruction. These animals, whose bodies resemble closed starfishes and sea-urchins inverted, were supported on a stalk formed of calcareous discs, and rooted like plants to the sea-bottom. At death, the body, or "head," which is composed of jointed

FIG. 28.



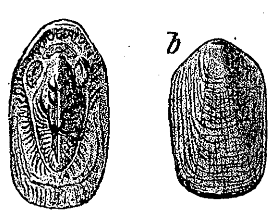
TRENTON CRINOIDS (*Cystids*). *a.* Pleurocystites sqamosus, Bill. *b.* Amygdalocystites florealis, Bill.

plates, commonly fell to pieces, and only the scattered plates remain. The stem usually separated into its constituent discs (the little "grindstones" of the boys), though fragments several inches in length occasionally remain. The great number of discs and fragments of stems implies an abundance of Crinoids, though complete forms, or even dissevered heads, are rare.

Bryozoans. Bryozoans flourished, and left their delicate coralline secretions, rivaling in beauty, and surpassing in delicacy true corals.

Brachiopods. Brachiopods — animals of Molluscan aspect and Annelidan affinities — were the predominant type of the age. They not only existed in great numbers, but belonged to several genera embracing many species. Upwards of forty species have been identified from the rocks of the State. Because of the prevalence of this type in this and the succeeding ages, Brachiopods have probably been more relied upon than any other forms in determining the succession and equivalency of strata, where stratigraphical evidence is wanting. The genera *Lingula*, *Discina*, *Crania*, and *Rhynchonella* have lived through, in some of their species, to the present time, and stand as remarkable examples of persistency among changing scenes and varying life-forms.[1] Other genera, as *Orthis* and *Leptæna*, had long life-histories. Even some species maintained a scarcely modified existence through great stretches of time.

FIG. 29.

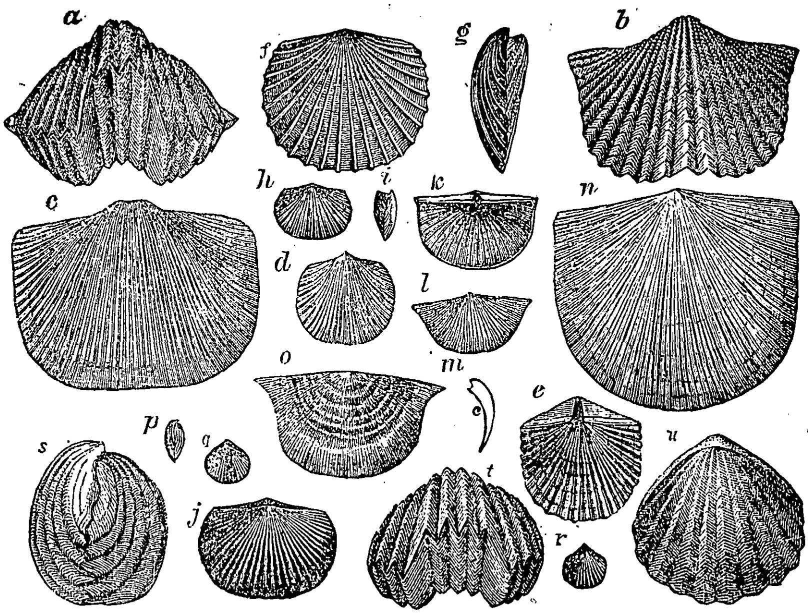


A TRENTON LINGULA. Species of the same genus now live in the Atlantic. *a.* Cast of interior of ventral valve of *Lingula Elderi*—Whitf.—showing muscular impressions. *b.* Exterior of *Lingula Elderi.*

[1] It has of late been customary to refer all the earlier species of linguloid shells to other genera than Lingula, as Lingulepis and Lingulella, and to maintain that true Lingulæ did not then exist. But the recent investigations of Prof. Whitfield have demonstrated the existence of Trenton Lingulæ, at least, and have rejustified former assertions as to their great antiquity.

Of the more than forty species found in the State, the following may be selected as best characterizing the formation, though most of them extend upward into the two following horizons, which, however, are but subdivisions of the Trenton group: *Orthis bellarugosa*, *O. lynx*, *O. pectinella*, *O. plicatella*, *O. perveta*, *O. testudinaria*, *O. subequata*, *O. tricenaria*, *Streptorynchus deltoideum*, *S. filitextum*, *S. deflectum*, *Strophomena alternata*, and *Leptæna sericea*.

FIG. 30.

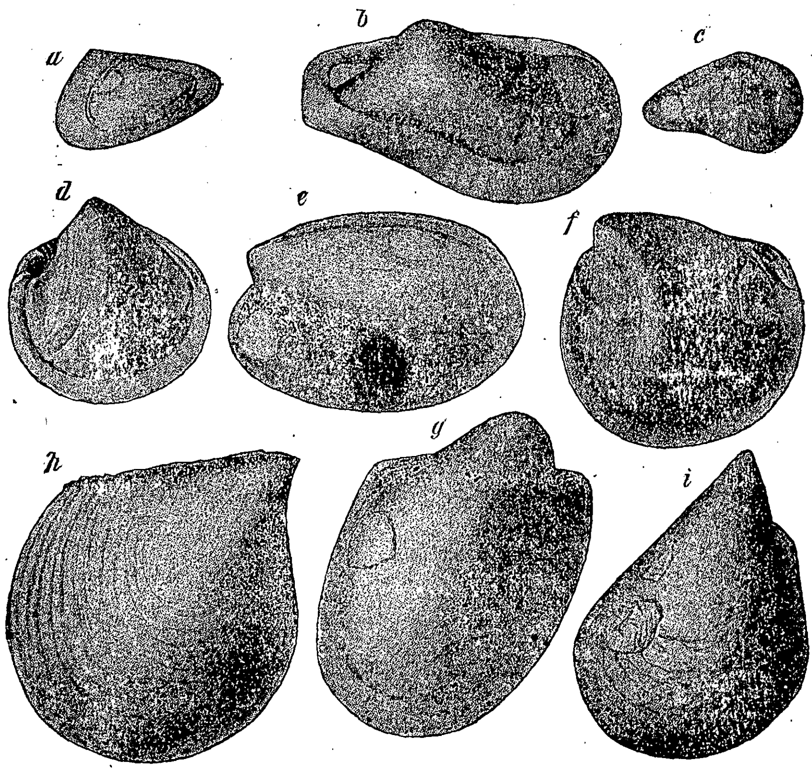


TRENTON BRACHIOPODS. *a* and *b*. Orthis lynx. *c*. O. occidentalis. *d*. O. testudinaria. *e*. O. tricenaria. *f* and *g*. O. pectinella. *h* and *i*. O. plicatella. *j*. O. borealis. *k* and *l*. Leptæna sericea—Sowr. *m*. Section of same. *n*. Strophomena alternata—Conrad. *o*. S. rugosa. *p*, *q* and *r*. Side, dorsal and ventral views of Zygospira recurvirostra—Hall. *s*, *t* and *u*. Rhynchonella capax—Conrad. (Dana and Logan Figs.).

Lamellibranchs. The true Mollusks, *the Lamellibranchs* — animals of the clam-type — are well represented among the fossils of the period. They all belonged to the four genera *Ambonychia*, *Tellinomya*, *Cypricardites*, and *Modiolopsis*. Cypricardites is represented by seven species, and Tellinomya and Ambonychia by five each, beside some undetermined forms referable to each genus. Some of the species are very closely similar to each other, and difficult to distinguish specifically. Some of them are very abundant, and have not been found to rise into the succeeding beds, and hence are valuable guides in determining the horizon. Their general characteristics are illustrated in the accompanying figures.

Gasteropods. Among univalves, twenty-four species of *Gasteropods* are known to have been present. Many of these seem to so closely resemble the snails of the present day that they are often regarded as such by unpracticed observers, quarry men, and others. Closer inspection, of course, reveals their distinctness. Several of these were not found in the rocks of the later periods, and are highly characteristic of this horizon. Among such may be mentioned *Helicotoma planulata*, *Raphistoma lenticularis*, *R. Nasoni*, *Trochonema*

Fig. 31.



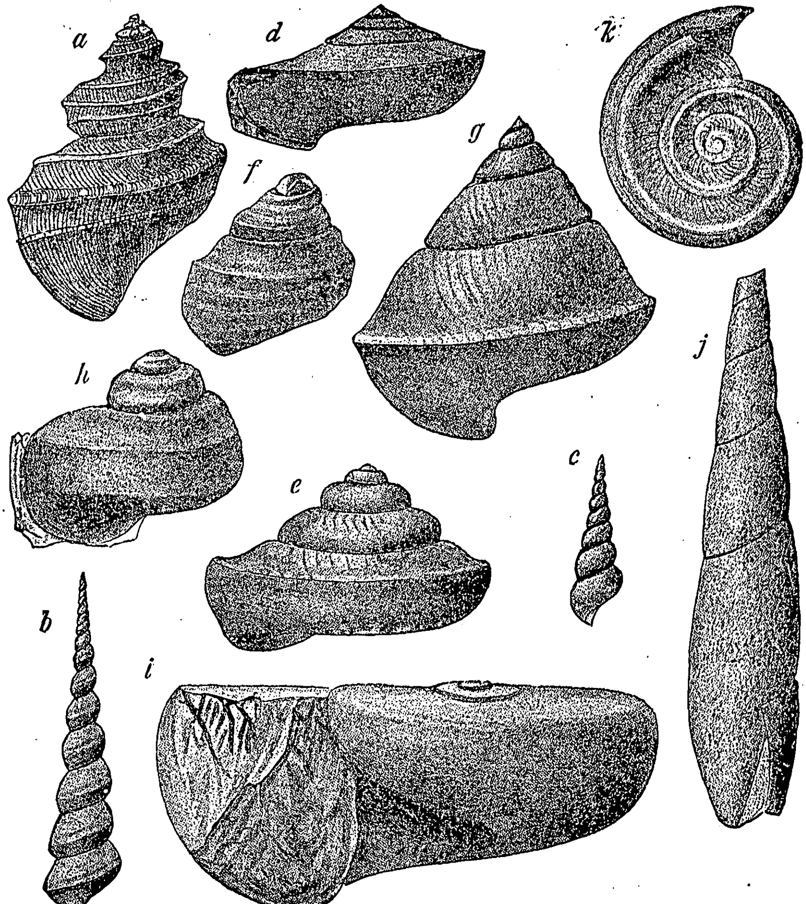
Trenton Lamellibranchs. *a.* Modiolopsis plana — Hall. *b.* Tellinomya nasuta — Hall. *c.* T. ventricosa — Hall. *d.* Cypricardites rotundatus — Hall. *e.* C. ventricosus — Hall. *f.* C. Niota — Hall. *g.* C. Megambonus — Whitf. *h.* Ambonychia lamellosa — Hall. *i.* A. attenuata — Hall.

umbilicatum, *Pleurotomaria subconica*, *Murchisonia gracilis*, and *Maclurea Bigsbyi*. The second, fourth, fifth and sixth of these extend into the immediately succeeding beds in the northeastern part of the State, where the two horizons coalesce and possess a common character.

Heteropods. The closely similar Mollusks, classed as *Heteropods*, were quite abundant and characteristic, *Bucania bidorsata*, *Bellerophon bilobatus* and *Cyrtolites compressus* being the leading species.

Pteropods. Of the *Pteropods* there were three known genera, represented by one species each, viz.: *Ecculiomphalus undulatus*, *Pterotheca attenuata*, and *Hyolithes Baconi.*

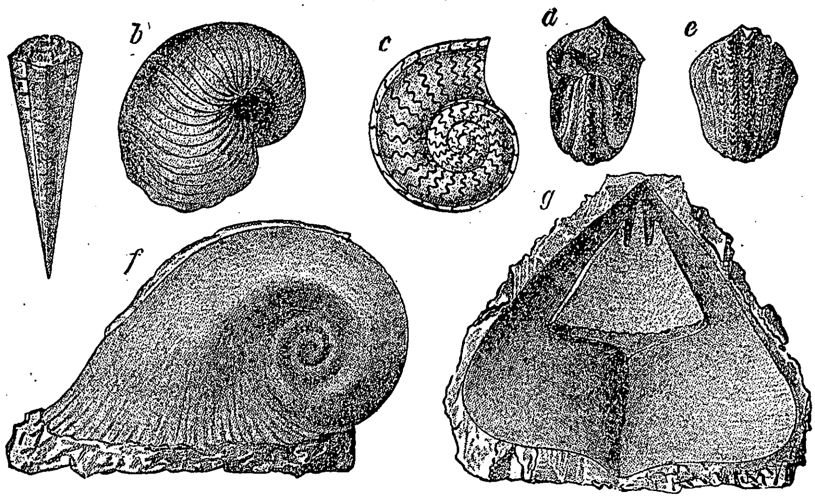
FIG. 32.



TRENTON GASTEROPODS. *a.* Murchisonia Helicteres — Salter. *b.* M. pagoda — Salter. *c.* M. gracilis — Hall. *d.* Raphistoma lenticularis — Sowr. *e.* R. Nasoni — Hall. *f.* Cyclonema percarinata — Hall. *g.* Pleurotomaria subconica — Hall. *h.* Trochonema Beachi — Whitf. *i.* Maclurea Bigsbyi — Hall. *j.* Subulites elongatus — Conrad. Helicotoma planulata — Salter.

Cephalopods. But the largest, most remarkable, and probably most highly organized of the Mollusks, were the *Cephalopods*, which sometimes attained giant dimensions. The Cuttle-fishes and Squids of to-day represent the type, and probably closely resemble the ancient extinct species in respect to the animal itself, but not at all in regard to its protecting shell. The modern Pearly Nautilus more nearly represents them in this respect. The ancient order possessed a straight, curved, or coiled shell, divided into a series of chambers by thin plates *(septa)*, which were perforated in the center or toward one side by a tube *(siphuncle)*, connecting the various chambers. The outermost chamber was the largest, and the only one supposed to have been occupied by the animal. As the Mollusk grew and became too large for his chamber, he is supposed to have moved forward and partitioned off the abandoned space, by the secretion of a new septum.

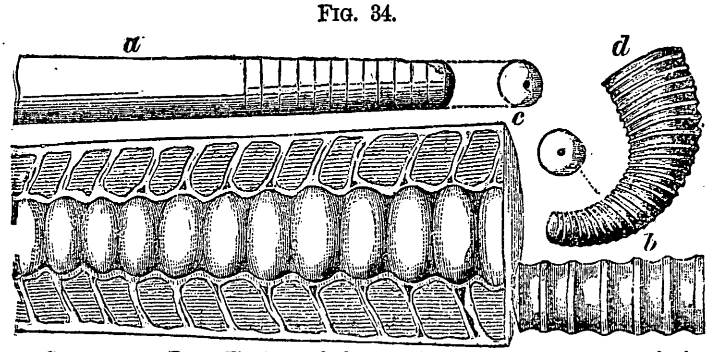
FIG. 33.



TRENTON HETEROPODS AND PTEROPODS. *a*. Hyolithes Baconi — Whitf. *b*. Bellerophon bilobatus — Sowr. *c*. Cyrtolites compressus — Conrad. *d*. and *e*. Bucania bidorsata — Hall. *f*. B. Buelli — Whitf. *g*. Pterotheca attenuata — Hall.

In the Trenton epoch, the Cephalopods were largely of the straight-shelled, or *Orthoceratite* type. There were, however, those of curved shells, as *Cyrtoceras*, and of coiled shells, as *Gyroceras* and *Lituites*. The Orthoceratites sometimes attained a diameter of nearly a foot, and a length of 12 feet or 15 feet. Their great size and cylindrical

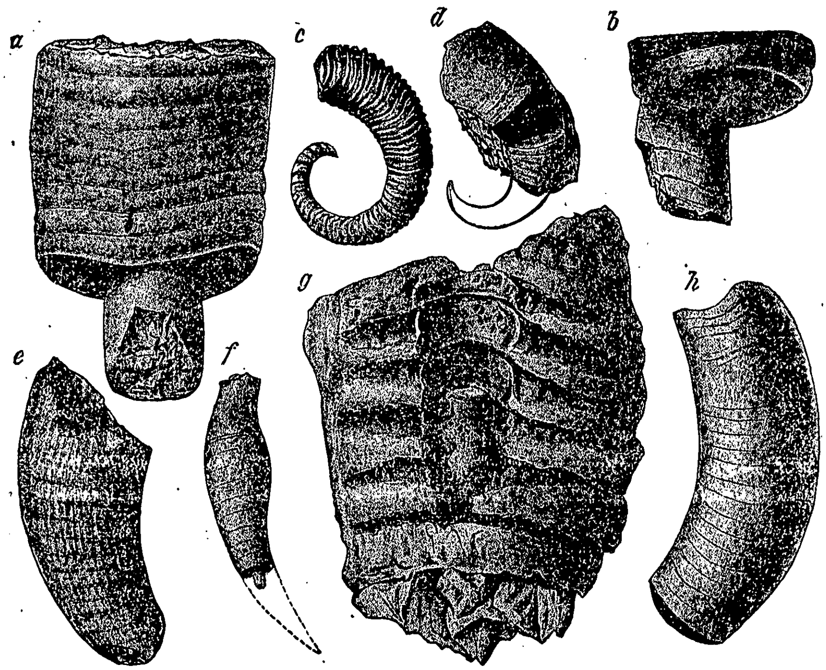
FIG. 34.



TRENTON CEPHALOPODS (Dana Figs.). *a*. Orthoceras junceum — Hall. *b*. O. vertebrale — Hall. *c*. Ormoceras tenuifilum — Hall. *d*. Cyrtoceras annulatum — Hall.

form give rise to the popular impression that they are fossilized serpents. When split longitudinally, as they not unfrequently are by the fracturing of the rock, the siphuncle and septa give an appearance resembling the backbone and ribs of a vertebrate, seemingly confirming the impression that they are snakes or fishes, forms only found in much later ages. Upwards of thirty species of Trenton Cephalopods occur in the State, of which the following may be mentioned as representative: *Orthoceras junceum*, *O. multicamera-*

FIG. 35.



TRENTON CEPHALOPODS. *a.* Endoceras subannulatum — Whitf. *b.* Fragment of same showing siphuncle. *c.* Gyroceras duplicostatum — Whitf. *d.* Oncoceras brevicurvatum — Hall. *e.* O. Pandion — Hall. *f.* O. Mumiaformis — Whitf. *g.* Fragment of Orthoceras Beloitense — Whitf. *h.* Cyrtoceras planodorsatum — Whitf.

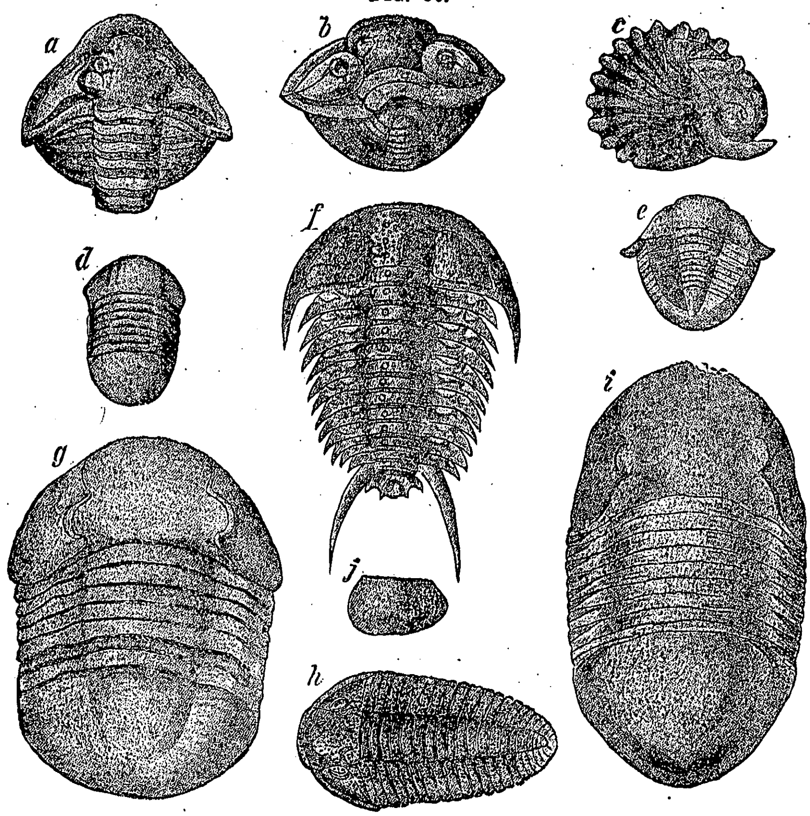
tum, *Actinoceras (Orthoceras) Beloitense*, *Ormoceras tenuifilum*, *Endoceras annulatum*, *Gonioceras anceps*, and *Lituites occidentalis*. The giant forms of this class were doubtless masters of the seas, and preyed upon such inferior animals as were not agile enough to escape them, or were unprotected by shells or other defenses.

Annelids. The calcareous bottom of the ocean was apparently uncongenial to the sand-boring *Annelids*, but occasional worm-like tubes imply at least their limited existence.

Crustaceans. Among the *Crustaceans*, there were large numbers of the little Entomostracans, *Leperditia fabulites*, which protected its back by growing a pair of mollusk-like shells. Certain layers just above the St. Peters sandstone are thickly strewn with these little shells.

Trilobites, which were so preponderant in the Potsdam period, still held a prominent place in the Trenton seas, though now dominated

FIG. 36.



TRENTON TRILOBITES. *a*. Calymene senaria—Conrad. *b*. Anterior view of the same. *c*. Lateral view of the same. *d*. Illænus crassicauda—Wahl. *e*. I. ovatus—Conrad. *f*. Ceraurus pleurexanthemus—Green. *g*. Asaphus Susæ—Calvin. *h*. Dalmania callicephalus—Hall. *i*. A. gigas—D'Kay. *j*. Leperditia fabulites—Conrad. (An Entomostracan.)

by the great Orthoceratites. The genera of this epoch are all new, embracing *Calymene*, *Asaphus*, *Illænus*, *Ceraurus*, *Encrinurus* and *Dalmania*. The remains, as before, are mainly disjointed, consisting of detached glabellæ, cheeks, pleuræ, and pygidia. The largest of the Trilobites, *Asaphus gigas*, sometimes attained a length of one foot. *Calymene senaria*, *Illænus crassicauda*, *I. ovatus*, *I. taurus*, *Ceraurus pleurexanthemus*, and *Dalmania callicephalus* are among the representative species.

General Remarks on Life. Comparing this fauna with that of the Potsdam period, the most striking contrasts are in the great development of the large Cephalopods, the appearance of abundant Lamellibranchs, the great increase in number and variety of the Gasteropods, the *apparent* introduction of Corals of diverse branches, the increase of Crinoids, and the decline of Trilobites — on the whole, a much ampler and more diversified life-series. A part of this greater amplitude is undoubtedly due to more favorable conditions of preservation, but there was doubtless a real increase in the number of living individuals and in the variety of forms. It is to be remarked, however, that the striking differences between the faunas of the two periods are more apparent than real, when viewed more comprehensively than from the standpoint of State formations — less real, indeed, than all known collections appear to indicate; for while the Potsdam sands were being collected along the shore and in the shallow seas, there were probably more quiet areas of calcareous accumulation elsewhere, where species adapted to such conditions, like those of the Trenton fauna, may have abounded. On the other hand, while in our region quiet seas prevailed during the Trenton epoch, fostering the life we have just described, there doubtless were sandy bottoms and shallow seas elsewhere, where species loving those conditions, and more allied to the Potsdam fauna, prevailed. It is to be confessed, however, that either observation has not determined such contemporaneous faunas, or else, which is quite possible, they have not been correctly correlated. Notwithstanding such qualifications, however, it is quite necessary to observe that while the great types remained essentially the same, there was a very important change in the special forms — a vastly greater change so far as the record shows, than took place in the corresponding types in all the Tertiary age.

Contribution of Life to Rock Formation. As the ages crept on, successive generations of these low forms of life died, and contributed their dust to the slowly growing sediments. Though the contribution of each little being was small, the total result in the lapse of time was an important accumulation. Earthy matter, borne back from the land, mingled with the calcareous contributions of life, so that layers of shale alternate with those of limestone, and shaly leaves and partings occur in the limestone beds.

Dolomization of the Beds. The rock is partly magnesian and partly simple limestone, and this peculiarity deserves passing notice. The stony parts of marine animals are mainly simple carbonate of lime. Their comminuted remains should, therefore, form simple limestone. But the ancient limestones are nearly all magnesian. Essentially all the limestones in Wisconsin, except that under consideration, are so, and even this is partially magnesian. It is interesting to observe that the portions that are not magnesian are the more compact parts, which have, for that reason, been less permeated by modifying agencies. It is important to observe, further, that magnesian and non-magnesian limestones occupy the same horizon in adjacent districts. In the lead region of Southwestern Wisconsin, simple limestones constitute the same strata that in the Rock river valley are found to be quite highly magnesian. The only apparent reason for dolomization in the one region and not in the other, is the somewhat coarse, porous texture of the one, and the fine-grained, compact character of the other. Without entering upon all the considerations that bear upon the subject, it seems highly probable that the greater portion of the dolomization took place while the sediments were yet beneath the depositing ocean, and that it was effected by the reaction of the magnesia of the sea-water upon the calcareous deposit, forming the double carbonate of lime and magnesia, in place of the simple carbonate of lime — the comminuted product of organic remains.

The Trenton strata, and they may be taken as typical of magnesian limestones generally, derived the material of their growth from three sources: 1st, the stony parts of marine life (which the animals derived by extraction from the sea-water); 2d, fine, earthy wash from the land, and 3d (probably) the chemical contribution of magnesia from the ocean.

SUBORDINATE DIVISIONS. *Lower Buff Limestone.* In the slow progress of growth there were variations both in the life and in the attendant oceanic contributions. There was first formed upon the St. Peters sandstone a stratum of rather rough, coarse, thick-bedded, magnesian limestone, somewhat impure from the presence of earthy constituents and not very fossiliferous, owing, for the most part, to the disintegration of the life-remains. This stratum, whose thickness may be estimated at 25 feet, is designated the Buff limestone.[1] The original color was really a bluish gray, but on weathering, the protoxide iron compounds changed to the hydrated sesquioxide, producing a light buff color.

Lower Blue Limestone. A slight change ensued on the completion of this stratum. Its upper layers were, in some parts, slightly worn and smoothed, probably by wave action, and a slightly different

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[1] This is the "Quarry rock" of the Lead region.

formation ensued. The worn surface and the character of the succeeding life suggest that this was due to a shift of currents and a lessening of depth, but it was an altogether trivial circumstance in geological history. There followed an accumulation of thinner layers, separated by shaly partings, indicating that the earth-wash was relatively greater than before. The conditions for the burial and preservation of organic remains were more perfect, and their mummied remains are now disentombed, after the long lapse of intervening time, in wonderful perfection. This is peculiarly true of the strata in the Lead region locally known as "Glass rock" (including the "Upper Pipe Clay").

Upper Buff Limestone. After the accumulation thus of an average thickness about equal to that of the stratum below — the deposit being designated the Lower Blue limestone — there was a return, essentially, to the conditions before prevalent. This gave rise to a second buff limestone whose maximum known thickness in the Rock river valley, where it is best characterized, is 55 feet. It is closely similar to the Lower Buff limestone. (Special characteristics, Vol. II, p. 295.)

Upper Blue Limestone. Afterward, by a second reversal of oceanic conditions, a shaly limestone, like the blue limestone below, was built up to the moderate thickness of 15 feet, constituting the Upper Blue limestone. (Vol. II, p. 296.)

These alternations are best characterized in the Rock river valley, but have their apparent equivalents, in the Lead region, in the "Buff limestone," "Blue limestone," "Brown rock," and "Green rock" of that region. (Vol. II, pp. 681–2 and 695, and Vol. IV, pp. 412–414.) It is worthy of remark that with each change of circumstances there was a corresponding change of life, the faunas of the two Buff strata being nearly identical, as were likewise those of the Blue limestones. In the former case, Lamellibranchs and great Orthoceratites were conspicuous, and in the latter, Brachiopods and Bryozoans. In addition to the testimony of fossils, a wealth of life is indicated by interstratified carbonaceous shales at some horizons, which yet retain sufficient combustible organic residue to take fire when heated, and to burn with a bright yellow flame.

Metallic Deposits. If we interpret correctly, there was, during the growth of these sediments, another and important, though not bulky, contribution, in the form of metallic deposits. In the southwestern portion of the State, rich zinc mines, and less important ones of lead and copper, occupy this horizon. Our view, as elsewhere elaborately explained (Vol. IV, pp. 367–576), is that the metallic material was accumulated simultaneously with the rock-formation itself, being extracted and precipitated from sea-water by the agency of life and its decomposition-products. The oceanic currents passing over the region are held to have been locally enriched by metallic substances derived from the metalliferous lands of the north. The metallic material thus deposited in a disseminated condition through the sediments, was subsequently concentrated in the fissures, openings and soft portions of the formation, by the percolation of atmospheric waters, charged with oxygen, carbonic acid, and organic substances which extracted the ore from the rock, and redeposited it where now found, substantially as explained in detail in the report cited.

State Distribution. The Trenton limestone appears as a surface formation skirting the area of the St. Peters sandstone, and like it, eroded so as to present a ragged and interrupted outline, which can only be appreciated by consulting the maps. In general, it may be said to form an irregular band stretching from the Michigan line, a few miles above the mouth of the Menominee, southward through the Green-Bay-Rock-River valley to the southern limit of the State, and to be extensively exposed in the borders of the river valleys of the southwestern portion of the State, and to occupy some small areas in St. Croix and Pierce counties, in the northwestern portion. Like all the associated Palæozoic formations, it originally extended considerably further toward the center of the State, and has been worn back by the erosion of the ages.

American Distribution. This formation constitutes an almost continuous belt eastward to Quebec, and northwestward to an undetermined distance in the British possessions. Eastward, leaving Wisconsin a few miles to the west of Green Bay, it curves eastward through the upper peninsula of Michigan, concentric with the curve of Lake Michigan, and, crossing the straits, appears at intervals in the islands north of Lake Huron, and passes beneath Georgian Bay, reappearing near its southeastern extremity, from whence it strikes southeastward, to the foot of Lake Ontario, and crossing into New York, swings entirely round the Adirondacks, occupies the Lower Ottawa basin, from whence it stretches down the St. Lawrence valley to the enlargement of the river below Quebec, beyond which its horizon is concealed by the waters of the river.

Tracing westward from Wisconsin, its outcropping edge appears as an irregular belt in northeastern Iowa, whence it stretches north to the vicinity of St. Paul, and thence, passing at first southwestward, it recurves to the northwest, and extends along the base of the

Archæan belt for an undetermined distance. It appears also on the opposite side of the Archæan belt, in the Hudson Bay basin.

Along the Appalachian belt it occurs also from New Jersey to Alabama. It occupies a limited area in Missouri, and in southern Illinois. In the western mountains its area has not been defined.

GALENA EPOCH.

FIG. 37.

SECTION illustrating the relations of the Galena limestone (*Ga.*) to the Trenton limestone (*Tr.*) below, and to the Hudson River shales (*H. R.*) above.

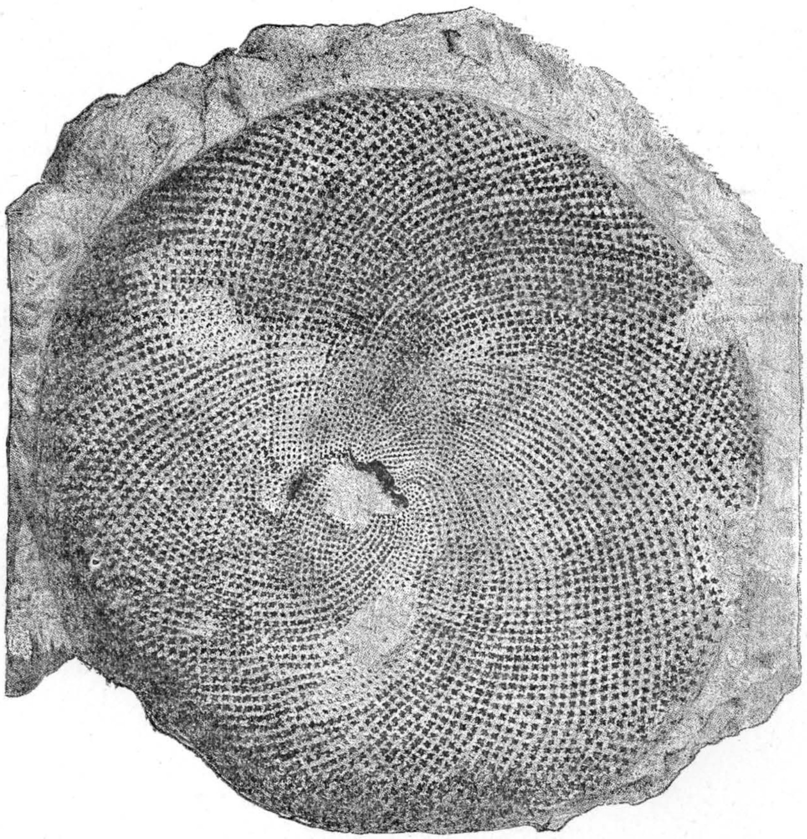
Synopsis of Characters. Formation named from the lead ore, galena, contained in it, and from its typical exposures at Galena, Ill. Consists of buff, coarse-grained, thick-bedded dolomite, underlain by Trenton limestone, and overlain by Hudson River (Cincinnati) shales. Thickness about 250 feet. Changes to more argillaceous character to the northeast and northwest. Fossils not well preserved. Flint abounds at certain horizons.

For details see Vol. II, pp. 305–314 (Chamberlin), 562 (Irving), 683–685 (Strong); Vol. IV, pp. 90–91 (Strong), 239–247 (Fossils, Whitfield), 404, 407–410 (Chamberlin).

Oceanic Conditions. Appearance of the Central Arch. A slight, but important, change of oceanic conditions closed the Trenton epoch, and inaugurated the Galena. Limestone formation continued, but its character was affected by the new circumstances. At this stage the growth of the State seems to have first been visibly affected by what afterward became one of its leading stratigraphical features. As the strata now lie, they form a low arch having a north and south axis, extending through the center of the State, broad at the north, and narrowing and dying away at the south. The strata on the eastern side slope toward Michigan, which occupies a broad stratigraphical depression, and on the west toward Minnesota and Iowa, which occupy a similar basin on that side. During the epoch on which we are now entered, these broad features apparently began to be developed. Subsiding gulfs commenced to form on the east and west, with the Wisconsin axis projecting southward between them.

While, therefore, limestone continued to be deposited, it was modified by these conditions. Over the low arch in the southern portion of the State there accumulated a coarse-grained, rough, uneven-textured, thick-bedded, more or less cherty and often brecciated, dolomitic deposit, which has received the designation, Galena limestone. The present survey has demonstrated that, as this is traced northeastward obliquely down the side of the arch and into the area of the gulf-like depression of Michigan, it gradually changes to a finer-grained, more argillaceous limestone, indicating a more protected and quiet sea-bottom. Similar facts are indicated by the examinations of the Iowa and Minnesota geologists, with reference to the formation in the western basin.

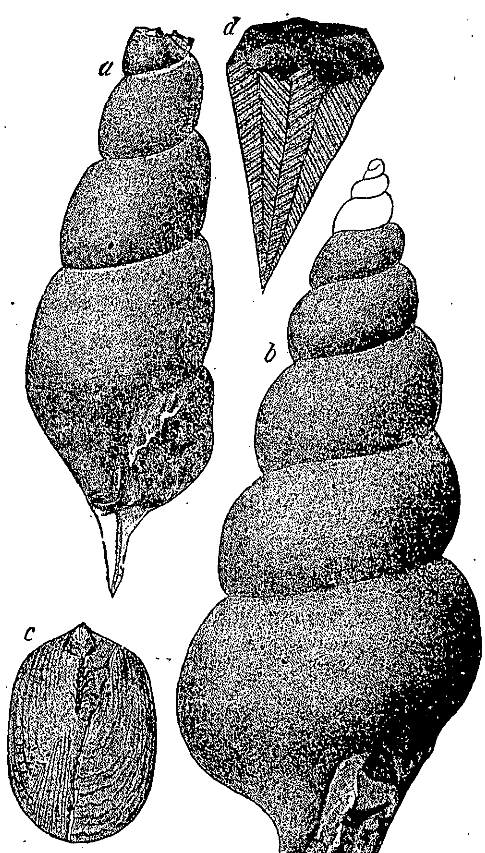
FIG. 38.



RECEPTACULITES OWENI, HALL. "Lead Coral" or "Sunflower Coral." Original specimen 9¾ inches in diameter. The reduction gives a somewhat unnatural appearance.

Life. The character of the life is accordant with these circumstances. In the coarse limestone of the arching area, very few well-preserved fossils are found, and these are such as, from their nature, could withstand the somewhat rough conditions attendant upon their exposed position upon the swell of the ocean bed. The most abundant and characteristic of these is the wonderful "Sunflower" or "Lead Coral" *(Receptaculites Oweni)*, which is highly characteristic of the formation. The real nature of the organism is not known, but it is regarded as a gigantic Foraminifer. Perfect specimens of the fossil have never been found. In the most complete condition in which it has been observed, it consists of a flat disc occasionally reaching nine inches or more in diameter, and varying in thickness from one-eighth or one-fourth of an inch at the center to nearly an inch at the circumference. The disc is symmetrically perforated with vertical tubes disposed in lines like the chasing on a watch. The surface markings are illustrated in the accompanying figure, which is from a photograph of the most perfect specimen yet known to have been found.[1] The disc is regarded as only the basal portion of the organism. Mr. Billings, the late eminent Palæontologist of the Canadian survey, maintained that this basal disc was surmounted by a conical dome of similar structure, inclosing a cavity within. Smaller species in other regions, and formations where conditions of preservation were better, illustrate this structure. Mr. C. C. Warner presented the writer with a specimen from Freeport, Ill., that quite clearly appeared to consist of a portion of the base, with a portion of the crown still attached. It is in harmony with all attendant circumstances to suppose that this conical or napiform organism, resting upon its broad base, was able easily to resist all forcible action while living, and that after death, the bottom, resting flatly upon the ocean bed, and possibly somewhat imbedded in it, sometimes remained whole, while the crown was crushed in and is never known to have been preserved.

FIG. 39.



CHARACTERISTIC GALENA FOSSILS. *a*. Fusispira elongata — Hall. *b*. Murchisonia major — Hall. *c*. Lingula quadrata — Eich.? *d*. Conularia Trentonensis — Hall.

Another characteristic

[1] Kindly loaned by Dr. D. S. Clark, of Rockford, Ill.

fossil occasionally found is *Lingula quadrata*, whose shell, by virtue of its phosphatic character, was better adapted to resist disintegrating agencies, than simple calcareous shells, as remarked of the Potsdam Lingulæ.

A third characteristic fossil is a large, stout Gasteropod, *Murchisonia major*, or *M. bellicincta*, var. *major*, either of which names implies a fitness to battle with hostile conditions. While these are not only the characteristic, but nearly the only large fossils that are commonly found, small Brachiopods and Corals, with fragments of many other forms, occasionally occur. There are also frequent worm-like tubes. The surface of many layers is plated with a tangled mesh of cord-like sea-weed impressions, indicating their abundance.

The rarity of well-preserved fossils is not to be interpreted as evidence of scantiness of life, but as an index of moderately forcible sea-action — not so violent as to interfere with the growth of life, or the retention of the greater portion of its remains, but sufficiently so to comminute all but the more resistant forms, as indicated.

The suggestion may be ventured that *tidal action* may have been indirectly an important agency. It is in harmony with the conclusions of recent investigations on the orbital history and tidal effects of the moon[1] as well as with the long known greater extent of the ocean in early geological ages, to suppose that the tidal wave was much higher and stronger than at present. It is also rational to suppose that in crossing the relatively shallow sea that covered the low arch which stretched southward from the northern land, the effects of the tidal waves must have been augmented. Now, whether such augmented tides would, or would not, in themselves, be competent to produce any considerable effects in an open (even though shallow) sea, 50 or 75 miles from land, is not here discussed, because definite data are wanting; but it is suggested that, if not in themselves effective, they might, in conjunction with wind waves (which might then also have been greater, because of increased rotation), have not only been efficient agencies, but might have produced results of a *peculiar character*. It is to this peculiar phase of action, that attention is called.

When the surface level remains practically constant, whatever effect wind waves produce is essentially constant until the wind changes. If fine material is stirred from the bottom, it is maintained in suspension during the continuance of the agitated state of the sea, and drifts long distances with the current, the result being the assortment and removal of the finer material. But if the sea level oscillates through any considerable height as compared with the depth of wave action, the case will be quite different. To illustrate, suppose the wind waves are competent to produce a given effect at a depth of 40 feet, that the mean depth of water is 50 feet, and the tidal oscillation 10 feet, above and below the mean level. It is manifest that without the tide the waves could not produce the given effects. But at low tide they would be, for a brief interval, within effective reach of the bottom, and would agitate it accordingly. But they would soon be lifted

[1] Particularly those of Mr. G. H. Darwin.

above effective action, and the agitated material would thus again be left in more quite waters, and would settle back into repose. Thus there would be an alternation of relatively forcible and quiet action. During the former the coarser material might be rolled and triturated and the finer stirred into suspension, while during the latter, both fine and coarse might, in large measure, settle back together, the fine insinuating itself between the coarse, tending to bind it together, and render it less easily disturbed by subsequent wave-action.

Such an alternating action would appear to offer us some aid in conceiving of the method of formation of extensive sheets of brecciated limestone. A large portion of the Galena formation is of this character. In the Niagara limestone, a single brecciated stratum may be traced 100 miles along the strike of the formation, and probably 50 miles or more back from its original margin. Much the larger part of the Silurian limestone of Wisconsin is of a rough irregular texture, which implies that the original material was heterogeneous. A systematic alternation between vigorous and quiet action like that now described would seem to aid greatly in supplying the needed conditions.

Variations in the Formation. The foregoing characters relate to to the Galena limestone as found distributed over the low arch of the south-central part of the State. As traced northeastward obliquely down the slope of the arch, and into the Michigan stratigraphical basin, over what may be conceived to have been a broad, deepening gulf, the deposit gradually changes through the introduction of clayey material, and a progressive increase in the fineness and compactness of the limestone material — changes beautifully consonant with the sub-marine conditions indicated. With this modification in the nature of the deposit, there was a corresponding change in the character and preservation of life forms. The ampler fauna of the Trenton beds below extended upward, and mingled with *Receptaculites Oweni*, *Murchisonia major*, and *Lingula quadrata*, which characterize the Galena proper, thus beautifully illustrating the palæontological principle that a fauna, apparently cut off in one region, may be flourishing luxuriantly in an adjacent one.

This merging of one rock into another — though the transition here is not great — well illustrates the dependence of deposits upon local marine conditions. It further shows the superiority of stratigraphical over palæontological evidence in determining the true correlation of formations where the stratigraphical method is applicable, for this northeastern equivalent of the Galena limestone has been heretofore uniformly referred either to the Trenton horizon below, or to the Hudson River above. The same fact will be further illustrated if the argument of Mr. C. B. Walcott, maintaining that this is the western equivalent of the Utica shale, shall be sustained by future investigation.

Metallic Contents. This formation, in the southwestern part of the State, is rich in lead and zinc deposits. The source and method of the original mineralization is essentially the same as that sketched for the Trenton deposits, and more fully set forth in the special discussion of the ore deposits of the region, in Vol. IV, pp. 365 et seq.

Distribution. As now exposed, this limestone forms a somewhat broad belt underlying the main portion of the Green-Bay-Rock-River valley, and occupying nearly all the higher lands south of the Wisconsin river in the southwestern part of the State. Like all the formations in this region, it has been much channeled by erosion, and its outlines now present a highly sinuous contour. In the eastern part of the State, the glacial planing of a later geological age has somewhat reduced and concealed its irregularity.

American Distribution. This has usually been regarded as the superficial member of the Trenton limestone group, and as partaking of the distribution outlined under that head. Mr. C. D. Walcott has recently argued with cogency that it is the western equivalent of the Utica shale of New York, and is hence to be ranked in the next higher horizon. The Galena limestone, in its typical development, is limited to a radius of little more than a hundred miles from the southwest corner of Wisconsin. Beyond that limit the formation grades into a more argillaceous and shaly deposit. Northeasterly it is traceable into the Upper Peninsula of Michigan, but in following its horizon onward into Canada, it does not appear in its place, according to the testimony of geologists, while the Utica shale, which is absent to the westward, there appears and extends thence onward, lying next the Trenton belt, into New York and the St. Lawrence valley, and also occupies the same horizon along the Appalachian belt. In Missouri the "Receptaculites limestone" is undoubtedly the equivalent of the Galena limestone. The formation must also have an extensive development along the west side of the Archæan belt that stretches northwesterly toward the Arctic ocean, since numerous large erratics from it occur on the plains of northern Dakota. It also occurs in the Hudson Bay region.

Hudson River (Cincinnati) Epoch.

FIG. 40.

SECTION illustrating the relations of the Hudson River (Cincinnati) shales (*H. R.*), to the Galena limestone (*Ga.*) below, and the Niagara limestone (*N.*) above.

Synopsis of Characters. Formation consists of shales of various hues, but usually blue and green, with intercalated limestones, reaching a total thickness of 200 feet and upwards. Fossils, in some portions, very abundant and well preserved; in others, rare.

The name of the formation has been the subject of much discussion. At the time of the issue of Vol. II, the tendency of judgment seemed to favor the setting aside of the name Hudson River, as it was not then proven that the formation in question touched the Hudson river, the rocks to which it was originally applied being referred to other geological horizons. The name Cincinnati, at which place the formation is well developed, had come into use on excellent authority, as a substitute, and was adopted in that volume. Recent investigations have, however, demonstrated the existence of the formation on the Hudson river, and removed the most serious objection to the use of the earlier name, and it will now doubtless be accepted, notwithstanding the fact that it remains an unfortunate selection, not being based on a typical and well-characterized development of the formation.

For details, see Vol. II, pp. 314–326 (Chamberlin), 685–688 (Strong); Vol. IV, pp. 248–266 (Fossils, Whitfield), 410–411 (Chamberlin). For area occupied by the formation, see atlas.

Character of the Deposition. After the slow growth of the Galena limestone had given that formation a maximum thickness of about 250 feet, the oceanic conditions were again slightly altered, giving rise to more turbid waters, from which settled down, over so much of the area of the State as then remained submerged, a mud bed, which destroyed or drove away those marine animals which live only in clear seas. There was, therefore, a change in the character of the deposit not only, but in the life which it imbedded, though neither of these changes were extreme. The turbidity of the waters was probably at most only slight and intermittent, and by the shifting of the currents there were apparently frequent intervals of limpid waters at any given point, during which clear-water life flourished, and the accumulating rock-material was, as before, mainly derived from it. There resulted from these shiftings, alternations of limestone and shale, but, from the nature of the case, these were very inconstant, and while the turbid waters were depositing shale at one point, clearer waters at another favored calcareous accumulation.

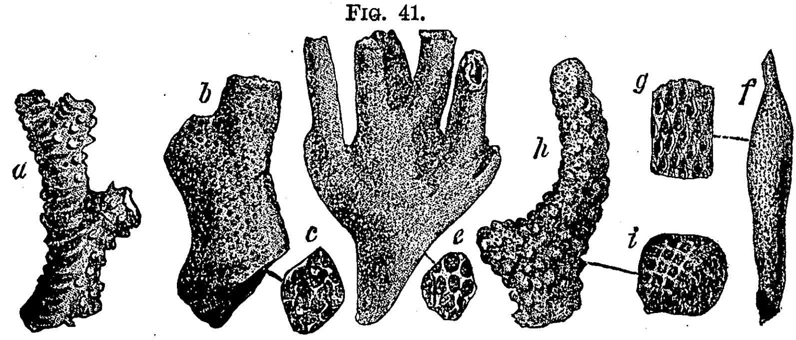
As a consequence of this, in examining the strata as they are now so finely exposed along the cliff east of Green Bay, for instance, we may start with a limestone layer and trace it horizontally until it passes into a clay shale, not only, but, following it further, it may be found passing through many variations of color, texture, and material, and if it could be followed far enough, it might be found to again grade into limestone. As a result of these combinations of fluctuating conditions, the total deposit consists of an interstratified series of shales and limestones, reaching a thickness varying from 125 feet to 240 feet or more, with a probable average of about 200 feet.

The limestone is more abundant than elsewhere in the vicinity of Little Sturgeon Bay, the most northeasterly point where the formation is exposed, and apparently least abundant where it overlies the central arch of the State, previously described. This distribution seems to indicate that in the former region the waters were still sufficiently deep, or, at least, quiet, to be measurably clear, while in the latter, they were agitated and turbid, but not so boisterous as to prevent the accumulation of fine sediment.

The shales of the series vary greatly as would naturally be the case from the conditions of accumulation just indicated. The material was derived from the adjacant land, partly by shore wash, but more largely from the contribution of rivers, and the character of the material which they brought down varied with that of the rocks and soil from which they came, and the altitude and slope of the land. It is not strange, therefore, that there should be found variations of color, running through gray, green, blue, and purple to red, buff and brown; gradations of texture, from a coarseness approaching a sandstone to fine unctuous clay; and varieties of composition, ranging through calcareous, silicious, aluminous, and, subordinately, carbonaceous, gypseous, pyritous, and other varities.

Stratification. From the manner of accumulation it will be correctly inferred that the sediments were evenly and thinly stratified, and, in some instances, very finely laminated, so that they now split into thin regular plates, almost rivaling in smoothness metamorphic slates. They are, however, very brittle and fragile.

FIG. 41.

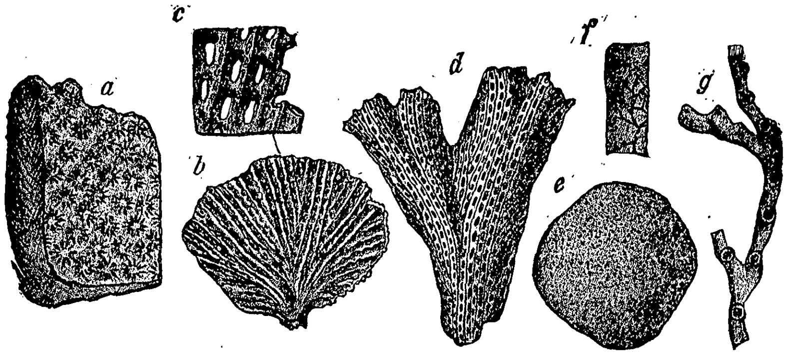


CORALLINE FOSSILS OF THE HUDSON EPOCH. *a.* Monticulipora rugosa — Ed. & H. *b.* M. (Chætetes) attritus — Nich. *c.* Magnified surface of same. *d.* M. (Chætetes) briareus — Nich. *e.* Magnified surface of M. briareus. *f.* M. (Chætetes) fusiformis — Whitf. *g.* Magnified surface of M. fusiformis. *h.* M. rectangularis — Whitf. *i.* Magnified surface of M. rectangularis.

Ripple Marks and Mud Cracks. The depositing conditions are further indicated by the existence of beautiful ripple-marks, sometimes of unusual size. Mud-cracked surfaces, so regularly marked as to resemble a pavement of octagonal bricks, have been observed. The former indicates a shallow sea, the latter, alternate exposure and submergence.

Life. Just as there was an easy transition from the physical conditions of the preceding epoch, so there was a correspondingly simple and natural transition of life. Those forms which were not adapted to the shallow and silted seas retired, while others, to which the new conditions were congenial, flourished in greater abundance.

FIG. 42.



CORALLINE FOSSILS OF THE HUDSON EPOCH. *a.* Constellaria polystomella, Nich. *b.* Fenestella granulosa — Whitf. *c.* Enlarged surface of F. granulosa. *d.* Stictopora fragilis — Bill. *e.* Fistulipora lens — Whitf. *f.* Aulopora arachnoidea — Hall. *g.* Portion of a branch of A. arachnoidea enlarged.

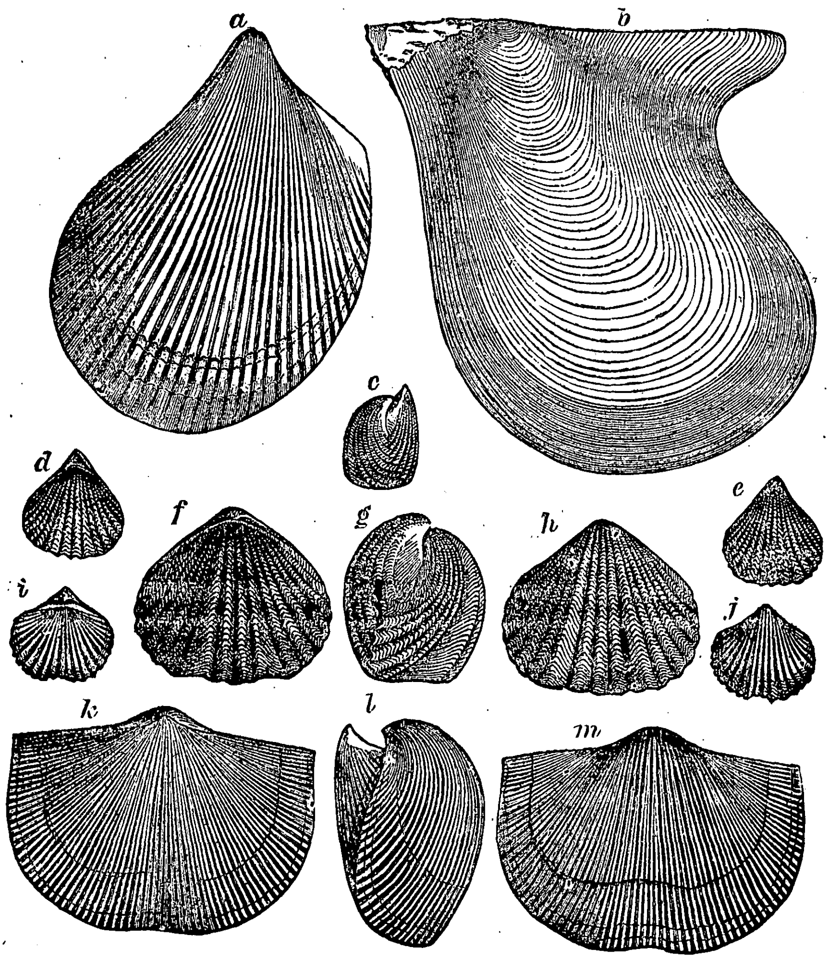
True Polyp Corals, those lovers of clear seas, were comparatively rare, while those delicate coralline forms, variously referred by different authorities to Bryozoans and Chætetoid Corals, flourished in extraordinary abundance. In some of the more quiet localities, Brachiopods were likewise very abundant, while over other large areas they appear to have been totally absent.

The Lamellibranchs, Gasteropods and Cephalopods almost wholly disappeared from our shores. None of the last named have been found, and but few of the others. In some localities in the Lead region, the beautiful little bivalve *Cleidophorus neglectus* is found in great numbers. Crinoids likewise were rare, and of Trilobites but a few remained.

A prominent characteristic of the life distribution is its irregular colonial character. Over certain areas forms of life, adapted to the conditions there presented, flourished in great luxuriance, while other and more considerable areas seem to have been quite untenanted. As illustrations may be cited the great abundance of coralline forms at Robert's quarry, near Pewaukee, and at Iron Ridge, where, from a few cart-loads of material thrown from wells, thirty species of beautiful coralline forms were collected, beside a considerable number of Brachiopods; and, again, the even greater abundance of little bivalves in certain localities in the Lead region. This localization of life is in harmony with the variableness of marine conditions already described.

General Considerations. The general conditions which brought about this era of sedimentation may be apprehended by considering

FIG. 43.



BRACHIOPODS AND LAMELLIBRANCHS OF HUDSON EPOCH. *a.* Ambonychia radiata — Hall. *b.* Pterinea demissa — Conrad. *c.* Rhynchonella Anticostensis — Bill., side view. *d.* Dorsal view of R. Anticostensis. *e.* Ventral view of R. Anticostensis. *f.* R. Capax — Conrad, dorsal view. *g.* Side view of same. *h.* Ventral view of same. *i.* Zygospira modesta — Hall, dorsal view. *j.* Ventral view of same. *k.* Orthis occidentalis — Hall, dorsal view. *l.* Side view of same. *m.* Ventral view of same.

the progress of the gentle coast-movement that was inaugurated in the preceding epoch. Evidence has been adduced to show that the central area of the State was then affected by a very gentle upward bending of the strata, attended by compensating depressions on either hand. A little further progress of this movement is thought to have shallowed the sea on the slopes of the rising area, and exposed its sediments to wash and wear and rearrangement, so that it became wrapped about with the blanket of silt which constitutes the formation under consideration. At the close of the epoch, the waters seem to have retired beyond our borders for a season, since the succeeding formations, as found elsewhere, are not present in Wisconsin.

Similar movements farther to the eastward caused a more considerable arching of the strata. A like axis extends southward from Lake Erie, through Ohio and Kentucky, into Tennessee, constituting the Cincinnati arch. It was mainly formed, as demonstrated by the Ohio geologists,[1] at the close of this epoch. Still further east, the Green Mountain range is maintained, by Professor Dana and others, to have been principally formed at this time, and there much more powerful disturbances are held to have taken place, resulting in the folding of the strata. It is quite possible that similar effects were felt throughout the Appalachian range, but this has not yet been demonstrated. An interesting system of movements may be discerned by combining these observations, viz.: (1) mountain-folding at the east, (2) a less forcible arching in western Ohio, and (3) a still more gentle flexure in Wisconsin.

Close of the Lower Silurian Age. The Hudson River shales complete the Wisconsin rock-series of Lower Silurian age. The progress of formation had been quiet and uninterrupted. The record it has left is clear and legible. Its close is marked by the noteworthy fact that, after a long period of partial submergence, the entire area of the State probably became land.

Probable Land Surface. It may be profitable to picture to ourselves some of the leading features of the land-surface. All the sedimentary strata formed subsequent to Archæan times were still lying in an almost horizontal position, very much as the sea deposited them. They had recently been very slightly arched, as we have seen, and, in earlier ages, some little lifting of the edges about the Archæan core, and corresponding settling of portions farther away, very probably took place. But the combined effect of all these was slight, and, as a result, the whole of the area occupied by the later formations was low and level. This area was extensive, occupying all the southern portion of the State, nearly or quite encircling the Archæan nucleus. The surface of the latter probably

[1] Geol. Surv. O., Vol. I, pp. 93 et seq.

rose higher than at present, for in the long ages that have intervened, it has been exposed to wash and wear, which have continually reduced its height. We have seen that it originally towered to lofty mountainous heights.

Geography. Our picture of the topography of the State would, therefore, be that of an elevated, perhaps mountainous prominence in the northern portion, encircled by lower lands from which a great, flat plain, scarcely above tide level, stretched away to the ocean, which lay beyond the State borders.

Land Plants. Over this land there probably grew more or less vegetation, for vegetal remains, claimed to be those of land plants, have been found in the Hudson River strata of Ohio and Kentucky. These were probably of the Cryptogamous class, and allied to those which constituted the strange plant-life of the Coal period.

Climate. The climate was probably warm, moist, and equable, for the life of the adjacent seas, particularly Crinoids and Corals, seem to indicate a warm temperature. The great extent of the sea, the depth and moisture of the atmosphere, the lowness and limited extent of the land, all would contribute to this result.

State Distribution. The Hudson River shales, because of their erodability, occupy but a limited area at the surface. They skirt the Green-Bay-Rock-River valley on the east, lying at the base of "The Ledge" which bounds the valley on that side, and whose existence is due to the removal of the soft shales, leaving the overlying and more resistant Niagara limestones projecting above in cliffs. In the southwestern part of the State, the formation underlies the "Mounds," and occupies a few other very limited areas, shown on the survey maps.

American Distribution. The surface distribution of the Hudson River formation is very similar to that of the Trenton formation already outlined, forming, as it does, a parallel belt along its outer border. Leaving Wisconsin in the valley of Green Bay, it sweeps around Lakes Michigan and Huron, distant but a few miles from their shores, appearing on the Manitoulin islands and the western shore of Georgian Bay. Thence it strikes southeastward to Lake Ontario, of which it forms the bottom, in part. Reappearing at its southeastern angle, it sweeps around the Adirondacks, outside of the formations previously described, and follows the St. Lawrence valley to its terminus, occupying the river channel in part, and also a part of Anticosti island. Where it strikes the Hudson, it sends a branch belt southward along the river that has given it a name, and thence along the Appalachian range to Alabama. At Cincinnati, the formation has its finest known development, and is exceedingly fossiliferous. This locality has a natural claim to give its name to the formation, and we yield it reluctantly in deference to the rules of geological nomenclature. The formation occupies a considerable area on the summit of the Cincinnati arch. At Nashville and vicinity, it is also well displayed, constituting the Nashville group of the Tennessee reports. In Iowa, the formation is known as the Maquoketa shales, and extends from the river of that name northwesterly into Minnesota to the vicinity of St. Paul, and then turns southeasterly, and is lost beneath later formations. Its equivalents in the western mountain region remain to be worked out.

Foreign Equivalents of Lower Silurian. The English Lower Silurian embraces the Arenig, the Llandeilo, and the Bala or Caradoc beds. These are best developed in Wales, in the land of the ancient Silures, whence the name is derived. They constitute the main portion of the southern uplands of Scotland, and are quite largely developed in Ireland. They occur also in northern and southern Scandinavia, and the Baltic provinces of Russia, in Bohemia (Etage D), in Bavaria, and in Spain. In short, as would be rationally expected, the foreign, like the American Silurian formations, are found gathering about the more ancient Laurentian nuclei, which were the centers of continental growth.

CHAPTER IX.

UPPER SILURIAN AGE.

Subdivisions. The Upper Silurian age may be regarded as embracing two periods: I, the *Niagara*, and II, the *Helderberg*, each of which presented subordinate phases which are classified as epochs. The epochs of the Niagara period are, (1) that of the advancing sea, marked by the *Oneida conglomerate* and *Medina sandstone*, (2) an epoch of oscillating transition, characterized by the *Clinton shales and ore beds*, (3) a stage of advanced sea in which was formed the *Niagara limestone*, and (4), a period of shallow and retiring sea, embracing a portion of the *Salina deposits*, as we would classify them.

The Helderberg period may be regarded as embracing (1) a stage of advancing and deepening sea, including the later deposits commonly referred to the Salina group, (2) an epoch of advanced sea marked by limestone accumulation — the *Lower Helderberg epoch*, and (3) a period of retiring sea, during which the *Oriskany sandstone* was in part, at least, deposited. In tabular form the classification may be presented thus:

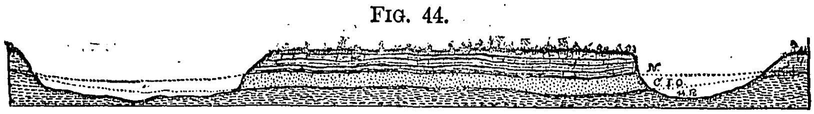
Age.	*Periods.*	*Epochs.*
Upper Silurian.	Helderberg.	Oriskany.
		Lower Helderberg.
		Salina.
	Niagara.	Niagara.
		Clinton.
		Medina.
		Oneida.

Terrestrial Interval. The terrestrial conditions above sketched seem to have continued for a considerable period, during which, obviously, no marine deposits were added to the surface of the State. The period, so far as Wisconsin was concerned, was not one of growth, like those which had preceded, but rather one of loss, because of surface waste.

Although no definite record was left in Wisconsin, yet this was not a lost interval in geological history. The ocean was elsewhere laying down the rocky tablets on which were being recorded the progress of the age. In other regions, notably in New York and along the Appalachian land-border, formations were in progress, constituting the Oneida conglomerate and the Medina sandstone, which, together, are reported to have attained in Pennsylvania a thickness of 2,500 feet. A still more complete record was kept by the deposits at the mouth of the St. Lawrence, now known as the Anticosti group. That region appears not to have been affected by the movements which interrupted deposition elsewhere, so that continuous deposits, stocked with an instructive series of fossils, teach the essentials of the ongoing history. They show, however, only a graduation to the next succeeding records of our own rocks, and, therefore, do not demand special consideration here.

CLINTON EPOCH.

FIG. 44.



SECTION illustrating the relations of the Iron Ridge Ore deposit, to the underlying Hudson River (Cincinnati) shales, and the overlying Niagara limestone.

Synopsis of Characters. The formation elsewhere consists of shales, limestones and iron ore, but in Wisconsin, only the iron ore beds of Dodge county and adjacant regions are referred to the epoch. Probably the overlying limestones are the equivalents of strata at the east referred to the Clinton epoch, but as they are closely joined to the Niagara limestone, and with it are the product of one limestone-making epoch, they are so treated here. The formation, thus limited, consists of local beds of iron ore, composed of small lenticular concretions of hematite, "flax-seed" ore. The maximum thickness is about 25 feet. The ore is easily reduced, and yields about 45 per cent. of the metal. No fossils found.

For details see Vol. II, pp. 327–335 (Chamberlin). For area occupied by the formation, see atlas.

The Clinton Iron Ore. After the terrestrial interval of waste, the history of Wisconsin formations was resumed in a special rather than a general chapter. The next deposit is peculiarly a local one. It attains its chief importance at Iron Ridge, in Dodge county, where it reaches its maximum known thickness within the United States — about 25 feet. Traced from this point it thins out and disappears within a short distance on either hand. A less important deposit occurs under the village of Hartford, but it cannot be traced over any considerable area. At Cascade Falls, east of Depere, the formation again appears, but does not reach an observed thickness of more than five feet, and does not appear to have any great areal extent. Along the eastern shore of Green Bay there is a thin ferruginous layer, only a few inches in thickness, which may be traced for a few miles, but it attains no importance. At many other observed points along its proper horizon, it is found to be entirely absent, or marked only by a little iron-staining. It is, therefore, pre-eminently, a local formation. It appears to have been formed in limited depressions on the surface of the Hudson River shales.

Character of the Ore. The deposit itself is a peculiar one. The ore is made up of little concretions of the oolite type, whence the name "shot ore." The concretions are, however, almost universally flattened, and have a reddish-brown color and glazed surface, which has suggested the not inapt name "flax-seed ore." By grinding these concretions to sufficient thinness on a lapidary lathe, their concentric structure may be well seen. At the center is found a hard transparent nucleus, which is apt to be broken out in grinding, owing to the relative softness of the surrounding ore. It is, therefore, apparent that these grains were formed by successive accretions about a silicious nucleus.

Their average diameter is about one twenty-fifth of an inch, but they vary from those that are quite minute, up to those that have a diameter of one-tenth of an inch, while there are still larger imperfect forms.

These flattened oölites lie, naturally enough, upon their sides, giving the rock a ready cleavage in a horizontal direction. They are bound together by just enough adhesive ore-powder to give the mass a moderate cohesion, forming a soft, friable, granular iron-rock. It is regularly bedded in horizontal layers from three to fourteen inches in thickness, and may be mined with the greatest facility. The ore is a partially hydrated iron-oxide containing about 45 per cent. of the metal. The layers rest in a slight measure unconformably upon the shales at their base.

Analogous ore deposits occur at the same geological horizon at various points eastward from Ohio, and northward from Alabama to Nova Scotia.

Fossils. In the Wisconsin beds, no fossils belonging to the deposit have been found, but elsewhere they occur in considerable abundance, giving the deposit the name "fossil ore," and demonstrating its marine origin.

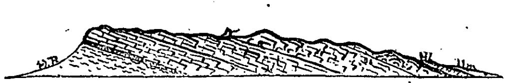
Method of Formation. Some difficulties arise in conceiving the precise method of formation, particularly since, in the Wisconsin deposits, no contemporaneous formation has been observed connecting the detached deposits, such as would naturally be expected if the whole region were submerged. As no marine fossils occur here, it seems probable that the ore accumulated in lakes, lagoons, or estuaries, and that the intermediate territory was not submerged.

The probable source of the ore is to be found in the iron-bearing waters coming from the low, flat land adjacent, or the more distant ferruginous rocks of the Archæan series. The location of the accumulation is not such as to make it highly probable that the latter was an important source. The ore was probably precipitated, as suggested by Prof. Newberry,[1] "in a manner similar to the 'mustard seed' ore now being deposited in some of the Swedish lakes which receive the drainage from ferruginous districts. While in process of transportation, the iron was a soluble protoxide, but by oxidation it was rendered insoluble and deposited. In the ages that have since passed, these limonite granules have lost a part of their water of combination, and have been converted into red hematite."

Correlation. The Clinton Epoch, as usually defined on the basis of formations elsewhere, embraces, besides the ore deposits, sandstones, shales and limestones. The limestone stratum, immediately overlying the Wisconsin ore deposits, was probably formed at the same time as the upper Clinton beds of the eastern localities, but there is here no good reason for separating it from the overlying limestones, with which it is continuous, and which embrace also deposits of the Niagara, and even Guelph epochs. To cut up our formations unnaturally to make them correspond to phases of deposition elsewhere, or to conform to a predetermined system of classification, would be doing violence to truth, and encouraging false conceptions of geological history. The epochs of deposition are often unlike in distant localities, and truth demands that they shall be so recognized in classification and correlation. This complexity of contemporaneous history is, of course, an inconvenience to the text-book student, and to the ideal systematist, but it is best to shape our thoughts to suit the facts of nature, rather than force them to accommodate the convenience of our conceptions.

Niagara Epoch.

Fig. 45.



Section illustrating the relations of the Niagara limestone (*N.*) to the Hudson River (Cincinnati) shales (*H.R.*) below, and the Helderberg (*Hl.*) and Hamilton limestones (*Hm.*) above.

Synoptical Notes. This epoch in Wisconsin embraces more than the corresponding one at the east, as usually limited. It appears that limestone formation began here earlier, and perhaps contin-

[1] Ohio Geol. Surv., Vol. III, p. 7.

ued later, so that a part of what is the equivalent of the Clinton formation, as there developed, is here placed in the Niagara, and possibly a part of the Guelph limestone, as found in Wisconsin, was formed contemporaneously with some referred to the Salina of New York. The epoch was pre-eminently one of limestone formation. Dolomites of varying texture constitute the entire deposit. Its thickness on the southern border of the State is about 450 feet; at Sheboygan nearly 800 feet. Coral reefs are the most notable peculiarity. Some portions of the formation are very fossiliferous. Name derived from Niagara Falls, the cap rock of which is of this formation.

For details, see Vol. II, pp. 335–389 (Chamberlin), 661 (Strong); Vol. IV, pp. 267–317 (Fossils, Whitfield), 410 (Chamberlin). For area occupied by the formation, see atlas.

Following the epoch of local iron-deposition, the sea advanced upon the land extensively, and buried all the eastern, southern, and southwestern portions of the State. Precisely how far inland it reached cannot now be determined, for, during the long exposure that has since intervened, a somewhat wide margin has been cut away from the deposit. From the ragged edge now left for our study, only the general fact stated can be surely determined. The previous land, owing to its flatness, appears to have suffered little erosion, in the interval of its exposure between the Hudson River and Niagara epochs, and what slight inequalities were produced were cut away and leveled up by the advancing beach, so that the floor of the formation was essentially level.

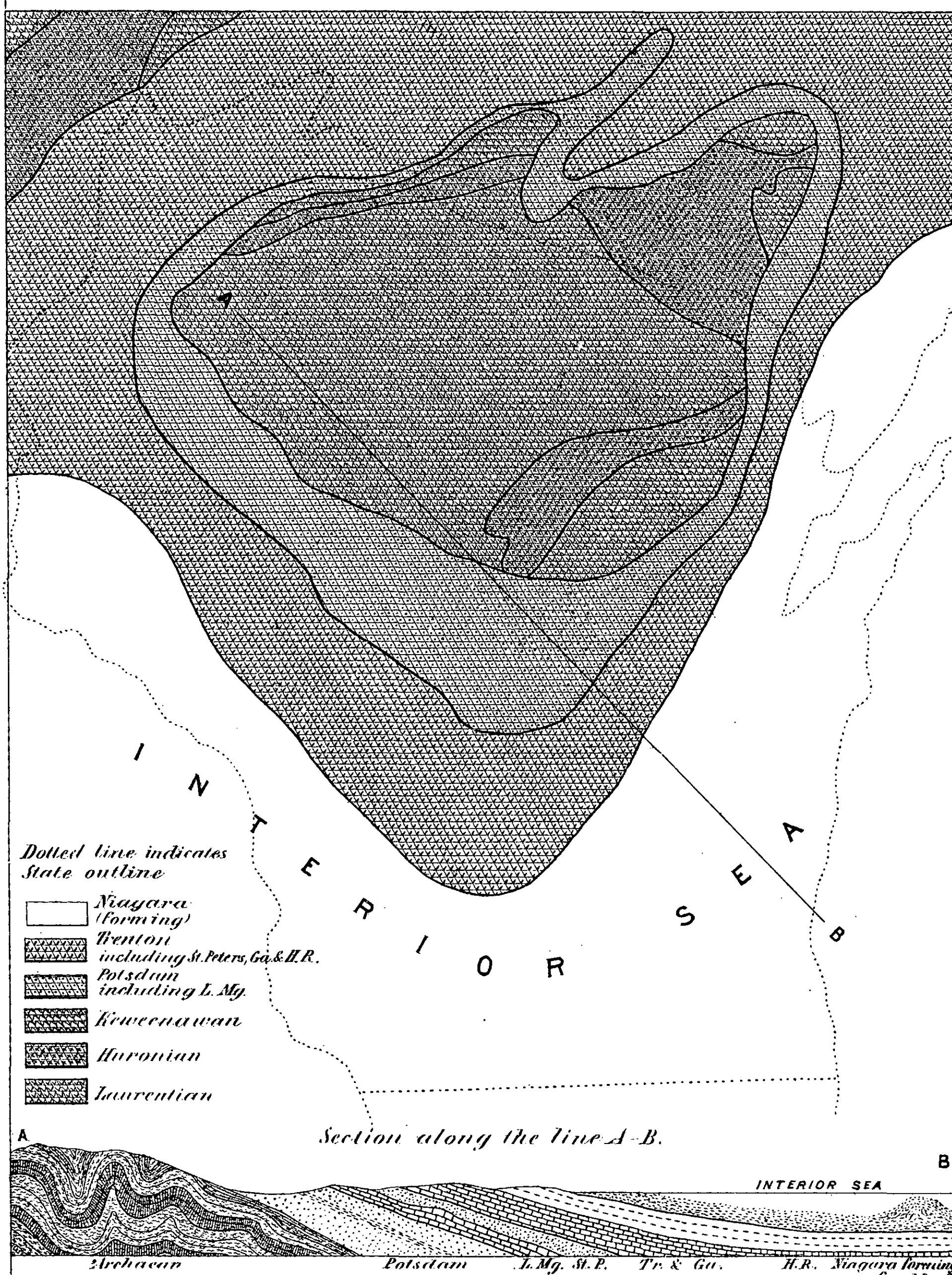
Subdivisions. The re-encroachment of the sea brought with it conditions unusually favorable to limestone formation. Its progress was characterized by changes in the phases of deposition and life, which may be regarded as sub-epochs, whose distinct designation is of some service in local study and description. They are not to be understood, however, as having any wide application. Indeed, one of the most instructive features of the formation is the fact that within the belt of 200 miles length, which the formation occupies along the shore of Lake Michigan, the strata undergo changes in the phases of deposition, so that the natural subdivisions at the south differ from those at the north, as indicated in part by the following classification of beds:

At the south —	At the north —
1. Guelph Beds.	1. Guelph Beds.
2. Racine Beds.	2. Racine Beds.
	3. Upper Coral Beds.
3. Waukesha Beds.	4. Lower Coral Beds.
	5. Byron Beds.
4. Mayville Beds.	6. Mayville Beds.

Such changes in formations as traced from one region to another

PLATE N° VII

HYPOTHETICAL MAP OF THE LAND IN THE NIAGARA PERIOD



are common geological phenomena, and are often much more conspicuous than here; but in this instance, the series embraces what are elsewhere held to be somewhat important division planes, viz.: those between the Clinton and Niagara, and between the Niagara and Guelph formations. But fossils, held to be characteristic of the Guelph epoch, are found as low as the Mayville beds, and those of the Clinton as high as the Upper Coral beds, showing that the classification which is appropriate at the east does not properly represent the epochs in our region, and hence the need of local terms, and subdivisions, distinctly understood to be such. There is a like need of caution and prudence in attempting to apply any detailed scheme of classification beyond the region for which it was constructed.

The Basal Deposits. Tracing the formation of these subdivisions historically, it is to be remarked that there first gathered a great stratum of calcareous material, which, on consolidation, became a coarse, rough, cherty, brecciated bed of buff magnesian limestone, reaching a maximum thickness of 100 feet and an average of perhaps 60 feet—the Mayville beds. This stratum occupies the area lying next east of the Green-Bay-Rock-River valley, and is represented in the protecting caps of the mounds of the Lead region.

There ensued a slight change of conditions under which the calcareous material was uniformly reduced to a fine powder, and spread with great evenness over the sea bottom, ultimately producing a beautiful, white, fine-textured magnesian limestone. Some diversity of conditions began to appear at this time, between the southern and the northern regions, resulting in the Waukesha beds in the former, and the Byron and Coral beds in the latter. This diversity is to be associated in thought with that noted in the Galena and Hudson River epochs, and was probably due to the same ultimate cause.

Coral Reefs. At the south there probably began to grow as early as this, the most ancient coral reefs yet identified, though their observed development only appears a little later. They probably had their seat upon the coarse underlying Mayville beds, whose texture shows that they were formed in relatively shallow water, to which present coral reef growths are limited. These grew upward through the succeeding strata, developing themselves most characteristically in the Racine beds. For 60 miles or more along the eastern border of the State, and probably extending southward into Illinois, there lay a chain of barrier reefs. They now appear as irregular domes and prominences of rock. Not only were they the habitat of Corals of a score or more of different species, but they were adorned by numerous Crinoids, and delicate Bryozoans, and enlivened by multitudes of unique Trilobites, while the lowly Mollusks crept over them, and the gigantic Cephalopods dominated the whole.

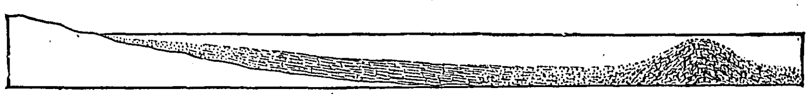
The individual reefs differed measurably from each other in the prevailing forms of life that dwelt upon them. One of them, now partially exposed near Saukville, presents a rock that is little more than a mass of coral remains imbedded in calcareous sand. One near Wauwatosa, the best exposed and most widely known, is notable for the abundance of its Trilobites, although other fossils are very abundant. At the quarries near Racine, where the reef character is less conspicuous, Crinoids grew in a profusion unsurpassed in these ancient seas, so far as knowledge extends. Other reefs present scarcely less striking peculiarities.

These reefs and the adjacent deposits illustrate more beautifully than anything else among the ancient formations, the method by which limestone deposits were formed. The reefs themselves are composed of the commingled relics of the life that grew upon them, in all stages of destruction. There may be seen coralline masses standing erect in the rock precisely as they grew, having entirely escaped destruction during their burial in the growing reef. In other instances, only remnants of masses are left, the greater portions having been broken down or worn away. There are detached fragments showing various degrees of wear, and also coarse and fine detritus, the ultimate product of the comminuting process. These, combined, make up the mass of the reef-rock. There is evidence that some of the material, after having been once solidified, was again broken up by the waves, and redeposited, forming a coarse, brecciated mass. The spaces between such masses are often filled with granular, sand-like material, in which fossils sometimes occur, as though the animals had sought the protection of these sheltered nooks, or as if their remains were driven by the waves into them. Evidences of worn hollows and recesses in the reefs may be found.

The striking likeness which these formations bear to modern coral reefs will be seen by comparison with the following vivid description of the latter by Prof. Dana:

"Generally the barren areas much exceed those flourishing with zoöphytes, and not unfrequently the clusters are scattered like tufts of vegetation in a sandy plain. The growing corals extend up the sloping edge of the reef, nearly to low tide level. For ten or twenty rods from the margin, the reef is usually very cavernous or pierced with holes or sinuous recesses, a hiding place for crabs and shrimps, or a retreat for the echini, asterias, sea-anemones and mollusks; and over this portion of the platform, the gigantic Tridacna, sometimes over two feet long and five hundred pounds in weight, is often found, lying more than half buried in the solid rock, with barely room to gap a little its ponderous shell, and expose to the waters a gorgeously colored mantle. Further in are occasional pools and basins, alive with all that lives in these strange coral seas. The reef rock, where broken, shows commonly its detritus origin. Parts are of compact, homogeneous texture, and solid white limestone, without a piece of coral distinguishable, and rarely an imbedded shell. But generally the rock is a breccia or conglomerate, made up of corals cemented into a compact mass, and the fragments of which it consists are sometimes many cubic feet in size." "Besides corals, the shells of the seas contribute to it, and it sometimes contains them as fossils, along with bones of fishes, exuvia of crabs, spines, and fragments of Echini, Orbitolites (disc-shaped foraminifers), and other remains of organic life inhabiting reef grounds."[1]

FIG. 46.



PROFILE illustrating the formation of the Niagara reefs and adjacent limestone. At the right, a mound-like coral reef is represented, on the slopes of which, coarse, broken, reef-material collected. On the adjacent sea-bottom, calcareous sand accumulated, illustrated by the dotted portion of the diagram. This grades into fine calcareous sediment, represented by the lined portions. Near the shore coarse material was again formed.

Formations Adjacent to the Coral Reefs. The depositions between and about the ancient Wisconsin reefs are similarly instructive. On the sides and at the bases, there accumulated a mixture of fragments and calcareous sands, growing finer and finer as the distance from the parent reef increased and the slope of the bottom became more gentle, until at length, having passed through the several granular stages, there was a graduation into white calcareous mud, which spread itself widely over the sea-bottom around the reefs, and between them and the adjacent land. This fine calcareous sediment gave rise to the white, compact limestones of the region.

On the sub-marine sand-plains (calcareous), about the reefs, life flourished, but with markedly less luxuriance than upon the reefs. Mollusks and Crinoids, however, appear to have been relatively more favored there than upon the reefs, and are abundant. Over the white mud flats there seems to have been a relative scarcity of life. The reef-frequenting forms are there rare. The great Orthoceratites were, however, quite abundant, as is well illustrated by their frequent remains in the white, compact limestone. From such observations as can now be made, it would appear that they frequented the vicinity of the reefs, for their remains seem to be most abundant in their neighborhood. This would be natural if they were, as supposed, predatory species, depending upon inferior animals, such as abounded on and about the reefs, for their sustenance.

[1] Corals and Coral Islands, pp. 174-5.

The ancient Niagara seas presented, therefore, the simultaneous accumulation of three classes of calcareous rock, viz.: the brecciated, the granular, and the compact, all derived essentially from the same source — the relics of the reef life.

Different Phase of Deposition North of the Reefs. These reefs have not been satisfactorily traced north of Washington and Ozaukee counties, and beyond that latitude they seem to have given place to another and scarcely less interesting phase of life-work. It is instructive to note, in passing, that it was in this same latitude that the lower formations, particularly the Galena, underwent a change that indicates similar oceanic conditions, viz.: a transition from a shallower exposed sea-bottom, to a deeper and more protected one, accompanied by a change from a more irregular, to a more homogeneous deposit.

As the reefs die away to the northward, there appears in their stead a more uniform and regularly stratified limestone, containing more aluminous and silicious material, probably the product of earthy-wash from the land. Over this area, the life, instead of being gathered together upon reefs, spread widely over the sea bottom and enriched the beds with its remains. More quiet conditions appear to have prevailed over this region, and the life relics were left unworn and unbroken to a greater degree than upon the more exposed reefs of the southern seas. Shells are to be found standing on their edges, in the hardened sediments, apparently undisturbed where death left them. Corals are to be seen in great abundance, resting on their bases as they grew. Nevertheless, nature's pervading law of universal change is here characteristically set forth. While mechanical forces left these fossils exceptionally intact, chemical agencies stepped in, in compensating activity, to effect their change. The skeletal products left by the living beings were composed essentially of lime-carbonate. In a large portion of the fossils, this was subsequently removed, particle by particle, and silica substituted in its stead, so that while their forms and structure are still beautifully preserved, often even in their most delicate details, the material has been entirely changed from lime-carbonate to silica. Silicified corals appear at certain horizons in numbers and perfection probably unrivaled elsewhere except in contiguous areas of Michigan.

Corals were the predominant form of life, greatly exceeding all others. Thirty species have been identified, and some of them were remarkably prolific in individuals. In this region, as well as in that farther south, there were beds of the large Brachiopod, *Pentamerus oblongus*, so thickly studded with remains as to suggest a likeness, in this regard, to the oyster beds of the present day, and were they not so different in real nature, they might almost be termed the oysters of the Silurian seas.

Toward the close of the epoch, the conditions in the northern and southern regions seem to have become more nearly alike.

A brief summary of the character of the subdivisions of the formation may be here serviceable. The fuller details will be found in Vol. II, p. 336 et seq.

THE SOUTHERN SERIES. *Mayville Beds.* Owing to the different conditions prevalent in the northern and southern regions, the succession of strata varies correspondingly. At the south the beds of this period consist of coarse, rough, thick-bedded, irregular, and, in part, brecciated and cherty, buff or gray, magnesian limestone, reposing on the Hudson River shales, and constituting the basal member of the group. This member likewise prevails in the northern region, where it has essentially the same characteristics. These have been designated the Mayville beds.

Waukesha Beds. At the south there repose on these the Waukesha beds, which vary in character, but over the greater area they consist of a fine-grained, compact, thin-bedded, white, magnesian limestone, as illustrated by the Waukesha and lower Pewaukee rocks. At some points they contain numerous nodules of white chert. These prevalent compact rocks sometimes give place to more granular forms, and these again to a brecciated variety similar to that found in the reefs. But this phenomenon develops less prominence (so far as the exposed portions of the formation show) than in the succeeding Racine beds.

Racine Beds. The rocks of this group are the immediate successors of the Waukesha beds, to which they are closely related. The rock, while universally a magnesian limestone, is highly various in character, including different grades of compact, granular, and brecciated rock. These graduate into each other horizontally as already explained. They include the greater part of the mound-like reefs already described.

THE NORTHERN SERIES. In the northern region, as best exhibited in the Green Bay peninsula, there occur the following subdivisions of the Niagara group:

At the base, there lie the *Mayville beds*, essentially as at the south.

Byron Beds. Overlying them is a compact, fine-grained, thin-bedded, white magnesian limestone which reaches a maximum observed thickness of 110 feet. At points the color changes to light gray and cream tints, and at some points is lined and mottled with pink in a very handsome manner. Some portions of this, as that near Brillion, is capable of taking a fair polish, and of subserving the purpose of a handsome ornamental marble. This stratum is nearly devoid of fossils except in the town of Byron, where *Leperditia fonticola* occurs in considerable abundance.

Lower Coral Beds. The Byron Beds pass up by a series of alternating coarse and fine-grained layers into a rough, heavy-bedded dolomite, of crystalline-granular, and rather soft texture, constituting the Lower Coral beds. They are characterized by an abundance of Favositoid corals, and by varieties of the Brachiopod, *Pentamerus oblongus.*

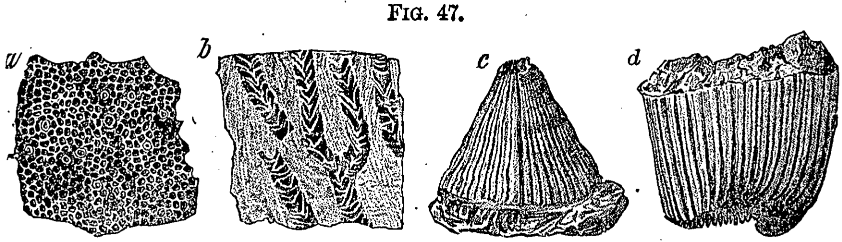
Upper Coral Beds. The Lower Coral beds pass above into thin-bedded, gray or buff dolomites, of rather hard, fine-grained, earthy texture, characterized by thin, irregular beds, containing much silicious material in the form of flint and silicified corals. These beds are exceedingly prolific in corals, with which are associated but few other species.

Racine Beds. Overlying these are layers regarded as the equivalents of the Racine beds at the south. They are here less irregular and varying in texture, being rather coarse, gray or blue dolomite, disposed in beds of medium thickness, which are only moderately fossiliferous, *Pentamerus ventricosus* predominating, associated with corals and Trilobites.

Guelph Beds. Overlying the foregoing at some points in the vicinity of Lake Michigan, is found a magnesian limestone not essentially different from the foregoing in lithological character — being a rough, thick-bedded, irregular, buff, gray or blue dolomite, — which was first demonstrated by the present survey to be the equivalent of the Guelph beds of Canada.[1] The distinction is a palæontological rather than a physical one. In the latter respect there is less difference between the Guelph and Racine beds than between either of the other members of the Niagara group. There was evidently no marked change in the physical history of the region, but essentially the same conditions prevailed from the beginning of the deposit of the Racine limestone to the close of the formation of the Guelph beds. During the time, however, life underwent a change, by the introduction of the species which characterize the Guelph horizon. This introduction was gradual, so that many localities show a mingling of the two faunas. There is also reason to believe that the introduction was local and colonial in character, the Guelph life taking possession of chosen localities, while the Racine fauna prevailed at others. Because of these intimate relations, the Guelph beds are regarded as but a subdivision of the Niagara group, and are classed with the other members, although the change in the life was somewhat more marked than that which accompanied the transition between the lower subdivisions.

Thickness. Measuring the series as a whole, it is found to reach a maximum thickness of nearly 800 feet. This greatest depth occurs at about the center of the belt, in the vicinity of Sheboygan, but north of the point where the water of the period began to deepen, and the ampler northern series to appear. The total thickness of the southern series is less.

FIG. 47.



NIAGARA CORALS. *a.* Astrocerium venustum—Hall. *b.* Cystostylus infundibulus—Whitf. *c.* Zaphrentis Racinensis—Whitf. *d.* Cyathoxonia Wisconsensis—Whitf.

Life. The general character of the life, and the interesting circumstances under which it grew, no less than the instructive results which it produced, have already been noted. It remains to call attention to some of its special forms.

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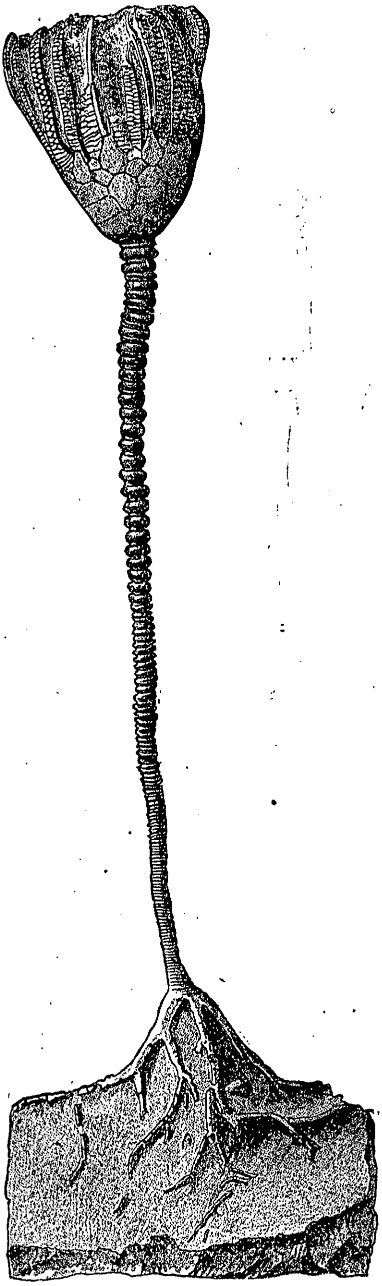
[1] Vol. II, pp. 336, 377 et seq.

Plants. While seaweeds may have existed abundantly, only obscure undeterminable forms referred to *Buthotrephis*, have been found.

FIG. 48.



NIAGARA CRINOID. *Eucalyptocrinus crassus*—Hall.

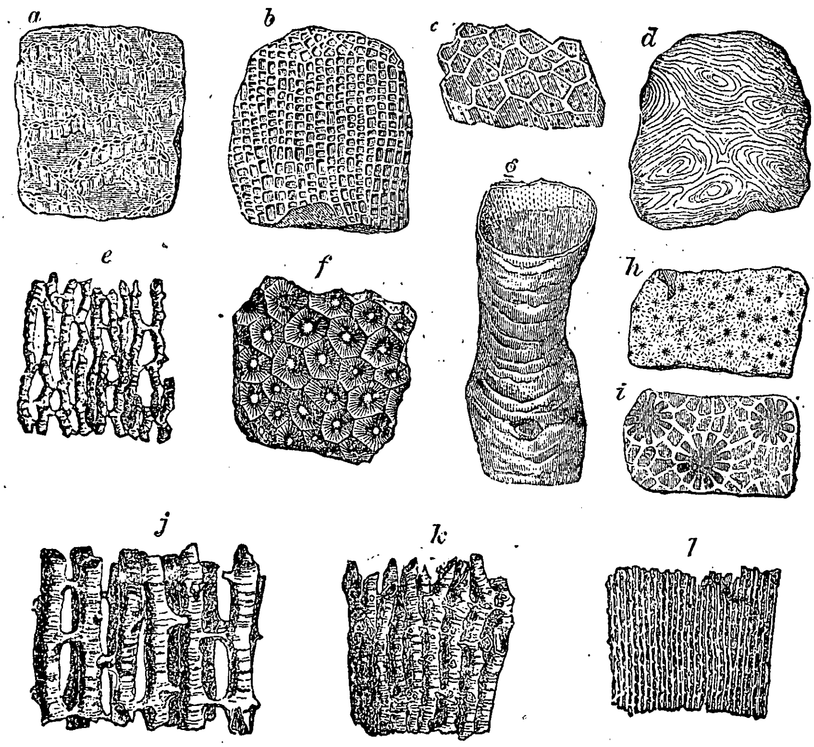
Protozoans. Of the Foraminifers, two small species of *Receptaculites* occur in the Racine beds, showing a continuation of the genus onward from the Galena limestone, but the species are greatly reduced in size. *Stromatopora concentrica* is abundant, and ranges entirely through the formation. Its classification is doubtful, being referred by some to calcareous sponges, and by others to foraminifers.

Corals. Corals were represented by upwards of forty determined species, beside fragmentary indications of others. Among them, the Favositoid corals greatly predominated, though the group embraced a wide range, both of species and genera. The leading genera were *Favosites* (a "Honey-comb coral"), *Astrocerium* ("Star coral"), *Heliolites* ("Sun coral"), *Halysites* ("Chain coral"), *Syringopora* ("Organ-pipe coral"), *Zaphrentis* (a "Cup coral"), *Amplexus*, *Diphiphyllum*, *Chonophyllum* and *Cystiphyllum.*

Crinoids. Among the Crinoidea, both the Cystids and Crinoids proper were well represented, the former by twelve determined species, the latter by more than twice that number. The abundance of these in chosen localities, particularly at Racine, is exceptionally great. Half of the Cystidean species belong to the genus *Holocystites.* Of Crinoids proper, the genera *Eucalyptocrinus*, *Cyathocrinus* and *Caryocrinus* were most common, the beautiful *Caryocrinus ornatus* being the leading species.

Bryozoans. The Bryozoans were well represented by several delicate forms, but were greatly inferior, in numbers and variety, to those of the Hudson River period.

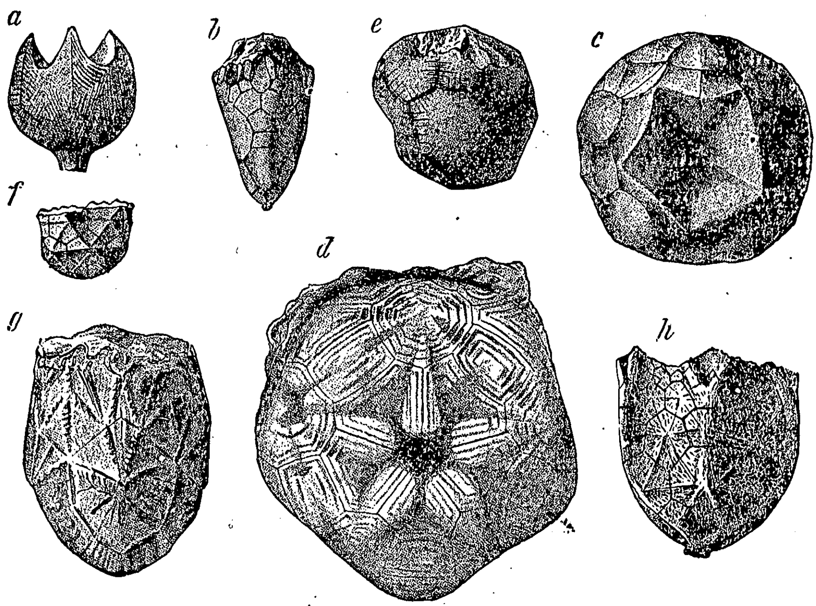
FIG. 49.



NIAGARA CORALS. *a.* Halysites catenulata — Linn. *b.* and *c.* Favosites Niagarensis. *d.* Stromatopora concentrica — Goldf. *e.* Syringopora retiformis — Bill. *f.* Strombodes gracilis — Bill. *g.* Chonophyllum Niagarense — Hall. *h.* Heliolites spinopora — Hall. *i.* Enlarged surface of H. spinopora. *j.* Syringopora verticillata — Goldf. *k.* S. Dalmani — Bill. *l.* S. compacta — Bill.

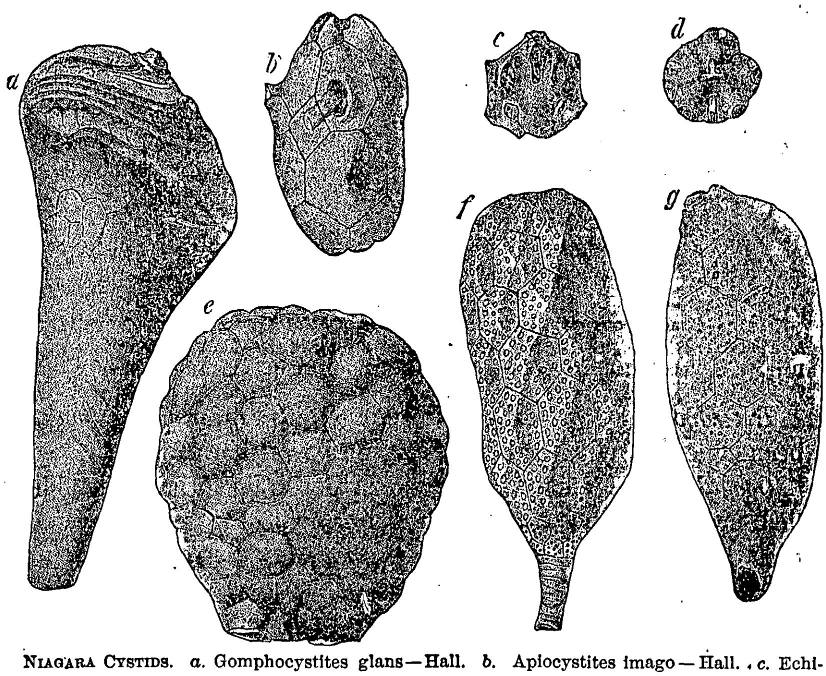
Brachiopods. Among the Brachiopods, of which upwards of forty species have been collected within the State, the genera *Orthis*, *Strophomena*, and *Rhynchonella* still prevailed, but less abundantly than in the Trenton period. *Spirifers* were introduced, five species being present. The genus *Atrypa* was represented by the prolific and widely varying species *A. reticularis*, and by *A. nodostriata.* The genus *Pentamerus* surpassed all other Brachiopods in number and size. The large *Pentamerus oblongus* occurred in great numbers and variety in the middle of the series, being rare toward the base, and apparently absent from the uppermost beds. The smaller, but handsomer, *P. ventricosus*, is very abundant in certain localities in the horizon of the Racine beds.

Fig. 50.



Niagara Crinoids. *a*. Stephanocrinus gemmiformis — Hall. *b*. Eucalyptocrinus obconicus — Hall. *c*. E. cornutus — Hall. *d*. E. ornatus — Hall. *e*. Cyathocrinus Cora — Hall. *f*. C. Waukoma — Hall. *g*. Caryocrinus ornatus — Say. *h*. Glyptaster occidentalis — Hall.

Fig. 51.

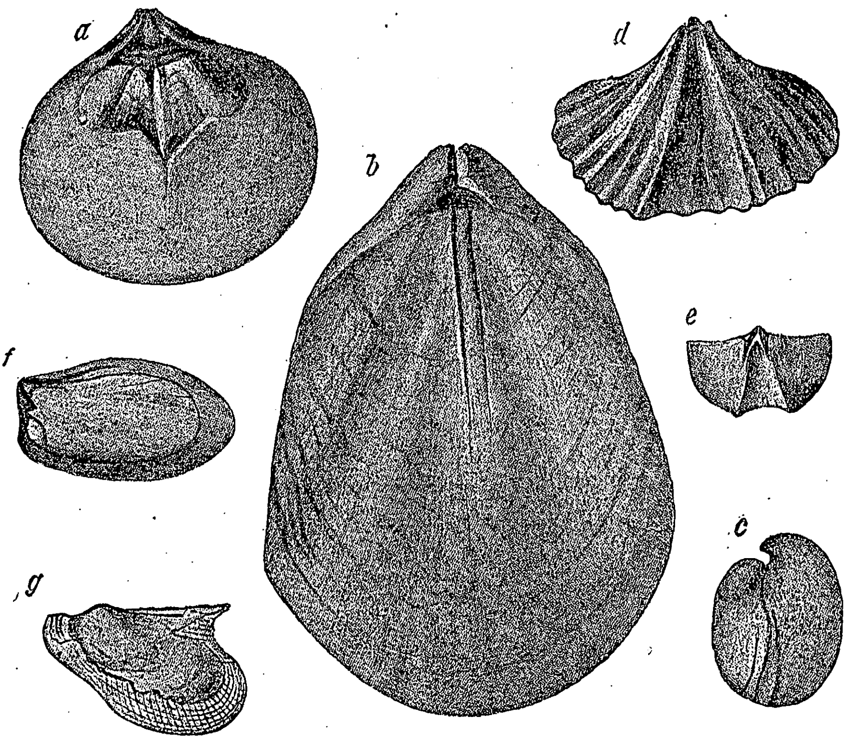


Niagara Cystids. *a*. Gomphocystites glans — Hall. *b*. Apiocystites imago — Hall. *c*. Echinocystites nodosus — Hall. *d*. Summit view of same. *e*. Holocystites ovatus — Hall. *f*. H. Cylindricus — Hall. *g*. H. abnormis — Hall.

Lamellibranchs. Lamellibranchs were not abundant, and mainly belonged to the genera *Leptodomus* and *Modiolopsis.* The large and beautiful *Megalomus Canadensis* characterizes the Guelph beds.

Gasteropods. Gasteropods were represented by forty species, among which those of the genera *Pleurotomaria*, and *Murchisonia*, predominated. Of these *Pleurotomaria Laphami*, *P. Hoyi* and *P. Halei* commemorate the services of worthy Wisconsin laborers in science.

FIG. 52.



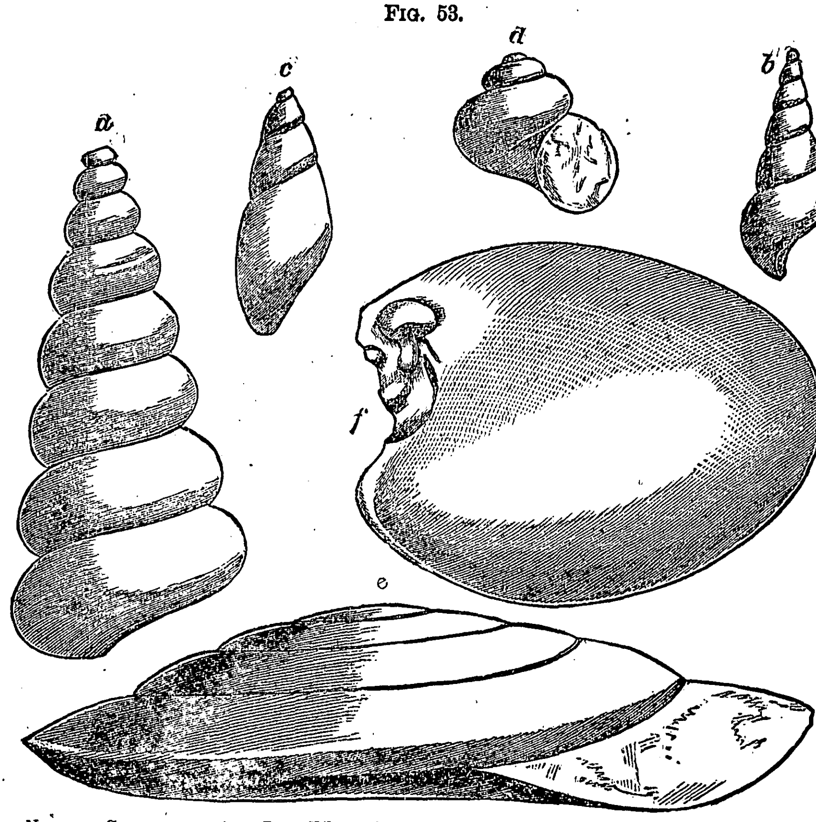
NIAGARA BRACHIOPODS AND LAMELLIBRANCHS. *a.* Obolus Conradi; cast of ventral valve. *b.* Pentamerus oblongus — Murch. *c.* Pentamerus ventricosus — Hall. *d.* Spirifera nobilis — Barr. *e.* S. Meta — Hall. *f.* Modiolopsis recta — Hall. *g.* Pterinea brisa — McChes.

Heteropods. Only a single Heteropod, *Bucania trigonostoma*, has been collected, while Pteropods have not yet been found.

Cephalopods. Thirty-five species of Cephalopods have been identified, more than one third of which belong to the genus *Orthoceras. Cyrtoceras*, *Phragmoceras* and *Gyroceras* were also abundantly represented.

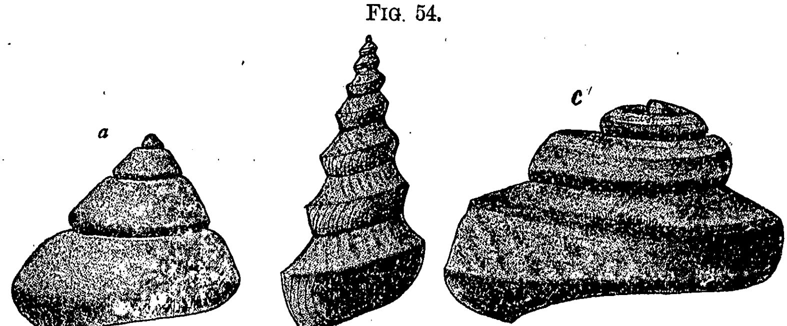
Crustaceans. Leperditia fonticola represented the Entomostracans. Among Trilobites, the handsome *Calymene Niagarensis* had a wide distribution, but the genus *Illænus* surpassed in size, number of species, and abundance all other forms. The *Illænus imperator* was one of the largest Trilobites that ever frequented our shores. The *Illænus Ioxus* and *I. insignis* were abundant and characteristic

FIG. 53.



NIAGARA GASTEROPODS (*one Lamellibranch*). *a*. Murchisonia macrospira — Hall. *b*. M. Boydi — Hall. *c*. Subulites ventricosus — Hall. *d*. Holopea Guelphensis — Bill. *e*. Pleurotomaria perlata — Hall. *f*. Megalomus Canadensis — Hall. (Logan Figs.)

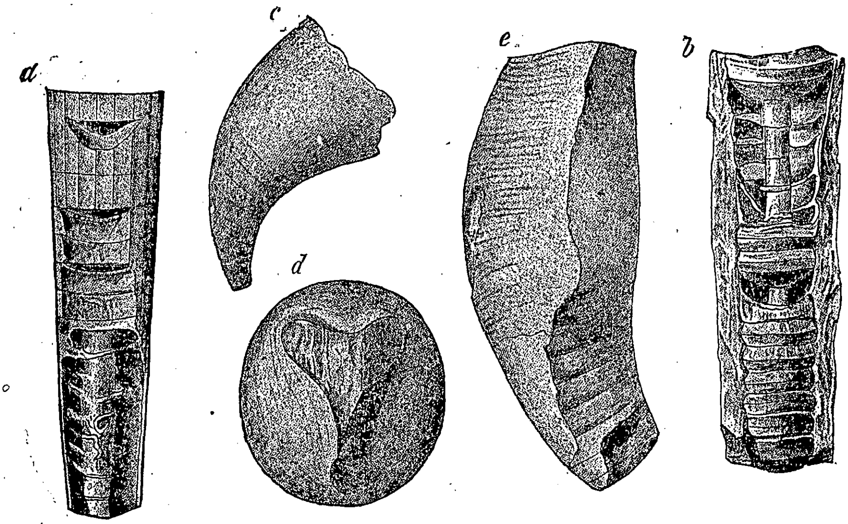
FIG. 54.



NIAGARA GASTEROPODS. *a*. Murchisonia Conradi — Hall. *b*. Pleurotomaria Laphami — Whitf. *c*. P. Hoyi — Hall.

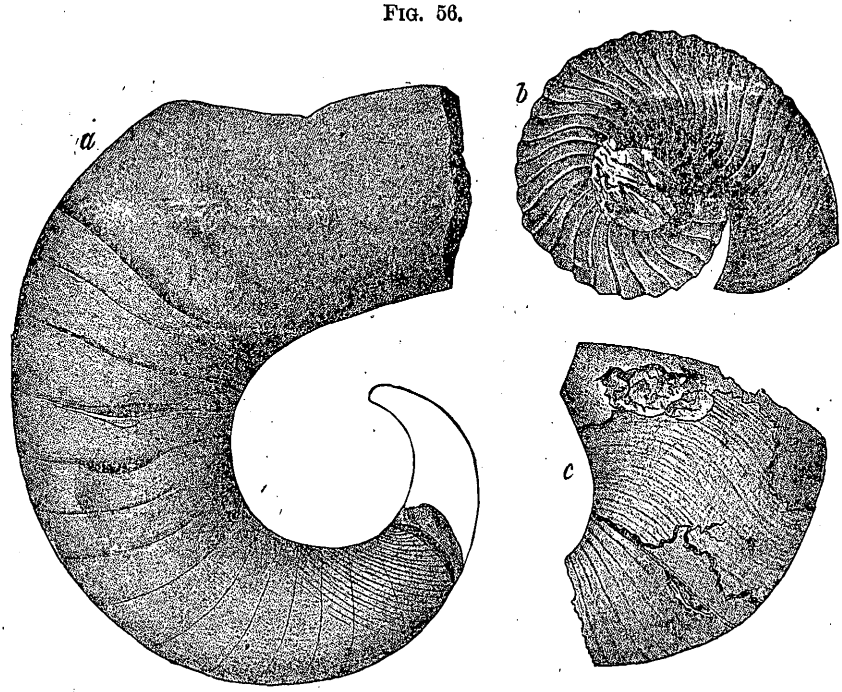
of the upper horizons, to which the whole group was mainly confined. *Ceraurus Niagarensis* was a notable form, while *Sphærexo-*

FIG. 55.



NIAGARA CEPHALOPODS. *a*. Orthoceras crebescens — Hall; a fragment showing depth of septa and position of siphuncle. *b*. O. annulatum — Sowr, *c*. Cyrtoceras brevicorne — Hall. *d*. Gomphoceras scrinium — Hall. *e*. Oncoceras Orcas — Hall x ⅜

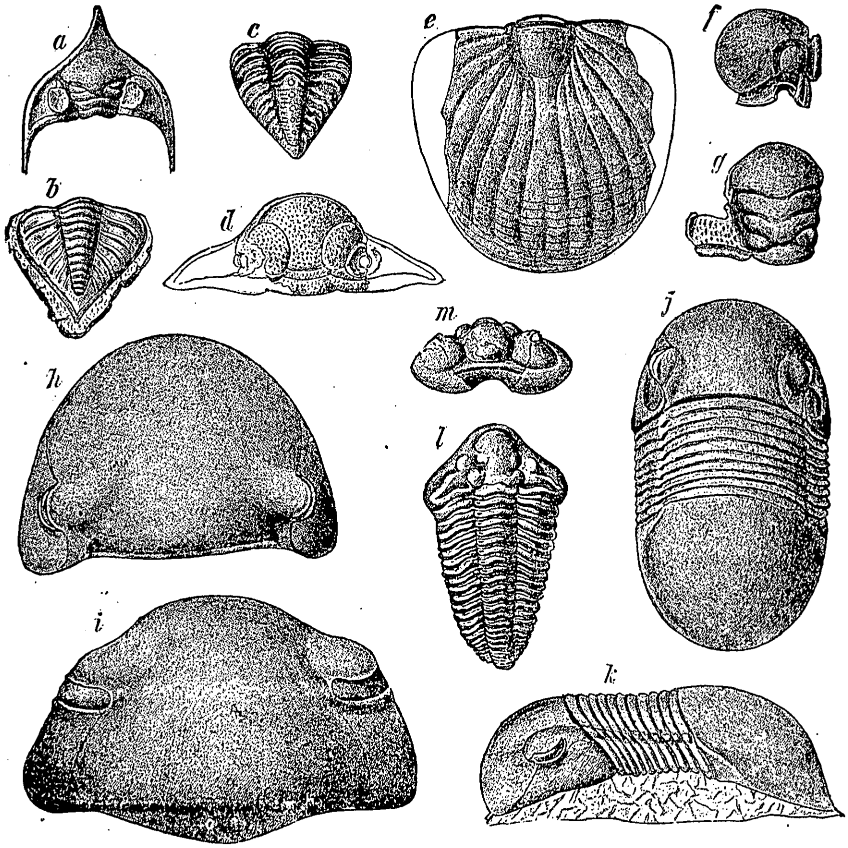
FIG. 56.



NIAGARA CEPHALOPODS. *a*. Gyroceras Hercules — W. and M. *b*. Trochoceras costatum — Hall. *c*. Phragmoceras Hoyi — Whitf.

chus Romingeri is one of the strangest of this strange group of fossils. All species, however, yield to the magnificent *Bronteus Laphami.*

FIG. 57.



NIAGARA TRILOBITES. *a.* Head of Dalmania vigilans—Hall. *b.* Pygidium of D. vigilans. *c.* Pygidium and part of thorax of Encrinurus ornatus—H. and W. *d.* Glabella and cheeks of Lichas breviceps. *e.* Pygidium of Bronteus Laphami—Whitf. (from a small specimen). *f.* Sphærexochus Romingeri—Hall. *g.* Glabella and part of one fixed cheek of Ceraurus Niagarensis—Hall. *h.* Head of Illænus insignis—Hall. *i.* Head of I. Ioxus—Hall. *j.* and *k.* I. Madisonianus—Whitf. *l.* Calymene Niagarensis—Conrad. *m.* Front and lower side of C. Niagarensis.

Comparison with Previous Faunas. Comparing the fauna of the Niagara with that of the preceding periods, it will be observed that no new type was introduced, and that the modifications in the facies of life consisted of changes in genera and species, and the relative development or repression of particular classes. Perhaps the most noteworthy feature is the great superiority of the radiate life in this period, as represented by the Corals and Crinoids, both of which groups vastly surpassed any previous development. The Cephalopods still held the lordship of the sea, and exceeded in numbers —

but apparently not in size — their predecessors of the Trenton seas. The Brachiopods held on their even, conservative course. The Lamellibranchs were inferior in numbers, but exceeded in size those of the Trenton epoch. The Gasteropods maintained their abundance and increased their size, but became relatively less conspicuous because outstripped by other and more striking forms. Bryozoans seemingly declined, and the Graptolites apparently, but probably not really, disappeared.

Colonial Tendencies. A characteristic of the life distribution of the period was the localization of special forms already alluded to. This found its most striking expression among the reef-builders, as already indicated. But in addition to this signal fact there seems to have been a prevailing tendency toward gathering into colonies, so that special localities are notable for peculiar richness in given types — as Racine, for *Crinoids;* Wauwatosa, for *Trilobites;* Waukesha, for *Orthoceratites;* Pewaukee, for *Pentamerus oblongus;* Burlington, for *Illænus imperator;* Kewaunee, for *Pentamerus ventricosus;* Saukville, for Corals, and Greenville for *Atrypa reticularis.* On the other hand, the Upper Coral beds of the Green Bay peninsula are remarkable for their uniformly rich abundance of Favositoid corals.

State Distribution. The Niagara limestone, as at present exposed, occupies nearly all the belt lying between the Green-Bay-Rock-River valley and Lake Michigan. Its outcropping lower ledges form the mural cliffs that skirt the valley on the east. From these the strata dip eastward beneath the lake, higher horizons appearing in succession as the lake is approached. Niagara limestone also caps the mounds in the southwestern portion of the State. These are but remnant portions of the original formation that undoubtedly once covered all the southern part of the State, the rest having been removed by the erosion of the ages.

American Distribution. The Niagara limestone has a less wide surface distribution in the interior than the Trenton and Hudson River formations. The interior sea was filling and contracting, and the extent of the formations was correspondingly reduced. Tracing eastward, like the preceding formations, it sweeps around the north edge of the basins of Lakes Michigan and Huron, and forms their western, northern, and northeastern shores. Leaving Lake Huron at the peninsula between it and Georgian Bay, it passes southeasterly to Niagara Falls, its denominative locality, and thence eastward beyond the center of New York, thinning out toward the Hudson. Along the Appalachian range, it occurs in Pennsylvania, Virginia, and Tennessee.

From Eastern Wisconsin, it swings across northern Illinois and extends northwesterly through Iowa into Minnesota, and perhaps has a considerable surface development in the British Possessions.

LOWER HELDERBERG EPOCH.

NOTE.—The place of this epoch in the Silurian system has already been given. Two small areas in Eastern Wisconsin are our only representatives of the formation, and these cannot be positively asserted to be of this age. The formation has an essentially eastern development, and derives its name from the Helderberg mountains, New York.

For fuller details, see Vol. II, pp. 390–394 (Chamberlin); Vol. IV, pp. 320–323 (Fossils, Whitfield).

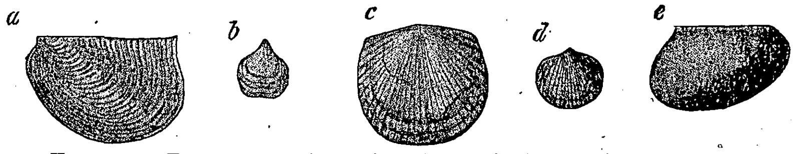
At two points in Eastern Wisconsin (Mud Creek, Milwaukee county, and Waubakee, Ozaukee county), there are small areas of rock referred, somewhat doubtfully, to the Lower Helderberg period. At the former locality, the rock is a hard, brittle, light-gray, magnesian limestone, distinguished by numerous minute, angular cavities, that give it a very peculiar porous structure. It is thin-bedded and laminated, by virtue of which it splits readily into flags and thin plates. Some layers exhibit an alternation of gray and dark-colored laminæ peculiarly characteristic of this formation.

At the other locality, a somewhat similar light-gray, thin-bedded, shaly, but less porous, dolomite occurs. In this area there are also found very thin beds of a softer dark dolomite, colored by carbonaceous matter, sometimes disposed in frequent black, or dark-brown laminæ, which give to the rock an appearance quite peculiar.

At the first locality, the rock is closely associated with the Niagara limestone, in a depression of which it appears to lie. It is overlain by rock of the Middle Devonian age (Hamilton). At the Waubakee locality, the formation is similarly related to the Niagara group, but is not known to be covered by any later formation, save the drift.

Fossils. Unfortunately these deposits have failed to leave us an unequivocal record of their age, since their stratigraphical and lithological characters are capable of more than one interpretation, and the fossils, to which we naturally turn for testimony, are either obscure or somewhat indecisive in character. At Mud Creek, a fair specimen of *Meristella nucleolata*, an *Orthis*, resembling a young *O. oblata*, and an imperfect specimen of a *Meristella* or *Pentamerus* were the only reward of repeated and diligent search. At Waubakee, the remains of *Leperditia* are very abundant, literally covering the surface of some layers, and are, to a greater or less extent, disseminated through the mass of some of the beds; but, unfortunately, the state of preservation is poor. A careful examination and comparison of a large number of specimens leaves little doubt that the fossil is *Leperditia alta.* In the carbonaceous matter of the soft dark layers, there are many indications of plant remains, among them forms resembling *Sphenothallus*. In addition to these, two species of *Orthis* have been found, one resembling *Orthis oblata*, and the other closely similar to *O. subcarinata*, but smaller. *Pterinea aviculoidea*, or a very closely allied species, an imperfect *Orthoceras*, and a doubtful *Inocaulis* are also present. The facies of this fauna is strikingly similar to that of the Lower Helderberg, and to that period the formation is referred.

FIG. 58.



LOWER HELDERBERG FOSSILS. *a*. Pterinea aviculoidea—Hall. *b*. Meristella nucleolata—Vanux. *c*. Orthis subcarinata—Hall. *d*. O. oblata—Hall. *e*. Leperditia alta—Conrad.

The Salina Epoch. If this reference be correct, it would appear that, at the close of the deposit of the Guelph limestone, the sea withdrew for an interval, during which the salt-bearing Onondaga beds of eastern localities were deposited in shallow basins, alternately connected with, and cut off from, the sea, thus acting as great evaporating pans, first filled and then dried, producing the peculiar saline formations. At the close of this salt-forming epoch, the sea advanced so as to encroach slightly upon the eastern border of Wisconsin, producing, in depressions of the Niagara surface, the local deposits above described, which were, when formed, doubtless more extensive than they now appear, having been worn away by subsequent denudation.

The thinning of the Lower Helderberg formation westward has been a common remark of geologists, in harmony with which we find its vanishing edge in Eastern Wisconsin.

After forming this little deposit, the waters again withdrew, leaving the State entirely land for another considerable interval.

A Different Interpretation. While this seems to be the best supported view, it may not be impossible that, as the Niagara sea was retiring, lingering deposits took place in depressions partially connected with the sea, in which the lagging fauna took an aspect similar to that of the Lower Helderberg.

American Distribution. The Lower Helderberg formation has an easterly distribution, signifying an easterly deepening of the sea. Wisconsin, if our identification be correct, lay on the western margin. In the adjoining states eastward, as in our own, it is barely recognizable. It is well developed in Ohio (the Waterlime), and in eastern New York, and southward along the Appalachian range through New Jersey, Pennsylvania, Maryland and Virginia, to Tennessee. It also occurs in New England and the Provinces, but its definite boundaries are not yet determined, or are the subject of difference of opinion.

Close of the Silurian Age. This closed the Silurian age, an era remarkable for its quiet, conservative progress. Its sedimentation was in the main slow, the product of quiet, almost silent, agencies. Slight oscillations of surface pervaded the age, but profound disturbances and volcanic disquietude were foreign to our shores.

Life Progress. So also in the life progress there were no great revolutions. No great types either entered or disappeared, so far as the *record* shows. It is not impossible, perhaps not improbable, that vertebrates may have existed in the seas, and that acrogenous trees overspread the land, since there are evidences of this elsewhere, and there are thought by many to be sufficient grounds for the belief, independent of the testimony of direct evidence. But even the presence of vertebrates, if real, was rather supplementary than revolutionary in its effects upon the faunal aspects of the age, for the dominant forms and the general facies remained the same. No evidence has been discovered that the vertebrates had yet made themselves felt by any important suppression or modification of preexistent forms.

Considered, therefore, in its general phases, whether physical or vital, quietude was the leading characteristic of the age.

Considered in detail, and from a local standpoint, there were changes, apparently somewhat abrupt, in the phases of sedimentation, and there were local interruptions of the series. So also among vital phenomena, there were seemingly sudden entrances and exits of genera and species, commonly well defined, often sharply so, but sometimes joined by gradational forms. While the general types remained essentially constant, there were transitions of species. All but a few were replaced during the age. This replacement does not *appear* to have been generally accomplished by gradational stages, but rather by abrupt passages. Whether this seemingly sudden introduction of new species and genera is real, or only apparent, is one of the debated questions of the day, and must await the more exhaustive studies of the future for its satisfactory settlement.[1]

[1] The "American school of evolutionists" maintain that new forms of life were developed (by whatever means they were developed) rapidly at certain stages, and under certain circumstances, so as to appear in the geological series as abrupt introductions, thus differing from the evolutionary view maintained more largely abroad, that species are developed by slow changes through a long series of gradational forms.

Foreign Equivalents of the Upper Silurian. The English Upper Silurian group embraces the Llandovery, the Wenlock, and the Ludlow groups of Wales. These occur also in northern England, Scotland, Ireland, and their equivalents are found in southern Scandinavia, in Finland, and in Russia, between the Baltic and the Urals, stretching onward into Asia, in Bohemia (Etages E-H 3d fauna of Barrande), in Germany in detached areas (Thuringia, Wald, Hartz Mts.), in France (?) and in Sardinia.

Interval Between Lower Helderberg and Hamilton Periods.

During the earlier ages there were breaks in the geological series occasioned by the temporary withdrawal of the depositing ocean, but the precise work accomplished in these intervals is yet unknown, and may ever remain so, because of the inaccessibility of the deposits then formed. In the less ancient eras, similar, but less prolonged, interruptions occurred, but the work accomplished during them is generally recorded by deposits elsewhere accessible.

As previously remarked, after the little Helderberg deposits on the eastern border of the State were formed, the waters retired for an interval measured by several successive deposits elsewhere. The remainder of the Lower Helderberg formation, the Oriskany sandstone, the Cauda-galli grit, the Schoharie sandstone and the Corniferous limestone form the record of the interval as found in the eastern portion of the interior basin. It is worthy of note that these are, in the main, shallow water formations, indicating that the sea, which retired entirely from our borders, became shallow there.

If we glance backward at the deposits of preceding intervals, similar instructive facts will be observed. Immediately before the Helderberg deposits, the Saliferous strata were formed, when the ocean was so far shallowed that it alternately occupied and retired from its flat borders. At a similar stage at the beginning of the Upper Silurian, the Medina sandstone records the work of a shallow sea.

In all these it appears, therefore, that where the sea retired from the Wisconsin area, it became shoal, throughout at least the eastern portion of the interior basin, and hence the oscillations that instituted these changes affected a wide contiguous area.

CHAPTER X.

DEVONIAN AGE, OR AGE OF FISHES.

The Devonian formations of the interior, in a generalized view, embrace (1) a basal sandstone series, (2) a central limestone group, and (3) an overlying shale and sandstone series. The upper limit of the system has been the subject of much discussion and difference of opinion, which means, undoubtedly, that there is no sharp and clear line of division between the Devonian and Carboniferous formations. As none of the formations in controversy occur in Wisconsin, it is unimportant to our purpose to determine the merits of the several views. The following scheme lies between the extremes of opinion:

Devonian Age ..	Closing Detrital Epochs ..	Chemung. Portage. Genessee. Hamilton.	Sandstones and Shales.
	Central Limestone Epochs.	Hamilton. (Western.) Corniferous.	Limestones.
	Opening Detrital Epochs..	Schoharie. Cauda-galli.	Grits

Of this great group, only a thin stratum from the central portion, the Hamilton, occurs in Wisconsin. The formations of the opening and closing detrital epochs are wanting, because it was only in its most advanced stage, in the middle of the period, that the sea reached our territory. We have therefore only to deal with the limestone-forming epoch.

HAMILTON EPOCH.

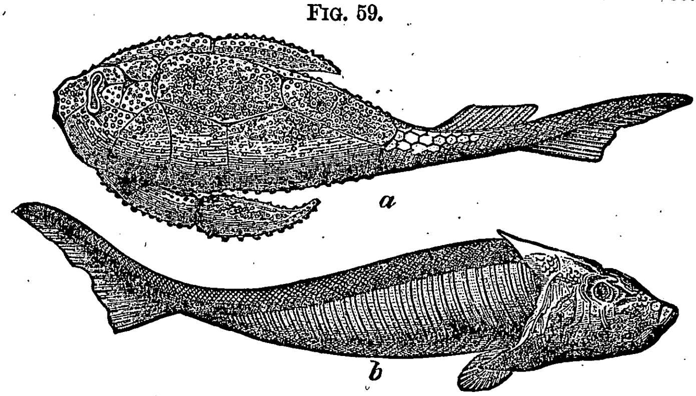
Synoptical Notes. Formation an impure limestone, of which a portion possesses valuable hydraulic properties. Contains numerous fossils, among which are land plants and fishes. Occupies only a limited area north of Milwaukee. Name derived from Hamilton, N. Y., where the formation is well developed.

For details, see Vol. II, pp. 395–405 (Chamberlin); Vol. IV, pp. 324–349 (Fossils, Whitfield).

Conditions and Character of Deposition. As the ages rolled slowly on, the sea that had retired in the later Silurian crept back upon the abandoned land, advancing until it encroached slightly upon the eastern margin of the State, where it deposited a magnesian limestone, mingled with silicious and aluminous material, forming a combination, a portion of which has recently become widely known for its excellent hydraulic properties — *the Milwaukee Cement rock.* Precisely how far the deposit originally extended is not known, as it has been reduced by eroding agencies. That portion which remains, occupies a limited area on the lake shore immediately north of Milwaukee, extending inland half a dozen miles. The cement rock proper is found on the Milwaukee river just above the city. It is a rather soft, usually thick-bedded, bluish-gray or ash-colored impure dolomite, weathering on exposure to a yellowish-buff color. Its chemical composition, which possesses unusual interest, is indicated by the following average of eight analyses:

Carbonate of lime	45.11
Carbonate of magnesia	30.89
Silica	16.61
Alumina	4.09
Oxide of iron, etc	3.25
	99.95

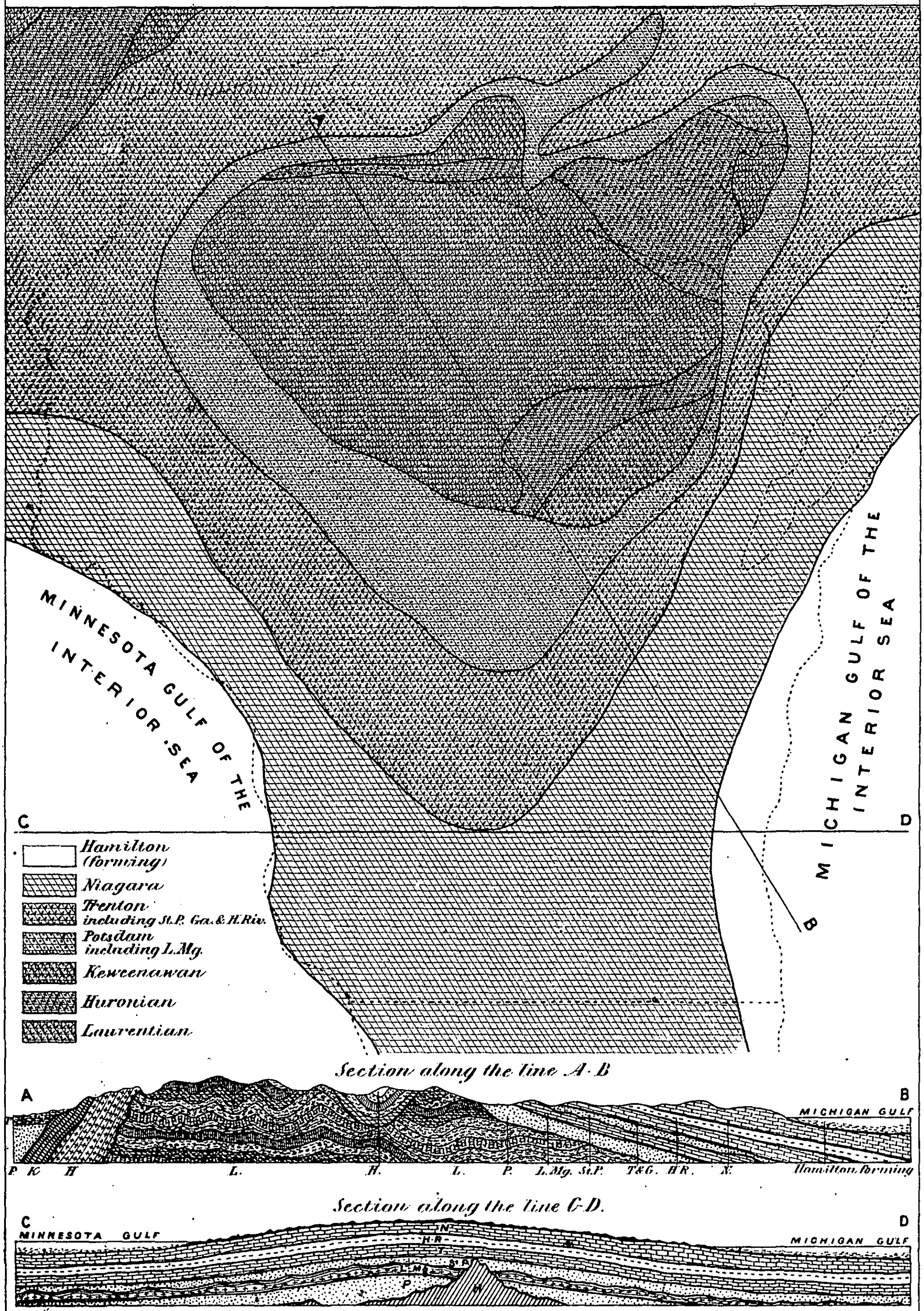
FIG. 59.



DEVONIAN FISHES. *a.* Pterícthys. *b.* Cephalaspis.

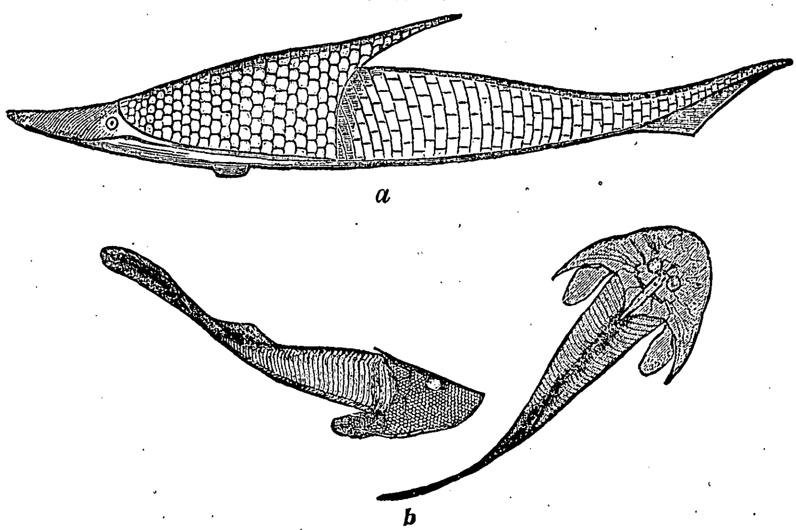
Life. *Vertebrates.* With this deposition there dawned a new era in the life-history of Wisconsin. While multitudes of the lower orders of life swarmed in the previous seas, no trace of a vertebrate has yet been found. The Hamilton period witnessed the introduction, into the Wisconsin series, of the highest type of animal life, though only in the form of its lowest class, fishes. But it would be an error to assume that the first introduction of vertebrates into our series marked their first appearance in geological history, for the seas no

HYPOTHETICAL MAP OF THE LAND IN THE HAMILTON PERIOD



farther away than Ohio were swarming with monster fishes, while yet the returning waters had not reached our shores, and in the still more distant European seas they flourished, apparently, about the time of the last previous retirement of the waters — the close of the Upper Silurian age. It might, perhaps, be an equal error to suppose that those earlier remains mark the first appearance of vertebrate life because no more ancient forms have been found, so that the absolute time of introduction of the vertebrate type, like that of the lower forms already discussed, is at present undetermined. It can only be affirmed that their remains on this continent have been first found in the earlier Devonian, and on the European, in the closing Silurian age. But still, while theoretical considerations are urged from certain quarters in favor of a much earlier introduction, it is difficult to understand how fish could have abounded in seas so favorable for their fossilization as those that girt our shores, without their remains being preserved, unless they consisted only of soft parts, and were entirely without the bony scales and defensive armor and the teeth with which they were so amply provided in the Devonian age.

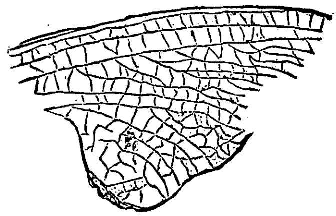
FIG. 60.



DEVONIAN FISHES. *a.* Pteraspis. *b.* Cephalaspis Lyelli.

Insects. Though none have yet been found within the State, the first known Insects appeared in this epoch. They belonged to Ephemeridæ, and were closely allied to our common May-flies or Cisco-flies. They are to be noted among the sudden apparitions of new forms widely diverse from all known preceding ones.

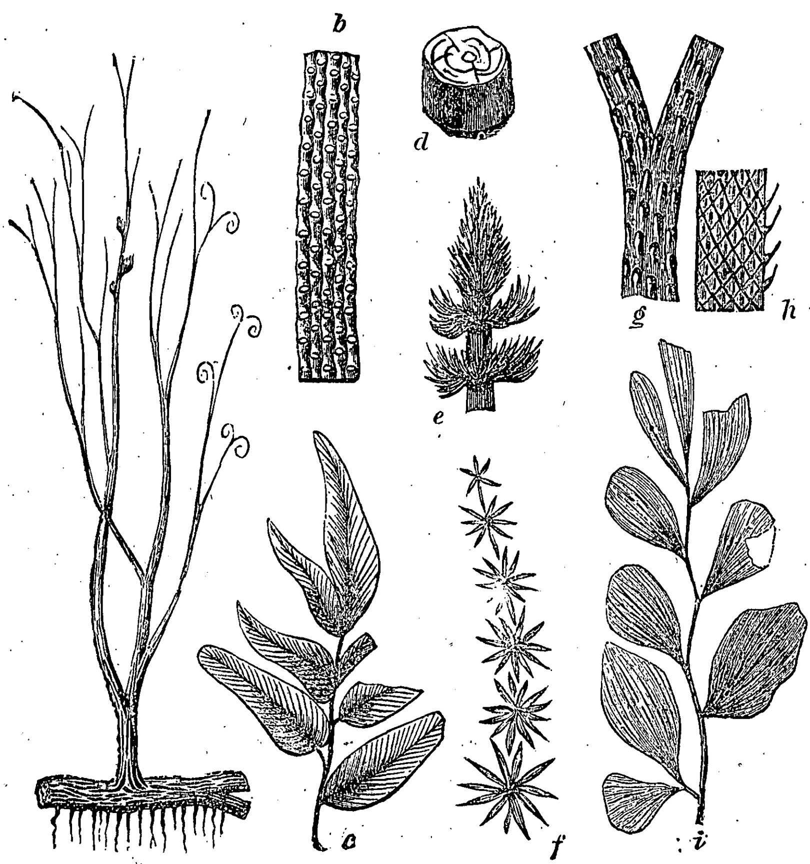
FIG. 61.



FRAGMENT OF THE WING OF A DEVONIAN INSECT. *Platephemera antiqua.*

Land Plants. This formation likewise furnishes the first identifiable remains of land plants found within the State, although they have been found elsewhere in the interior as low as the Cincinnati (Hudson River) shales. The relics belong to the interesting *Lycopods*, the leading type of the ancient acrogenous trees. It is probable that plants spread quite widely over the land, although the known forms appear to be frequenters of marshes and lowlands. Discoveries elsewhere render it probable that the landscape in the preceding ages, stretching back to the Lower Silurian, was diversified, if not

FIG. 62.



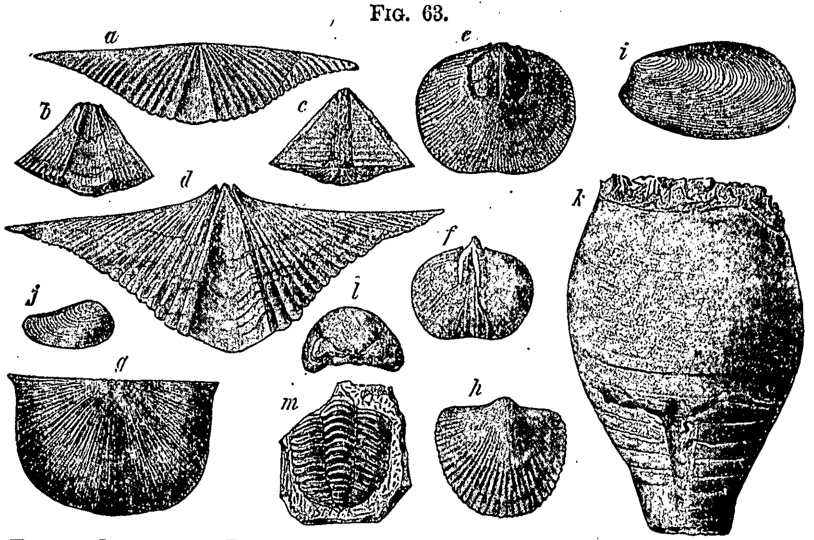
DEVONIAN PLANTS. *a.* Psilophyton princeps, restored. *b.* Sigillaria Halli. *c.* Neuropteris polymorpha. *d.* Prototaxites Logani. *e.* Fruit of Asterophillites latifolia. *f.* Asterophillites latifolia. *g.* Lepidodendron Gaspianum. *h.* Same enlarged. *i.* Cyclopteris obtusa.

somewhat generally clothed, with verdure. But it was verdure alone. The days of flowering plants had not yet come.

Invertebrates. Among the invertebrates whose history we have followed from their first appearance, there were interesting modifications, though the great types still held their places without radical change. In the bay of the sea that indented the Wisconsin border, some of the familiar invertebrate branches were almost wanting. The somewhat turbid waters almost entirely excluded the Corals and Crinoids, which are barely represented. Gasteropods were also rare. Brachiopods took the leading place, and among them the *Spirifers* had now come to be the ruling form. Among the new genera were *Chonetes*, *Productus*, *Cyrtina*, *Trematospira*, and *Leiorynchus*.

The Lamellibranchs were represented by but few species, among which those of the genus *Palæoneilo* were the most abundant. The gigantic Cephalopods did not frequent this shore, but the class was represented by the stunted forms of the genus *Gomphoceras*. Little *Phacops rana* represented the Trilobites.

FIG. 63.



HAMILTON INVERTEBRATE FOSSILS. *a.* Spirifera angusta—Hall. *b.* and *c.* S. aspera—Hall. *d.* S. pennata—Owen. *e.* Orthis impressa—Hall. *f.* Orthis impressa. *g.* Strophodonta demissa—Conrad. *h.* Atrypa reticularis—Linn. *i.* Modiomorpha concentrica—Conrad. *j.* Palæonello nuculiformis—Stevens. *k.* Gomphoceras breviposticum—Whitf. *l.* Head of Phacops rana—Green. *m.* Thorax and pygidium of same.

Mingled Fauna. A closer inspection of the specific forms, as given in the lists of Volumes II and IV, shows a decided preponderance of Hamilton species, some of which are highly characteristic. With these are associated a number of species representing a lower horizon, and a few Chemung forms belonging to a higher. This little deposit, therefore, seems to embrace within itself a somewhat comprehensive fauna, including representatives of three epochs of the Middle Devonian. This may have been due to its quiet, sheltered position, by virtue of which it escaped the more sweeping changes that characterized the wider and more open areas.

The Last Visit of the Ocean. At the close of the Hamilton period the ocean receded, and if it ever subsequently encroached upon our territory, it has left no known record of its intrusion.

American Distribution. As the ancient interior sea became filled, the formations were withdrawn more toward the center, and hence we find the Hamilton formation appearing more in the heart of the interior. It skirts the coal basin of the Lower Peninsula of Michigan, forms narrow belts and limited areas in Indiana, Ohio, Kentucky, Tennessee and Missouri. A belt crosses western Canada and the south central part of New York, and extends southward into Pennsylvania and Virginia. In Illinois it emerges from beneath the Coal Measures at Rock Island, and stretches thence northwesterly through Iowa, Minnesota, and the British Possessions to the Arctic regions. On the eastern Atlantic border, it occurs in Maine and New Brunswick, and at Gaspè.

Foreign Equivalents of Devonian Rocks. It is not to be presumed that the precise equivalent of our Hamilton rocks can be determined abroad. The Devonian system, of which with us it is a central part, finds its typical development in North and South Devon, England. It also occupies Cornwall, and Hereford, extending into adjacent shires. It embraces the famous Old Red Sandstone of Scotland. It also occurs in Ireland, and the Isle of Man. On the continent the Devonian formations occupy a large tract in the center, stretching from the Ardennes through southern Belgium, and across the Rhenish provinces. They appear in the cliffs below "fair Bingen on the Rhine." Eastward they are found in the Hartz mountains, Thuringia, Franconia, Saxony, Silesia, Moravia, and East Galacia, also in the Stygian Alps, and the Carpathians. In northern Russia they form a very extensive tract, stretching across the European portion of the empire.

General Survey.

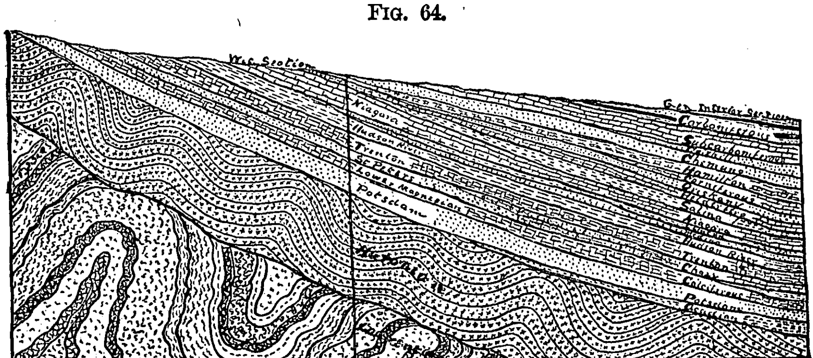
Past Great Era of Deposition. Coming Great Era of Erosion. The history of the formation of the substructure of the State was, it will be observed, in an unusual degree, simple and progressive. Starting with a firm core of the most ancient crystalline rocks, leaf upon leaf of stony strata were piled around it, adding belt after belt to the margin of the growing island, until it extended itself far beyond the limits of our State, and coalesced with the forming continent. An ideal map of the State would show the Archæan nucleus surrounded by concentric bands of the later formations in the order of their deposition. But during all the vast lapse of time consumed in their growth, the elements were gnawing, carving and channeling the surface, and the outcropping edges of the formations were becoming more and more jagged, and now, after the last stratum had been added, and the whole had been lifted from the waters that gave them birth, there ensued a prolonged era during which the history was simply that of surface-erosion. The face of the State became creased with the wrinkles of age. The edges of her rocky wrappings became ragged with the wear of time. The remaining Devonian periods, the great Carboniferous age, the Mesozoic era, and the earlier Mesozoic periods passed, leaving no other record than that of denudation.

It was only in the glacial period that deposition was again resumed and then in a form greatly diverse from that with which we have now grown familiar. In the interval, Wisconsin was a witness of, rather than a participant in, the history of rock-formation and life-preservation. For the sake of continuity and conformity to legal requirements, a brief sketch of the salient characteristics of these ages will be given, but before entering upon this, it may be profitable to take a sweeping backward look across the Palæozoic ages, and catch and group in distant perspective their grander outlines.

Summary Observations on the Wisconsin Palæozoic Series.

Groups of Deposits. Glancing comprehensively over the marine fossiliferous formations of Wisconsin, we observe that they gather into five main groups, reposing in succession upon the great crystalline formations. The Potsdam sandstone and Lower Magnesian

Fig. 64.

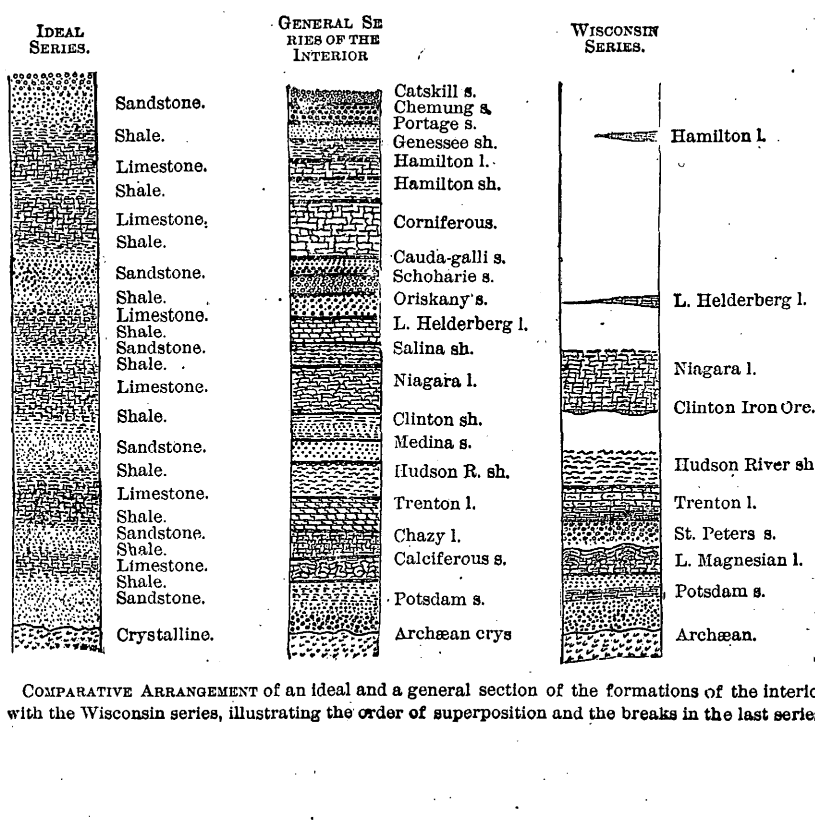


Generalized Geological Section of the formations of the Interior, designed to illustrate the relations of the Wisconsin series to the fuller system of the Interior Basin.

limestone constitute the first group. The St. Peters sandstone, the Trenton and Galena limestones and the mixed shales and limestones of the Hudson River series, constitute the second assemblage. The Clinton Iron ore deposits and the Great Niagara limestone, with its several subdivisions, constitute the third division, which is only completed by gathering to it the formations represented elsewhere. The fourth is merely represented by the little deposit referred to the Lower Helderberg, and the fifth by the Hamilton limestone. These are all separated by intervals.

Completion of the Series. If we extend our view beyond the limits of our special field, so as to embrace the related deposits that fill in part, or in whole, the gaps between the Wisconsin series, there will be added, (1) to the base of the first series, the Acadian group of the Atlantic border, and to its summit a part of the mixed rocks known as the Quebec group; (2) to the base of the second group, the Chazy limestone (though this may be represented by the St. Peters sandstone), and to its summit, some shales later than the Hudson River epoch, as represented with us; (3) to the third group, the Medina sandstone and a portion of the Clinton deposits, at its base, and, at its summit, that portion of the Saliferous deposits formed during the retreat of the sea; (4) to the fourth group, at its base, the remainder of the Saline series representing the advancing ocean, and, at its summit, the *Tentaculite*, *Pentamerus*, *Delthyris* and *Encrinal* limestones and shales, and the Oriskany

FIG. 65.



COMPARATIVE ARRANGEMENT of an ideal and a general section of the formations of the interior with the Wisconsin series, illustrating the order of superposition and the breaks in the last series.

sandstone; and (5) to the fifth group, at its base, the Cauda-galli and Schoharie sandy deposits, and the silicious Corniferous limestone, and, at its summit, the great shale and sand deposits of the Upper Devonian.

It will be observed that in most instances the additions are to be made both above and below, and hence that our formations are central to the several groups. The significance of this fact we shall see presently.

Order of Succession. Glance now at the succession of deposits in the several groups. In the first, coarse detrital sandstones form the great base of the formation. These give place, first, to alternating shales and limestones, and then to predominant limestone, while, in Wisconsin, the series is terminated by the peculiarly modified superior stratum of Lower Magnesian limestone, and perhaps a portion of the St. Peters sandstone, but in the larger view seems to find its completion in the mixed sandstones, shales and limestones of the Quebec series.

The second group is introduced by the St. Peters sandstone, has for its main middle portion the Trenton and Galena limestones, and is completed by the mixed shales and limestones of the Hudson River group.

The third series is introduced elsewhere by the Oneida conglomerate, Medina sandstone, and the Clinton shales, finds its great heart in the nearly 800 feet of our Niagara limestone, and is followed by the impure Saline group.

The advent of the fourth group, which is a subordinate one, is represented by the impure Saliferous deposits, which connect it with the preceding, its central portion is characterized by limestones, and its closing epoch by the Oriskany sandstone.

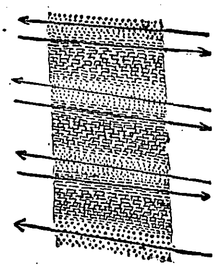
The fifth series begins elsewhere with the Cauda-galli and Schoharie grits, which give place toward its middle to the Corniferous limestone of the interior, and our own Hamilton deposit, while the series is closed by the great commingled accumulations of the Upper Devonian.

The similarity of succession in each of these groups is an interesting and instructive feature, and indicates a "cycle of deposition" in each period.[1] Viewed comprehensively, and perhaps with a touch of idealism, it may be asserted that each was inaugurated with shal-

[1] Dr. Newberry has very clearly and beautifully sketched these "cyles of deposition" in the Ohio report and in the article on Palæontology in Johnson's Encyclopœdia. They have also been set forth by Dr. Dawson and Prof. Alex. Winchell and have been discerned more or less distinctly by other geologists.

low-water detritus, which gave place at length to the deeper-water, organic, lime deposits, and these in turn to the mixed earthy and organic shales that close each period.

FIG. 66.



DIAGRAMMATIC SECTION intended to illustrate the ideal succession of deposits in an advancing and retreating sea. Dots represent sandstone, broken lines shale, and angulated lines limestone.

The physical changes that gave rise to this orderly succession are not far to seek. An advancing ocean formed the detrital base. As the beach moved onward and left the area in more quiet water, there gathered first the fine earthy sediments, and then the limestones of the clearer seas. These continued to grow as long as the sea maintained its advanced stage, and formed the great central deposit of the period. During the shallowing stages that attended the withdrawal of the sea, the earthy deposits mingled with the still persistent organic accumulations, and formed the shales, grits, and limestones that make up the typical closing deposition of each period. Each group, therefore, represents an oceanic advance and retreat, or, otherwise stated, a relative rising and sinking of the land — an orographic oscillation.

Definition of Period. This constitutes what we regard as a *period* in its technical sense, as distinguished from an *epoch*, which marks only a distinct phase of the activities of the period. Ideally there might be said to be three main epochs in each period: (1) that of advancing waters and coarse detrital deposits; (2) that of deep waters and limestone deposits; and (3) that of retiring waters and mixed shaly deposits; but practically such ideal symmetry is usually broken by minor oscillations and irregularities of movement. This, like all ideal schemes for the subdivision of geological time, encounters difficulties in its application, and cannot be rigidly applied without injury to the truth. It, however, represents a valuable idea, and applied with judgment and a flexibility always subservient to fact, is perhaps the best physical basis for the minor subdivisions of geological history. On this, or any other natural basis, periods and epochs will differ both in length of time and importance of results, and since minor oceanic advances and retreats are factors of greater ones, appeal must be taken to other circumstances, especially the phases of life, to determine the limitations and rank of the divisions. At the best, it is often largely a matter of judgment.

Viewing the successive series in their unity, it may be observed that the first, or Potsdam series, embraces much the most coarse and silicious material, the natural result of a sea advancing upon the crystalline formations of the Archæan lands; that the second contained a larger proportion of limestone, but embraced much clayey and earthy material; that in the third period, the limestone accumulations were greatly predominant, and reached their maximum development; that in the fourth period, fine earthy detritus mingled more freely in the deposits of the now narrowed seas, marking the approach of the final silting up of the interior ocean, which reached its essential completion, except in the region of the Plains, in the succeeding Carboniferous age.

Life Progress. We are now prepared to appreciate many of the changing phases of the life-history which were before without apparent significance, and perhaps seemingly inexplicable. Remembering (1) that at every stage there is a shore belt swept by the waves, and ever agitated by forcible action, furnishing conditions congenial to littoral species, and that (2) farther off shore there are varying degrees of depth and quietude suited to other species, and that (3) still more distant, there are yet less disturbed bottoms, the fit habitat of abysmal and pelagic species, it is manifest that we cannot rationally seek for an orderly succession of species, whatever may be thought to be their origin, by passing from a shore deposit to the next succeeding off-shore accumulation, and from that to the yet deeper-water deposits that may overlie it, but rather by tracing the shore deposit landward in its advance, and seaward in its retreat. The true succession will not, therefore, be found by rising vertically through an extended and complex series, but along a zigzag course, following the to-and-fro track of like conditions.

The difficulties of the study may be illustrated by the fact that the formations cannot be followed through this meandering course, because on the landward side they have been cut away by subsequent denudation, and, on the seaward side, have been buried by later accumulations, and it is only at some intermediate point where erosion has exposed the worn edges of the strata that opportunities for investigation have been presented. Here, only distant epochs, separated by a long landward advance, or seaward retreat, can be brought into comparison. The successors of the sand-loving species of the Potsdam seas, for example, are not to be sought in the overlying limestone, but in the next succeeding beach deposit that presented similar conditions. Only so far as species roam indifferently over the sea-bottom, without regard to its special conditions (or else are modified to suit them), can we expect them to range through successive strata, varying between limestone, sandstone, and shale.

The field within our purview is manifestly too narrow to sanction our entrance upon the far-reaching questions to which these thoughts lead. The problems that encompass the succession of life and the effects of varying geological conditions upon it, demand, for their adequate consideration, the whole realm of biologic facts and the entire field of possible geological knowledge. We must content ourselves with such an approach to them as the limits of our province permit.

CHAPTER XI.

THE CARBONIFEROUS AGE.

The Carboniferous age embraces (1) a period of the usual character, marked by detrital beds at the base, limestone in the center, and detrital beds again at the summit — the *Sub-carboniferous*, (2) an exceptional period of oscillation near the sea level — the *Carboniferous*, and (3) a period of mountain elevation on the Atlantic border, and of varying marine deposition in the western region — the *Permian*.

The Sub-carboniferous period was inaugurated by mechanical sedimentation, the sandstones and shales of the Catskill and Waverly epochs (according to the classification here adopted), but was mainly a period of limestone formation in the interior of the continent. As its waters retired, shallow seas again produced mechanical sediments, and led on to the Carboniferous period, which, but for its exceptional development, might be classed as the closing epoch of a single period, marked by a great advance of the sea, followed by a prolonged and fluctuating retreat.

The Carboniferous period was inaugurated by the deposition of a great stratum of coarse sediments, the Millstone grit, after which followed a complex alternating series of shales, sandstones, limestones, coal seams, and iron ore beds, altogether forming a series of exceptional industrial value.

The Permian period embraces the time occupied in the upheaval of the Appalachian mountains, contemporaneous with which, there were mixed sediments accumulating in the region of the Western Plains and beyond. (For details see Dana's Manual, Le Conte's Elements, and Andrew's Geology of the Interior.)

None of these formations occur in Wisconsin. They approach within less than 100 miles on the east, south and west, and must originally have come still nearer, as they have been much eroded since their formation. Wisconsin was then a peninsula that projected southward into the region of Carboniferous deposition, and stood as dry land in the midst of marshes and shallow seas.

Sub-carboniferous Period.

An incursion of the ocean followed the retreat that closed the Devonian age, spreading out over its floor the usual detrital sediments. As the waters deepened and clarified, they gave support to a luxuriant growth of marine life, among which Crinoids were so abundant that the sea bed may almost be said to have been a great submarine field of waving "stone lilies." From this prolific life-growth came the great "mountain limestone," the nucleal deposit of the period. But in time the waters shallowed and the period passed almost without interruption into the remarkable phase of geological growth presented by the succeeding period, for while the Sub-carboniferous limestone marks the climax of the marine work of the period, land plants enter the arena as a new agency at its close, and change the phase of the formation, diverting from the ocean, for a time, the supreme attention it has so long attracted to itself as the great architect of the earth's rock-structure.

Carboniferous Period.

Remarkable Plant Growth. In the Cambrian and earlier Silurian life-periods, we have had occasion to speak doubtfully of the existence of life upon the land. In the Upper Silurian age, some scant evidence of terrestrial life encourages the belief that the lands were not entirely destitute of verdure; but even this evidence has been questioned. In the Devonian era, terrestrial plant-life appeared apparently in considerable abundance, but it did not make any contribution of great moment to the accumulation of rock or land. But in the great Coal Age which now dawns, the land vegetation flourished in great abundance and luxuriance, and became a signal agent of geologic growth. The attitude of large areas of the continent was such as to favor, to an extraordinary degree, the growth of this class of vegetation, not only, but also to preserve its products for the use of subsequent ages. Throughout large portions of Pennsylvania, Ohio, West Virginia, Tennessee, Alabama, Indiana, Michigan, Illinois, Kentucky, Iowa, Nebraska, Kansas, Missouri, Arkansas and Texas, or, in other words, throughout the eastern portion of the great interior that had not already emerged from the ocean, the land oscillated near the level of the sea, sometimes slightly above, forming extensive marshes and lagoons, and, sometimes slightly below, admitting of the incursion of the ocean, resulting in beach deposits of grits and gravels, in estuarine, border-flat, and delta deposits of mud, and in clear-water accumulations of limestone.[1] At those stages in which the surface stood just above the level of the sea, the quaint swamp vegetation of the period prevailed in unparalleled luxuriance. Lepidodendrids, Sigillarids, Conifers, Calamites, and Ferns, arboreous as well as herbaceous, flourished, and shed their leaves, pollen, cones, spores or other fruit, and the exfoliations of their stems, into the marsh waters beneath, or into the interspersed lagoons, while at their death they themselves found a like watery burial.

It has been plausibly conjectured that floating vegetation formed on the interspersed lagoons and lakelets, and made its contribution to the accumulating plant deposits.

Preservation of the Vegetal Material. The vegetal matter that thus accumulated was prevented from undergoing the usual decay by the well-known preservative agency of water, and thus there gathered, in the lapse of time, beds of great thickness. The flatness of the country, and its dense vegetation, prevented, in a great measure, the inwashing of earthy material, so that the accumulation was almost purely vegetable. At length, however, by a slight change in the relative levels of land and water, the ocean returned, bringing its accustomed detrital material, and spread it over the vegetable beds. These beds, thus buried, formed the initial stage of a layer of coal. Repeated oscillations attended by repeated growths and burials multiplied the coal seams, and at length gave rise to the completed coal measures.

The vegetal material thus sandwiched between the earthy sediments was compressed by the weight of overlying strata, and underwent a slow chemical change, resulting in the loss of a portion of the constituents of the tissues, and the recombination of the remainder. Most of the oxygen, a considerable part of the hydrogen, and some carbon, were removed, as carbonic acid, water and volatile hydro-carbons, while a large part of the carbon, and a considerable portion of the hydrogen, with some oxygen, remained, forming bituminous coal.

In undergoing this transformation, the vegetable material gradually passed from its original woody, or cortical state, through various lignitic stages to that of bituminous or soft coal, and this, in regions subsequently subjected to stratigraphical disturbance, was changed into anthracite, or hard coal, by the heat and pressure to which it was subjected, by which the volatile bituminous matter was expelled.

[1] The western portion of the great interior was meanwhile overspread by a somewhat deeper, clearer sea in which continuous marine deposits gathered.

Among the series of coal beds and associated strata are interstratified beds of iron ore — an indirect result of the marshes of the period and their vegetation, only less important than the coal itself. Bearing in mind the method of iron-ore deposition, already explained, it is evident that the marshes and lagoons, and the abundant

FIG. 67.

CARBONIFEROUS FERNS. *a*. Pecopteris Strongi. (Lesquereux.) *b*. Neuropteris flexuosa. (Lesquereux.) *c*. Callipteris Sullivanti. (Lesquereux.) *d*. Hymenophyllitis alatus. (Lesquereux.) *e*. Alethopteris Massilonis. (Lesquereux.) *f*. Neuropteris hirsuta. (Lesquereux.) *g*. Sphenopteris Gravenhorsti. *h*. Pecopteris lonchitica. (Lesquereux.)

vegetation, furnished to an unusual degree, the conditions requisite for the extraction and deposition of iron ore. As these are closely associated with coal for their reduction, limestone for their fluxing, and sandstone and fire clays for furnace purposes, the combination is one of extraordinary industrial advantage.

Life. The new attitude which the land assumed toward the sea at the close of the Sub-carboniferous period, was accompanied by a marked change in the character of the life.

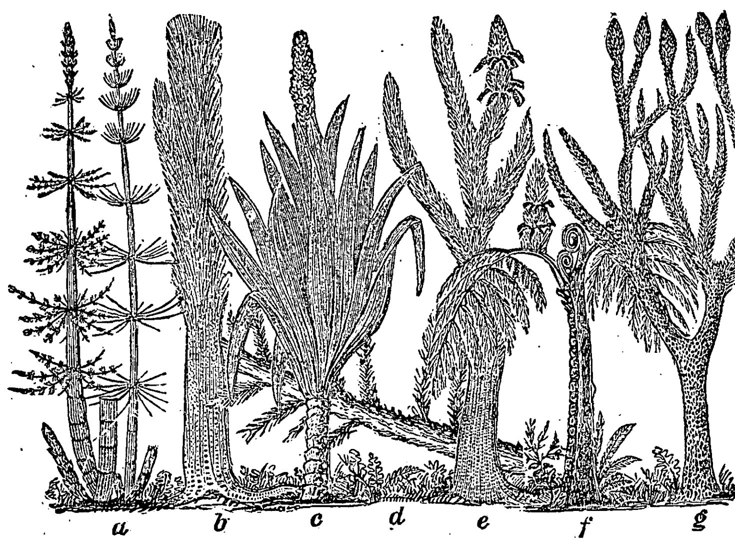
Plants. By far the most striking and characteristic expression of life-progress, was the pronounced development of vegetation during the Carboniferous age. The great beds of coal, widely scattered over the continent, indicate a clothing of verdure of more than tropical luxuriance. We are not left in doubt as to the nature of these "forests primeval." Well preserved remains show them to have been of the same essential character as those of the preceding Devonian age, differing mainly in their wider range, ampler variety, and surpassing growth. Not only were there flowerless plants (Acrogens), but Phenogamous plants were also represented by Gymnosperms. Flowers in the ordinary sense were probably entirely absent. Of the Acrogens there were *Ferns*, *Equiseta* and *Lycopods*, all of which much surpassed their modern representatives. There were both herbaceous and true ferns, the latter of which attained great size, single fronds sometimes attaining a length of six or eight feet, while the former were probably the most abundant of the coal-forming plants.

Among Lycopods, *Lepidodendrids* and *Sigillarids* were the principal forms. Both were of great size, reaching at times a height of 60 or 80 feet, placing them in marked contrast to the little Lycopods — the Ground Pines — of the present day, which, under the most favorable conditions, rarely reach a height of 4 or 5 feet. The exterior of their trunks seems to have been composed of dense firm tissue, while the interior was probably more cellular, as it is often wanting in erect stumps, while prostrate stems are much compressed. The exterior was marked by the peculiar and characteristic leafscars, which, in the Sigillarids, were arranged in vertical rows, and in the Lepidodendrids in oblique series passing spirally around the trunk.

The Carboniferous *Equiseta* were sometimes two feet in diameter and 30 feet high, while their modern representatives — our common scouring rushes — are but low, slender, herbaceous, plants, though Mr. Ernst reports a slender species 30 feet high from near Caraccas.

Besides these peculiar forms of vegetation, which grew profusely in and around the marshes, and which were the principal contributors to the coal formation, *Conifers* wooded the uplands. They were allied to the modern Araucarian Pines, and were, as Professor Dana has remarked, the modern feature of the Palæozoic forests. Their gymnospermous character is indicated by their exogenous structure, and the nature of their fossil fruit.

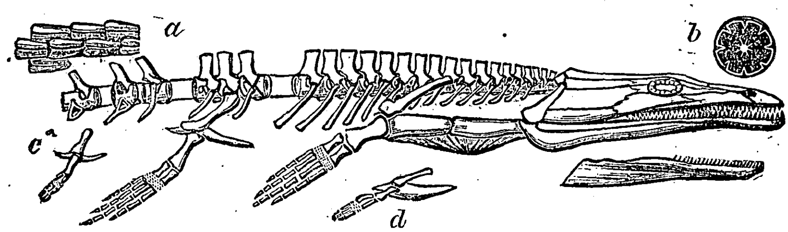
FIG. 68.



CARBONIFEROUS TREES (restored by Dawson). *a*. Restoration of a Calamite. *b*. and *e*. Restoration of Sigillaria. *c*. Cordaites restored. *d*. Araucarites gracilis. *f*. Megaphyton, a Coal-fern restored. *g*. Restoration of a Lepidodendron.

Besides these highly developed plants, there were doubtless many herbaceous ones which have left no distinct traces by which they can be identified. The warm, moist climate indicated by the nature of the vegetation would be favorable to various fungi, but these, from their nature, would hardly be preserved, however copious their growth.

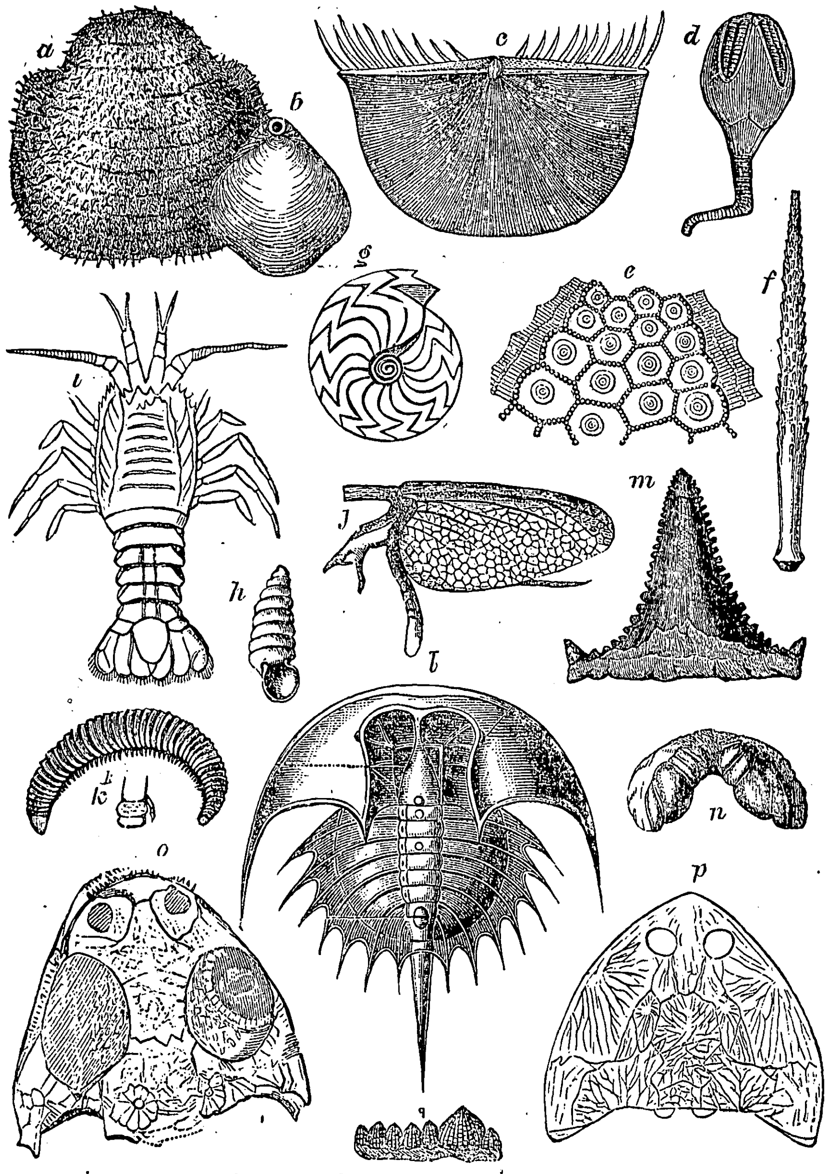
FIG. 69.



A CARBONIFEROUS REPTILE. Archægosaurus. (*Fig. from Le Conte.*)

There is no reason for believing that marine vegetation was less abundant during the Carboniferous age than formerly, but the immeasurably greater relative proportion of marsh and land vegetation make it much less prominent in the life-history of the period.

FIG. 69*a*.



CARBONIFEROUS FOSSILS (Dana). *a.* Productus Nebrascensis. *b.* Athyris subtilita. *c.* Chonetes Dalmaniana (Le.C.). *d.* Pentremites pyriformis. *e.* Archæocidaris Wortheni. *f.* A. Shumardana. *g.* Goniatites crenista. *h.* Pupa vestula (x 2/3). *i.* Anthrapalæmon gracilis. *j.* Dictyoneura anthracophila. *k.* Xylobius sigillariæ. *l.* Euproops Danæ. *m.* Tooth of shark, Carcharopis Wortheni. *n.* Tooth of Cestraciont shark. *o.* Skull of Amphibamus grandiceps (x 2). *p.* Tuditanus radiatus (x 1/2 Cope). *q.* Teeth of shark, Orodus mammillaris.

Vertebrates. Ganoid and Selachian fishes existed in great numbers, but were now overshadowed by the Amphibians and true Reptiles, which first appeared in the formations of this age, marking a decided advance in animal life. The Amphibians were of the Labyrinthodont order, a pre-eminently comprehensive type. Being true Amphibians, they embraced a combination of aqueous and aerial organs, connecting the two great animal types, the marine and the terrestrial. Unlike our present Amphibians, they had bony scales and armor-plates, and were equipped with large, conical teeth of labyrinthine internal structure—features that allied them to the plated fishes, and Saurian reptiles. The first true Reptiles also made their appearance during this age.

In the fauna there seems to have been no wide-spread extermination. Some new and somewhat different forms, to which the changed conditions were congenial, were introduced, while many old forms declined, and some few became extinct.

Invertebrates. In the lower branches of the animal kingdom there were less obtrusive innovations than in the higher. The persistent Corals and Crinoids still maintained their existence, though some of the most important and characteristic genera of each had disappeared. Mollusks were no longer confined to the sea, but lived upon the land and in the fresh and brackish inland waters. Brachiopods were still exceedingly abundant, while Lamellibranchs, Gasteropods (to which the fresh-water Mollusks belonged), and Cephalopods continued throughout the Carboniferous period to hold an undiminished course.

Trilobites, which had persisted since the Potsdam period, now made their last appearance. Insects, which began their known existence in the Devonian age, seem to have flourished throughout the Carboniferous. They were represented by several orders, and in some instances attained a size quite superior to that of the most nearly related forms of later times. Along with these true insects there were Scorpions, Spiders and Myriapods, in form closely allied to those of the present day.

The Appalachian Revolution.

The Permian Period. It has already been observed that the eastern Interior Sea grew shallow after the Sub-carboniferous period, and remained oscillating near the water level during the Coal period proper. During this time, the earth's crust throughout the affected region was slowly settling, but the sediments built it up with even pace, until, at its close, the sea retired, though it continued, in the region of the great plains and in other distant areas, its work of deposition in the formation of the Permian beds.

With this pause, in the eastern interior region, there closed a long era of sedimentary accumulation, stretching from the Potsdam period onward, during which, along the western Appalachian margin, there had accumulated a thickness of deposits roundly estimated at 40,000 feet. That this pile of sediment, notwithstanding its great thickness, was essentially a shallow-water deposit, is shown by ripple-marks and wave-rolled material, interlaid at various intervals from its base to its summit. There had been, therefore, a subsidence to some such extent as seven miles during the period of their accumulation.

This era of settling was followed by one of the great epochs of upheaval. According to the theory already explained, the pressure of the contracting crust was felt at a disadvantage along this belt of sagging strata, and they were bent, folded and crumpled, into the long system of rock-waves that form the Appalachian mountain system. In some cases the strata were fractured and faulted to the extent of 10,000 feet.

The character of the folds, which are strongest and closest on the Atlantic side, as well as the inclination of their slopes, which are steepest on the inland side, are thought to show that the active force came from the ocean, and was resisted by the great land area of the interior. The results of flexing and folding were such changes in the character of the rock as those with which we have become familiar in the earlier and more profound Archæan revolutions, save that in the later era the metamorphism was very much less marked. The interior of the continent was elevated bodily in some moderate measure by this disturbance, but otherwise was not materially affected.

This epoch of profound mechanical movement did not interrupt the ceaseless action of the ocean, which continued its work of sedimentation throughout the somewhat long period occupied by the revolution. But in this instance, fortunately, we are able to reach and read the oceanic record, as well as the more impressive mechanical one. The Permian strata in the regions both of the American and Russian plains, are conformable to the Coal measures, and contain the remains of closely allied animals, indicating continuity of succession. But in western Europe, the Permian strata are unconformable to the Coal measures below, while they underlie, in harmonious stratification, the succeeding Mesozoic deposits, indicating continuity with the following period. In eastern America the Permian strata are absent, indicating that the land began to be elevated before they were formed. Now when we consider that the active force of Appalachian upheaval came from the direction of the Atlantic, and must have reacted with equal force in the opposite direction, there is little reason to doubt that the European and American disturbances were contemporaneous, and hence follows the conviction that the uplifting began at the close of the formation of the Coal measures, or in other words, near the beginning of the Permian period, and ceased before its close, so that its upper strata rest unconformably upon the Coal measures in their changed attitude, and so that also the sediments of the succeeding era of Mesozoic quiet were deposited concordantly upon them. In brief, therefore, the Permian formation bridges the era of Appalachian revolution, and there is here consequently no real break in the succession.[1]

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[1] See Le Conte, Elements of Geology, p. 400.

MESOZOIC ERA.

CHAPTER XII.

THE AGE OF REPTILES.

In Europe the formations of this age are divided into three groups, viz.: (1) the Triassic, because composed of three distinct subdivisions in Germany, where first carefully investigated, (2) the Jurassic, so well displayed in the Jura mountains, and (3) the Cretaceous, because it embraces the great chalk deposits of England and France. In America the two first divisions are not so distinct from each other as to make the application of the European classification very natural, and hence has arisen the practice of combining the terms, and dividing the American Mesozoic into (1) the Jura-Trias, and (2) the Cretaceous.

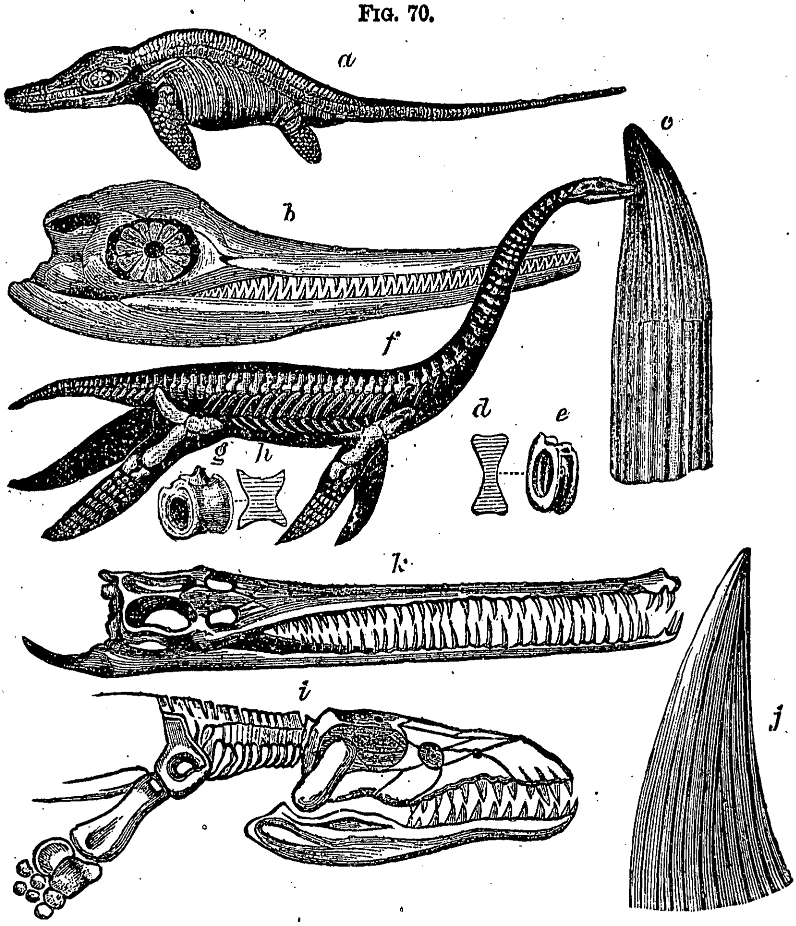
The first series is developed on the Atlantic and Gulf borders, and in the western plains and mountains, but is nowhere known to closely approach Wisconsin. The second series occurs in the same general regions, but in the upper Missouri and Mississippi valleys it extends farther east, covering portions of Iowa and Minnesota, and may possibly have once lapped upon our State, though no evidence of it has been found, except some drift on the northwestern edge that is probably Cretaceous, but which may have been brought from Minnesota.

Effects Following the Appalachian Revolution. The Appalachian revolution produced marked changes in the geography of the continent, the land being amplified, the ocean contracted, mountain ranges raised from the sea and thrown athwart atmospheric currents, at the same time diverting those of the ocean, and inaugurating new climatic conditions. The theater of active marine deposition was consequently transferred to new quarters.

Changes of Species. This physical transformation was likewise closely followed by an extraordinary change of living species, a change which, for suddenness and seeming universality, has no parallel in the fossiliferous series. This was formerly referred to the catastrophe of the revolution itself, which has been falsely pictured as convulsive in violence. It is demonstrable, however, that it was a slow and measured flexure of strata, under the pressure of a steady and powerful, but not violent, force, and was utterly incompetent, in itself, to destroy, or even greatly alter, the life in the adjacent seas. Furthermore, the extinction of species was not strictly contemporaneous with the mountain-making, but followed it, as indicated by the fact that the transition took place in the midst of the conformable series of western Europe, and not at the break between that series and the uplifted rock of the Coal measures, showing, there, at least, demonstrably, that the life-catastrophe, if it may be so called, succeeded at a considerable interval the stratigraphical one.

The mountain elevation may have been none the less, however, an influential circumstance in the life-transformation, through the indirect agencies which it brought into play. The lifting of lofty mountain ranges in the midst of what were before semi-tropical seas, or warm and humid plains, must have been attended by climatic changes profoundly affecting both land and sea. To these altered conditions, life, which has ever shown a capacity to adapt itself to

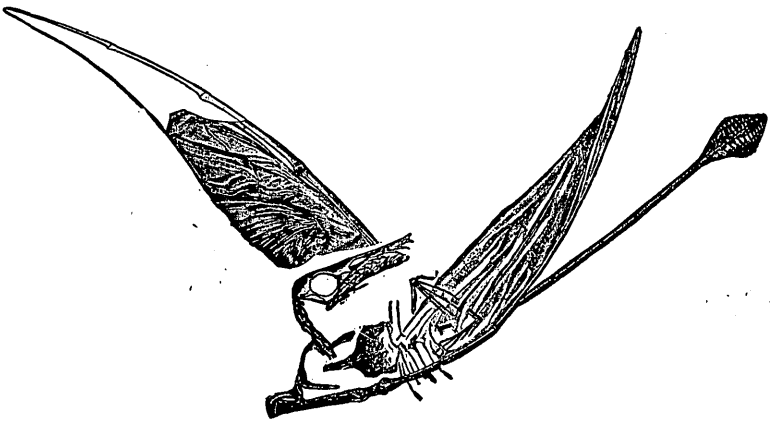
FIG. 70.



MESOZOIC REPTILES. *a*. Ichthyosaurus communis (x 1-100). *b*. Head of same. *c*. Tooth of same, natural size. *d*. and *e*. View and section of vertebra of same (x 1-8). *f*. Plesiosaurus dolichodeirus (x 1-80). *g*. and *h*. View and section of vertebra of same. *i*. Head of Pliosaurus. *j*. Tooth of same, natural size. *k*. Mystriosaurus Tiedmanni. (*Figs. from Dana and Le Conte.*)

new circumstances, whatever may be the means by which such adaptation has been accomplished, conformed. But it is to be observed, *per contra*, that the fauna which replaced the previous one was like it in being semi-tropical, and in demanding essentially the same climatic conditions.

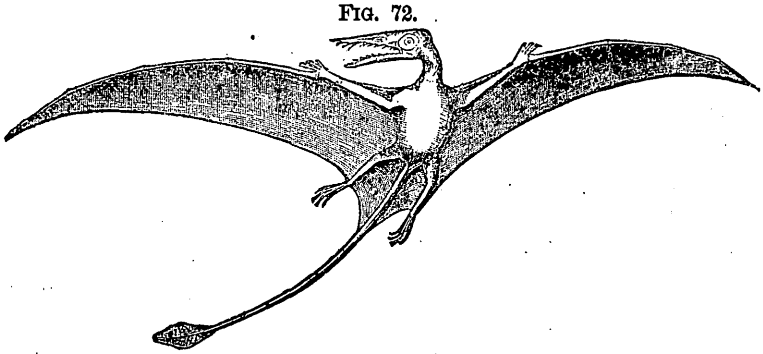
FIG. 71.



PTERODACTYLE (Marsh).

Reptiles. The leading characteristic of this new life-era was the enormous development of the Reptilian type. Not only were they monstrous in size, but they seem to us scarcely less than monstrosities in structure. Anatomical features, now found only in diverse

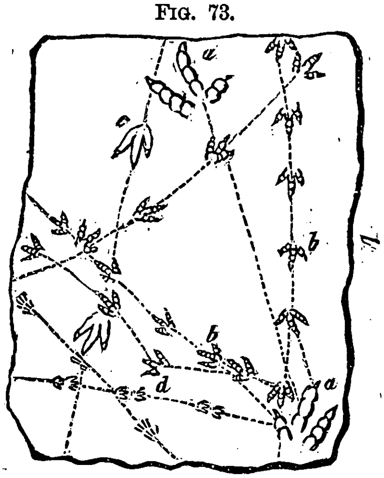
FIG. 72.



PTERODACTYLE RESTORED (Marsh).

orders, were then combined in single individuals. There were great swimming Saurians, which, like the Ichthyosaurus, not only combined characteristics of a fish and a lizard, as its name implies, but also of the whale and the crocodile, with many that were peculiarly and indisputably its own, or like the Plesiosaurus, that, with fish-like vertebræ and general Saurian character, had a turtle-like body, snake-like neck, and Cetacean paddles. There were enormous land-reptiles of like comprehensive structure, uniting, as the Dinosaurus, hollow bones and other bird-like features, with mammalian characteristics, while in general structure they were pronouncedly Saurian reptiles. There were also flying reptilian forms of even stranger composite constitution, embracing, as in the Pterodactyles, reptilian head, jaws and teeth; hollow bones and keeled sternum, like birds; with extended membraneous wings, like bats.

FIG. 73.



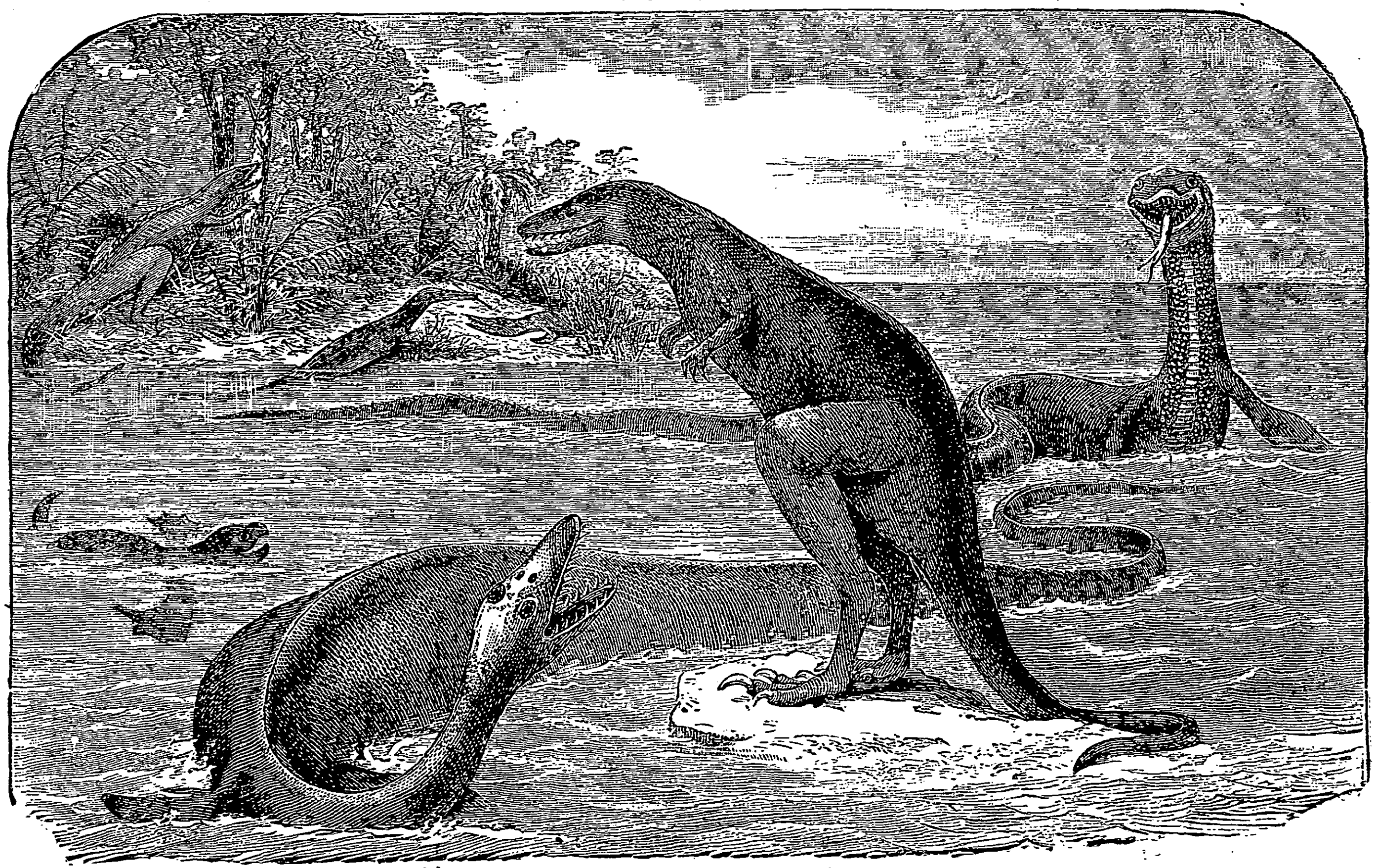
TRACKS on a slab of sandstone from the Connecticut valley, formerly regarded as ornithic, but now generally considered reptilian. (*Fig. from Dana.*)

With these seemingly aberrant forms, there were associated, during the earlier portion of the era (the Triassic), Amphibians of the Labyrinthodont type, that had appeared in the Carboniferous age, and Crocodilians, precursors of the present dominant reptilian form.

It appears, therefore, that the sea, earth and air were peopled and ruled by Reptiles. The Reptiles were preeminently the Mesozoic "lords of creation." Not only were the types more diverse, and to our conceptions, more strange than those of any succeeding era, but the number of species vastly outnumbered those of later ages. Their enormous size may be realized by comparison with living forms. Amphibians, that are now chiefly represented by frogs, and similar diminutive animals, were then represented by the Labyrinthodonts, of a size comparable to that of an ox. The Sea-Saurians reached, in some instances, a length of 70 or 80 feet, while some of 30 or 40 feet length had stout, powerful bodies. The Dinosaurs were even more ponderous. Some had the elephantine proportions indicated by a length of certainly 30 or 40 feet. An Atlantosaurus that lived in the western region is thought to have had a total length of 100 feet. Crocodilians, two or three times the length of modern representatives, and huge turtles, 15 feet across, were among the lesser attractions of the reptilian menagerie.

Rapidity of Reptilian Development. The reptilian type, therefore, which is first found in the Carboniferous period, attained, by a rapid development, its maximum in numbers, size, variety and strangeness of forms, before the close of the Mesozoic age. Its

Fig. 74.



Mesozoic Reptiles. (*Restored by Cope.*)

further history is characterized by decline, though, in individual orders, there is advance in organization and in distinctness of reptilian characteristics.

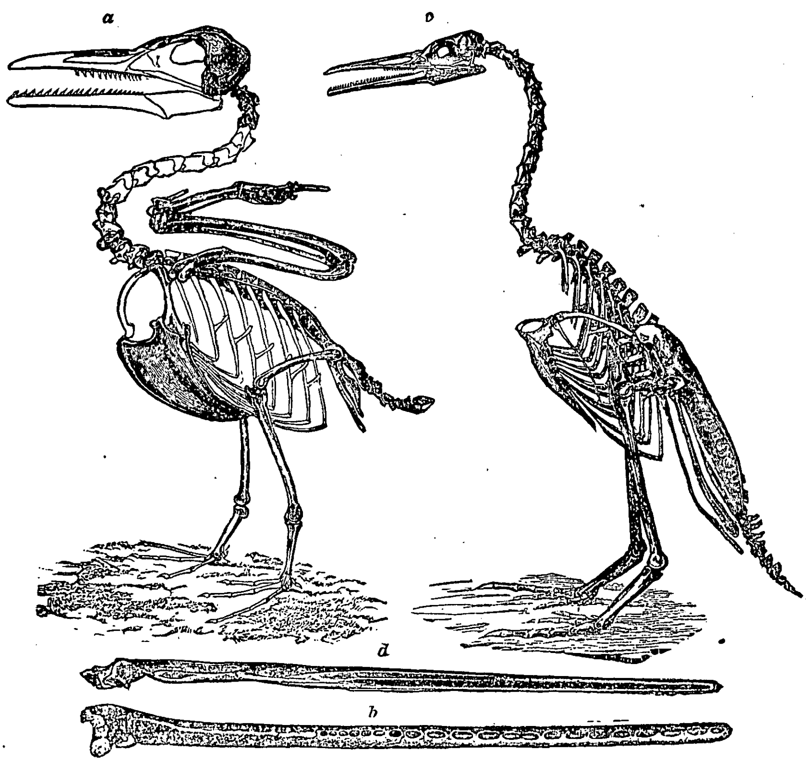
FIG. 75.

THE BIRD OF SOLENHOFEN. Archæopteryx macrura. (*Fig. from Dana.*)

The great reptilian type is presented to us by the geological record as an instance of rapid development. Having its apparent beginnings in the Carboniferous age, and being then rare, if we may judge from the paucity of remains, for the preservation of which the conditions were favorable, it had reached, by the middle Mesozoic, an expansion truly astonishing. Its great orders, with one or two exceptions, were already organized and diversified by a wide array of genera and species.

It is important to remark that this great development took place in a new field, a fresh habitat. The extraordinary vegetation of the Carboniferous period extracted a vast quantity of carbonic acid

FIG. 76.



a. Restoration of Ichthyornis Victor (x 1/3 Marsh). *b.* Left lower jaw, top view (x 3/4). *c.* Restoration of Hesperornis regalis (x 1-12 Marsh). *d.* Left lower jaw, top view (x 1/3). (*Figs. from Dana.*)

from the atmosphere, which was probably only in part replaced by animal life and other sources of the liberation of the gas, so that the air was purified of this ingredient, and rendered more fit for air-breathing animals. There was thus opened a new realm for animal occupancy. Into this the reptiles entered, and speedily attained a remarkable development. It was seemingly the room and richness of this new field that called forth the size, numbers, and diversity of its occupants. This, if we read geological history aright, is not an isolated, but, on the contrary, a common and characteristic fact. It was the plenitude of resources and the richness of opportunities, that called forth the great evolutions of life, and not paucity of resources or severe conditions of existence. These had their own peculiar and profound influence, but it appears to have been largely suppressive and fixative in character.

The greatness of the reptilian development and the force of the preceding remarks will be emphasized as we proceed to consider the reptilian characters presented by the higher vertebrates, the Birds and Marsupials, that had their apparent advent during the age.

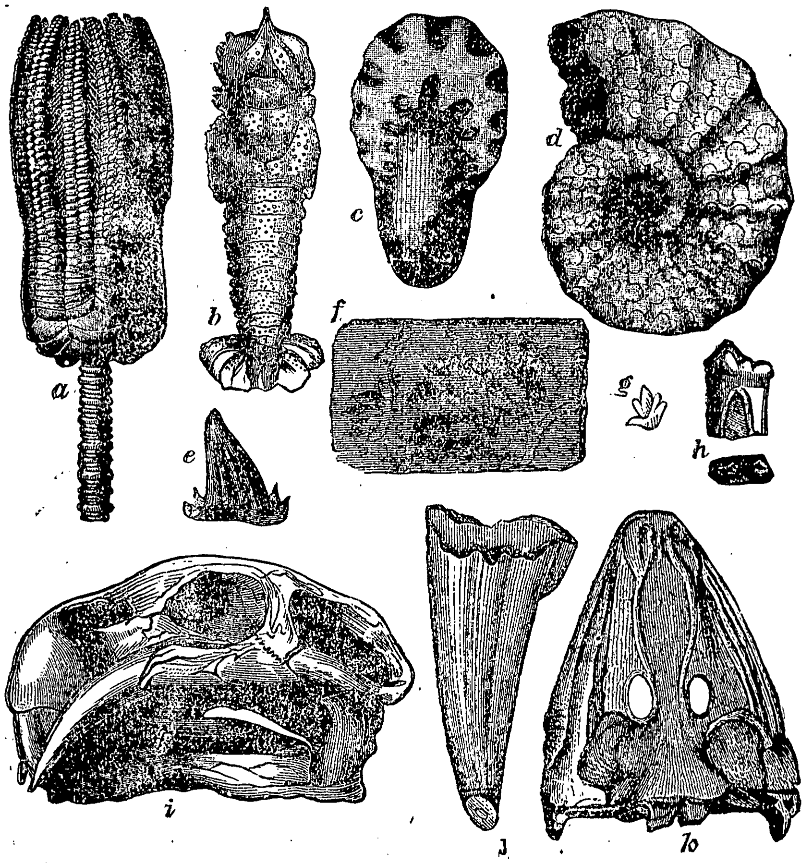
Reptilian Birds. The celebrated fossil bird of Solenhofen is the earliest of known ornithic forms. Though a true bird, possessed of a full clothing of feathers, it was armed with teeth, as Prof. Marsh has recently determined, and had a long vertebrated tail to which the caudal feathers were attached in rows on either side, two to a joint. The same investigator has made the remarkable discovery of a new type of toothed birds — the Odontornithes. They belonged to two distinct orders. The one corresponded to the Struthious birds of the present day, represented by the ostrich, and had abortive wings and was incapable of flight, but was covered with feathers and had an elongated bill set with many sharp, conical teeth, fixed in grooves, a form of dentation characteristic of the lower types of reptiles. The other order, corresponding to our ordinary birds, had a keeled breast-bone, and evident powers of flight, yet lacked the horny beak of common birds, and was provided instead with a long bill, armed with conical teeth, inserted in distinct sockets after the method of the higher reptiles. We have, therefore, at this early date, the noteworthy fact that there was a remarkable diversity between these Mesozoic birds, notwithstanding their reptilian affinities and convergence toward that type.

Mammals. The first known Mammals appeared in the Triassic period, and were of the Marsupial type — the lowest of the class — and were besides possessed of some special reptilian features.

Fishes. It has been previously observed that the fish type, which preceded the reptiles in the vertebrate succession, had reptilian features. This character lingered through the Mesozoic age, though dying away as the predominant modern type, the Teliosts, appeared, as they did in the Jurassic period.

Invertebrates. Among the lower orders of animals, while seemingly universal change of species marks the advent of the age, and many minor facts of interest present themselves, yet in the general sketch of life which alone is here admissible, we may content ourselves with noting the most instructive feature — the culmination of the Cephalopods. They had appeared among the earliest forms of well-preserved life, as a well differentiated type. The ruling family was then the *Orthoceratite*, which, in its simplest form, may be defined as a straight-sided cone, with smooth surface, plane septa, and simple, central siphuncle. It early manifested a tendency to depart

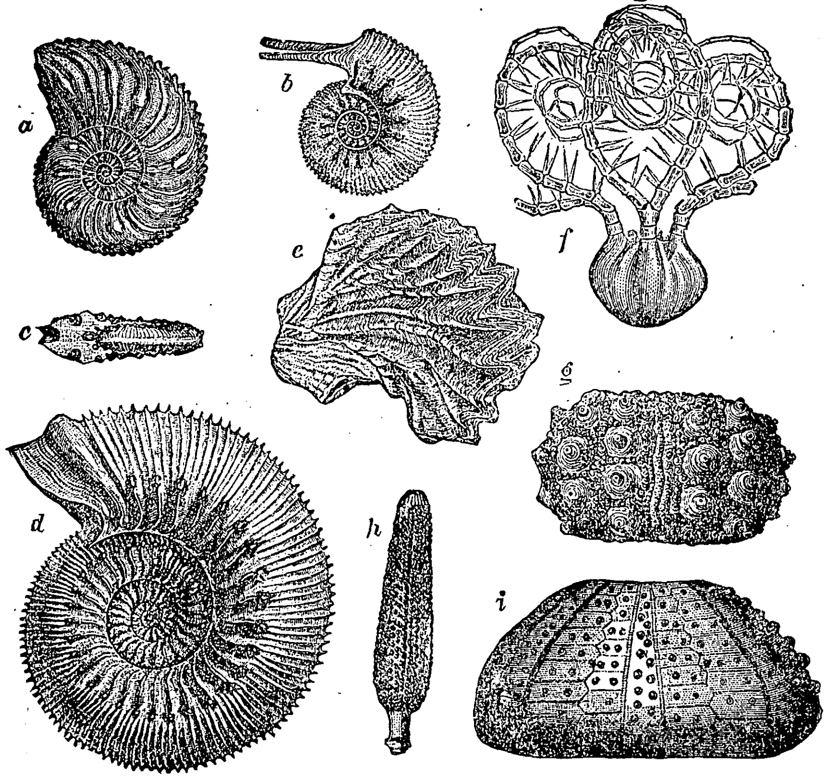
FIG. 77.



TRIASSIC FOSSILS. *a.* Encrinus liliformis. *b.* Pemphyx Sueurii. *c.* Ammonites tornatus *d.* Ceratites nodosus. *e.* Tooth of Hybodus apicalis. *f.* Tracks of Cheirotherium (x 1-12). *g.* Tracks of Cheirotherium—a Labyrinthodont. *h.* Tooth of the Microlestes antiquus. *i.* Dicynodon lacerticeps. *j.* Tooth of Mastodonsaurus giganteus (x 1-12). *k.* Skull of same. (*Figs. from Dana and Le Conte.*)

from this simple form—indeed had departed when first observed—(1) by the curving or coiling of the shell, (2) by plication of the septa, and more especially of the sutures, (3) by the eccentric position of the siphuncle, and (4) in its modification in form, and, at length, (5) by surface ornamentation. In the intermediate ages the *Goniatites* and *Ceratites* mark stages of this development, and in the Mesozoic era the culmination is reached in the beautiful *Ammonites* and their allies. The coiling had progressed not only to the extent of the complete rolling up of the shell in itself, but the successive coils were compressed, as it were, upon the underlying ones, giving an equitant relation to them. The septa are bent into pocket-like depressions, and unite with the shell wall by an exceedingly intricate suture. The siphuncle, instead of being central, is as far as possible

FIG. 78.



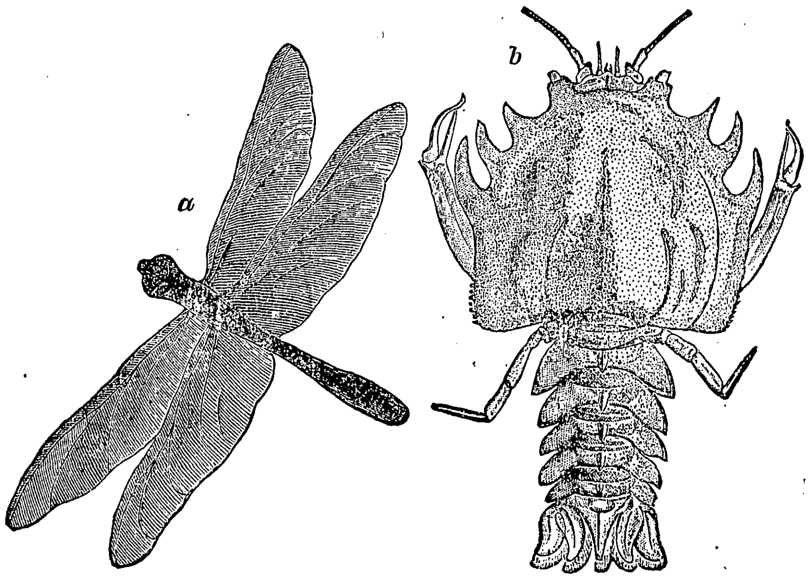
JURASSIC FOSSILS. *a.* Ammonites margaritanus. *b.* and *c.* A. Jason. *d.* A. Humphreysianus. Ostrea Marshii. *f.* Saccocoma pectinata. *g.* Cidaris Blumenbachii. *h.* Spine of C. Blumenbachii. *i.* Diademopis seriale. (*Figs. from Dana and Le Conte.*)

eccentric. The surface, so far from being plane, is variously corrugated and beautified by ornamentation.

During the later stages of the era, interesting divergences from these climacteric forms took place, seemingly as though the acme of progress along the lines previously pursued had been reached, and divergences took the place of retrogade development. Some of the forms were partially uncoiled, others, as the *Baculites*, wholly so, while they retained the complication of septa and other features of the higher type. In some instances, the uncoiling was unsymmetrical, assuming a hooked form. In still others, the coiling, which had previously been confined to a plane, was elevated into a spire after the fashion of Gasteropods.

These remarks are applicable, however, only to the earlier portion of the era — the Triassic and Jurassic periods. With the opening of the last stage — the Cretaceous — a marked transition of verdure-forms was inaugurated. While in the Carboniferous age, the

FIG. 79.



JURASSIC CRUSTACEAN AND INSECT. *a.* Æschna eximia (Hager). *b.* Eryon Arctiformis. (*Figs. from Le Conte and Dana.*)

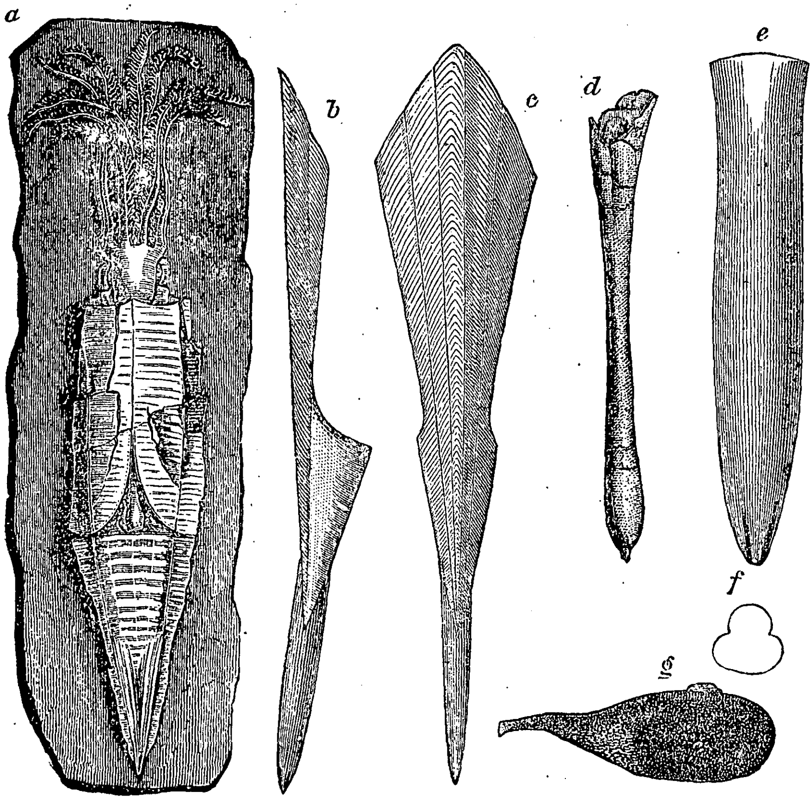
Acrogens predominated, and in the Jura-Trias, the Gymnosperms, during the Cretaceous, there were introduced the first known forms of the geologically modern Angiosperms, and our familiar friends, the Oak, Poplar, Maple, Beach, Hickory, Willow, Sycamore, Sassafras and Tulip-trees, as well as the Sequoias and Palms, began to adorn the earth, and foreshadow the modern era.

The vegetation of this age, like that of the preceding and other ages, where favorable circumstances existed, gave rise to accumulations of coal, which, however, has not usually passed beyond the lignitic stage.

There was also added to the Cephalopod type the *Belemnites*, which had an internal pen-like or club-shaped bone, and an external form similar to the squids and cuttle-fishes of the present, which, indeed, were represented at the time.

Plants. The aspect of plant life was less markedly changed than that of the animal kingdom. The *Sigillarids* and *Lepidodendrids*, which had passed their culmination in the Carboniferous age, had now ceased to characterize the forests of the age, and were supplanted by *Conifers*, *Tree-ferns* and *Cycads*. The last was a comprehensive, or, if you please, undifferentiated type, which, while a true Gymnosperm, related to the pine, had the aspect of the palm, and the habit of unrolling its leaves like the fern.

Fig. 80.

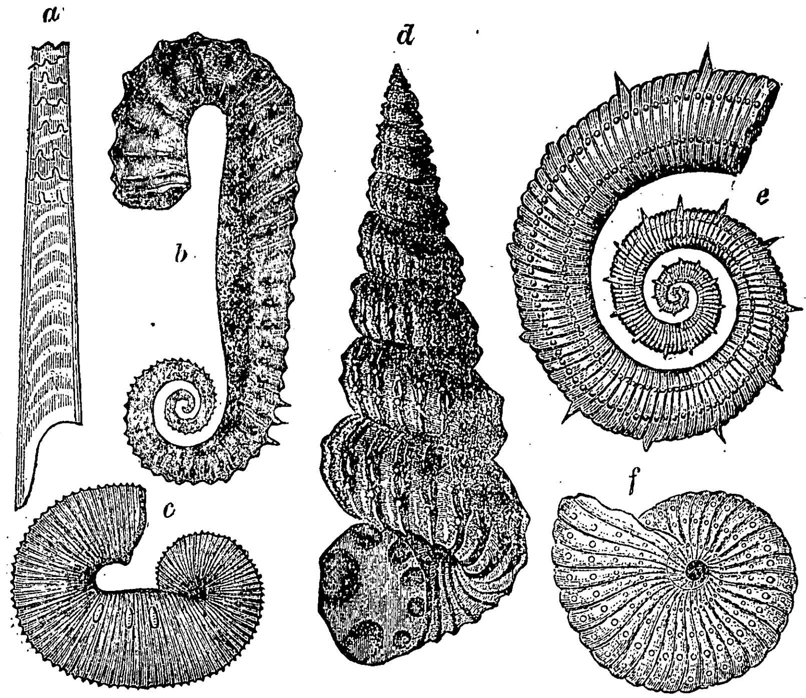


Jurassic Belemnites. *a.* Acanthoteusis antiquus (x ⅓). *b.* Complete osselet of a Belemnite, side view, reduced. *c.* Dorsal view of same. *d.* Belemnite clavatus. *e.* and *f.* B. paxillosus. *g.* Ink bag of Belemnite. (*Figs. from Dana.*)

Chalk Formation. These marked changes in the life-history were not attended with any notable variation in the standard method of submarine rock-accumulation, save in one instance, which deserves passing notice. More or less satisfactory evidence of the existence of *Rhizopods* in the earlier ages has been found, and they have sometimes been thought to have made larger contributions to rock-growth than could be asserted on the basis of proof. But in the Cretaceous period, Rhizopods developed, especially in western

Europe, a supreme importance, and gave rise, through the accumulation of their innumerable little shells, to the great chalk deposit, which characterizes the age.

FIG. 81.



CRETACEOUS CEPHALOPODS. *a.* Baculites anceps x ⅙ (Woodward). *b.* Ancyloceras Matheronianum. *c.* Scaphites æqualis (Pictet). *d.* Turrulites catenatus (D'Orbigny). *e.* Crioceras, restored (Pictet). *f.* Ammonites chicoensis (Gabb). (*Figs. from Le Conte and Dana.*)

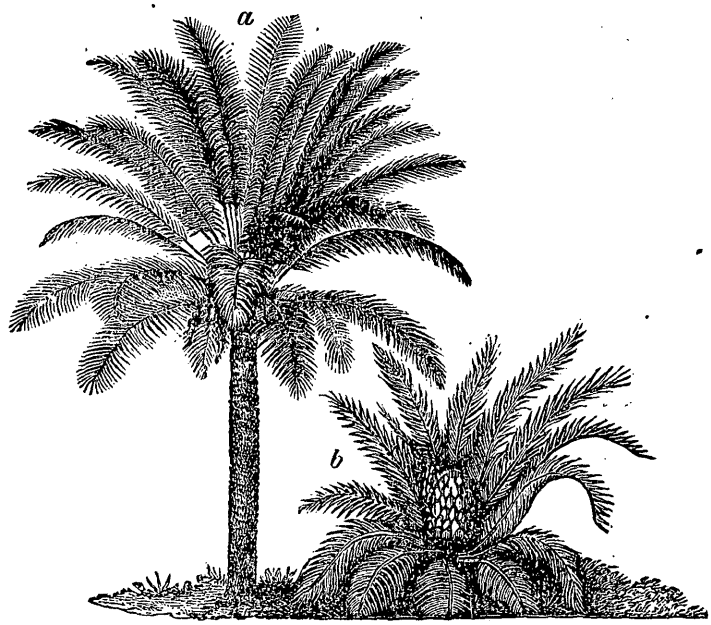
The Rhizopods are deep-sea species, and form deposits in the abysmal waters of the ocean, far out beyond the reach of shore-wash and silt-accumulation. How far back into more ancient ages this method of deposition in the depths of the ocean may have extended is unknown. Such accumulations are now in progress, and it has been plausibly maintained that the chalk accumulation of to-day is directly continuous with that of Cretaceous times.[1]

If there were sufficient basis in observation for the belief that in earlier ages these minute forms contributed largely to the formation of limestone, it would relieve us of a perplexing difficulty that frequently arises in the attempt to give a precise and detailed explanation of the manner in which vast sheets of limestone, nearly destitute of fossils, were formed. For, while in general terms it is

[1] Le Conte, Elements of Geology, p. 473 et seq.

easy enough to attribute them to the comminuted relics of Mollusks, Corals, and similar organisms, it is less easy to realize how such almost universal comminution could be accomplished under condi-

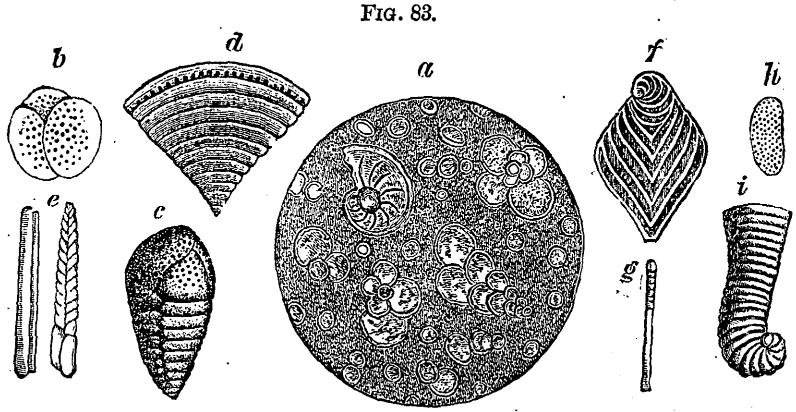
FIG. 82.



JURASSIC CYCADS. *a.* Cycas circinalis x 1-120—a living Cycad of the Moluccas (Decaisne). *b.* Zamia spiralis, a living Cycad of Australia.

tions so quiet as to permit of the accumulation of the resulting fine material. If it could be rationally attributed to fragile, microscopic organisms, whose structure had been destroyed by the molecular

FIG. 83.



CHALK-FORMING RHIZOPODS. *a.* Chalk as seen under the microscope (Nicholson). *b.* and *c.* Chrysalidina gradata (D'Orbigny). *d.* and *e.* Cuneolina pavonia. *f.* and *g.* Flabellina rugosa. *h.* and *i.* Lituola nautiloidea. (*Figs. from Dana and Le Conte.*)

and crystalline changes which all old limestones have manifestly undergone, it would contribute to our intellectual ease and comfort, at least.

Geography of the Age.

The theaters of rock-accumulation were more detached and scattered than in previous ages, owing to the growing extent and complexity of continental outlines. There were, (1) a narrow belt or series of detached basins along the Atlantic border,[1] (2) a broad bay occupying the lower Mississippi valley and stretching up to the vicinity of Cairo, (3) a very considerable arm of the sea reaching northward from the gulf through the region of the Plains to the Arctic sea, and (4) the several interlocked seas or bays between the Palæozoic lands of the western mountain region, whose boundaries have not yet been fully deciphered, and which, in any event, would be too complicated for summary description. (See accompanying geological map of the United States.)

The area of deposition approached us most nearly on the west. During the Cretaceous period, the waters advanced nearly across Minnesota, filling up the inequalities of the old eroded surface, and leaving a sheet of carbonaceous and calcareous sediment. Though a soft, erodable formation, a portion of it has survived to the present time. It is not impossible that it may have reached the Wisconsin borders, but no traces of it *in situ* have yet been discovered. Fragments of lignitic coal, that are possibly Cretaceous, have occasionally been found near the border, in the St. Croix region. But as the drift is here from the northwest, these may have been transported from Minnesota or elsewhere. The lignite may, however, be a local land deposit of uncertain age. Whatever may have been the extent of Cretaceous waters, it is worthy of note that there was a westerly depression which brought the western border of our State down again, nearly or quite, to the level of the sea.

Mountain Making.

The progress of the Mesozoic age was interrupted in America by the intervention of an epoch of mountain lifting, at the close of the Jura-Trias, separating it from the Cretaceous, and forming a natural two-fold division, in distinction from the three-fold European classification commonly adopted in our geological treatises. The great event of this epoch of disturbance was the elevation of the Sierra

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[1] Really the irregular edge of a more extensive deposit buried by later deposits of the Atlantic

Nevada range, with which the Wahsatch and some other members of the Cordilleran system appear to have sympathized to some extent.

Igneous Ejections. Another incident of the era was the extrusion of igneous matter along the Atlantic border region, from Nova Scotia to North Carolina. These ejections are closely confined to the areas of Jura-Trias sandstone. The igneous rock is associated with the sandstone in a manner seemingly similar to that of the Keweenawan system of Lake Superior. They have been adjudged, however, to be intrusions and not the result of overflows.

CENOZOIC ERA.

CHAPTER XIII.

TERTIARY AGE.

Elevation at the Close of the Mesozoic Age. At the close of the Mesozoic age there was a general elevation of the continent, affecting more especially its western portion, and connecting it with the main eastern area from which it had been previously separated by a long arm of the ocean — a mediterranean sea — stretching from the region of the present Gulf to the Arctic ocean. In connection with this general elevation there was an increase in the flexure of some of the pre-existing folds.

Lacustrine Deposition. The effect of general elevation above noted was to retire the sea to the very borders of the present continent, and its further constructive agency was confined to the laying on of a mere fringe to the continent, save that in the Gulf region, the Mississippi bay was filled, and the Florida reef projected. But as if to compensate for the retreat of the ocean and the relatively feeble part it played in continental construction, aqueous deposition assumed a new and important phase. Great lakes formed in the western interior of the continent, and carried on the work of sedimentation in a manner quite comparable to that of the ocean itself. So far as the American continent is concerned, the period might be designated *the Great Lake Age.* Successive groups of lakes mark the periods of the age, and their deposits cover large areas of the Great Plains and Cordilleran region, embracing within themselves the largest portion of the Tertiary deposits of the time.

These lakes were the natural result of the general elevation of the western region, and of the complicated system of mountain folds and faults which so pre-eminently characterize it. Between these rock-wrinkles, linear basins were formed, and in these the surface waters were entrapped, filling them to the brim and either overflowing or else reaching that state of expansion at which evaporation equals precipitation. For the greater part, the former condition prevailed in the earlier history of these lakes, while the latter is the prevalent phase assumed by their more recent successors.

Similar lakes were doubtless formed in earlier ages in regions where the strata were much warped or folded, but in none of those ages is there evidence that they became, as now, a conspicuous geological agency. Some examples may perhaps be found among the Triassic basins of the Appalachian region. At the close of the Post-Carboniferous revolution, it is probable that basins between the mountain folds were not uncommon in the Appalachian region. We have at times been inclined to refer the Keweenawan sandstones of the Lake Superior basin to ancient lacustrine action, but the scanty evidence seems rather to favor its reference to a gulf of the sea.

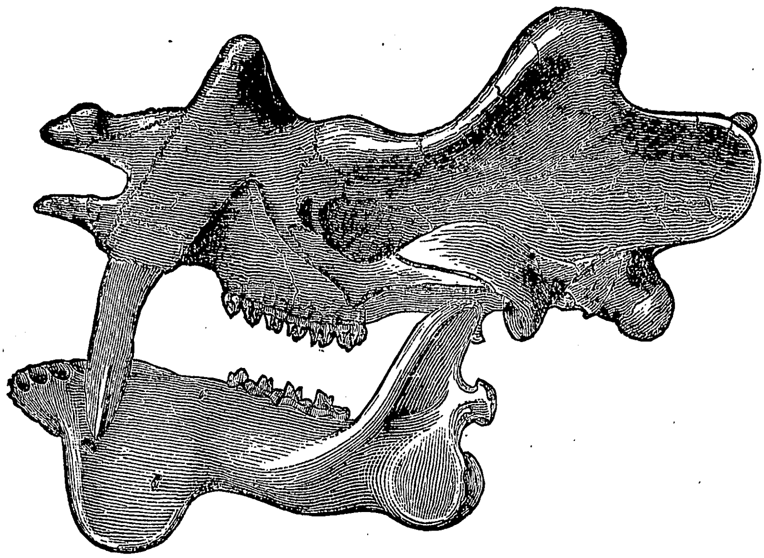
Life. The life which was gathered in the sediments of the great Tertiary lakes manifestly stands somewhat in contrast to that which was entrapped by oceanic deposits. The inhabitants of the waters were lacustrine instead of marine species. In addition to this, there was a very much larger contribution of land-life. The sweet waters, shallow shores, bays, and land-locked armlets of the lakes, were attractive resorts for all manner of land animals, quite in contrast to the bitter waters, rough winds, and violent waves of the ocean, which repel land-life, except such species as may be adapted to profit by these special circumstances. The result was a fossilized fauna of great richness and variety, embracing not only fresh-water forms, but the herbivorous and carnivorous species that frequented the lake shores, the insects and birds that gathered about them, together with the plant-life that flourished along their borders.

Dominance of Land Life. Land-life, therefore, assumes a predominant place among the fossils of the era, and in this betokens the progress of the age, for a signal feature of the dawn of the modern era was the passage of life dominance from the sea to the land. In all the earlier ages, marine life held undisputed pre-eminence. In the latest, while it may yet surpass in numbers, the scepter of power and superiority of organization has passed to the land.

The foreshadowing of this transition had appeared in the preceding ages, in the terrestrial Dinosaurs, the highest and the mightiest of the reptiles, and in the still higher, but less powerful birds. Among the forests, modern Angiospermous trees had largely replaced the ancient and inferior Acrogens and Gymnosperms.

Modern Aspect of Life. The life of the Tertiary age was of a conspicuously modern type. The change in forest types, already noted, was far advanced. The Tertiary groves were strikingly like those of our own warm-temperate zone. The animal-life was likewise, but less notably, modernized. The rule of the huge reptilian monsters had passed away, and their huge forms no longer shook the land. The great reptilian Dinosaur yielded to the still greater mammalian Dinoceras. The latter was an animal of great strength and elephantine proportions. whose skull presented three pairs of

FIG. 84.

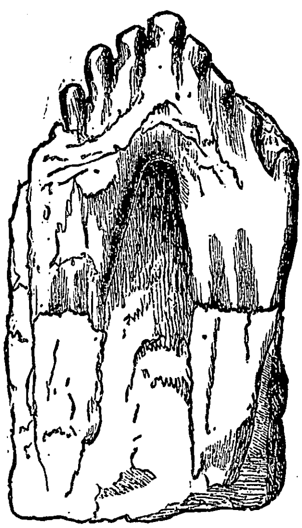


SKULL AND LOWER JAW OF DINOCERAS MIRABILE, x 1/8 (Marsh).

bony prominences like the bases of horns, one pair on the nose, one on the cheeks, and one on the forehead. If all of these were armed with horns, like those of the Rhinoceros, to which the animal bears a resemblance, it is little wonder that he displaced even the reptilian monsters. (It is quite possible, however, that the cold produced by the Post-Cretaceous elevation may have been more efficient in bringing about this result than the horns of the Dinoceras.) At the beginning of the Tertiary, the whole reptilian class sank to a subordinate position, and found safety in less unwieldy forms and in retreats less congenial to the mammalian type, which now succeeds to the supremacy, and becomes the characteristic life of the age.

Mammals. Among the mammalian forms, the more abundant at first were (1) the non-ruminant Herbivores, whose nearest present relatives are the Hog, Horse, Tapir, and Rhinoceras; (2) Rodents of the Squirrel type; (3) Monkeys, allied to the Lemurs, together with (4) Carnivores, akin to the Fox, Wolf, and Cat. Later, there were true Ruminants, Edentates, and other representatives of modern types.

FIG. 85.

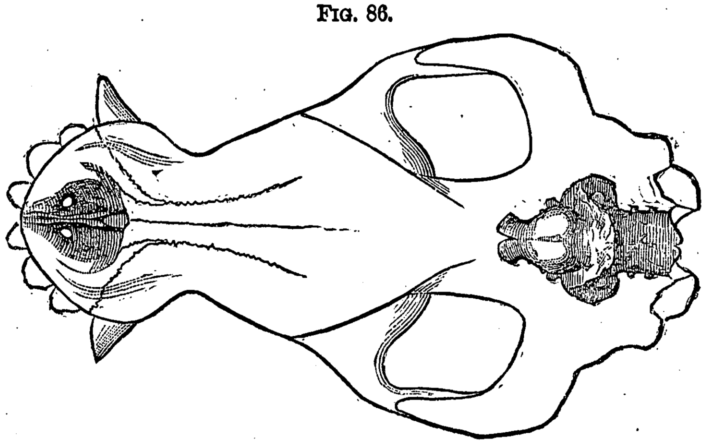


TOOTH OF ZEUGLODON CETOIDES x 2/3.

Marine Forms. Among the marine life that frequented the continental shores were Whales, Seals, Walruses and Dolphins, among which the most conspicuous was the Zeuglodon, which combined the characters of the Whale and Seal, and attained a length of 70 feet or more. These left their relics in great abundance on the shores of the ancient Mexican Gulf.

Special Mammalian Forms. Among the great group of mammalian forms, special interest attaches to the *Coryphodonts,* because of their comprehensive, undifferentiated character, to the *Dinocerata,* from their apparently unusual horn-development, to the *Tillodonts,* because of their peculiar rodent-like dentation, to the now celebrated *Eohippus* (dawn-horse) and *Orohippus* of the Eocene, and to their successors, the *Mesohippus, Miohippus (Anchitherium)* of the Miocene, and *Protohippus (Hipparion)* and *Pliohippus* of the Pliocene, as the predecessors of the modern horse, and to the Monkeys, because they are the first representatives of a type to which modern theories have given great interest. In the last epoch there appeared the first known species of the *Elephant* and the *Mastodon,* which became the monster forms of the Post-Tertiary age. The saber-toothed Lion, Tigers, rivaling in size the Bengal of the

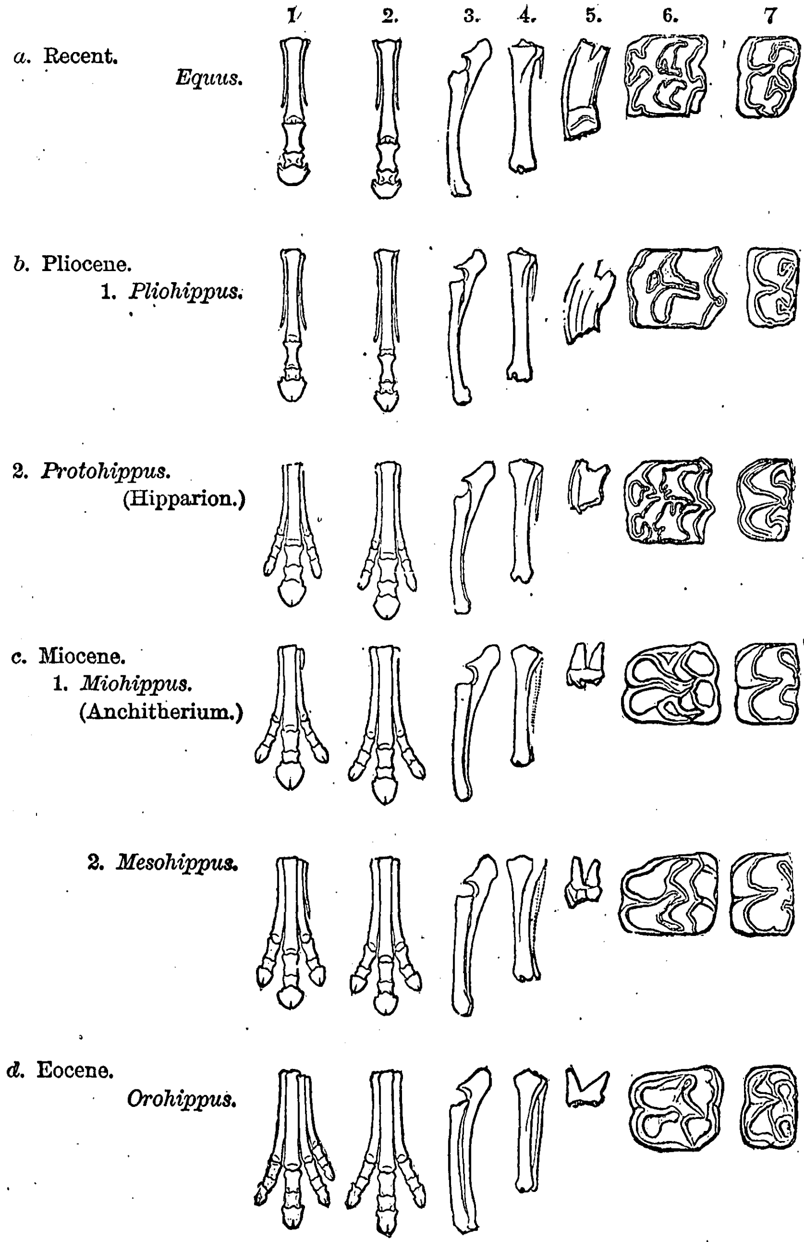
FIG. 86.



OUTLINE OF SKULL AND BRAIN CAVITY OF *Coryphodon hamatus,* about 1-5 natural size (Marsh).

present jungles, true Camels, Deer, and insectivorous and other modern mammals appeared toward the close of the Tertiary. On the eastern continent, the *Dinotherium*, *Palæotherium*, and other strange forms, attended with a full menagerie of Carnivores and Herbivores, characterize the life of the age.

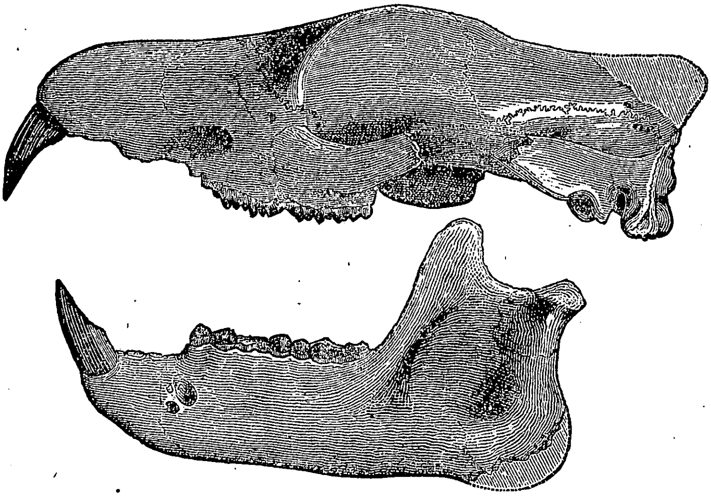
FIG. 87.



ILLUSTRATIONS OF THE CHARACTERS OF SUCCESSIVE GENERA UNDER THE HORSE TYPE. (From Marsh.)

As remarked concerning the Reptiles of the Mesozoic, the development of the Mammals in the Tertiary age was rapid, and the expansion of the type remarkable.

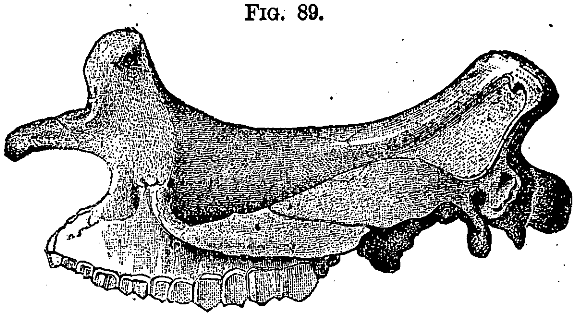
FIG. 88.



SKULL AND LOWER JAW OF *Tillodontia* (Marsh).

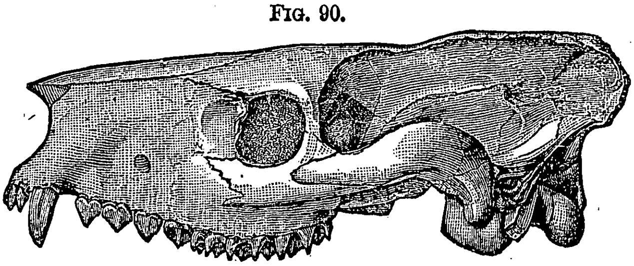
Birds. Birds had assumed the modern form. Their toothed jaws had given place to beaks, and their long reptilian tails had been abbreviated.

FIG. 89.



SIDE VIEW OF SKULL OF BRONTOTHERIUM INGENS x 1-12 (Marsh).

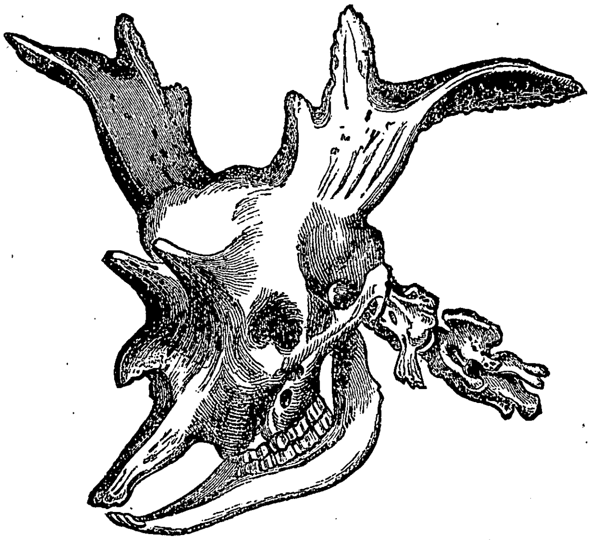
FIG. 90.



EPOREODON MAJOR x ¼ (Marsh).

In the seas the invertebrate life had, in all its great branches, made progress toward modern forms, but these changes do not demand notice in detail.

FIG. 91.



HEAD OF A MIOCENE MAMMAL. Sivatherium giganteum, greatly reduced.

FIG. 92.

NUMMULINA LÆVIGATA.

DISTURBANCES.

Mountain Making. The quiet progress of the era was interrupted by orographical disturbances. At the close of the Eocene period there was a moderate elevation along the Atlantic. At the close of the Miocene, the Coast range was formed, and the western area, generally, involved in the movement. At the close of the Pliocene, or in other words, at the close of the age, there was a general continental elevation which lifted the whole to a height several hundred feet above its present altitude. This appears to have been most felt at the north, where there are evidences of elevation to a height of 1,000 feet to 2,000 feet above the present continental position.

In foreign countries even more considerable disturbances occurred, so much so that the age apparently surpassed all preceding ones since Archæan times, in the mountain flexures produced. The Pyrenees, Alps, Appenines, Carpathians, Himalayas, Andes, and doubtless others, whose geological history is unknown, received their final elevation in this age. It would be an error, however, to assume that these mountain systems were produced *de novo* at this time. Their real growth, in many instances, doubtless in most, began far back toward the beginning of the history of the earth's corrugation, but they received their last and most conspicuous uplift in this late era.

Igneous Eruptions. From the Miocene period onward to the Quaternary, indeed almost to the present, the western mountain region has been the theater of extraordinary igneous activity. Nor is that region alone in this respect. South America, Europe, southeastern Asia, and other less well known regions, experienced similar volcanic activities. Indeed the Tertiary age might be designated the Age of Eruptions. A part of this seeming predominance is doubtless due to the superficial position of the ejected material, and the fact that it has not been so largely removed by subsequent disintegration as similar formations of earlier periods. Nevertheless it appears clear that there was a real preponderance of igneous activity, though it may have been inferior to the igneous display of the closing Archæan age.

In the western region there were great eruptions of both the crater and fissure types. Immense volumes of molten rock came welling up from the depths of the earth, intruding itself more or less widely among the rocks through which it passed, and spreading itself upon the surface in great sheets, only to be succeeded, again and again, by similar out-flows until a great series of igneous sheets were piled up.

Recent investigators (Richthofen, King and Dutton) are agreed in the observation that the earliest ejections were of the chemically intermediate class, represented by propylites, and andesites, that these were succeeded by the more acid trachytes and rhyolites, while the last flows were the basic basalts.

Among the many other instructive lessons which this observed succession may teach, when its cause and history are fully elucidated, is one of importance to students and unscientific readers, viz.: that volcanic phenomena are not, in their real nature, sudden and convulsive, but are rather intermittent manifestations of what is really a very slow action that runs a long course, stretching over a great lapse of time, during which varying series of products are thrown forth at successive, but often widely separated intervals. While sudden catastrophes of limited extent are characteristic of geological history, yet the too popular conception of convulsions, affecting profoundly whole continents or mountain ranges, or any considerable proportion of the earth's crust, are the products of an unrestrained imagination, utterly unsupported by geological evidence. The earth throughout known geologic history, at least, has always been a quiet, steady-going, well-behaved planet.

CHAPTER XIV.

GEOLOGICAL WORK IN WISCONSIN BETWEEN THE DEVONIAN AND GLACIAL PERIODS.

In pursuing the course of geological history through these later ages, we have been led away from the boundaries of Wisconsin into regions more and more remote, until, at the close of the Tertiary age, we find ourselves on the borders of the continent itself. But has Wisconsin no recorded history during the interval? Most assuredly she has her record. Wisconsin played her part in the enactments of the later ages, as in the earlier, but it was not in the sphere of growth, but of denudation. Wisconsin was not receiving, but giving. The growth of the younger areas was at the expense of the older. After her own early completion, Wisconsin thenceforth gave of her substance to the building up of her younger sister States.

Erosion. Leveling of the Heights. We have seen that the marine growth of our State ceased with the Middle Devonian, at which time it ascended finally from the ocean, so far as demonstrative evidence shows, and thence forward became dry land. From this time onward, to the close of the Tertiary, its history is that of erosion. From the very earliest appearance of *Isle Wisconsin*, that portion exposed to atmospheric agencies had been decomposed and washed down to the sea, while a relatively small portion was driven away by the winds. As the land enlarged by the gathering of its rocky wrappings about it, the area subject to erosion increased, and when at length it was completed, she entered fully on a long history of erosion, that was only interrupted by the extraordinary work of the glacial period to be presently described. During this interval, the mountainous Archæan portion was cut down from its once lofty height essentially to its present low altitude, and relatively smooth surface. Instead of a height of thousands of feet to which the northern part of the State once attained, it is now nowhere more than 2,000 feet above the sea.

Carving of the Plains. Quite in contrast with this leveling of the mountains was the effect upon the Palæozoic strata that occupy the southern portion of the State. When these first ascended from the ancient sea, they presented an exceedingly plane, smooth surface. Under the wear of the ages, however, these plains were channeled and carved into hills and valleys by running streams. Precisely what kind of surface was formed is known from a study of the driftless area of the southwestern portion of the State, for on this region the agencies of the glacial period did not act, and it remains to-day an unmarred monument of the erosion that began as early as the Devonian age, and continued to the present time. A glance at any good physical map of that region will show the peculiar, dendritic symmetry with which the little streams gather into the larger, beautifully illustrating the typical character of a drainage which began upon an essentially plane surface, and carved its lines in horizontal formations. By glancing at the geological maps accompanying this report, the beautiful manner in which these streams have successively cut through the underlying formations of the area, giving to them intricate outlines, will be seen to be quite unique. Similar surfaces were doubtless presented throughout the entire area of the horizontal strata, but they were elsewhere much modified by glacial agencies.

A Comparative Measure of Glacial and Pre-glacial Effects. We have in this close contiguity of glaciated and non-glaciated areas of the same age and formation, a circumstance of great advantage in estimating the character, and precise effects of the glacial agencies. We are not left to those wild drafts upon an unrestrained imagination that sometimes characterize views entertained of glacial action.

It becomes, therefore, a matter of much theoretical interest, as it is of much practical concern to all industries affected by topography, to study the origin and character of the surface inequalities of the State.

Features Due to Flexures of the Strata. The Laurentian upheaval, predetermined, in that most ancient period, the great drainage systems of the State. From it, as an elevated center, the waters have been shed, throughout all subsequent ages, toward all points of the compass, upon the surrounding lower lands. As the result of this prime cause, modified by the circumstances of later times, there arose the salient topographical features of the State, viz.: a central elevation, with a short, abrupt declivity northward, and a long sloping decline to the south, attended by corresponding drainage systems.

Among the modifying circumstances of later ages, the most prominent was the elevation of a low broad arch, extending southward through the central portion of the State. This low swell is broad at the north, where it abuts against the Archæan elevation, and tapers gradually southward to a point, and dies away in northern Illinois. This divides the southern slope into two subordinate ones, the one declining gently to the southeast, and terminating in the basin of Lake Michigan, the other to the southwest, and, as a present drainage feature, is terminated by the Mississippi river, but stratigraphically extends onward under Iowa and Minnesota to somewhere near their centers. There is, therefore, a southeastward and a southwestward drainage slope.

The symmetry of this system is broken by Military Ridge,[1] a transverse elevation extending obliquely from north of east to south of west, across the central axis, in the southern portion of the State. This ridge diverts to the right and to the left, in a quite remarkable manner, the streams descending from the north. The Wisconsin river, which lies throughout all its upper course on the back of the low central arch, turns abruptly westward on encountering Military Ridge, and flows along its northern face until it joins the Mississippi, and thereby passes around its western extremity. All the streams on the east on encountering it turn abruptly to the northeast, and find escape into the valley of Lake Michigan. Along the south face of Military Ridge, the waters for a stretch of no less than 150 miles in extent, gather themselves together to form the Rock river. Other transverse swells similar to Military Ridge, but of less importance, give rise to minor features of topography and drainage.

These grander features are mainly the result of flexures of the strata, some, as those affecting the Archæan strata, of the most profound character; others, as those affecting the Palæozoic strata, of the most gentle and subdued nature.

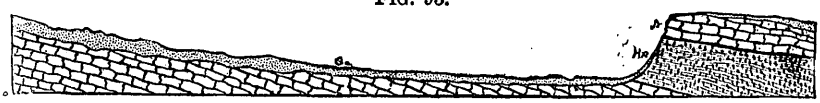
Features Due to Erosion. Another and scarcely less important class of physical features arise, not from elevations or bendings of the strata, but from peculiarities of erosion. It is obvious that if a group of strata are exposed to wear, those which are most resistant, either because of hardness or insolubility, will be relatively less affected than those of a more yielding character, and inequalities of surface and peculiarities of drainage will result. This will be especially true if the strata are somewhat inclined, and present their upturned edges to erosive action, as is the case with the inclined beds on the eastern and western flanks of the central arch of the State.

The most striking topographical feature that owes its origin to

[1] This term is commonly applied only to that portion of the ridge in the southwestern part of the State, where it is more conspicuous than elsewhere.

such a cause is the Green-Bay-Rock-River valley. By reference to the maps and numerous sections of the region found in Vol. II and the atlas, it will be seen that this notable valley lies in the horizon of the soft Hudson River (Cincinnati) shales, having for its floor, mainly, the hard Galena limestone. On the east it is bordered by a protecting sheet of the hard resisting Niagara limestone. The valley owes its origin to these stratigraphical circumstances. The soft shales are easily worn and washed away, thereby continually undermining the more obdurate limestone, causing it to stand forth in mural escarpments, or to rise in abrupt slopes on its eastward side, while on the other hand, the hard, sloping floor of the underlying limestone, kept the streams, in pre-glacial times, hard against the eastern wall.

FIG. 93.



SECTION across the Green Bay valley, illustrating its relations to the Galena limestone (*Ga.*), upon which it is based, to the Hudson River (Cincinnati) shales (*H. R.*), in whose horizon it mainly lies, and to the Niagara limestone (*N.*), which forms the cliffs bordering it on the east.

On the east side of this valley, the rock slope inclines regularly toward Lake Michigan, and the pre-glacial streams doubtless pursued regular courses down the slope. Their present directions are marked by many anomalous features, but these are mainly due to the drift, for the discussion of which we are not yet prepared.

Many interesting minor features in other portions of the State are likewise due to differences in the resisting power of the strata. Among these are the numerous instances in which the Lower Magnesian limestone stands forth in cliffs, rough outliers, rude embattlements, or castellated towers, over-jutting the Potsdam sandstone, whose easy removal has set them forth on the crowns of the hills. Similar, but usually less striking and picturesque projections, are caused by the rapid removal of the St. Peters sandstone, leaving a protruding cap of the overlying Trenton limestone. The western half of the State, especially in the immediate vicinity of the Mississippi, is rendered picturesque by the free-hand carving of the artist Time. There is here no rivalry of the wonderful West, but, without destroying its industrial value, nature has given, at once, relief to her structure, and beauty to the landscape, while teaching an instructive lesson in the laws of her sculpture.[1] From the almost level plains of Central Wisconsin, there rise abruptly to a height sometimes exceeding 200

[1] Some of the chromo-lithographs of the report exhibit examples of this.

feet, castles and towers of sandstone, the monumental remnants of an eroded formation, whose preservation is due to a protecting crown of resisting rock.

In the region of the crystalline rocks, the same principles of unequal erosion held sway, but found a different expression in harmony with the character of the rock. Penokee Range owes its prominence to the hard, silicious schists that form its crest. The Baraboo quartzite ranges stand forth boldly because of the extreme hardness of the quartzites that compose them. They have not only resisted the erosion of the later ages, but they withstood the elemental wars and the wave-beatings of the Primordial ages. The scattered knobs of quartz-porphyry of Central Wisconsin are monuments of similar endurance. The Rib and Mosinee hills of the Wisconsin Valley, the quartzite ridge that diverts the Chippewa river at the mouth of the Flambeau, the cliffs of the Pipestone region of Barron county, the iron-bearing mounds of Black River Falls, the Watseewinse mountain, and neighboring ridges in the Peshtigo valley, and the quartzite ridges of the Menominee iron region, are all protuberances due in like manner to superior endurance. The ridges of the Copper-bearing series, and especially their peculiar saw-tooth sky-lines, are due to the combined effects of inclined strata and unequal hardness.

The Great Depressions. *The Valley of the Mississippi.* From this consideration of the prominences of the State, we may turn to its depressions. The great features that deserve attention under this head are the Mississippi Valley, and the basins of the Great Lakes. The course of the Mississippi river, when considered in relation to the underlying strata, is peculiar. It lies upon the edges of sloping strata, which reach their summit height along the central arch of Wisconsin, and dip downward beneath Iowa and southern Minnesota, and find their greatest depression somewhere in the interior of those States. Along the out-cropping edge of this sloping series, the Mississippi pursues a curving course, approximately coinciding with the strike of the beds. It is manifest, therefore, that its course was not established by the depression of the strata, else it would have passed more directly southward from St. Paul, through central Iowa.

If our interpretation, based upon a fuller consideration of the circumstances of the case than is here admissible, be correct, the course of the Mississippi here represents approximately the shore-line of the Devonian sea at the time of its last advance upon our territory. The course of the river is thought to have been determined along the shore-line by its beach accumulations and its erodable littoral deposits, just as the course of the lower Milwaukee and that of the Des Plaines were determined along the shore of Lake Michigan by much feebler beach action in later times, and just as scores of other river-courses have been determined by similar circumstances. It is scarcely necessary to remark that the thin edges of the Devonian strata have since been worn away, but they appear at no great distance to the west. These remarks apply only to that portion of the Mississippi river which lies adjacent to Wisconsin and which traverses, for the most part, a driftless region. The special channel of the uppermost portion, as well as that of the lower stretches, is found in greater or less measure in Quaternary deposits, and is doubtless of post-glacial origin, but even in these portions the river has probably followed approximately its old course.

Greater Depth of Ancient Channels. The Mississippi river now runs in a channel at least 100 feet above its ancient bed. An artesian well at La Crosse shows loose material to the depth of 170 feet, and one at Prairie du Chien, to a depth of 147 feet. The surface at the latter well is about 40 feet above the surface of the river, that of the former, by eye-estimate, is about the same, but no trustworthy measurement is at hand. These borings are on the side of the valley, and probably do not represent the maximum depth of the ancient channel. Rock river, a tributary of the Mississippi, runs, at Janesville, at least 250 feet above its ancient valley, a fact which strengthens the probability that the maximum depth of the ancient Mississippi channel was greater than that indicated. That the valley was filled, during the drift period, to a height of from 50 to 75 feet above its present surface, is shown by the observations of Mr. Strong on its gravel terraces. It has been re-excavated to its present depth since the glacial period.[1]

The Basin of Lake Michigan. When we attempt to discuss the erosion which has been accomplished in the valley of Lake Michigan in pre-glacial times, we tread upon battled ground. Certain geologists maintain that the great basin now occupied by the lake owes its essential features to glacial excavation, performed in the period next succeeding the era now under consideration. Others, on the contrary, maintain that it is only a slightly modified river-valley, whose outlet was blocked up by glacial debris, and is not, in any essential measure, due to glacial erosion. A full consideration

[1] Major Warren has maintained (Am. Jour. Sci., Dec., 1878), that the entire Mississippi valley was excavated since the glacial period, but there is overwhelming evidence that this view is not applicable to the portion under consideration.

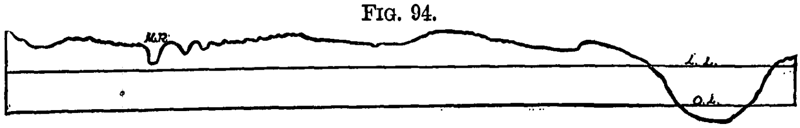
of the question manifestly involves a critical study of the glacial action that ensued in the next period, but it may be as well for the judicial character of our final conclusion, to consider now, before we have become impressed by the peculiar agencies of the succeeding period, what was the probable amount and character of the pre-glacial erosion. We are in an exceptionally favorable position for doing this.

If we place ourselves upon the low central arch of our State, in the middle of the Devonian age, we shall find the sea wrapping around the southerly projecting point of land, and encroaching upon our borders on the east, and probably touching them on the west. If there was a greater incursion and consequent preponderance of deposition on either side, it was manifestly on the east, for a remnant of the formation remains, notwithstanding all that may have been removed by pre-glacial action, and all that may have been cut away by the glacial erosion which affected that border, but was entirely absent from the other. It is, therefore, manifest that no erosion antedating this period can have favored the eastern side as compared with the western. If we examine the slopes of the arch, we shall find no essential difference. If we examine the water-shed areas, we shall find at least an equally great drainage descending on the west. If we attempt to estimate the entire amount of territory tributary to the Mississippi on the one hand, and to a supposed river occupying the basin of Lake Michigan on the other, it appears quite manifest that the advantage is in favor of the Mississippi. If we consider their relative slopes — an important consideration in determining erosion — it is difficult to find a basis in known fact, or in the probabilities of the case, for the belief that the Lake Michigan area was the more favorably situated for erosion, unless it be maintained that the depression of the Cretaceous period was more unfavorable to the erosion of the western than the eastern side, which would depend upon the special attitudes the two slopes assumed, which is essentially unknown.

If we descend to more direct evidence, and examine the extent to which the strata have been cut away from the slopes of the arch on either hand, it is a conspicuous fact *that the worn edges of the strata are farther away from the water-shed on the west side, than they are on the east side*, as a glance at the geological map will show. That some of the strata, at least, once overlay this arch, is made clear by remnants in the southern part of the State. The "Blue Mounds," for instance, are capped by Niagara limestone, and lie only a few miles west of the axis of the arch, and belong to the western slope, but they are nevertheless nearer the main body of the Niagara on the east, notwithstanding the fact that the latter has been subjected to glacial planing, in addition to pre-glacial erosion. The same mounds demonstrate that the Hudson River shales, an especially erodable formation, originally curved over the water-shed. But on the west they have been cut away to some distance beyond the Mississippi (except remnant patches), while on the east they appear as a continuous sheet 40 miles west of the lake. The present position of the Silurian strata, therefore, not only does not favor the idea of exceptionally great erosion upon the eastern slope, as compared with that of the western, but points directly to an opposite conclusion, though the difference is not great.

Again, we have thus far failed to find on the Lake Michigan shore the deep tributary valleys which should characterize it, if it had been on the margin of so deep a valley as that of the present lake. The deepest drift penetrated by artesian wells, so far as known to the writer, is 170 feet. It will be no answer to this to maintain that these tributary valleys were entirely filled, and concealed by glacial drift, for the recorded striæ, and other evidences of drift movement, show that the ice pushed westward from the lake, a direction favorable to the excavation, rather than the filling of such tributary valleys. Furthermore, the thickness of the drift in this region is not such as to fill and conceal important river valleys. We, therefore, fail to find a trustworthy basis in the facts of the case, for supposing extraordinary erosion upon the eastern borders of the State, as compared with the western.

FIG. 94.



PROFILE from Minnesota to Michigan across Wisconsin, near the parallel of 44° N. latitude (i. e., near the center of L. Michigan), showing the relative characters of the Mississippi and Lake Michigan valleys. Data drawn from railroad and lake surveys. The line *L. L.* represents the level of Lake Michigan. *O. L.* the ocean level.

It will be instructive in this connection to compare the character of the Lake Michigan basin with that of the Mississippi valley, an unquestioned example of river excavation. The bed of Lake Michigan constitutes, as Dr. Newberry has well pointed out, a broad, boat-shaped depression, 60 to 80 miles wide, *descending more than* 300 *feet below the sea level, and more than* 800 *feet below the ancient bed of the Mississippi;* or, what is really the true basis of comparison, *about* 1,200 *feet below the Mississippi valley, excluding its narrow cañon, which would be filled in the bottom of a glaciated lake basin.*

The accompanying profile makes evident the great difference between the two valleys.

An inspection of the Lake Survey charts shows an absence of the pronounced topographical features that characterize surfaces arising from river erosion.

But another consideration of grave moment arises when we consider the possibility of an outlet for the waters which are supposed to have performed so great erosion. As before observed the present mud-bed of the lake lies 300 feet below the ocean level. It is fair to allow at least 100 feet or 200 feet for the sedimentary accumulations in the bottom of the lake, for not only a sheet of glacial drift presumably lies there, but the sediments of all subsequent time. From the known thickness of these upon its shores, and the large amount of material that is yearly being eroded from its banks and carried back into the deeper waters of the basin, the thickness of the latter is probably considerable, so that the rock bottom is probably at least 400 feet or 500 feet below tide water.

It is manifest, therefore, that if eroded by river-action, the bottom must not only have been elevated the 400 feet or 500 feet necessary to bring it to the sea level, but as much more as would be requisite to cause the water to drain away to the distant ocean, with the velocity requisite for efficient erosion. Four hundred feet is thought to be a very moderate allowance for this additional elevation, and 500 feet would be necessary to any great efficiency. This makes the total requisite elevation from 800 feet to 1,000 feet. But this elevation must have affected the Mississippi valley, and would, we reason, have given it an altitude which would have caused an erosion vastly exceeding that actually found, for the underlying formations are as erodable as those of the Michigan basin.

This difficulty is not satisfactorily escaped by assuming a tilting of the land, for the other great lake basins present similar extraordinary features, and any supposable elevation which will satisfy the conditions of the whole problem must be widespread, and necessarily involve the whole of Wisconsin. Furthermore, any such tilting ought to have manifested itself in its effects on the shape and contour of the Mississippi valley, but such features have not been discovered.

Another grave consideration presents itself when the question of the outlet of this supposed river is raised. If it were competent to excavate so broad and deep and smooth a basin as that underlying Lake Michigan, it seems necessary to suppose that it must have eroded a correspondingly broad and deep valley down to the sea.

It is taxing our credulity heavily to suppose that a river could excavate such a boat-shaped basin as Lake Michigan presents, and yet have a narrow, cañon-like outlet to the sea, through precisely similar formations — very heavily, indeed, if we suppose that the same phenomenon is repeated in the case of each of the Great Lakes. It is manifest that no such broad valley formed the outlet of Lake Michigan, much less so of Lake Superior. It is maintained that an old channel, having a depth of perhaps 200 feet, has been traced south from Lake Michigan to the vicinity of Bloomington, from which point it probably extends onward. It has been urged, and apparently with very good reason, that this was an old channel of discharge from the area of Lake Michigan. The depth of this, let it be observed, is quite harmonious with that of the ancient valleys of the Rock and Mississippi rivers, and lends support to the view that, in pre-glacial times, a river drained the Lake Michigan area southward, into the Mississippi, and that it was then eroded in a manner quite similar and to a depth quite comparable to that of the area on the west side of the Wisconsin arch. In short, all the evidence which we can gather, after eliminating glacial agencies, seems to support the simple, rational view, free from violent hypotheses, that erosion upon the east and west sides of our State in pre-glacial times went forward in like manner and with like results, giving rise on the one hand to the Mississippi valley, and on the other to a similar valley occupying the site of Lake Michigan.

That the Michigan valley may have been broader and deeper than the Mississippi, may perhaps have been true, but aside from the necessity of explaining the present great basin, it is difficult to assign good reasons for such a supposition. The writer has ground for theoretical bias in favor of the hypothesis of a deep, broad, pre-glacial valley, as will appear from the discussion of the courses of the subsequent glacial movements and the cause of the driftless area, but this is not deemed a valid reason for magnifying pre-glacial erosion beyond what a fair estimate of evidence and the necessary circumstances of the case warrant. While, therefore, it is maintained that a valley of very considerable dimensions occupied the lake basin, it is not believed that it had the breadth and general depth and symmetrical contour which the lake now presents.

The Basin of Lake Superior. If we turn our attention to the greatest of the lakes, we shall find that it presents features of the same extraordinary character. Though less regular in contour of margin and bottom, it is, like Lake Michigan, a broad, deep basin, descending more than 400 feet below the ocean level. It has sometimes been remarked that Lake Superior occupies a synclinal trough, and that, therefore, no appeal to erosive forces is necessary to account for its origin. But this is a misapprehension. The stratigraphical trough which it occupies was formed in ancient Keweenawan times, and was subsequently filled — during the Cambrian and Lower Silurian ages — to some hundreds of feet above the present lake level, with horizontal sedimentary accumulations. It is, therefore, as necessary to account for its excavation as though the Silurian beds were parts of a wide-spread horizontal series, as in the case of the other Great Lakes. But in this instance, the south shore is bordered, throughout almost its entire extent, by an elevated rock terrane. It is only toward the east, near the extremity of the lake, that there is any doubt as to its continuity.

Now let it be observed again that a river system, supposed to be competent to excavate the basin of this greatest of known lakes, should have a broad valley leading out to the sea. The eastern portion of the Peninsula of Michigan presents no evidence of such a broad, deep valley, but on the contrary, a collation of known outcrops, shows that no broad valley existed. The glacial forces moved in such directions as to have further excavated it, had it existed, and to have kept it open, as in the case of the lake basins on either hand. Its supposed position was directly in the channel of great glacial movement, and it is quite incredible that the present topography could have been assumed if such a broad valley ever existed. The case is different with a cañon-like valley which might be the outlet of a somewhat considerable drainage system, which carved the basin somewhat deeply, as rivers do. But this is quite a different hypothesis from one which presupposes the excavation of a broad basin, 1,000 feet or more in maximum depth. Solvent agencies were here inoperative, because of the insoluble nature of the sandstone removed.

We, therefore, arrive at the same conclusion concerning the preglacial work of this region, that has been previously stated in relation to the Lake Michigan basin, viz.: that while it was the site of a very considerable drainage-erosion, its surface was left, like that of the Mississippi valley, on the opposite side of the Archæan nucleus, deeply carved and creased by stream-channels, but not excavated into the broad deep basin now presented.

It will be remarked that this discussion is confined as closely as practicable to those phases of the question of the origin of the Great Lake basins which enter as topographical features into the study of Wisconsin. The question of the Origin of the Great Lake

Basins, considered by itself, demands a much wider collocation of facts and comprehensiveness of discussion, and necessitates, of course, a full consideration of glacial and other possible agencies. The continuation of the discussion must therefore be deferred till the glaciation of the region shall have been considered.

Former Extent of Palæozoic Formations.

From the discussion of the erosion which the face of the State suffered during its long exposure to atmospheric agencies, we find an easy passage to the consideration of the question of the former extent of the strata.

Recalling the method of their formation as marine sediments, it is manifest that, when first elevated, they must have presented smooth margins, curving gracefully about the primitive island. As we now find them, however, their edges present sinuous and jagged outlines, off the margin of which lie detached outlying areas, while, within the margin, the beds have frequently been cut through by the channels of streams. All this is manifestly the work of drainage-erosion. The relationship which these ragged edges bear to the streams that formed them is too conspicuous to escape even casual observation. These rocky wrappings of the State have been frayed out by the wear of time.

The outlying patches afford us much aid in determining the former extent of the strata. The most conspicuous examples are found in "The Mounds" of the southwestern portion of the State. These are elevated prominences, which owe their long escape from the wear that swept away the whole of the surrounding formation mainly to two circumstances: first, they stood upon the ancient water-shed, and hence were less exposed than adjacent areas to the wear and solution of drainage, and second, to the fact that they are capped by a protecting crown of exceptionally hard, silicious Niagara limestone. The bases of the mounds are formed of Cincinnati shales.

When the position and relation of these mounds is considered, it becomes quite clear that the Niagara limestone once extended from the eastern portion of the State over the central arch, embracing the Blue Mounds which stand near its summit, and the Platte, Sinsinawa, and other mounds on its western slope, and joined the great Niagara limestone area that underlies Iowa and Minnesota on the west. But it is manifest that an erosion which swept away forty miles of strata on the south of the Blue Mounds must, during the same period, have cut away a considerable formation on the north.

It is a necessary inference, therefore, that this formation originally covered a very large area in the southern portion of the State. Similar observations upon other formations lead to similar views concerning their former greater extension.

It is our judgment, from a somewhat careful consideration of the data bearing upon the subject, that the Potsdam sandstone, and Lower Magnesian and Trenton limestones, originally wrapped entirely around the Archæan core of the State, but that they never buried the island thus formed, which always stood as a source of material and a sentinel of the growing State, whose motto, "Forward," impressed thus early upon it by Nature's seal, forbade it, having once risen from the ocean, ever again to subside completely beneath it. The Niagara group may once have covered one-third of the area of the State, embracing the older nucleus between arms extending high up on either side, but probably not surrounding it. The Devonian beds probably only extended a short distance inland from the Michigan shore, while on the western side, their probable limit, as already suggested, was the present position of the Mississippi river.

CHAPTER XV.

QUATERNARY AGE.

As here classified the Quaternary Age embraces only a single period, and that a relatively short one, but its nearness and importance to us have naturally led us, as in the case of all the later ages, to relatively magnify it. Its subdivisions may be thus presented:

Quaternary Age — Glacial Period.	Terrace or Fluviatile epoch. Champlain or Lacustrine epoch. Second Glacial epoch. Interglacial epoch. First Glacial epoch.

First Glacial Epoch. We now approach a most remarkable chapter in the earth's history. In Nature's writing it is recorded on the worn, polished and engraved surface of the rocks, and registered in that mantle of commingled clay, sand, gravel, and rounded rock of diverse character, which covers not only the greater portion of our State, but all the northern interior and eastern States, together with a large part of the British possessions, and extensive areas elsewhere in the higher latitudes of both hemispheres. The true interpretation and the discussion of the cause of the phenomena and the precise method of deposition, has not yet completely emerged from the region of doubt and conflict, and properly enough so concerning some portions, owing to the diversity of the deposits. But the facts concerning the leading features of the formation in Wisconsin, taken in connection with observations elsewhere, are so clear and decisive that we shall adopt the language of positive narration. This is done, however, for the sake of ease and simplicity of description, rather than from a disposition to ignore opposing opinion.

Accumulation of Ice. The climate of the Tertiary age was, in the main, warm, as shown not only by the character of the animal inhabitants of the continent, but by the existence, in Arctic regions, of a warm-temperate fauna and flora.

Quite in contrast with this, the Quaternary age was inaugurated by a period of exceptional cold. The rigor of the climate was such in northern regions that the snow-fall of the winters failed to

FIG. 95.

THE VIESCHER GLACIER, SWITZERLAND (from a photograph). The white portion on the distant mountain slope is the *neve* or snow-field, the source of the glacier. The line of rock-rubble in the center of the ice-stream is formed by the union of two glaciers near the source. The rubbish on either side, near the extremity, constitutes a portion of the lateral moraine. The glacier terminates a short distance below, indeed the melting edge is shown in the foreground.

disappear during the summer, and a certain residue of snow was left over as a foundation for the new fall. It is manifest that this remnant would, by its cooling effects, hasten the snow-fall of the following autumn, and tend to increase the accumulation of the succeeding winter, as well as to augment the intensity of its cold and prolong the season of snow-fall into the spring, and so in turn to strengthen itself for the resistance of the heat of the succeeding summer. Thus there was a tendency to cumulative effects.

Through the continued operation of the original cause of cold, thus aiding itself by its own effects, there gathered in time a great depth of snow upon the northern regions. The full extent of the snow-fields thus accumulated cannot be positively stated, but that they were immense is beyond question. In accordance with physical principles well illustrated in the perpetual snow of Arctic and Alpine regions, the accumulated mass solidified below by virtue of its own pressure and natural tendency to coherence, aided by the penetration of water melting above and congealing below. Thus the snow-field became an ice-sheet, only snow-frosted, as it were, on the surface.

Glacial Flow. This is not so remarkable, but it is an almost incredible fact that the sheet of seemingly solid ice so formed, *flowed* like a *stiff liquid.* The whole interior of Greenland, so far as known, is covered by such an ice-sheet several thousand feet thick, which is slowly flowing out into the sea on its margin, where it is continually being broken off in great icebergs which float away towards the mid-Atlantic. The Antarctic continent is even more completely buried beneath an ice-mantle, seemingly of even greater thickness, which gradually creeps out into the Antarctic ocean, and sheds the immense bergs that people the southern seas. Incredible, therefore, as it may seem, it is an undeniable fact that the continued accumulation of snow gives rise to immense ice-sheets, which creep over the surface of the land in a manner seemingly quite inconsistent with their brittle, rigid nature.

The law of flowage of these masses has been repeatedly demonstrated, by the exact observations of Agassiz, Forbes, Tyndall and others, to be essentially similar to that of viscous fluids. The ice-streams that creep down from the snow-fields of the Alps wind through tortuous valleys, descend precipices like frozen cascades, heap themselves up in sudden curves, flow faster over steep slopes and slower over gentle declivities, are retarded by friction along the sides and bottom, and flow faster in the center and at the top, as do fluids.

Limit of Ice. During the rigor of the glacial climate, such ice sheets as now mantle the Arctic regions crept down from the north, and overwhelmed the greater portion of our State, and adjacent territory, and crept on southward to the vicinity of the Ohio river. The exact limit of the actual ice-margin has not been accurately determined. The southern limit of drifted material, mainly due to the ice, but in part carried on beyond it by streams and lakes accumulating at its edge, has been approximately determined, and this may be taken as indicating, nearly enough for our present purpose, the extension of the ice itself. This limit, beginning with the Atlantic, is found on the islands of Nantucket, and Martha's Vineyard (King and Upham), whence it passes to and traverses Long Island (Mather, Cook, Smock and Upham), and thence passes to Staten Island and across New Jersey with a northward curve, to the vicinity of Belvidere (Cook and Smock). Thence northwesterly it crosses Pennsylvania to Cataraugus county, New York, where, turning southwesterly, it passes to the vicinity of the Ohio river, on the border of that State (Lesley, Lewis and Wright), thence westerly to the neighborhood of Cincinnati (Newberry and the Ohio geological corps). Westward it follows approximately the Ohio river into Illinois (Cox, Collett), crossing the lower portion of that state above the highlands (Worthen). It extends across Missouri somewhat south of the Missouri river in the vicinity of the Osage (Swallow), thence across the eastern portion of Kansas (Mudge), and curving northward pursues a course about parallel to the Missouri river, distant from it twenty to one hundred miles (Aughey, Todd, Winchell and the writer), stretching northwestward to the vicinity of the northern limit of the United States, where it turns westward and crosses the Yellowstone river about forty miles above its mouth (White). The latter part of this course has only been quite imperfectly determined, and the further extension northward and westward remains yet to be ascertained.

Effects of Glacial Action. The effects which this moving sheet of ice produced upon the surface of the land have been found almost as difficult to appreciate and clearly comprehend, as the fact of ice-movement itself. It is well-nigh impossible to rid ourselves of the idea of the ice's rigidity. Even while we admit and assert, as facts force us to, its capability of flowing, we are wont to think of a moving glacier as an inflexible plow or plane, cutting down prominences, filling up valleys, and pushing along in front of it all the loose material encountered in its pathway. In reality, however, the pliancy (whatever may be its real nature) that gives the property of flowage gives the same kind and degree of flexibility of action on the glacial margin and bottom, so that in some measure a glacier is enabled to mold itself to inequalities, and may flow over loose material as well as push it in advance.

The proper conception of its action, as we view it, is that of a very stiff, viscous liquid, into the base of which is incorporated rocky fragments and earthly debris, which act upon the rock floor, not as a rigid plane, but as a flexible rasp, scratching it with the coarser, and polishing it with the finer material, at the same time detaching and bearing away rock fragments which in turn score the surface beyond. We do not conceive of this material imbedded in the bottom of the ice, as rigidly fixed in position, but as held by the viscous tenacity of the ice, and moving along with it where the resistance of the bottom is not greater than the tenacity of the embracing ice, and to that extent wearing and scoring the bottom. Nor do we conceive of an imbedded fragment as moving absolutely with the ice, but just as the bottom of the ice is retarded by its friction, and the upper portion flows faster over it, so the embraced rock-fragment, because its friction on the bottom is greater than that of the surrounding ice, is still more retarded, and the ice flows on over and around it. Thus while in a sense it moves along with the ice, it is continually lagging behind, owing to its greater friction. Whenever such an imbedded fragment meets with too stout an obstacle, its progress may be stayed for a time, until, by the aid of adjacent ice-action, the obstacle is escaped or removed, or it may remain permanently, and become an example of sub-glacial accumulation. Thus projecting ledges of rock may, to a certain extent, comb out from the bottom of the ice the rock-fragments set in it, and protect themselves by material gathered on their "stross" side.

When advancing, the margin of the ice-sheet plows up in front of it a certain portion of the loose material it encounters, and mingles with it that which itself bears along, forming a bordering ridge, which constitutes its terminal moraine. But the thin margin of the ice is often incompetent to push along all the unconsolidated material in its path, and so is forced to over-ride that which it cannot push. This is a matter of observation on existing glaciers. It appears also to be a well sustained opinion that in the thin portion near its margin, if not elsewhere, a glacier is not, in all situations, competent to carry further all the material it has brought, and hence deposits a portion of it, forming a sub-glacial accumulation.

Our conception of glacial action is, therefore, that of an immense rasp, which is not only flexible in the sense of adapting itself to the inequalities of its bottom, but yielding in its hold upon the imbedded material. Its work is that of (1) filing down prominences, (2) filling or deepening valleys according to their position relative to its movement, (3) bearing the eroded material forward, greater or less distances, according as it may or may not find lodgment on the bottom, and, at length, (4) heaping up terminal ridges along its margin, and to a greater or less extent, beneath its thinned edge. It is manifest that as it retreats by melting, this marginal depositing belt will be carried back successively over the whole area occupied by the ice, and this will leave spread over the surface an irregular coating of the mixed material produced. This material consists of (1) the soil, and perhaps remnants of the vegetation that originally covered the area, (2) of the sands, gravels, and clays which the streams had previously formed by their own appropriate action on the surface, (3) of loose fragments of rock which the ice found already detached from the strata by various previous agencies, (4) of masses of rock of greater or less size, which the glacier itself or accompanying agencies forced from their places, (5) of the new material which was formed from these various classes by the rubbing, crushing, and other forcible action to which they were subjected under the ice, giving rise to fine rock flour (the grist of the glacial grinding), worn pebbles of various sizes, and scratched and rounded bowlders formed from the larger rock-masses, and (6) of the material which was ground and rasped from the rock floor by the passage of the glacier over it. These products, so far as simple glacial action is concerned, are in the main confusedly commingled, producing a *bowlder clay*, or what is now coming generally to be designated *Till.* This varies in the proportions of clay, sand, gravel, and bowlders, according to the nature of the parent rock and the circumstances of its formation.

Attendant Water Action. The ice action is never free from the attendant agency of water, derived from the melting of the ice during the warm season, and probably also to some extent from the heat of friction, and conduction from the earth's interior under the deeper portions; for not only do streams flow from glaciers during summer, but at all seasons of the year. This is true of Arctic glaciers as well as Alpine, and it is doubtful if this can be satisfactorily accounted for by summer waters retained in basins or embayments beneath the ice, or from springs, which is essentially the same thing in Arctic regions where the whole surface is covered with a glacier.

These waters work upon the material not only along the margin of the glacier, but in channels beneath it, assorting and stratifying it, giving rise to beds of gravel, sand, and laminated clay, according to the force of the current. When the surface beneath the glacier is comparatively level, the sub-glacial streams are liable to constantly change their courses, and the advancing ice may over-ride their abandoned channels, incorporating their stratified deposits in the true glacial deposit. Stratified deposits may likewise be formed in pools that gather along the melting edge of the ice, and by subsequent advance of the glacier, may become involved in the common deposit. Repeated advances and retreats of the ice-margin, due to secular changes, may likewise produce rude stratification in the glacial deposits.

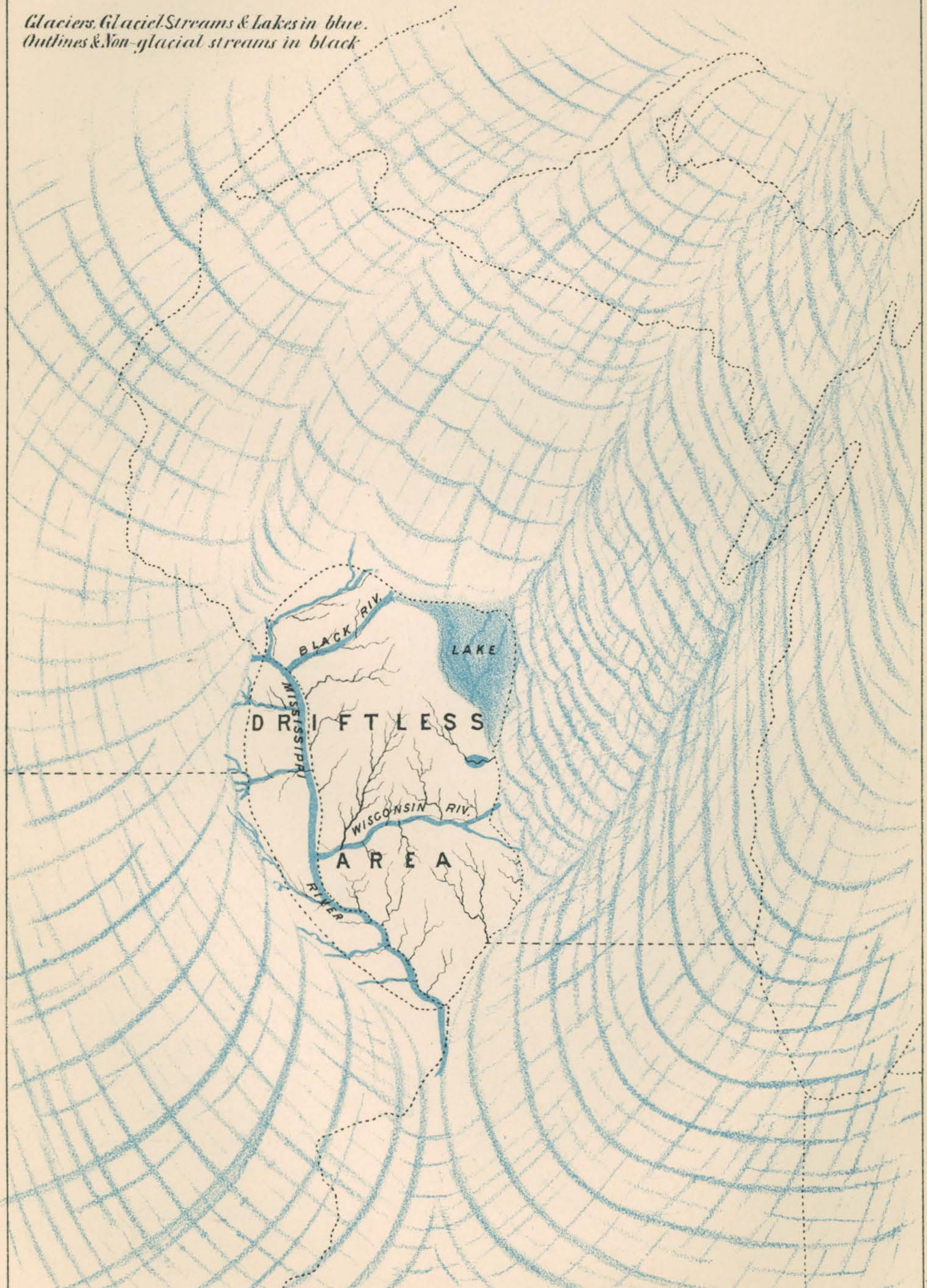
The assorted and stratified drift produced by glacial waters is obviously contemporaneous with the glacial deposit itself, taken as a whole, and, while a true modified drift, it is to be distinguished from those modifications of the drift which are due to subsequent aqueous agencies, not in any way directly connected with glacial action. These two classes are often confounded under the term Modified Drift.

It will be readily deduced from the foregoing considerations, that the work of a glacier is of a nature altogether peculiar and distinctive, and that, where satisfactorily exhibited and critically studied, it ought to be discernible by indices that are unmistakable. The graving of the underlying rock is of a character produced by no other known agency. Other agencies, however, produce somewhat similar markings, but they are clearly distinguishable. The grounding of icebergs doubtless produces scoring and abrasion of the subjacent surface (though the actual observation of this is prevented, in the case of existing icebergs, by the submergence of their bottoms), but it is manifest that the gouging of an iceberg, moving at an appreciable rate, attended almost necessarily by rotation, when brought to a standstill, would be markedly different from that of a continually flowing, flexible rasp. The action of ice-floes, or fringing ice, driven upon the beach by wind and tide, produces scratching and polishing, but this has a character of its own, and is attended by other characteristics of beach action which sharply distinguish it from true glacial striation. In local and exceptional instances, sliding earth-movements abrade and scratch the surface, but this is obviously confined to peculiar local situations, and does not produce a polishing and graving that ought to be mistaken for that of a glacier.

Unlike these or other striating agencies, glaciers sometimes smoothly polish extensive flat areas, giving them a beautiful glistening surface lined with long, parallel striations, some deep and sharply cut, some as fine and delicately traced as if by a diamond point. In other instances they polish ascending and descending slopes with equal beauty, or they plane and groove the sides of precipitous cliffs. Striations on the face of vertical walls, beside being horizontal, sometimes incline upward and sometimes downward. Glaciers sometimes even plane and grave the *under side* of overhanging rock in a way that could only be done by a substance moulding itself to the surface, and they likewise sometimes polish and striate *the sides of crevices in the face of vertical walls.* They so commonly plane and polish all sides of a projecting dome or boss of rock, that the distinctive name *roches montounées* (sheep's back) has been applied to them. They score hill-tops and adjacent valley bottoms separated in altitude, hundreds, and in mountainous districts, even thousands of feet. In short, they do a work that, if seen in its entirety, is absolutely referable to no other known agency. Add to this the local nature of the transportation, and all the peculiarities of direction and of changes of altitude involved in the transfer, the method in which the debris is spread or heaped, the existence of terminal moraines, and all the multitudinous details relating to the origin and distribution of the material, and consider the combined testimony of the whole, and the character of the agency that produced the results ceases to be a matter of doubt in any large area favorably situated for observation, and fully and critically examined.

General Direction of Ice Movement. Returning from this digression upon the character and method of glacial action, intended to prepare the way for the better apprehension of the following facts, we observe that the striations on the surface of the rock, no less than the direction from which the material has been borne, show that the great ice-sheet, as a whole, moved in a southerly direction from the Canadian highlands to the limit already designated. The prevailing movement in the interior was southwesterly, while that of the Atlantic border was southeasterly. Locally there were many departures from these general directions. It seems not improbable that the fuller investigations of the future will show that the great ice-sheet was lobate in marginal outline, and that the separate lobes had generally internal divergent motions of their own, such as have been demonstrated to characterize the lobes of the later glacial advance. But it is to be remarked in candor that the special details of this earliest and greatest glacial advance are relatively meager. The greater portion of its area was over-ridden by a later glacier,

HYPOTHETICAL MAP OF WISCONSIN
DURING THE FIRST GLACIAL EPOCH.



which obliterated past positive identification the records of the earlier period. In Wisconsin, certain features of the movement, however, are quite clearly discernible.

Calling to mind the pre-glacial topography of the State, it will be remembered (1) that the northern part, including the adjacent portion of the Upper Peninsula of Michigan, rose to a considerable altitude above the surrounding regions, (2) that there lay on the north of these heights the valley of Lake Superior, presumably not as broad and deep as now, but yet a great valley pointing southwestward, and continued by relatively low lands in that direction, (3) that there lay upon the east the valley, even then of great extent, wherein now lies Lake Michigan.

Courses of the Ice Streams. The ice-sheet, flowing slowly down from the north and northeast, was led away to the southwest by the Superior valley, and to the southward by the Michigan valley, while the northern heights, standing between the two, resisted the current and assisted in diverting it on either hand. These great glacial streams in passing down these valleys excavated them more deeply. They here did their greatest erosive work, because of the exceptional depth and strength of their flow, and because of their downward direction in entering the valleys. The northern portions of the basins of Lake Michigan, Lake Superior and Lake Huron, are all deeper than the southern, and the eastern portions of Lakes Erie and Ontario, than the western, or, in other words, the extremity which the glacier first invaded and last left is most deeply excavated.

The Driftless Area. The combined capacity of these great valleys in leading away the advancing ice, aided by the diverting influence of the highlands, protected all but the eastern and northern margins of the State from powerful glacial action. A large area in the southwestern portion bears no evidence of having suffered glaciation, and hence has been designated the *Driftless Area.* This area, which includes a narrow strip on the west side of the Mississippi in Iowa and Minnesota, and a portion on the east side in northwestern Illinois, will be found outlined on the accompanying map, plate IX. By inspection it will be observed that it does not occupy a highland area, but rather the opposite, and on the other hand it is quite as remarkable that the highland area lying northeast of it — the direction whence the glacial stream came — is covered by drift, and, in its upper portion, heavily so. The ice, therefore, mounted the highlands and descended the southerly slope to the central part of the State — a distance of 100 miles, roundly speaking — and terminated on the southern slope.

By extending our view beyond the State, it will be found that on the east glaciation prevailed uninterruptedly to the Atlantic, and that on the west a stream considerably more than 300 miles wide passed southward. The currents that passed by on either hand converged in southern Iowa and northern Illinois, and joined near the mouth of Rock river, and from thence onward appear to have been confluent.

A partially separated ice-stream came across the Wisconsin highlands, being parted from the others perhaps by Keweenaw Point, and the Huron mountains, acting as a barrier, and the Keweenaw Bay valley as a channel. This stream passed the highlands and descended the southern slope nearly to the center of the State. But because of its relative thinness and the breadth of the southern slope on which it spread itself — resulting in feebler motion — together with its favorable attitude for melting and for receiving the influences, springing from the relatively dry and heated Driftless Area south of it, it appears to have been consumed by the time it reached an extension of 100 miles, and hence failed to overwhelm the region south of it. The streams on either hand were carried southward by their respective valleys, and did not converge soon enough to overspread the Driftless Area. It, therefore, escaped, fortunately, and stands as a remnant of pre-glacial topography, invaluable as a standard of comparison for the estimate of the effects of glaciation.[1]

These general facts with reference to the earlier glacial movements seem sufficiently sustained by the evidence now at command; but from the fact that nearly the whole of our glaciated territory was overspread by the advance of a later ice-sheet, we know comparatively little of the details, either of the movement or its deposits. Resting, therefore, with this general sketch, we may pass on to the subsequent history which will bring forth the essential details of the age, and of its remarkable agency.

Retreat of the Ice. After occupying the advanced position to which it had attained for a period whose duration is not known, but which was probably relatively brief, since the deposits thin out on the margin, instead of being accumulated in a vast terminal moraine, as might have been expected if it stood at its maximum limit for any long period, the ice began to retreat. The young student will understand that the ice continued its onward flow, but was

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[1] For a fuller discussion of the subject of the Driftless Area, see Annual Report of Wis. Geol. Surv., pp. 21–32. See also the earlier discussions by Winchell, Annual Report, Nat. Hist. Survey of Minn., p. 35 et seq.; Irving, Wis. Geol. Survey, Vol. II, pp. 632–3; Dana, Am. Jour. Sci., April, 1878, p. 250 et seq.

melted back faster than it advanced. How far to the north this retreat carried the margin has not yet been ascertained, but the growing tendency of the gathering evidence is to throw it farther and farther back, and it is thought to be quite safe to believe that it withdrew entirely from our territory, if not from the Canadian highland.

INTERGLACIAL INTERVAL.

It is difficult to measure trustworthily the interval that ensued between this retreat and the advance of the later glacier. Two lines of evidence have received some study from the writer, which lead to concordant, though perhaps not very definite, conclusions. One of them relates to the changes in the relative directions of movement in the two great glaciers, and the differentiation of the glacial lobes which fringed the later one, and gave it a characteristic contour. This work of the readjustment of parts and movements is thought to have occupied some considerable time, if it does not indicate an entirely new origin. But an opinion based on this evidence should be held very lightly, for among the Alpine glaciers of recent times, relative changes of size, and of rate and phase of motion, take place contemporaneously, and, therefore, it is not impossible to suppose that the first great sheet retreated more rapidly in some areas than in others, and suffered division of its margin into lobes, which, when it readvanced, took the observed forms and directions.

The other line of investigation is based upon a comparison of the relative amounts of erosion which contiguous areas of the earlier and the later drifts have suffered. From repeated estimates based on such comparisons made at many different points over considerable portions of the glaciated area of the Interior, the impression gained is, that the amount of erosion suffered by the older glaciated surfaces is at least twice that of the newer; or, in other words, that the time between the first and second glaciation, estimated by the erosion-measure, was fully equal to the time that has elapsed since the latter. The subject is still under investigation, and this judgment is expressed subject to modification in the light of further evidence. But the general conclusion, that an interval of some considerable magnitude intervened, seems clearly indicated.

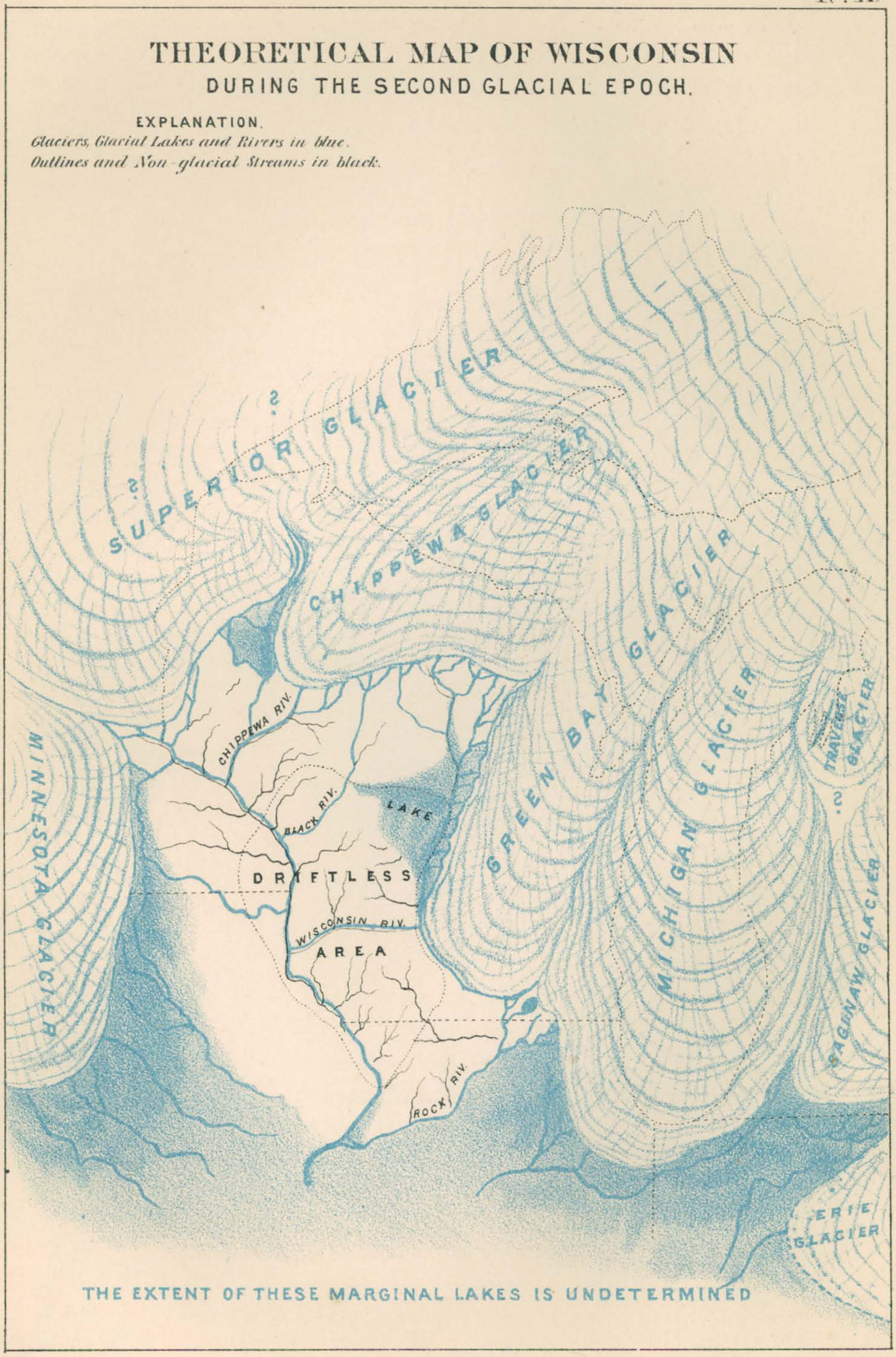
SECOND GLACIAL EPOCH.

NOTE.— In the descriptive volumes of this report, two distinct glacial periods are not formally stated, although the fact of a second advance, with an intervening interval, is indicated. This was due partly to the fact that investigations were still in progress, which made it injudicious to prejudge results by broad conclusions, in advance of the fullest available data, and partly to the fact that the existence of two such periods had not been generally recognized by American geologists, although the doctrine of separate glacial periods had been entertained by several in this country, following the lead of the Scotch school. The only American evidence then adduced, aside from theoretical presumptions, consisted of supposed superpositions of newer upon older till, separated by supposed inter-glacial deposits—a class of evidence to be received with great caution, since temporary oscillations, or the shifting of sub-glacial streams, may produce strikingly analogous phenomena. Where the section exposed to observation chances to be parallel to the glacial margin, or the course of a sub-glacial stream, the phenomena may seem to be much more prevalent than is really the case. A further and more important ground of doubt arises from the fact that certain sub-aqueous deposits so closely resemble true Till, that they have been mistaken for it, and there is perhaps no case of superposition of beds supposed to represent two glacial periods that is not still open to these doubts. Our present firmness of conviction arises (1) from the discovery and working out of an extended moraine, stretching across the whole of the glaciated area, and belonging to a system of glacial movements which differ in many important respects from the earlier ones; and (2) from the differences of surface contour, due to the greater erosion of the earlier, as already indicated. We believe that this line of evidence, when developed in its fullness, will prove entirely demonstrative. Only a small part of the results now gathered fall specifically within our present province as chronicler of the geological history of Wisconsin, but the total result is, in some important measure, the outgrowth of investigations begun in this State.

When the ice a second time moved down upon the land, it found its pathway already smoothed by the preceding glacier, and strewn with its debris. The later ice followed the great channels of its predecessor, though with some important variations owing to the changed conditions of the two epochs, and other attendant circumstances. The glacial movements in, and adjacent to, Wisconsin, were of the following remarkable character:

Lake Michigan Glacier. A great ice tongue thrust itself down the basin of Lake Michigan, taking a form closely similar to that of the lake, but broader and longer. Its western margin is now marked by the Kettle Range, extending from Kewaunee county southward, essentially parallel to the lake, through Manitowoc, Sheboygan, Fond du Lac, Washington, Waukesha, Jefferson, Walworth, Racine and Kenosha counties, into Illinois, sweeping thence around the south end of the lake, concentric with it, and northward to the northern part of the Lower Peninsula of Michigan, being joined by the marginal moraine of a similar lobe which occupied the basin of Lake Huron and Saginaw Bay. In other words, it had essentially the contour of Lake Michigan expanded 20 to 40 miles on each side.

Green Bay Glacier. Another tongue of ice was thrust down alongside this, having the Green-Bay-Rock-River valley for its axial


THEORETICAL MAP OF WISCONSIN
DURING THE SECOND GLACIAL EPOCH.
EXPLANATION.
Glaciers, Glacial Lakes and Rivers in blue.
Outlines and Non-glacial Streams in black.
SUPERIOR GLACIER
CHIPPEWA GLACIER
GREEN BAY GLACIER
MICHIGAN GLACIER
TRAVERSE GLACIER
SAGINAW GLACIER
MINNESOTA GLACIER
ERIE GLACIER
CHIPPEWA RIV.
BLACK RIV.
LAKE
DRIFTLESS
WISCONSIN RIV.
AREA
ROCK RIV.
THE EXTENT OF THESE MARGINAL LAKES IS UNDETERMINED

channel. It expanded eastward until it came into contact with the Lake Michigan glacier, and on the western side until it reached a little beyond the center of the State. The margin of this glacier separated from that of the Lake Michigan glacier in the northwestern part of Walworth county, and thence curved westward across Rock river to the northeastern corner of Green county, thence swept rapidly to the northward, passing through Dane, Sauk, Adams, Waushara, Portage, Waupaca and Shawano counties, and into Lincoln, where it joined the margin of a third glacial stream, the Keweenaw or Chippewa Valley glacier.

The Chippewa Valley Glacier. This came over the highlands apparently from the Keweenaw Bay valley, and descended that of the Chippewa river. Its margin, starting from its junction with the Green Bay glacier in Lincoln county, ran southwesterly through Taylor into Chippewa county, crossing the Chippewa river just below the great bend. Thence it curved rapidly northward running near the line between Chippewa and Barron counties, beyond which it followed the water-shed between the Chippewa and Numakagon rivers to the vicinity of Lake Superior.

Lake Superior Glacier. In this latter portion the glacier just described lay in contact with a greater one that passed southwesterly through Lake Superior into Minnesota. The eastern margin of this separated from that of the Chippewa glacier in southeastern Burnett county, and thence ran southwesterly through Barron, Polk, and St. Croix counties, from the latter of which it passed into Minnesota, swept across the Mississippi south of St. Paul, and across the Minnesota south of Minneapolis, and thence extended onward to the northwest, recurving northward, to an undetermined distance.

The relationship of these glacial lobes to the great valleys is conspicuous. The two greater ones occupied the Great Lake basins, the two minor ones, the bays lying between them. Of the latter the Green Bay lobe was much the longer and more important.

A similar lobate nature characterized the glacial margin throughout the whole of the Great Lake region.[1] A lobe extended southwestward from Lake Huron through Saginaw Bay, and occupied the central part of the Lower Peninsula of Michigan. Another extended southwesterly through the western portion of Lake Erie basin, across northwestern Ohio and southeastern Michigan, into Indiana, having

[1] On the Extent and Significance of the Kettle Moraine, by the writer, Wis. Acad. of Sci. See also An. Report U. S. Geol. Surv., 1882.

See also Natural History Survey of Minn., 1880, by Warren Upham.

its axis in the Wabash valley. Less conspicuous lobes are thought to have occupied the Scioto and Grand river valleys in Ohio and the region of the Finger lakes of central New York. On the west a prolonged lobe extended southward into central Iowa. A similar one occupied the James river valley in Dakota, and perhaps others may characterize the more northwesterly margin, the details of which are as yet only in part wrought out.

Internal Ice Movement. The manner of movement of the ice in detail within each of these glaciers was quite extraordinary, and, previous to its determination in respect to the Green Bay glacier, seems to have been unsuspected as an attribute of glaciers in a relatively plain country. The precise direction of drift movement may be determined (1) by the markings on the rock surface, (2) by the direction in which the material has been transported, (3) by the nature of the abrasion which prominences have suffered, (4) by the trend of elongated domes of polished rock, (5) by a linear arrangement of the deposited material, and occasionally by other means. Exceptional opportunities for the positive determination of the courses pursued in Eastern Wisconsin are afforded. Rock striations are found in sufficient frequency to be in themselves quite decisive, especially as their situations are such as to awaken no suspicion of special local deflection, and particularly as they conform to a symmetrical system. But in addition to this there are several isolated knobs of Archæan rock protruding through Silurian sandstones and limestones, which afford peculiarly convincing evidence. These have suffered forcible abrasion and rounding on the side exposed to the advance of ice, and are grooved and polished, while trains of erratics stretch away in definite lines along the direction of striation on the parent knob, and parallel to the grooving of the surrounding region. The bowlders near the parent rock are mainly large and moderately scratched and worn. As they are traced away in the distance they become smaller, more scattered and more rounded.

Again, over a considerable portion of the region, there are elongated elliptical hills and linear ridges, interspersed with correspondingly elongated valleys and marshes, all of which are arranged in lines parallel with the groovings on the rock. Many minor phenomena harmonize with, and confirm the data derived from these sources. The direction of movement is, therefore, determined beyond question.

In the case of the Green Bay glacier, where the evidence is most complete and positive, it appears that the central portion, occupying the trough of the valley, moved strictly along its course, ascending from Green Bay through Lake Winnebago to the water-shed of Rock river, and then descending its valley; that on the west side of the axis the course rapidly diverged to an almost due westerly direction in the northern portion of the lobe, and a southwesterly course in varying degrees near its extremity. On the eastern side, immediately after surmounting the rock escarpment that borders the valley, the course turned to the southeastward, toward the margin of the lobe. *All these movements took place without regard to the local slope of the surface.* Unifying them into a system, it appears that the central movement was along the axis of the lobe, and that from this the flow diverged toward the margin on each side, and immediately next the margin was nearly at right angles to it.

That portion of the Lake Michigan glacier which lay within Wisconsin conformed strictly to this law, the movement being from the lake up the slope westerly and southwesterly to the margin. The same system of movement has been found to inhere in other lobes, and may now be regarded as a well demonstrated law of movement.

The Kettle Moraine. The most striking result of the second glacial advance was the production, along the margin of the ice-sheet, of a great moraine, the most gigantic and most remarkable yet known to characterize glacial action. It consists of a great ridged belt of drift disposed in grand loops along what was the glacier's margin. Its re-entrant angles penetrated deeply between the adjoining lobes, marking their line of contract. That portion of the moraine which lay between, and was formed by the joint action of the Green Bay and Lake Michigan glaciers, constitutes a succession of irregular hills and ridges, locally known as the Kettle Range, from the peculiar depressions which characterize it. As this was the first portion to receive systematic investigation, and a specific determination of the true nature and method of its formation, and as this moraine will need a specific name to distinguish it from other similar accumulations, the term Kettle Moraine may fittingly be applied to it.[1]

[1] It should be remarked in this connection that there are two or more concentric moraines, constituting a belt, rather than a single moraine. These are often forced into contact and confusion, so that their distinct discrimination is impracticable, while at other points they are quite distinct, and separated by several miles distance. It is proposed to apply the name Kettle Moraine to the outermost member, when clearly distinguishable, and to extend its use, or that of the term Kettle Range, to the entire group where they are confused so as to be indistinguishable. The Kettle Moraine, therefore, designates the morainic ridge produced by the extreme advance of later glaciation. Names for the inner moraines are not here proposed, because, although distinguishable in Wisconsin, as

Interlobate Moraines. This ridged belt of drift is a true terminal moraine, formed of the heterogeneous material accumulated at the margin of the ice, and plowed up before it at the time of its greatest advance. Those portions that lay in such a singular way between two adjacent glacial lobes have some likeness to a medial moraine, but are not such in any proper sense, for the true medial moraine consists of superficial matter borne passively on the surface of a glacier, having been formed by the junction of lateral moraines in the union and coalescence of two glaciers, which then move forward as one, the moraine lying longitudinally to the glacier, and parallel to its motion. But, on the contrary, the intermediate portions of the Kettle Moraine lie along the face of two approaching ice-sheets, which may have met and antagonized each other, to some extent, but did not coalesce, and, furthermore, they lie transverse to the glacial motion, and are strictly marginal, and are, in real nature, terminal moraines, differing from other portions simply in being formed by two glaciers pushing from opposite directions. We propose for such portions, on account of this peculiarity, the special designation, *Interlobate or Intermediate Moraines.*

Characteristics of the Kettle Moraine. The characteristics of the Kettle Moraine are striking. It is not merely a simple ridge plowed up by the smooth edge of the ice, as is too apt to be the mental image of a terminal moraine, fashioned after the similitude of lateral and medial Alpine moraines, but it consists of an irregular assemblage of drift hills and ridges, forming a belt usually several miles in width. It is probably owing to this width, and the very massiveness of its character, that it so long escaped general recognition as a moraine.

Its Superficial Aspect. The "Kettles." The superficial aspect of the formation is that of an irregular, intricate series of drift ridges and hills, of rapidly, but often very gracefully, undulating contour, consisting of rounded domes, conical peaks, winding, and occasionally geniculated ridges, short, sharp spurs, mounds, knolls and hummocks, promiscuously arranged, accompanied by corresponding depressions that are even more striking in character. These depressions, which, to casual observation, constitute the most peculiar and obtrusive feature of the range, and give rise to its descriptive name in

indicated in Vols. II and III, they are displayed in greater distinctness and definition elsewhere, especially in Minnesota and Dakota, from some of the characteristic localities of which it is proper that fitting names should be selected, and such will be announced, if not sooner proposed, in connection with the results of the wider studies of the writer upon the formation, now in progress.

Wisconsin, are variously known as "Potash kettles," "Pot holes," "Pots and kettles," "Sinks," etc. Those that have most arrested popular attention are circular in outline, and symmetrical in form, not unlike the homely utensils that have given them names. But it is important to observe that the most of these depressions are not so symmetrical as to merit the application of these terms. Occasion-

FIG. 93.

GENERALIZED SKETCH OF THE CHARACTERISTIC TOPOGRAPHY OF THE KETTLE MORAINE.

ally they approach the form of a funnel, or of an inverted bell, while the shallow ones are mere saucer-like hollows, and others are rudely oval, oblong, elliptical, or are extended into trough-like or even winding hollows, while irregular departures from all these forms are most common. In depth, these cavities vary from the merest indentation of the surface to bowls sixty feet or more deep, while in the irregular forms the descent is not infrequently one hundred feet or more. The slope of the sides varies greatly, but in the deeper ones it very often reaches an angle of 30° or 35° with the horizon, or, in other words, is about as steep as the material will lie. In horizontal dimensions those that are popularly recognized as "kettles" seldom exceed 500 feet in diameter, but, structurally considered, they cannot be limited to this dimension, and it may be difficult to assign definite limits to them. One of the peculiarities of the range is the large number of small lakes, without inlet or outlet, that dot its course. Some of these are mere ponds of water at the bottom of typical kettles, and from this they graduate by imperceptible degrees into lakes two or three miles in diameter. These are simply kettles on a large scale.

Next to the depressions themselves, the most striking feature of this singular formation is their counterpart in the form of rounded hills and hillocks, that may not inaptly be styled inverted kettles. These give to the surface an irregularity sometimes fittingly designated "knobby drift." The trough-like, winding hollows have their correlatives in sharp, serpentine ridges. The combined effect of these elevations and depressions is to give to the surface an entirely distinctive character.

These features may be regarded, however, as subordinate elements of the main range, since these hillocks and hollows are variously distributed over its surface. They are usually most abundant upon the more abrupt face of the range, but occur in greater or less number on all sides of it, and in various situations. Not infrequently they occur distributed over comparatively level areas, adjacent to the range. Sometimes the kettles prevail in the valleys, the adjacent ridges being free from them; and again, the reverse is the case, or they are promiscuously distributed over both. These facts are important in considering the question of their origin.

Composite Character of the Range. The range itself is of composite character, being made up of a series of rudely parallel ridges, that unite, interlock, separate, appear and disappear in an eccentric and intricate manner. Several of these subordinate ridges are often clearly discernible. It is usually between the component ridges, and occupying depressions evidently caused by their divergence, that most of the larger lakes associated with the range are found. Ridges running across the trend of the range, as well as transverse spurs extending out from it, are not uncommon features. The component ridges are themselves exceedingly irregular in height and breadth, being often much broken and interrupted.

The united effect of all the foregoing features is to give to the formation a strikingly irregular and complicated aspect.

Morainic Material. The material of the moraine embraces all the forms of material common to drift. This topic, which is one of primary importance in determining the origin of the deposit, really divides itself into three subordinate ones, all of which need discriminative attention: (1) the *form* of the constituents, (2) their *arrangement* as deposited, and (3) their *source*.

(1) Premising that Kames, and those deposits which have been associated with them in the literature of the subject, are described as composed mainly of sand and gravel, it is to be remarked in distinction that *all* the four forms of material common to drift, viz.: clay, sand, gravel, and bowlders, enter largely into the constitution of the Kettle Range, in its typical development. Of these, gravel is the most conspicuous element *exposed to observation*. This qualification is an important one in forming an adequate conception of the true structure of the formation. It is to be noticed that the belt at many points exhibits two distinct formations. The upper-

most — *but not occupying the heights of the range* — consists almost wholly of sand and gravel, and lies like an irregular, undulating sheet over portions of the true original deposit. This superficial formation is confined mainly to the slopes and flanks of the range, and to depressed areas between its constituent ridges; though, when the whole belt is low, it often spreads extensively over it, so as sometimes to be quite deceptive. But, where the range is developed in force, this superficial deposit is so limited and interrupted as to be quite insignificant, and not at all misleading; and, at some points, where it is more widely developed, excavations reveal unequivocally its relationship to the subjacent accumulations. In such cases, the lower formation shows a more uneven surface than the upper one, indicating that the effect of the latter is to mask the irregular contour of the lower and main formation. Notwithstanding this, the upper sands and gravels are often undulatory, and even strongly billowy, and the bowls and basins in it commonly have more than usual symmetry. A not uncommon arrangement of this stratum is found in an undulating margin on the flank of a ridge of the main formation, from which it stretches away into a sand flat or a gravel plain.

Setting aside this, which is manifestly a secondary formation, it is still true that gravel forms a large constituent of the formation. Some of the minor knolls and ridges are almost wholly composed of sand and gravel, the elements of which are usually very irregular in size, frequently including many bowlders. But notwithstanding these qualifications, *the great core of the range*, as shown by the deeper excavations, and by the prominent hills and ridges that have not been masked by superficial modifications, *consists of a confused commingling of clay, sand, gravel, and bowlders, of the most pronounced type.* There is every gradation of material from bowlders several feet in diameter, down to the finest rock flour. The erratics present all degrees of angularity, from those which are scarcely abraded at all, to thoroughly rounded bowlders. The cobble-stones are spherically rounded, rather than flat, as is common with beach gravel, where the attrition is produced largely by sliding, rather than rolling.

(2) *Stratification.* As indicated above, the heart of the range is essentially unstratified. There is, however, much stratified material intimately associated with it, a part of which, if my discriminations are correct, was formed simultaneously with the production of the unstratified portion, and the rest is due to subsequent modification. The local overlying beds, previously mentioned, are obviously strati-

fied, the bedding lines being often inclined, rather than horizontal, and frequently discordant, undulatory or irregular.

(3) *Source of the Material.* This, so far as the range in Wisconsin is concerned, admits of the most unequivocal demonstration. The large amount of coarse rock present renders identification easy, and the average abrasion that has been suffered indicates, measurably, the relative distance that has been traveled. The range winds over the rock formations in a peculiar manner, so as to furnish fine opportunities for decisive investigation. Of the many details collected, there is room here for a single case only. The Green Bay loop of the range surrounds on all sides, save the north, several scattered knobs of quartzite, porphyry, and granite, that protrude through the prevailing limestones and sandstones of the region. These make their several contributions to the material of the range, *but only to a limited section of it, and that, invariably, in the direction of glacial striation.* Any given segment of the range shows a notable proportion of material derived from the formation adjacent to it, in the direction of striation; and a less proportion, generally speaking, from the succeeding formations that lie beyond it, backward along the line of glacial movement for three hundred miles or more. It is undeniable that the agency which produced the range gathered its material all along its course for at least three hundred miles to the northward, and its largest accumulations were in the immediate vicinity of the deposit. For this reason, as the range is traced along its course, its material is found to change, both lithologically and physically, corresponding to the formations from which it was derived.

Topographical Relations. The location of this remarkable moraine, we have already indicated in outlining the ice-lobes that formed it. It will be observed by noting its relations to river valleys and water-sheds, and more especially by comparison with the topographical map of the Survey atlas, that its loops are distributed over the State in apparent disregard of local diversities of surface. It undulates over the face of the country, varying in its vertical oscillations at least 800 feet. In some portions it occupies water partings, in others lies on slopes, and in still others stretches across valleys. It is incredible, therefore, that it could have been formed by any such agency as beach action, shore-ice, or the stranding of icebergs, for its want of horizontality and its peculiar attitude on slopes make the action of such agencies impossible, and no supposable warping of the crust could bring it into the proper attitude.

Mode of Formation. When the foregoing characteristics and relations are studiously considered, with all the multitudinous details that cannot here find place, there seems no escape from the conviction already expressed, that this is a great moraine, formed along the sinuous margin of a lobate glacier.

The structure of the range indicates an alternating retreat and advance of the ice mass. During the former, drift material accumulated at the foot of the melting mass, which, when the glacier advanced, was plowed up into massive ridges. Repeated oscillations gave rise to parallel ridges, and the irregularities incident to advance and retreat explain the complexity of the range. Where later advances were equal to the earlier ones, the accumulations of drift material were forced into a single great ridge. Where any advance failed to equal a former one, there was an interval between the accumulations of the two, and a depression resulted, whose form depended on the relations of the two accumulations, but was usually more or less trough-like in nature. This was the origin of at least a portion of the characteristic winding, serpentine hollows. Where tongues of ice were thrust into the accumulated material, a jagged, broken outline resulted. If masses of ice became incorporated in the drift, as Col. Whittlesey has suggested,[1] their melting gave rise to depressions, and this is probably the origin of some of the "Kettles" that characterize the moraine. The greater number of them, however, were probably due to the irregularities of the glacial edge, and the inequalities in the amount of drift material acted upon — an explanation which applies at the same time to the irregular hills and mounds which are inseparably associated with the depressions in cause, as well as position and contour. Certain of the hollows may be due to under-drainage, through the action of strong underground streams that occasionally flow, as full brooklets, from the base of the moraine.

Effects of Contemporaneous Drainage on the Moraine. The voluminous drainage of the glacier, when it was in its advanced stages, pushing against the debris in front of it, was probably quite general and promiscuous, *over the moraine*, and this assorted much of the material, and gave rise to stratified sands and gravel, and the other evidences of water action which characterize the formation. The changing attitudes of the material, as it was forced along, would, it is thought, give peculiar opportunities for the washing out of the

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[1] Smithsonian Contributions to Knowledge; Fresh-Water Glacial Drift, of the N. W. States, by Chas. Whittlesey, p. 5.

finer material, and the rounding of the coarser, resulting in the preponderance of gravel so often observed.

Drainage Gaps and Plains. The moraine is frequently cut across by gaps, attended on the outside by plains, and long streams of gravel and sand, which represent the more important points of discharge of the glacial floods.

Associated Lakes. The formation and bursting of lakes, due to temporary retreats and advances of the ice-foot, was very likely a common phenomenon, and gave an unusual phase to torrential action. Some of the minor ridges, mounds and depressions may owe their origin to such a cause.

When the surface about the margin of the glacier was low, lake-like expansions of water gave opportunity for silt deposits, which frequently fringe the range.

In these various ways, and perhaps others unrecognized, the glacial waters wrought their own peculiar work upon the moraine, to an extent scarcely less important than that of the mechanical action of the ice itself.

Glacial Oscillations. Secondary Moraines. The oscillations referred to in the preceding paragraph are regarded as being only those relatively slight changes in the elongation of the glacier, which arose from periodic variations of seasonal temperature and precipitation. There were, however, greater oscillations attendant upon the final retreat of the ice. After it had melted backward from its outer moraine a considerable distance, it again advanced and formed a second moraine within the first. In some parts this second advance reached nearly or quite to the position of the first, and the two moraines were commingled so as not to be readily separable; but in other portions it failed by several miles to reach the former position, and so left a distinct moraine within the outer one, separated from it by a comparatively level surface.

By a still later advance, a third and usually quite inferior line was formed, not everywhere, however, now distinguishable. Still farther within, marking still later stages of retreat, are local morainic ridges, or feeble indications of later halts and advances, that have not as yet been fully traced out. It is not improbable that sufficiently critical search would make it possible to map the margin of the retreating ice-lobes at several successive stages, as it withdrew, under the influence of a progressive amelioration of the climate.

Present researches do not indicate any encroachment of glacial ice subsequent to the retreat now sketched.

The Ground Moraine. Till. In its retreat, the glacier left spread out over the surface of the country, in an irregular sheet, the rock rubbish rasped from the surface over which it had passed. This constituted the ground moraine of the glacier — its most important product. It embraces a mixture of material derived all along the pathway of the glacier for several hundred miles northward, the largest proportion being from the immediate vicinity of the deposit.

Mammillary Hills. This material, while spread as a rude irregular sheet over the abandoned surface, nevertheless presents some

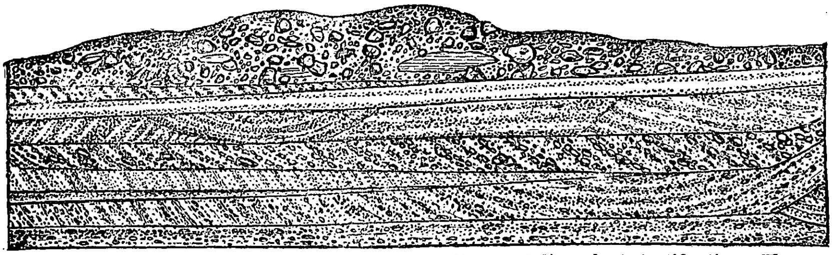
Fig. 97.

Mammillary Hills ("Lenticular hills" of Hitchcock).

peculiar tendencies to aggregation that deserve passing notice. A special tendency is observed over certain considerable areas lying not far distant from the Kettle Moraine, to accumulate in mammillary or elliptical or elongated hills, of smooth, flowing outline (the "Lenticular hills" of Hitchcock). These are arranged in lines, and their longer axes invariably lie parallel to the movement of the ice. In some localities, especially in Dodge and Jefferson counties, these are mainly replaced by long parallel ridges, sometimes several miles in length, with corresponding linear marshes interspersed. These correspond accurately to the direction of ice motion. They usually have the same composition as the prevailing sheet of till with which they coalesce, and of which they are to be regarded as but local aggregations.

Effect of the Glacial Accumulations on Drainage. The drift deposit blocked up many of the old valleys, destroying the ancient drainage lines, and by its own irregularities presented a new and peculiar surface, formed in disregard of drainage demands. On its irregularities of surface, waters collected, giving rise to the numerous lakes that characterize the area. The Kettle Moraine accurately marks the limit between the lake-bearing and the lakeless areas. On the outside (southern side), well-established drainage systems prevail, while within, there are in Wisconsin 2,000 or more lakes, great and small, and many more marshes, which represent extinct lakes, that were filled at the close of the glacial period, and which swelled the total number to many thousands. From the retreat of the glacier to the present time, drainage erosion has been engaged in cutting down the lips of the lakelets, establishing new channels, and perfecting new river systems, which, if unobstructed by human agencies, will in time, doubtless, drain all the lakes, and restore the region to its former lakeless condition.

FIG. 98.



SECTION OF VALLEY DRIFT AT BELOIT, illustrating oblique and discordant stratification. The material is well rounded gravel and sand. The coarser upper portion is due to secondary accumulation, arising from wash from an adjacent slope. (R. D. Salisbury.)

Valley Drift. Some interesting modifications of the drainage systems took place during the glacial epoch, that deserve passing notice. When the ice of the last period was in its most advanced stage, its waters gave peculiar size and importance to such streams as were situated so as to become the great channels of its discharge. The Lake Michigan glacier poured most of its waters southward in a broad sheet over the Illinois plains, and later, through the valley of the Illinois river. The Green Bay glacier discharged largely through the Rock river valley, filling up its old channel to a depth of 350 feet (including the debris left by the earlier glacier), with a deposit of finely assorted sand and gravel, producing a beautiful level plain three to five miles wide, and extending forty miles or more southward from the moraine. A considerable discharge from the west side of the glacier passed down the Sugar river and spread over its valley a sand plain of equal extent. From the Madison lake region there was a discharge westward into the Wisconsin river.

By reference to the map it will be seen that the western margin of the glacier lay across what is now the great bend of the Wisconsin river, presenting a barrier to the passage of waters through that channel. But this does not seem to have been the course of the river in pre-glacial times. It appears, instead of making this detour to the eastward, to have then kept on southward across the Baraboo ranges, entering the lower narrows of the Baraboo river, and finding exit through the gorge at Devil's Lake, which is regarded as an old river cañon. This course, the glacier blocked up by the massive morainal ridge which is now seen just east of Devil's Lake, and by the lesser drift ridges north of the lake. To these it owes its existence. The waters of the whole of the Upper Wisconsin valley were, therefore, shut off from their accustomed channels of discharge, and so collected in a large lake occupying the plains of Juneau, Adams, Wood and Jackson counties, until they rose to the water-shed between the Wisconsin and Black river valleys, where they found an avenue of exit through the Black river, the flood plains and high gravel terraces of which testify to the former great discharge through its channel. That portion of the glacier which lay across the Lower Wisconsin valley of course discharged its waters down that channel, giving rise to gravel terraces, remnants of which still bear witness to the fact.

The Chippewa Valley glacier gave origin to a large river sweeping down the channel of the Chippewa river, and spreading out a broad, deep, valley-deposit, which has since been deeply terraced. The St. Croix valley was one of the avenues of discharge for the Lake Superior glacier, as its broad capacious channel and great gravel deposits show. The Mississippi led away other portions of this glacier's floods, derived from the Minnesota region. The courses of all these streams below the Kettle Moraine are marked by great breadth and capacity, and contain remnant portions and usually great deposits of the drift gravels borne down by the glacial waters. There results, hence, the interesting fact that all those streams which arise in the drift-bearing area, and subsequently cross the Driftless Area, are marked by high terraces of drift gravels which they have borne down and deposited along their courses, while those streams which lie wholly within the Driftless Area are devoid of these characteristics.

Along the immediate margin of the glacier, there were many minor streams, now extinct or insignificant, pouring forth from it, and expanding into local lakes, forming plains of gravel, sand, and silt, by the deposition of the material they bore out from the great glacial mill, so that the flank of the moraine is fringed with fluviatile and lacustrine plains.

Ingathering of Streams Immediately Above the Moraine. As the glaciers retired within their moraines, the waters accumulated more freely between the ice and the skirting drift-barrier, and gave rise to lacustrine deposits within the moraine. These ponds, joining each other, gave rise to streams which gathered together within the range, and discharged across it at the lowest available point, thus tending to swell the main channels of discharge, and to give rise to the greater streams that formed immediately after the retreat of the ice commenced. By a glance at the map it will be seen that the branches of the Rock, Wisconsin, and Chippewa rivers gather into the main stream just above the moraine, in a notable way — the manifest effect of the morainic barrier.

Special Channels of Discharge. After the Green Bay glacier had retired north of the Rock river water-shed, its floods were probably largely discharged through the Wisconsin river valley. In like manner, after the Lake Superior glacier had retired within the Superior basin, its waters were probably discharged, partly through the St. Louis and Kettle rivers in Minnesota, partly through the Brule and St. Croix rivers, the head waters of which are connected by a broad ancient channel, and partly through the Numakagon river. The Brule-St. Croix channel, being the lowest of these, was doubtless the main channel of discharge after the ice had so far retreated within the Superior basin as to admit of the accumulation of a common lake along its foot, and a common point of discharge. The result of this great overflow, if we interpret correctly, was the production of the extensive sand and gravel plains of the upper St. Croix, now known as the "Barrens." It may be remarked, that the "Barrens" of the northern region, generally, may be attributed to similar action of glacial waters.

It will be observed from this enumeration that there were many important channels of discharge across water-sheds during the glacial epoch, that now only appear as extinct channels. Some of these have been the sources of unwarranted speculation concerning former changes of drainage systems. They find adequate and admirably consistent explanation as necessary phenomena attendant on the melting of the glaciers.

"*Forest Beds.*" Between the two glacial epochs, abundant vegetation doubtless clothed the land and accumulated in peat beds, humus soils, and other accustomed ways. The advancing ice of the second glacial epoch buried these to some extent, (1) by pushing its moraines over them, (2) by possibly over-riding them in some instances, and (3), and most notably, by the fluviatile and lacustrine deposits that it gave rise to, and that reached on beyond the area over-spread by the ice. These beds constitute a part, at least, of the buried vegetable deposits included under the term "Forest beds," in the extended application which that term has come to have. No opinion is here expressed as to the Ohio deposits to which it specifically belongs, but the drift-buried vegetal beds of Wisconsin belong to at least three epochs, one of which is the inter-glacial one here noted.

Cause of the Glacial Climate. The agencies which produced the exceptional climate of the glacial period are still subjects of inquiry. Opinion has tended largely to attribute it to one of two classes of influences, viz : (1) *Geographical changes*, particularly a northern elevation and extension of the land and consequent modification of the oceanic currents, and (2) *Astronomical causes*, particularly periods of great eccentricity of the earth's orbit, whereby long cold winters and short hot summers, and the reverse, are produced. In both cases the glacial effects are attributed rather to the combination of indirect influences brought into play, than to the direct effects of the agencies themselves. The tendency of earlier opinion was toward the former, while more recent opinion seems to have inclined toward the latter agency. Perhaps the present tendency may be said to be toward a combination of the two.

There seem to be trustworthy evidences of a greater elevation of the land, particularly that adjacent to the north Atlantic, at the beginning of the glacial period, and of a depression at its close, the latter perhaps due to the ice itself.

On the other hand, recent investigations on the great moraine of the second epoch, and comparisons between the older and younger drift-sheets, have developed a notable harmony between drift phenomena and a modification of Croll's astronomical hypothesis. The more essential points, briefly stated, are as follows: Two periods of great eccentricity occurred about 200,000 years and 100,000 years ago, respectively, with a period of low eccentricity between, and one since, in the midst of which we now are. The two stages of great eccentricity are supposed to have furnished conditions favorable to two glacial epochs, or rather two groups of glacial epochs. By groups of glacial epochs we mean this: The precession of the equinoxes reverses the perihelion relations of the northern and southern hemispheres every 10,500 years, so that the long winters and short summers of the northern hemisphere will in that time be replaced by short winters and long summers, while the southern hemisphere will enjoy the opposite conditions. Now if long winters and short summers produce glaciation, the reversal of the conditions will probably have the opposite effect, and glacial epochs would succeed each other every 10,500 years during the period of great eccentricity, as maintained by Croll. But when an ice-sheet of great extent has become well developed, it probably has considerable power to perpetuate itself by its own effects on the climate, as urged by Wallace; so that it might endure the unfavorable conditions of the adverse period due to precession, being only caused to retreat a moderate distance, from whence it would readvance when the cycle of precession brought back long winters and short summers.

Under this view there should be two great glacial epochs each consisting of subordinate epochs of ice advance and retreat. As each cycle consumed 21,000 years, not more than two of these subepochs would be likely to occur during the maximum stage of eccentricity in such a way as to leave distinct moraines, though there might be one or more during its decline.

Now, as already noted, we find two great drift sheets, the older one very much more worn than the younger. If the former be referred to the earlier stage of maximum eccentricity and the latter to the more recent one, there will at least be a concordance between fact and theory. But the more striking coincidence is the fact that the margin of the later drift is marked by two great morainic belts, lying close together, and often coalescing, attended by a smaller one usually, at a greater distance within. If these be attributed to the influences brought into play by the cycles of precession, the harmony of phenomena and hypothesis becomes quite impressive,[1] and justifies a certain measure of belief that the truth will be found in this direction. Much more investigation of the drift phenomena throughout the globe will be necessary before anything like demonstrative conclusions can be reached.

Origin of the Great Lake Basins. We are now prepared to add somewhat to our previous discussion of the probable agencies that produced the basins of the Great Lakes. It will be recalled that, by a comparison of their valleys with the erosion accomplished by the Mississippi, and by a consideration of other evidences, it was concluded that, while very considerable valleys had doubtless been excavated by the drainage erosion of pre-glacial times, there was not only a want of evidence, but an inherent improbability, that the great basins we now find were so produced. The question now arises, Did the great glaciers, which made these valleys their main channels, complete what pre-glacial erosion failed to do? Very diverse opinions

[1] A fuller discussion of this correspondence was presented, by the writer, before the Wisconsin Academy of Sciences, in December, 1881.

are entertained in regard to the erosive power of glaciers, it being maintained, on the one hand, that they are peculiarly fitted to plow out great broad troughs, and, on the other, that they have almost no erosive power, and are quite incompetent to excavate lake basins. Both extremes are quite surely in error. That glaciers have a notable erosive power, the turbid streams that issue from them testify. That in the glacial period they wrought a great work upon the face of the land, the drift stands as an unimpeachable witness. That the drift was produced by mechanical action and not by disintegration, its character, particularly the large ingredient of calcareous and magnesian clays, demonstrates. Clays produced by disintegration contain very little of these ingredients. Because glacial corrasion in certain areas near the ice margin, or out of the line of the great glacial streams, where only relatively thin ice acted for but a short time, has been small, it is not safe to conclude that it might not be great beneath the deep strong currents that ground upon their beds for a long period. The *differential* action of the ice should not be overlooked. Like other flowing fluids, it must have acted efficiently in favorable situations, and quite otherwise under the opposite conditions. Now it is quite reasonable to suppose that the greatest erosion would be accomplished in the beds of the glaciers' great channels, and these we now know to have been the great lake troughs.

The basins themselves present many features, especially those of breadth and smoothness, that betoken glacial action, as well pointed out by Dr. Newberry. But, on the contrary, there are other features that stand as checks against extravagant ideas of glacial erosive agency, among which are the projecting shore points, islands, shoals, and some inequalities of bottom. These are not numerous nor marked, but are sufficient to teach that the great valleys were not supremely dependent upon glacial wear, however much they may have been modified by it. Still again, if the amount of drift be computed, and that portion of it which can be fairly supposed to have been derived from the lake bottoms be restored to them, it does not appear that it would be sufficient to fill them. Such a computation would, of course, be decisive, if it were not for the uncertainty of the data. These, with other considerations that cannot here find place, raise a grave doubt as to the competency of both pre-glacial and glacial erosion combined to produce the observed results. Neither, nor both together, seem to offer a full and satisfactory explanation, though both, we maintain, were important factors.

The writer has been gathering facts for some time that seem more and more, as their number increases, and their bearing is considered, to point to a third agency that may have played an important part in the formation of these great depressions. It is impossible here to discuss the evidence, and premature to arrive at conclusions, but it would be unsatisfactory to dismiss so fruitful a theme as the origin of these great features, without, at least, a suggestion of what may prove to be coming light, however penumbral it may, at present, be.

The view has been entertained in the earlier chapters that the accumulation of sediment over a wide area was competent to produce a depression of the crust. The same principle would seem to obtain in the case of land ice. During the last glacial epoch great ice-tongues were pushed down into these valleys, weighting them with perhaps 2,000 feet or 3,000 feet of ice. That the strata should have sagged under so great a burden, so long sustained, seems quite possible. The depression beneath these must have been compensated for by elevation elsewhere, presumably in the adjacent region in the form of a rim about the glacial tongue. Another effect of this ice must have been to reduce the temperature of its rock bottom to the freezing point, and maintain it there so long as the ice remained, giving opportunity for the cooling and consequent contracting effects to be deeply and widely felt. While the coefficient of contraction for rock is small, yet the total effect on a segment of the crust one hundred miles wide might be appreciable. Whatever influence this might have had would have been in the same direction as that produced by the weight of the ice, and would have been added to its effects.

If the ice produced any notable effects in these ways, there would probably be a tendency to return to the previous condition on its removal, owing to the elasticity of the earth-substance, the greater relative burden of adjacent regions, and returning warmth. But the basins were at once occupied by water and began to be filled with sediment, which, in some measure, counteracted the tendency to return to the primitive condition. Besides, imperfect elasticity would probably prevent a full return, and, in any event, a long period must be consumed in its accomplishment.

Now, as indicated, quite an array of facts are gathering that seem to point to both a depression during the glacial occupancy and a tendency to return since. There seem, therefore, some grounds for believing that one element in the production of the lake basins was a subsidence of their bottoms, due to glacial occupancy. The change of dip produced by such a subsidence would be so slight as not to be very obvious, unless attention be directed to it. The dips on the Wisconsin shores of the lakes favor the hypothesis.[1]

THE GREAT LAKE EPOCH (CHAMPLAIN).

Evidence was long since collected by Prof. Dana and others, showing that the final retreat of the ice was attended by a depression of the eastern portion of the continent, affecting it most at the north. Evidence to the same purport, as we shall presently see, is furnished by our own State. A general result of this was to slacken the southward flowing streams, and to facilitate the accumulation of broad lakes over the territory abandoned by the ice. The special situation of the Great Lakes favored this in a peculiar degree, and there gathered in their basins volumes of water much surpassing in area and depth their present magnificent dimensions.

Combined Glacial and Iceberg Action. It is probable that these lakes gathered gradually as the ice retreated, so that before it had retired from the basins, they formed great fringing lakes by their union along its border. This gave rise to a peculiar phase of deposition that embraced at once glacial and iceberg action. The depth of the waters was manifestly incompetent to give rise to bergs of great size, but "glacier-blocks" were probably very abundant.

The result of such action, if we correctly interpret it, was the formation of clayey deposits, interspersed with rock-fragments of moderate size, bearing the smoothed and scratched surfaces of glaciated fragments. But this limited iceberg action would be complicated by deposits derived from the shore-side of the lake, through drainage, the wear of the waves on previous glacial accumulations, and the action of ice upon the shores, for it should not be overlooked that the winters of the declining glacial epoch must still have been severe, resulting in powerful shore-ice action, in which the incorporation of beach rock, and its consequent transportation back into the lake, played a conspicuous part.

That this limited phase of iceberg action was a factor in the closing glacial history of our region, is thought to be more than probable, both from the nature of the case, and from the character of certain deposits that seem to be thus best explained. But it is yet a question of inquiry as to how extensive and important an element

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[1] Mr. Jamieson, of the Scotch Survey, has anticipated me a few weeks in the publication of almost identical views, so far as the effect of the weight of glaciers is concerned, and has given them a wider application, as indeed I had also. His views appear in the October number of the Geological Magazine, just received.

it may have been. The part it played in Wisconsin geology was seemingly quite subordinate, but it was probably important elsewhere.

Overlying the Till on the eastern margin of the State, are light-colored, stony clays that differ from the usual glacial product in being more homogeneous, less rocky, and in presenting a subdued, semi-lacustrine surface. These are believed to have been formed under the modifying influence of the marginal glacial lake.

Deposits of the Expanded Lakes. *The Red Clay and Beach Deposits.* There succeeded this, on the Lake Michigan border, a shallow-water deposit of stratified clay, sand, and gravel, reaching a maximum thickness of about 60 feet, overlain by a stony, red clay deposit, reaching a maximum thickness of 75 feet, over which, in the northern lake-border counties, there is a second shallow-water deposit, reaching a thickness of about 60 feet, which is surmounted by a thin stratum of red clay, rarely, if ever, exceeding 20 feet in thickness.

The red clays are unquestionably sub-aqueous deposits, and indicate, by their landward extent, the former extension of the lake. The Quaternary map of the Survey atlas exhibits their extent to the eye, and it is only necessary here to remark that, beginning on the lake shore near Milwaukee, the area widens to the north until the Kettle Range is reached, by which its western boundary is deflected to the eastward, until it passes that barrier, and swings around upon the western side, and, passing the water-shed, occupies the Green Bay valley. It ascends this valley to a few miles south of Fond du Lac, and reaches up the Upper Fox river beyond Berlin, while in the Wolf River valley it extends beyond Shawano. West of Green Bay it appears in much less amplitude than to the southward.

Former Change of Level. It is to be observed that this margin is not a horizontal line, such as would naturally be expected to mark the limit of a former expansion of the lake, and that, therefore, the relative altitudes at the time of the lake expansion must have been different from those which obtain at the present day. The heights to which the formation rises are, therefore, significant of the amount of relative change of altitude which the surface has suffered. At its southern extremity, it reaches an altitude of a little more than 100 feet above Lake Michigan. Where its western limit crosses the northern line of Ozaukee county, it is about 200 feet. A few miles east of this it rises upwards of 300 feet. At the northwest corner of section 36, town of Lynden, Sheboygan county, it is 315 feet. In the town of Rhine, of the same county, the limit is found at 322 feet; at the middle of the north line of section 21, town of Meeme, Manitowoc county, at 248 feet, and on the opposite side of the Kettle Range, at St. Nazian, at the same height. North of this its limitation is less well defined. There are some indications that it passed entirely over the Kettle Range, in the central portion of Manitowoc county, or at least that the waters of the period did. Nowhere north of this was it observed at a height exceeding 330 feet above Lake Michigan. Near Chilton, it reaches an elevation of 372 feet; north of Stockbridge, 358 feet; south, 390 feet; in section 6, Marshfield, 401 feet; in section 5, Taycheedah (T. 15, R. 23), 315 feet. These have been selected from a large number of observations, either because more reliable, or because more significant, on account of their positions. A more general and comprehensive appreciation of the facts may be gained by a comparison of the map of Quaternary Formations with the Topographical map of the Atlas. It will be observed that the formation rises gradually from its southern extremity to the region of Lake Winnebago, beyond which it declines.

Local Flexure. These facts indicate, beside something of a general northward depression, *a local sag* in the Lake Winnebago region. *It is interesting to observe that this is at a point which has repeatedly suffered depression in previous geological ages.*

Bordering the shores of Lake Superior, there occurs a similar red clay deposit associated with stratified sands and gravels, the exact succession of which has not yet been determined. This rises to its greatest known height near the western extremity of Lake Superior, or more precisely, in the axis of the trough of the Lake Superior basin, where it reaches a known altitude of 560 feet above the lake, and probably somewhat farther west, a maximum height of 600 feet. The observed altitudes on either hand are less. There appears to be indicated, therefore, not only a general northward oscillation of level — either of land or water surface, since these deposits are higher here than on Lake Michigan — but a moderate local flexure of the strata in the trough of the Lake Superior synclinal, *an old line of weakness.*

Before the full and precise significance of these deposits of the ancient expanded lakes can be adequately interpreted, the depositions throughout the whole of the Great Lake district must be studied, and their connections and equivalence determined — a work of detail involving much time and labor. Until that is accomplished, we must content ourselves with the general facts taught by the

Wisconsin deposits, strengthened by the broad fact that similar formations border the whole Great Lake area. It is safe to assert the general proposition that the lakes were greatly expanded, and united with each other by broad straits, and that they gave rise to thick lacustrine deposits, partly of stony clays and partly of so-called modified drift.

Southwesterly Discharge of the Great Lakes. There is also satisfactory evidence, the data for which is drawn mainly from without our State, that Lake Michigan then discharged southwesterly into the Mississippi, through the Illinois valley, and that Lake Erie likewise poured its waters through the Maumee-Wabash valley into the Father of Waters. What were the circumstances that prevented the discharge of these lakes through the St. Lawrence valley, as they now do, is one of the interesting problems yet awaiting solution.

Reversal of Drainage. Later, there came a reversal of the drainage direction, and the Great Lakes began to pour forth their waters into the northern Atlantic. There followed this a gradual withdrawal to their present shrunken, though still ample, dimensions.

Stage of Medium Expansion of Lake Michigan. There was an intermediate stage in the case of Lake Michigan, very much subsequent to the earlier expanded stage, but still at least some hundreds of years since, when it stood 15 or 20 feet higher than at present. At that time it cut back the border of the lake, forming clay and rock terraces, portions of which still remain, since the recent wearing back of the shore has not yet entirely passed the line of the old encroachment. Where the lake at that period had its margin on lowland, instead of against clay or rock cliffs, it formed beach ridges of sand, gravel, or chip-stone, that with equal clearness mark its former border.

Present Work of the Lake. From the stage which these ancient beaches and terraces mark, the lake retired, and it is now advancing at a lower level, repeating before our eyes the old-time geological work of waters, in that it is eroding its banks, assorting the material, accumulating gravel and sand on its beach, and finer material in successive grades in the quieter, off-shore waters. Thus the leading deposition within our borders to-day carries us back by the uniformity of its methods to the Laurentian sedimentation which was the first clearly discernible stage in the history of Wisconsin formations. *The first and the last were essentially alike.*

Formation of Soil. The retreat of the glaciers left, as before remarked, spread over the surface subjected to their action, a sheet of confused and commingled earthy and rock material, scraped from the surface of the areas lying northward, and partaking of the diverse natures of the parent sources. This intermixed material contained ingredients from a large variety of rocks of various mineral composition, and, therefore, furnished a substratum remarkably well fitted to yield a soil rich in all requisite mineral constituents. But this was left by the glacier in a crude uncongenial state. Upon this, the atmosphere, the rain, the sunlight and the frost began their work of aeration, disintegration and chemical reaction, and developed deep, rich, and enduring soils. To these, increasing vegetation added its contribution of organic action, and residual humic products. As the surface was washed and blown away, these agencies penetrated deeper and deeper, renewing from below what was lost above. *And this work still goes on.*

Quaternary Life History.

Recurring to life-history, we may recall the fact that the life of the closing Tertiary period, last considered, was that to which a warm climate only would be congenial. The southward extension of glacial climate necessarily drove this life from the region, so far as it could not modify itself to the climatic change, forcing along after it Arctic species, and at length completely sweeping away all life, breaking the continuity of its history, so far as our region is concerned.

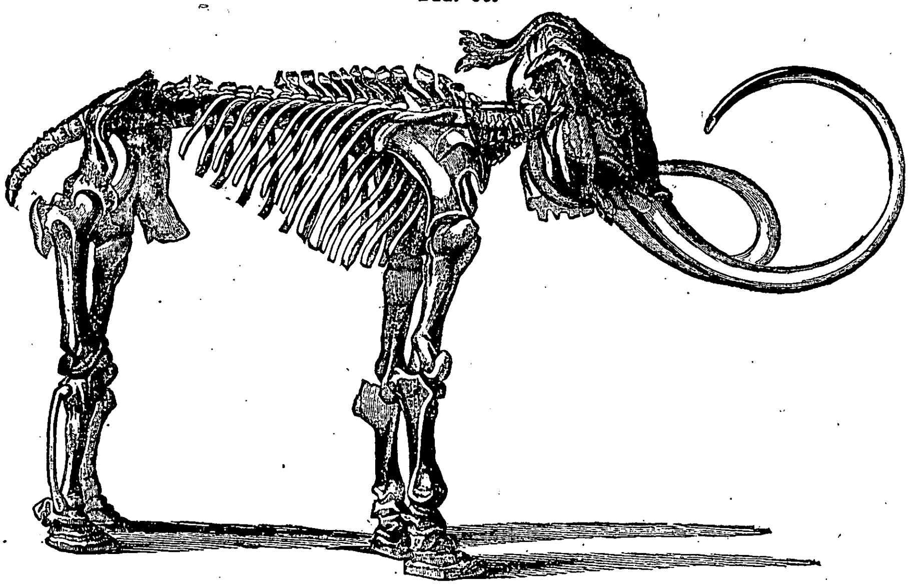
With the retreat of the first great ice-sheet there doubtless followed, closely after, the Arctic and cold-temperate species, so that the land abandoned by the ice was promptly occupied by advancing vegetation and abundant animal life.

Plants. During the inter-glacial period there is evidence of considerable coniferous growth, the formation of peat deposits, and other indications of a verdure-clothed land. With the second advance of the ice, this was overwhelmed, and for the most part destroyed, within the glaciated area, but near the margin and in favored spots, it appears to have been merely over-ridden and buried, leaving it as testimony to the events of the period. In the region south of the Kettle Moraine, that was not covered by the later advance, vegetable deposits appear to have been much more extensively buried, by the agency, as it would seem, of lacustrine and fluviatile action, associated with and springing from the glaciation of the period. Great lakes and rivers appear to have formed during the depression that attended the glacial retreat, and by these the vegetable deposits are thought to have been buried.[1]

[1] Compare Newberry on Forest Beds, Geol. Surv. of Ohio, Vol. II, p. 30 et seq., and Vol. III, pp. 38 and 39.

Mammals. Following the close of the second glacial epoch, there reappeared upon our territory, a great mammalian fauna. Elephants and Mastodons roamed over our State. The relics of a considerable number of them have been exhumed from our swamps or taken from the crevices of the Lead Region. Attending these there were other Mammals together with the lower orders of land life. The remains of a species of the genus *Bos*, allied to the Buffalo, several species of the genus *Cerves*, closely allied to modern

FIG. 99.



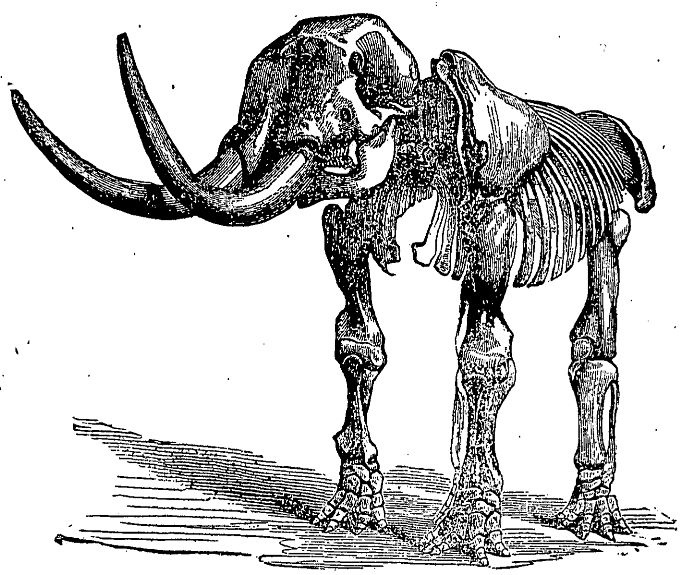
SKELETON OF THE MAMMOTH (Elephas primigenius).

species of Deer, portions of different individuals of *Megalonyx Jeffersoni*, the tooth of *Dicotyles compressus*, an extinct species of Peccary, remains of the genus *Canis*, allied to the Gray Wolf, and others resembling the Prairie Wolf, and an extinct species of Raccoon, with other mammalian remains, have been found in the crevices of the Lead Region, but as that area was not covered by the drift agencies, it is impossible to assert that these are all post-glacial species, although from the predominance of modern forms, it is probable that they are. The Mastodon was undoubtedly the king of the brute Mammals of the day.

The very modern aspect of the fauna is apparent. In a wider view this becomes more conspicuous. The continental peculiarities were the same as now. In North America, Herbivorous mammals were the dominant forms, and in South America, Edentates, in the Europe-Asian continent, Carnivores, and in Australia, Marsupials.

Man. In this Post-glacial period appear the first remains of the chief of Mammals — Man — so far as investigations within our State are concerned. It is not consistent with our limitations to discuss here the evidence bearing upon the first appearance of the human species, but it is worthy of note that the definite discrimination be-

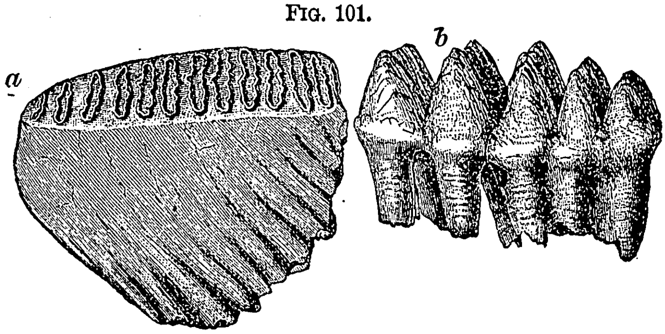
FIG. 100.



SKELETON OF MASTODON AMERICANUS (M. Ohioticus) — Owen.

tween the earlier and later glacial epochs, as here set forth, and the marking out of the definite limits of the glaciation of the latter, afford a means of discrimination in respect to the antiquity of remains found within the drift, that is worthy of thoughtful consideration. It is manifest that, if the earlier glacial epoch is separated from the later by a period anything like that which has elapsed since, as we have suggested, it is a matter of prime importance to

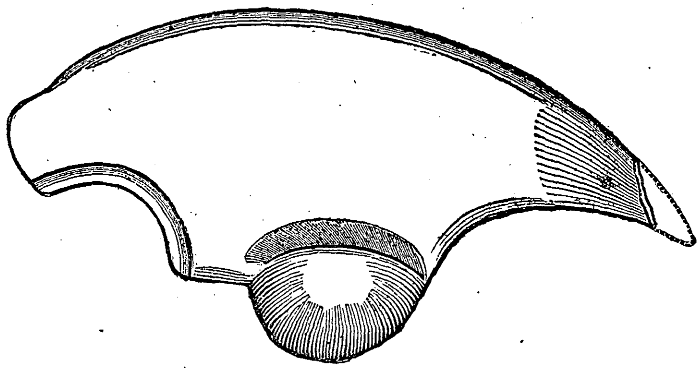
FIG. 101.



a. Tooth of Elephas Americanus, x ¼. *b*. Tooth of Mastodon Americanus, x ¼.

determine whether human relics, found within the drift, or beneath it, belong to the earlier or later epoch. It is evident that, if man existed in the inter-glacial epoch, a wide field for research lies along the outer margin of the Kettle Moraine, where the overflowing glacial waters spread out extensive, but thin sheets of detrital material upon the earlier glacial surface, burying whatever it may have borne.

FIG. 102.



CLAW-CORE OF MEGALONYX, X ½.

No relics trustworthily indicating great antiquity have yet been found in Wisconsin. The State is exceedingly rich in stone implements, and transcends all other countries in the yield of copper weapons and utensils which it has rendered to the enterprising Antiquarians of the State.

Except in the northern part, our territory is dotted with the mounds of a departed race, which has left us these geological evidences of its occupancy. But aside from the recognition of these physical results, this is the field of the antiquarian, rather than that of the geologist, and marks the border-land, where the history of the great physical past yields to the greater history of the intellectual present.

PSYCHOZOIC ERA.

CHAPTER XVI.

AGE OF MIND.

The propriety of recognizing the present as a Psychozoic era, distinct from the Cenozoic, has not been universally recognized, and perhaps the basis on which the era has been founded has not been altogether that here urged. If the distinguishing of this as a new era is simply a recognition of the superior mental attributes of man, considered merely as such, the propriety of the classification may be fairly questioned; for, however pre-eminent man's intellectual and moral nature, as compared with the organisms that characterized earlier geological ages — however much man may transcend the Mammals, Reptiles, Fishes, and Invertebrates of the preceding eras, unless that superiority — or man, its working embodiment — is an efficient *geological* agent, it does not entitle him to special recognition in a *geological* classification. An epoch of poetry or an age of science would be incongruous in geognosy, however much either might outrank a mollusk or a reptile.

The recognition of the Psychozoic era is here maintained as an important one, *on a strictly geological basis*, for it is contended, in opposition to the high authority of Lyell and others, that man is the most important organic agency yet introduced into geological history. It is affirmed that man more powerfully affects the course of geological progress than did Mammals, Reptiles, Fishes, and Mollusks, in the days of their reigns. This is due not so much to the direct as to the *indirect* influence of man. The excavations, constructions, and transportations of material which he effects, are considerable, when the brevity of his predominance is considered, but these are slight compared with the effects that spring indirectly from his activities. The cultivation of the soil very greatly increases the erosion and transportation of surface waters, and consequently the sedimentation of the bodies of water into which the streams pour their silt-burdened waters. The increase of turbidity thus occasioned in time affects the life of the streams and the coasts, and consequently influences the organic element of deposition. The entire land life is being revolutionized through man's agency, and to a very considerable extent, that of the waters. In the latter sphere he has but begun to systematically exert his power. That he will ultimately modify in a considerable degree marine life, scarcely admits of question.

Without enlarging upon the many phases of man's influence, these citations are perhaps sufficient to indicate that both the organic and inorganic agencies of geological progress are powerfully influenced by him, and that a new and profoundly marked era was inaugurated when he became the dominant organic being. The fact that this influence springs from man's intellectuality, more than from his animal force, renders the term Psychozoic a fitting one.

This era, however, did not become a reality, until man's sway became generally felt, and can scarcely be said to be now more than inaugurated. It may be held to have commenced when the land was first generally cultivated, and when native animals and plants were largely replaced by those selected and propagated by man. For this reason we would designate the initial stage the Agricultural Epoch.

The Archæological ages, Palæolithic (Ancient Stone Age), and Neolithic (Newer Stone Age) are not here recognized as strictly geological epochs, and if they were, they should probably be classed with the Cenozoic era, as man did not then, as an intellectual being, very greatly affect the course of geological growth.

In Wisconsin, the potent influences of this new era have only been felt within the memory of our oldest citizens. It may be safely asserted that the present generation has witnessed greater changes in the surface, in the vegetation, and in the animal life, than ever before took place in an equal length of time, since the dawn of authentic geological history, excepting possibly certain stages of the glacial period. This is the physical work of an intellectual agency. *This is the geology of the living present.*

PART II.

LISTS OF

I.	**Chemical Analyses,** - -	Compiled by R. D. Salisbury.
II.	**Minerals,** - - -	Compiled by R. D. Irving.
III.	**Rocks,** - - - -	Compiled by R. D. Irving.
IV.	**Fossils,** - - - -	Compiled by R. P. Whitfield.
V.	**Phænogamous Plants,** -	Compiled by G. D. Swezey.
VI.	**Fungi,** - - - -	Compiled by W. F. Bundy.
VII.	**Crustaceans,** - -	Compiled by W. F. Bundy.
VIII.	**Lepidopterous Insects,** -	Compiled by P. R. Hoy.
IX.	**Fishes and Reptiles,** - -	Compiled by P. R. Hoy.
X.	**Mammals,** - - -	Compiled by Moses Strong.
XI.	**Birds,** - - - - -	Compiled by F. H. King.

CHAPTER I.

CHEMICAL ANALYSES.

COMPILED BY R. D. SALISBURY.

LIMESTONE.

FORMATION.	LOCALITY.	ANALYST.	Calcic carbonate.	Magnesic carbonate.	Silica.	Alumina.	Ferric oxide.	Water.	Insoluble.	Total.
Lower Magnesian	Oconto Falls	G. Bode	49.41	39.78	7.64	1.47	1.69	....	.....	99.99
Lower Magnesian	Ripon	G. Bode	51.68	40.93	3.16	3.09	.60	.70	.....	100.16
Lower Magnesian	Poygan	W.W. Daniells	49.75	38.19	....	1.	59	1.19	9.44	100.16
Lower Magnesian	Madison	W.W. Daniells	66.82	30.40	1.09	.44	1.45	.35	[1].63	....
Lower Magnesian	Grant River	E. T. Sweet	42.14	34.56	17.03	3.56	1.51	1.28	.....	100.08
Mendota	Greenbush	W.W. Daniells	55.68	36.52	4.18	2.17	1.45	.58	.....	100.58
Trenton	Beloit	W.W. Daniells	52.63	36.40	1.96	3.	27	....	5.74	100.00
Trenton	Beloit	W.W. Daniells	47.97	38.39	1.75	1.	60	....	10.29	....
Trenton	Beloit	W.W. Daniells	48.54	34.86	1.87	2.	23	....	12.50	100.00
Trenton	Beloit	W.W. Daniells	49.30	43.87	1.99	1.	42	....	3.42	100.00
Trenton	Bristol	W.W. Daniells	56.07	35.32	4.45	2.08	.69	.46	[1].58	99.65
Trenton	Bristol	W.W. Daniells	84.02	5.33	7.03	2.21	.83	.61	[1].39	100.42
Trenton	Sec. 36, T. 5, R. 2 E.	W.W. Daniells	85.54	3.98	6.16	2.26	.95	.93	[1].95	99.87
Trenton	Benton	W.W. Daniells	97.92	1.60	....	1.	10	....	.....	100.62
Trenton	Sec. 3, T. 2, R. 3 E.	E. T. Sweet	85.54	3.98	6.16	2.26	.95	.[2]03	.....	99.875
Galena	Watertown	G. Bode	54.05	44.14	1.57	.07	.17	....	.....	100.00
Niagara	Williamstown	W.W. Daniells	50.52	40.97	3.57	3.49	.77	.48	.....	99.80
Niagara	Stockbridge	W.W. Daniells	50.54	40.37	4.52	2.67	1.02	.70	.....	99.82
Niagara	Clifton	W.W. Daniells	53.95	44.28	.....	.10	.30	....	1.23	99.86
Niagara	Taycheedah	W.W. Daniells	55.03	44.34	.....	....	.31	.29	.26	100 23
Niagara	Delafield	W.W. Daniells	54.91	42.77	1.35	.46	.43	.26	1.35	100.18
Niagara	Delafield	W.W. Daniells	55.18	41.70	.....	.18	.57	.45	1.73	99.81
Niagara	Byron	W.W. Daniells	54.25	44.48	.....	.10	.26	.11	.67	99.87
Niagara	Pewaukee	W.W. Daniells	52.86	42.98	.....	.3	2	.49	3.44	100.09
Niagara	Racine	W.W. Daniells	52.16	45.50	.....	.8	2	.67	.28	[3]99.65
Niagara	Racine	W.W. Daniells	55.23	43.52	.....	.9	2	.25	.40	[4]100.47
Niagara	Port Washington	G. Bode	55.41	43.48	.50	.61	....	....	.....	100.00
Lower Helderberg.	Near Milwaukee	G. Bode	54.57	43.41	1.49	.21	.32	....	.....	100.00
Lower Helderberg.	Near Milwaukee	G. Bode	54.69	41.82	1.57	.48	1.44	....	.....	100.00
Lower Helderberg.	Fredonia	G. Bode	53.23	41.57	2.91	1.46	.83	....	.....	100.00
Lower Helderberg.	Fredonia	G. Bode	56.55	41.50	1.29	.17	.49	....	.....	100.00
Lower Helderberg.	Fredonia	G. Bode	52.79	43.78	3.09	.10	.24	....	.....	100.00
Huronian	Bad River	E. T. Sweet	50.52	33.41	.....	....	1.19	....	13.85	incom.
Hamilton [6]	White Fish Bay	W.W. Daniells	49.12	38.76	8.59	3.	51	....	.....	[5]100.05

[1] Ferrous oxide.
[2] Phosphoric acid.
[3] Sulphate of lime, .10; Phosphate of lime, .12.
[4] Sulphate of lime, .65; Phosphate of lime, .10.
[5] Sulphate of lime, .07.
[6] Cement Rock.

SANDSTONE.

FORMATION.	LOCALITY.	ANALYST.	Silica.	Ferric oxide.	Lime.	Magnesia.	Alumina.	Potassa.	Soda.	Total.
St. Peters............	Mineral Point	E. T. Sweet...	96.74	1.45	.63	.08	.71	....	....	99.61
Lake Superior........	Bass Island.........	E. T. Sweet...	87.02	3.91	.11	.06	7.17	1.43	.22	99.92
Keweenawan.........	Leihy's Falls	E. T. Sweet...	69.78	7.93	.49	1.17	15.43	2.64	2.42	99.86
Keweenawan.........	....	....	54.50	....	....	....	....	....	....	....
Keweenawan.........	....	....	49.94	....	....	....	....	....	....	....
Keweenawan.........	....	....	55.91	....	....	....	....	....	....	....
Keweenawan.........	....	....	51.98	....	....	....	....	....	....	....
Keweenawan.........	....	....	75.24	...	....	....	....	....	....	....
Keweenawan.........	....	....	72.14	....	....	....	....	....	....	....
Keweenawan.........	....	....	68.91	....	....	....	....	....	....	....

CRYSTALLINE ROCKS.

LOCALITY.	Silica.	Alumina.	Ferrous oxide.	Magnesia.	Lime.	Soda.	Potassa.	Water.	Titanic oxide.	Silicic fluoride.	Total.
Sericite-schist.											
....	49.00	23.65	8.07	.94	.63	1.75	9.11	3.41	1.39	1.60	99.25
Quartz diorite.											
Sec. 2, T. 47, R. 27..............	46.31	11.14	21.60	trace	9.68	6.91	....	4.44	.....	.....	100.77
Serpentine.											
Presqu' Isle	38.24	1.48	......	14.83	1.42	....	....	9.53	.....	.....	[1]100.00

[1] Ferrous and ferric oxides with a little soda, 34.50.

MAGNETIC SCHISTS

LOCALITY.	Silica.	Alumina.	Ferric oxide.	Ferrous oxide.	Lime.	Magnesia.	Manganic oxide.	Phosphoric acid.	Sulphur.	Water.	Total.	Metallic iron.
Penokee Gap	31.84	.38	42.90	19.17	1.37	1.29	1.18	......	......	.38	98.46	44.94
Penokee Gap	42.90	.....	34.77	15.82	1.33	2.62	1.73	......	trace	.47	99.74	36.64
Penokee Gap	30 73	.....	43.89	19.48	1.91	1.63	.87	.02	......	.55	99.08	45.87
Sec. 14, T. 44, R. 3 W	18.47	6.30	67.06	8.38	2.48	2.28	1.05	.13	......	.45	100.60	53.45
Sec. 33, T. 44, R. 2 W	4.68	.....	65.91	27.49	1.79	.....	.56	......	trace	.....	100.43	67.66
E. of Potato River	40.50	5.10	46.06	5.02	.79	.54	1.41	......	.12	.55	100.08	36.14
Sec. 15, T. 44, R. 3 W	33.89	1.15	49.44	8.46	3.16	2.40	.34	......	......	1.50	100.34	41.19
Sec. 16, T. 44, R. 3 W	39.53	.11	36.41	15.77	1.52	2.52	3.12	trace	.42	.54	99.94	37.75

IRON ORES.

LOCALITY.	Ferric oxide.	Ferrous oxide.	Silica.	Insoluble silicious matter.	Alumina.	Lime.	Magnesia.	Manganic oxide.	Phosphoric oxide.	Sulphur.	Water.	Total.	Metallic iron.
Penokee Gap......	42.897	19.173	31.838	......	.384	1.373	1.293	1.126	.....	.....	.378	98.462	44.941
Penokee Gap......	15.535	7.851	......	......	.....	......	.....	.....	.....	.....	......	....	17.103
Penokee Gap......	......	......	27.03	......	.....	......	.....	.....	.....	.....	......	....	49.40
Penokee Gap......	34.770	15.819	42.896	......	.....	1.330	2.623	1.726	tr'ce	tr'ce	.471	99.735	36.693
Penokee Gap......	......	......	34.06	......	.....	......	.....	.....	.....	.....	......	....	44.03
Penokee Gap......	43.885	19.479	30.734	......	.....	1.91	1.632	.873	.021	.....	.545	99.079	45.871
Penokee Gap......	49.157	9.07	......	......	.....	......	.....	.....	.....	.....	......	....	41.465
Penokee Gap......	43.402	16.598	......	40.693	.....	......	.....	.....	.....	.....	......	100.693	43.292
Penokee Gap......	54.825	24.602	17.276	......	.....	2.043	.660	.625	tr'ce	tr'ce	.282	100.323	57.52
W. of Penokee Gap	49.435	8.460	33.894	......	1.151	3.156	2.403	.337	.....	.....	1.500	100.336	41.192
W. of Penokee Gap	36.411	15.767	39.532	......	.110	1.516	2.516	3.120	tr'ce	.421	.543	99.939	37.751
E. of Penokee Gap	67.064	8.322	18.472	......	.305	2.483	2.280	1.050	.127	.....	.450	100.613	53.465
E. of Penokee Gap	44.241	16.797	36.508	......	1.025	1.383	2.156	.193	tr'ce	.150	1.078	100.541	41.934
E. of Penokee Gap	40.420	12.331	39.171	......	1.139	1.373	1.890	.553	tr'ce	.....	2.559	99.036	37.885
E. of Penokee Gap	65.913	27.488	4.684	......	.....	1.786	.....	.563	tr'ce	.....	......	100.431	67.665
E. of Penokee Gap	49.254	5.112	......	......	2.059	1.687	1.586	.193	.....	.199	......	100.183	35.449
E. of Penokee Gap	40.056	5.051	40.495	......	5.100	.786	.540	1.405	.....	.129	.554	100.081	36.141
Vulcan Mine	84.98	1.17	10.56	......	1.43	.62	.28	.18	tr'ce	.07	1.22	100.51	60.04
Cascade Mines	83.70	......	10.67	......	3.54	.75	.34	tr'ce	.24	.03	.87	99.94	58.59
Cascade Mines	71.98	......	......	25.26	.68	.16	.06	.01	.07	.04	1.03	99.29	50.39
Magnetic Mine	78.35	......	......	19.64	tr'ce	.69	.21	.10	.151	.58	......	99.721	54.845
Negaunee	65.40	......	22.67	......	1.46	.45	.66	6.71	.16	.04	2.46	100.01	45.18
Foster Mine	44.33	......	47.10	......	2.14	.36	.13	.16	.13	.06	5.19	99.60	31.03
Lake Superior Mine	79.80	......	12.52	......	2.05	.45	.53	.10	.30	.03	4.25	100.03	55.86
Winthrop Mine....	84.66	......	12.70	......	.13	.40	.007	1.41	.084	.02	.71	100.121	59.26
Spurr Mountain ...	89.21	.....	6.28	......	2.67	.67	.19	tr'ce	tr'ce	.35	......	99.37	62.45
Michigamme Mines	61.631	29.109	3.280	......	2.12	1.07	.....	tr'ce	.057	.005	1.497	98.769	66.73
Edwards Mine.....	55.80	21.65	15.41	......	4.34	.77	.87	.10	.12	.16	.81	99.95	55.86
Jackson Mine	93.75	......	3.27	......	.73	.61	.23	tr'ce	.32	.03	1.09	100.03	65.62
Lake Superior Mine	86.70	......	9.82	......	1.64	.57	.24	tr'ce	.14	.02	.61	99.74	60.69
Breen Mine........	85.00	......	9.45	......	1.47	.99	1.18	.12	.02	.09	1.77	100.09	59.50
S. E. cor. sec. 25, T. 40, R. 17 E.	44.06	19.62	18.98	......	7.82	2.54	1.66	.20	.12	.21	4.32	99.53	46.16
Keyes' & Fisher's, T. 40, R. 18 E	75.47	trace.	14.28	......	4.31	.88	.43	.23	.08	.09	3.94	99.71	52.83
Quinnesec Mine ...	90.20	.76	4.24	......	3.81	.36	.09	tr'ce	.11	.03	.57	100.17	63.60
Emmett Mine.....	93.85	......	1.40	......	.72	.87	.....	.60	.11	.09	[1]2.36	100.00	65.70
Emmett Mine	81.57	......	5.55	......	.....	3.15	1.80	.....	.295	.056	[1]7.579	100.00	60.33
Emmett Mine	83.86	......	6.76	......	.....	2.70	1.60	.....	.10	.020	[1]4.96	100.00	58.70
Vulcan Mine	......	......	12.91	......	.31	.09	.03	.....	.027	.....	6.45	....	60.13
Norway Mine......	85.20	......	7.50	......	2.30	4.10	.62	.....	.040	.022	......	99.882	59.64
Cyclops Mine......	95.90	......	1.30	......	.62	.36	.30	tr'ce	.04	.01	......	98.53	67.13
Quinnesec Mine ...	93.87	......	2.10	......	.83	.60	.....	.15	.07	.02	......	97.63	65.70
Quinnesec Mine ...	93.28	......	4.36	......	1.29	.48	.....	.03	.08	.04	......	99.56	65.30
Quinnesec Mine ...	89.07	......	5.40	......	2.21	......	.....	.....	.024	.....	......	....	65.35
Eagle Mine........	89.79	......	3.82	......	3.11	.95	.77	.....	.51	.03	......	98.97	62.80
Iron Ridge.........	72.50	......	7.75	......	8.40	.56[2]	.64[2]	1.40	.....	.....	[1]8.75	100.00	50.75
Iron Ridge.........	74.40	......	9.11	......	2.26	6.72[2]	.41[2]	.....	1.00	.....	[1]3.10	100.00	52.08
Iron Ridge.........	79.25	......	6.18	......	2.49	6.81[2]	.14[2]	.....	1.13	.....	[1]4.00	100.00	55 475
Iron Ridge.........	76.74	......	10.09	......	4.00	......	.....	1.05	.....	.....	6.00	97.78	53.72
Iron Ridge.........	77.34	......	8.57	......	5.00	.55[2]	6.64[2]	3.50	2.75	.....	[1]2.65	100.00	54.14
Iron Ridge.........	78.75	......	6.40	......	4.50	2.00[2]	tr'ce	3.30	.75	.....	3.00	98 70	54.13
Iron Ridge.........	41.67	......	15.12	......	12.74	15.48[2]	8.25[2]	2.56	1.53	.....	[1]2.65	100.00	29.17
Iron Ridge.........	76.51	......	10.13	......	5.21	.75[2]	tr'ce	3.10	.....	.....	4.30	100.00	53.56

[1] Water, etc. [2] Carbonate.

KEWEENAWAN DIABASE.

LOCALITY.	Silica.	Alumina.	Ferric oxide.	Ferrous oxide.	Lime.	Magnesia.	Potassa.	Soda.	Water.	Total.
Fond du Lac Mine, Douglas Co.	48.28	17.35	11.43	4.02	6.27	6.58	1.14	1.83	2.66	99.56
Ashland Mine, Ashland Co....	53.69	22.10	8.53	3.65	4.31	2.09	1.39	1.99	2.61	100.36

KAOLIN.

Locality.	Silica.	Alumina.	Ferric acid.	Lime.	Magnesia.	Potassa.	Soda.	Water.	Carbonic acid.	Total.
Sec. 24, T. 22, R. 5 E	70.82	18.98	1.24	.24	.02	2.49	.10	5.45	.02	99.36
Sec. 24, T. 22, R. 5 E	70.25	17.68	2.32	.33	1.49	1.69	.39	5.61	......	99.76
Sec. 24, T. 22, R. 5 E	69.34	19.19	1.75	.44	.39	3.30	2.43	2.67	......	99.51
Sec. 26, T. 22, R. 5 E	58.86	28.87	2.48	.16	.98	2.57	.07	9.98	......	99.97
Sec. 10, T. 21, R. 5 E	......	......	2.88	......	......	1.25	.08	......	......	......
Sec. 10, T. 21, R. 5 E	......	......	1.17	......	......	1.51	.81	......	......	......
Sec. 24, T. 22, R. 5 E	......	......	......	......	......	1.21	......	8.84	......	......
Sec. 24, T. 22, R. 5 E	......	......	2.34	......	......	2.30	......	......	......	......
Sec. 24, T. 22, R. 5 E	......	......	......	......	......	1.96	......	6.30	......	......
Sec. 24, T. 22, R. 5 E	......	......	......	......	......	2.33	.10	8.84	......	......
Sec. 26, T. 22, R. 5 E	......	......	1.93	......	......	1.84	.27	......	......	......
Sec. 26, T. 22, R. 5 E	......	......	......	......	......	2.65	.21	7.96	......	......
Sec. 26, T. 22, R. 5 E	......	......	......	......	......	2.95	.83	......	......	......
Sec. 5, T. 22, R. 6 E	78.83	13.43	.74	.64	.07	.37	.07	5.45	.01	99.60
Sec. 4. T. 22, R. 6 E	......	......	4.43	......	......	1.21	.46	......	......	......

LACUSTRINE CLAYS.

Locality.	Silica.	Ferric oxide.	Alumina.	Calcic carbonate.	Magnesic carbonate.	Water.	Total.
Ashland	58.09	4.44	25.32	4.31	4.01	4.09	100.26
Bay City Creek	64.56	4.11	18.86	6.40	3.53	2.56	100.02

MARL.

Locality.	Calcic carbonate.	Magnesic carbonate.	Silica.	Ferric oxide.	Alumina.	Sulphuric acid.	Water.	Organic matter.	Total.
Pierce, Kewaunee county	86.09	7.18	1.48	.1	9	.44	1.67	2.95	100.00

CARBONACEOUS SHALE.

Locality.	Carbon.	Earthy matter.	Moisture.	Carbonic acid.	Total.
L'Anse Iron Range	20.86	77.78	1.37	....	100.01
Near Shullsburg	43.60	....	.30	.88	....

SOILS.

FORMATION AND LOCALITY.	Organic matter.	Ferric oxide.	Alumina.	Silica.	Manganic oxide.	Lime.	Magnesia.	Soda.	Potassa.	Phosphoric acid.	Carbonic acid.	Sulphuric acid.	Total.
Prairie Loam, South Central Wis	4.24	8.16	4.17	79.59	.18	1.30	1.04	.49	.19	.06	.52	.03	100.00
Peaty Soil	21.40	5.74	4.80	64.49	.13	1.62	.72	.51	.14	.12	.25	.08	100.00
Red Marly Clay, Kewaunee County	5.84	4.39	13.44	60.26	.12	5.03	3.48	.15	....	.19	7.08	.02	100.00
Red Marly Clay, Lake Superior	......	4.44	25.32	58.09	....	2.41	1.91	....	....	....	4.00	water 4.09	100.26
Red Marly Clay, Lake Superior	......	4.11	18.86	64.56	....	3.58	1.70	....	....	....	4.65	2.56	100.02
Red Clay, Ashland	......	4.40	34.72	48.74	....	2.41	1.91	....	....	....	4.00	4.09	100.27
Silicious Red Clay, Ashland	......	4.11	25.85	57.60	....	3.58	1.70	....	....	....	4.65	2.57	100.06
Loamy Soil, Douglas Co.	9.60	.90	2.90	[1]80.36	....	.68	.40	....	....	....	.79	3.15	98.78
Sandy Soil, Barrens, Douglas Co.	.80	1.00	.74	[1]94.08	....	.64	.12	....	....	....	.65	.87	98.40

[1] Insoluble silicates.

NATIVE WATERS—GRAINS PER GALLON.

LOCALITY.	Sodic chloride.	Sodic iodide.	Calcic bicarbonate.	Magnesic bicarbonate.	Sodic bicarbonate.	Ferric bicarbonate.	Sodic sulphate.	Potassic sulphate.	Sodic phosphate.	Alumina.	Silica.	Organic matter.	Total.
Bethesda Spring, Waukesha	1.160	.....	17.022	12.388	1.256	.042	.542	.454	tr'ce	.122	.741	1.983	35.7100
Iodo-Magnesian, Beloit	.3362	[1].0049	14.5196	12.2803	.1406	.0396	[2].1326	.3123	.0104	.0590	.7581	tr'ce	28.5936
Hygeia Spring, Waukesha	1.250	.....	16.726	13.142	2.265	.575	.524	.820	.040	.720	.150	tr'ce	38.2110
Horeb Spring, Waukesha	.1792	.....	10.752	6.8768	......	.....	1.2432	.....	.....	.2252	.7336	.....	20.0200
Fountain Spring, Waukesha	trace	.....	13.778	9.195	1.021	.048	.360	.....	.....	.097	.564	.311	25.3670
Gihon Spring, Delavan	.4704	.....	10.2704	7.140	......	.1960	.952	.....	.....	.1288	.756	.....	19.9126
Buckhert's Fountain, Watertown	......	.....	12.094	5.818	1.898	.100	......	.054	.....	.....	.305	.346	20.6150
Gomber's Well, Brodhead	.3248	.....	6.6584	4.8552	.0280	.2296	.1729	.....	.....	.1288	.6888	1.792	13.2720
Mineral Spring, St. Croix	.053	.....	11.193	7.248	.790	.....	.524	.....	.....	[3].492	.265	tr'ce	20.5650

[1] Trace of sodic bromide. [2] Calcic sulphate. [3] Iron not separated from alumina.

NATIVE WATERS — SUBSTANCES IN 1,000 PARTS.

LOCALITY.	Sodic chloride.	Potassic chloride.	Calcic chloride.	Sodic sulphate.	Potassic sulphate.	Calcic sulphate.	Magnesic sulphate.	Sodic bicarbonate.	Calcic bicarbonate.	Magnesic bicarbonate.	Ferric bicarbonate.	Silica.	Alumina.	Organic matter.	Total.
Magnetic Well, Watertown.	.013	....	....	.015	....	....	....	.020	.171	.125	....	.014	.....	.....	.358
Richmond Spring, Whitewater	.015	....	.032	.004	.014	....	....	.038	.452	.328	.012	.020	tr'ce	.043	.960
Market Square, Milwaukee.	.432	.026	....	.030	....	.164	....	.044	.369	.361	....	.041	.....	.....	1.467
Eureka Spring, Milwaukee.	3.353	....	....	.260	....	....	....	.130	.409	.180	....	.123	.188	.....	4.643
Rahn's Artesian Well, Manitowoc	.....	.013	.384	.638	....	.991	.824	....	.432	....	....	.020	.....	.....	3.302
Oakton Spring, Pewaukee..	.003	....	....	.011	....	....	....	.006	.249	.218	.010	.013	.003	.004	.507
Siloam Spring, Milwaukee.	.016	....	....	.050	....	....	....	.016	.225	.135	....	.010	.....	.....	.452
Schweickhardt's Spring, Wauwatosa	.004	....	....	.010	....	....	....	.009	.205	.154	.007	.035	.....	tr'ce	.424
Lowe's Springs, Palmyra ..	.023	....	....	.021	....	....	....	.023	.227	.103	....	.020	.....	.....	.417
Spring at East Troy	.007	....	....	.019	....	....	....	....	.212	.138	....	.024	.....	.....	.400
Mineral Rock Spring, Waukesha	.005	....	....	.017	....	....	....	.022	.176	.140	....	.019	.....	tr'ce	.379
Nemahbin Mineral Spring, Delafield	.019	....	....	.019	....	....	....	.021	.209	.095	.001	.018	.002	.....	.384
Artesian Well, Madison.....	.012	....	....	.027	....	....	....	.035	.145	.124	.010	.026	.....	.....	.379
Lethean Spring, Waukesha.	.012	....	....	.016	....	....	....	.023	.170	.106	.002	.014	.002	.....	.345
Trout Springs, Waterville.	.018	....	....	.017	....	....	....	.018	.179	.081	....	.016	.....	.....	.329
Hacket's Spring, Hale's Corners	.004	....	....	.019	....	....	....	.008	.151	.111	.006	.015	.002	.....	.316
Milwaukee River, above dam	.004	....	....	.007	....	.009	....	....	.112	.103	....	.055	.....	tr'ce	.290
Artesian Well, Fond du Lac	.074	....	....	.073	....	.010	....	....	.105	.083	....	.012	.....	.....	.357
Mineral Spring, Appleton ..	.006	....	....	.023	....	....	....	.052	.076	.056	.003	.015	.....	.011	.242
Lake Michigan, Milwaukee.	.006	....	....	....	....	.009	....	....	.079	.035	....	.016	.....	.....	.145

CHAPTER II.

MINERALS OF WISCONSIN.

By R. D. Irving

In this chapter are listed all the mineral species that have come to my knowledge as existing within the State of Wisconsin. A brief list of Wisconsin minerals by the late Dr. Lapham is published in the second volume of this series.[1] The latter list was intended, however, merely as preliminary, and includes rather the results of Dr. Lapham's own previous researches, than those of the investigations of the Geological Survey. It is thus naturally very defective, omitting the names of a number of the most abundant and important of Wisconsin minerals, besides including the names of several species whose existence has not been substantiated by the investigations of the Geological Survey. It is not, of course, pretended that the present list is a complete one; it is merely a record of observations to date.[2]

Immediately after the name of each mineral, I have added its chemical formula. For the physical properties reference may be made to any good manual of mineralogy. The principal optical and microscopic characters of the rock-forming species as seen in the thin sections, so far as is necessary to an understanding of the rock descriptions of this series of reports, are, however, included.[3]

The order in which these species are successively referred to is that of Dana's Mineralogy, and is indicated in the following preliminary enumeration:

Native Elements.
1. Gold.
2. Silver.
3. Copper.
4. Iron.
5. Sulphur.
6. Graphite.

Sulphides.
7. Galenite.
8. Bornite.
9. Sphalerite.
10. Chalcocite.
11. Niccolite.
12. Pyrite.

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[1] Vol. II, pp. 207–30. Annual Report for 1873.

[2] May, 1882.

[3] For the optical and microscopic characters of the several rock-forming species, I have used the works of F. Zirkel, H. Rosenbusch, G. W. Hawes, and R. Pumpelly, as well as my own experience.

Sulphides — continued.
13. Chalcopyrite.
14. Marcasite.
15. Arsenopyrite.
16. Tetrahedrite.

Chloride.
17. Halite.

Fluoride.
18. Fluorite.

Oxides.
19. Cuprite.
20. Hematite.
21. Menaccanite.
22. Magnetite.
23. Rutile.
24. Pyrolusite.
25. Limonite.
26. Turgite.
27. Wad.
28. Quartz.

Anhydrous Silicates.
29. Enstatite.
30. Hypersthene.
31. Pyroxene.
32. Amphibole.
33. Chrysolite.
34. Garnet.
35. Zircon.
36. Epidote.
37. Biotite.
38. Muscovite.
39. Wernerite.
40. Anorthite.
41. Labradorite.
42. Oligoclase.
43. Microcline.
44. Orthoclase.
45. Tourmaline.
46. Andalusite.
47. Cyanite.
48. Datolite.

Anhydrous Silicates — continued.
49. Titanite.
50. Staurolite.

Hydrous Silicates.
51. Laumontite.
52. Chrysocolla.
53. Calamine.
54. Prehnite.
55. Appophyllite (?).
56. Natrolite (?).
57. Analcite (?).
58. Chabazite (?).
59. Stilbite (?).
60. Heulandite (?).
61. Talc.
62. Glauconite.
63. Serpentine.
64. Kaolinite.
65. Saponite (?).
66. Sericite.
67. Chlorite.

Phosphate.
69. Apatite.

Sulphates.
70. Barite.
71. Celestite.
72. Anglesite.
73. Leadhillite.
74. Gypsum.
75. Melanterite.

Carbonates.
76. Calcite.
77. Dolomite.
78. Smithsonite.
79. Cerussite.
80. Hydrozincite.
81. Malachite.
82. Azurite.

Hydro-carbons.
83. Lignite, carbonaceous matter in shales, etc.

1. Gold. Gold might naturally be expected to occur, in small quantities at least, anywhere within the region of crystalline rocks in the northern part of the State; and it has in fact been reported from that region at a number of points. So far as my own tests are concerned, however — and I have no other reliable information, — these reports have always failed of proof save in one instance. In some samples of a quartz carrying pyrite and arsenopyrite brought me from the northern part of Clark county, I found minute quantities of both gold and silver.[1] It is not to be expected that gold in quantity will ever be found in Wisconsin.

2. Silver. Minute quantities of silver are found associated with the native copper of the Lake Superior region, and with the native copper which forms one of the materials of the drift prevailing over all of the State except its southwestern quarter.

[1] Trans. of the Wis. Acad. Sci. Arts and Letters, Vol. I.

The silver-bearing sandstone of the Porcupine mountain region of Michigan[1] has been traced across the Montreal river to Bad river in Wisconsin; and on the Montreal it has been found to contain minute quantities of copper and silver. There is no probability that silver in quantity will ever be discovered in Wisconsin.

3. COPPER. Native copper occurs both in the series of rocks described in this report as the "Copper-Bearing" or Keweenaw series, and throughout the drift covered portions of the State, in fragments that have been carried from the copper regions of the Northern Peninsula of Michigan and of Northern Wisconsin. These drifted fragments, which are particularly abundant in the eastern part of the State, and which often give rise to fallacious expectations, run from a few ounces to several hundred pounds in weight. According to Dr. Lapham, one found near Hustisford in Dodge county had a weight of 487 pounds. These fragments are known to have come from the copper-bearing rocks of the Lake Superior region, not merely by their occurrence in the northern drift, but also from the fact that they often carry adhering particles of the rock with which they were originally in place. The abundance in Wisconsin of these copper drift fragments, which are also found as far east as central Ohio, and as far west as central Iowa, is plainly to be connected with the peculiar courses of the glaciers of the Lake Superior and Lake Michigan basins. With the unusual abundance of drift copper in Wisconsin is in turn to be connected the unusual abundance of prehistoric copper implements, which are plainly merely hammered from drift copper fragments.[2]

Native copper in place has been found in the northern part of the State at a number of points in Ashland, Bayfield, Douglas, Burnett, and Polk counties, or, in other words, all the way across from the Michigan to the Minnesota boundary. Descriptions in detail of the occurrence of this copper are given in Vol. III of this series.[3] Briefly, it may be stated here that the copper of these regions occurs, (1) in veins transverse to the bedding of the formation, (2) in impregnations of altered and often highly epidotic amygdaloid layers, and (3) in impregnations of sandstone and conglomerate layers. Native copper has not yet been obtained in paying quantity in Northern Wisconsin; but there are a number of points at which its occurrence has been noted during the progress of the survey, where the indications are such as would warrant considerable exploitation. This would seem to be especially true of a region from the vicinity of Moose river southwestward into Minnesota. With the exception of the immediate vicinity of Snake and Kettle rivers in Minnesota, this region is virgin territory, so far as the copper miner is concerned. It was not reached by the explorers who, during the times of the mining excitement in the Lake Superior region thirty-five years since, spread themselves over nearly every other part of the Lake Superior country.

4. IRON. Metallic iron exists in nature both in masses that are plainly of extra-terrestrial origin, and in particles imbedded in the ultra-basic volcanic rocks. None of the latter iron has been discovered in the Wisconsin basalts, but iron of meteoric origin has been found certainly at one place, possibly at two or three.

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[1] Vol. III, pp. 200, 203, 206. See also the Copper-bearing Rocks of Lake Superior, by R. D. Irving, Monographs of the U. S. Geol. Survey, Vol. V.

[2] See Vol. II, p. 619.

[3] pp. 167–206, 357–362, 403–410, 415, 422–427.

The place referred to is "in Washington county on the farm of Lewis Korb," where the iron was found in a number of masses varying from eight to sixty-two pounds in weight. This iron was first brought to the notice of the scientific world by Dr. I. A. Lapham. It has been fully examined and described by Dr. J. Lawrence Smith.

5. SULPHUR. Native sulphur in small quantities is occasionally met with in the lead region in the southwestern part of the State, where "its presence is due to the decomposition of iron pyrites. It is usually found in a pulverulent form. Some pieces weighing as much as an ounce were seen in a cabinet at Hazel Green, which are said to have been obtained from a small sheet in some of the Buncome mines. It is said to be not uncommon in this vicinity. Other localities where it is found are Mineral Point, and the Crow Branch diggings." [1]

6. GRAPHITE. Graphite is known in Wisconsin only as an ingredient of certain carbonaceous schists of the Huronian series, in which condition it has been observed in the Penokee [2] and Menominee regions. [3] A portion of the black dusty material represented in Figs. 4 and 6, in Plate XV A, Vol. III, is of a carbonaceous nature.

7. GALENITE. GALENA. (PbS=lead 86.6, sulphur 13.4=100.) The principal occurrence of this mineral is, of course, in the lead region of the southwestern part of the State; but in small particles it is very widely diffused, occurring in the limestone beds of all parts of the State, and the shales of the Cincinnati group. It has also been reported from the crystalline rock region of the northern part of the State; but no well authenticated instance of such an occurrence has come to my knowledge. The galena of the lead mines of the southwestern part of the State is commonly very coarsely crystalline, occurring in distinctly outlined cubic crystals, often of large size, or in aggregated masses whose broad cleavage surfaces indicate a coarse crystallization. This galena carries almost no silver. The common associates of the galena of the lead mines are ferruginous sphalerite, calcite, pyrite and marcasite, with rarer chalcopyrite, barite, dolomite, cerussite, smithsonite, malachite and azurite.

Full descriptions of the modes of occurrence of this mineral in the lead region will be found in Vols. I, II, [4] and IV [5] of this series.

8. BORNITE. PURPLE COPPER ORE. ($FeCu_3S_3$=sulphur 28.06, iron 16.36, copper 55.58=100.) Bornite is found as a very rare mineral in the copper diggings near Mineral Point. [6]

9. SPHALERITE. ZINC BLENDE. (ZnS=sulphur 33, zinc 67=100, but often having part of the zinc replaced by iron.) This is one of the most abundant minerals in the lead region, where it is raised in quantity as an ore of zinc, occurring almost invariably associated with the galena of the horizontal deposits. It is not found in perfect crystals, but in crystalline aggregates, which have nearly always a dark brown or black color, on account of the replacement of a part of the zinc by iron.

[1] Vol. II, p. 692.
[2] Vol. III, p. 136.
[3] Vol. III, p. 716.
[4] pp. 645-752.
[5] pp. 367-568.
[6] Vol. II, p. 692.

Sphalerite is also occasionally met with in isolated crystals or small nests in the limestone beds of other portions of the State.

10 CHALCOCITE. (Cu_2S=sulphur 20.2, copper 79.8=100.) Chalcocite is mentioned by Dana[1] as occurring on Left Hand river in Douglas county. Lapham mentions chalcocite also as occurring at Mineral Point, but I find no other authority for either of these occurrences.

11. NICCOLITE. COPPER-NICKEL. (NiAs=arsenic 56.4, nickel 43.6=100.) Minute quantities of niccolite have been detected in a diabase in the immediate vicinity of Copper creek, Sec. 23, T. 47, R. 14 W., Douglas county.[2]

12. PYRITE. IRON PYRITES. (FeS_2=sulphur 53.3, iron 46.7=100.) Pyrite is of course a widely diffused mineral in Wisconsin. It occurs in especial abundance in the lead region, where it is associated with the galena of the lead mines, often in very perfect and large sized crystals. But pyrite is also of common occurrence in all the limestones of the State, and is not unfrequently met with in the sandstones also. The pyrite of the Potsdam and St. Peters sandstones has often been altered to hematite, while preserving its crystalline shape.[3] Some considerable masses of red and brown ore, as for instance those of the vicinity of Ironton, Sauk county, have resulted from an alteration of this kind. Pyrite is also widely diffused among the crystalline schists of the northern part of the State, in which it occurs in more or less minute particles. Such disseminated pyrite in beds of gneiss has often by its decomposition brought about the change of the gneiss into clay. As singularly free from pyrite may be mentioned the rocks of the Keweenawan series in the vicinity of Lake Superior. While this mineral has in a few rare instances been noticed in little transverse veins, and even in the mass of some diabases of the series, its almost universal absence from both eruptive and sedimentary members is very striking. Although so widely diffused, pyrite has not been met with in Wisconsin aggregated in sufficient quantity in any one place to make its use profitable.

Pyrite is not often met with in thin rock sections, but when present, produces an entirely opaque section, black in transmitted, and brassy metallic-lustered in reflected light. It is very often surrounded by a halo of brown iron oxide, produced by its alteration. Pyrite as seen in the thin section is shown in Fig. 1, Plate XIII A, and Fig. 3, Plate XV A, Vol. III.

13. CHALCOPYRITE. COPPER PYRITES ($CuFeS_2$ = sulphur 34.9, copper 34.6, iron 30.5=100). Chalcopyrite occurs in the limestones of the lead region, both as an associate of the lead ores and in independent limited crevices, as for instance in the immediate vicinity of Mineral Point.[4] This chalcopyrite is commonly intimately mixed with pyrite, and often very much oxidized, the result being a crumbling mixture of chalcopyrite, pyrite, brown oxide of iron, malachite, azurite, and cuprite. To the north of the lead region, in the limestones and sandstones of Richland, Sauk, and Vernon counties, chalcopyrite has been met with in similar limited crevices. It has also been occasionally noted in minute particles among the crystalline schists of the northern part of the State. Although a number of tons of a quite rich ore have been raised from the crevices near Mineral Point, it does not appear probable that this mineral will ever be found in Wisconsin in sufficient quantity to be of commercial value.

[1] Vol. III, p. 345.
[2] System of Mineralogy, 5th edition, p. 785.
[3] Vol. II. p. 575.
[4] Vol. II, p. 741.

14. MARCASITE. WHITE IRON PYRITES (FeS_2=sulphur 53.3, iron 46.7=100). This mineral has the same composition as pyrite, from which it differs, however, in its crystallization, its much paler color as seen on a fresh surface, its inferior specific gravity, and its great liability to decomposition. It is an abundant mineral among the lead mines of the lead region, occurring frequently in globular and coxcomb[1] shapes. It is also met with in fragments in the lacustrine clays in the vicinity of Lake Michigan.[2]

15. ARSENOPYRITE. MISPICKEL. ARSENICAL PYRITES (FeAsS=arsenic 46.0, sulphur 19.6, iron 34.4=100). As mentioned already, arsenopyrite has been detected in minute particles in vein quartz from Clark county.

16. TETRAHEDRITE. GRAY COPPER ORE ($Cu_8Sb_2S_7$, but varying greatly in composition, part of the Cu being often replaced by one or more of Fe, Zn, Ag_2, Hg, or Co, and part of the Sb_2 by As_2). Gray copper in small quantities has been detected in small transverse veins in the copper-bearing rocks of Ashland and Douglas counties, but it is a very rare mineral in Wisconsin.

17. HALITE. COMMON SALT (NaCl=chlorine 60.7, sodium 39.3=100). Sodium chloride is of course widely spread in Wisconsin in the waters which reach the surface in the shape of springs. As a solid substance, however, its only known occurrence is in the shape of microscopic cubes contained in some of the liquid-filled cavities of the quartz of granitic, gneissic and other rocks; and also in the quartz of certain veins. It is not certain that these crystals are always sodium chloride; they may also be at times chloride of potassium, or some other alkaline chloride.

18. FLUORITE. FLUORSPAR (CaF_2=fluorine 48.7, calcium 51.3=100). The only occurrence of fluorite yet noted in Wisconsin is one observed by myself on Bad river in Ashland county. At the falls which this river makes in the southern part of T. 45, R. 2 W., a pinkish granite intersects coarsely crystalline gabbro of the Keweenaw series. The fluorite, in minute purplish particles, was noted in rare and small nests in this granite, along with quartz, calcite, and ripidolite.[3] The complete absence of fluorite — which is so common an associate of lead ores — from the lead mines of Wisconsin is worthy of note.

19. CUPRITE. RED COPPER ORE (Cu_2O=oxygen 11.2, copper 88.8=100). Cuprite occurs in small quantities as one of the results of oxidation of the copper-pyrites of the vicinity of Mineral Point. It has also been noted in small quantity associated with native copper on Left Hand river in Douglas county.[4]

20. HEMATITE. SPECULAR IRON ORE. RED IRON ORE (Fe_2O_3=oxygen 30, iron 70=100). The sesquioxide of iron is of course a widely diffused mineral in Wisconsin. In the shape of the metallic-lustered or specular variety it is met with, for instance, in small nests and veins in the quartzites of the Baraboo river region of Sauk and Columbia counties,[5] and forming the larger part of heavy layers of iron ore in the Penokee region of Ashland county,[6] and in the vicinity

[1] Vol. II, p. 693.
[2] Vol. II, p. 28.
[3] Vol. III, pp. 172–174.
[4] Vol. II. p. 28; also Dana's Text Book of Mineralogy. p. 469.
[5] Vol. II, p. 506.
[6] Vol. III, pp. 118–136, 156–163, 257–301.

of the Menominee river, in Marinette county.[1] In the Penokee region the specular oxide is often intimately mingled with magnetite, these two minerals impregnating layers of quartzose schist in very varying proportions.[2] Somewhat similar occurrences are to be observed in the vicinity of Black River Falls, Jackson county;[3] but the iron oxide ingredients here are chiefly the red hematite and magnetite. Red hematite in greater or less quantity is found at numerous places in the State. At Iron Ridge, in Dodge county,[4] where it sometimes takes on some of the look of a specular hematite, it forms the principal part of a large deposit of iron ore. Mingled with the brown oxide it forms the principal part of the iron deposits of the region about Ironton in Sauk county.[5] Its occurrence in nests and fillings of small cracks in the Potsdam and St. Peters sandstones, where it has resulted from an alteration of pyrite, has already been noted.[6]

As accessory rock constituents, both the specular and red varieties of hematite are widely diffused, the red colors of all kinds of rock being due to the presence of the latter variety. The red hematite is especially common, however, in the fragmental rocks, such as sandstones and clays, while the specular variety is more especially characteristic of the rocks of crystalline texture.

As seen in thin sections the earthy red hematite presents itself usually as an aggregate of fine scales, which are more commonly opaque or nearly so, but sometimes transmit a red light in very thin sections. The specular hematite is always translucent in the thin section, and of a deep blood red color. It often presents itself in minute hexagonal scales. A representation of the appearance of the earthy hematite in the thin section is given, Fig. 5, Plate XIX A, Vol. III. The specular variety is not figured in these reports.

21. Menaccanite. Ilmenite. Titanic Iron Ore. ((Ti Fe) $_2O_3=Fe_2O_3$, with the Fe partly replaced by Ti, the proportion between the two varying; TiO_2 10 to 60 per cent.). Except as an accessory rock constituent, titaniferous oxide of iron is not known in Wisconsin. The titanic iron commonly so called is, as indicated above, a titaniferous hematite, with which mineral it coincides closely in crystallization. But magnetite is also frequently titaniferous; and when occurring as a rock constituent is more commonly so than not. When the crystalline outlines are apparent it is easy to distinguish in thin rock sections between titaniferous magnetite and titanic iron proper. But titaniferous magnetite is commonly without evident crystalline outlines, its boundaries in rock sections being usually formed by some previously crystallized mineral. It is thus often not possible to be certain whether we have to do with titaniferous hematite or titanic iron proper, or titaniferous magnetite. As characteristic for titanic iron, as compared with magnetite, are often mentioned in the books a peculiar rod-like form — the rods being often aggregated in various ways — and a gray, translucent to opaque substance which frequently surrounds and permeates the titanic iron having plainly resulted from its decomposition.[7] This substance is supposed to be a titanate of lime. But I have found numbers of instances in which both rod-like forms and gray decomposition-product occur in a mineral which is plainly titaniferous magnetite, and not titanic iron properly so called. True menac-

[1] Vol. III, pp. 437–534, 610, 617, 667–718.
[2] Vol. III, pp. 156–162.
[3] Vol. II, pp. 497, 498.
[4] Vol. II, pp. 327–335.
[5] Vol. IV, pp. 49–56.
[6] This Vol., p. 00.
[7] See Wichmann in Vol. III, p. 610.

canite then, although probably existing somewhat abundantly in the Wisconsin rocks, has not been certainly proved to do so. If we extend the term titanic iron, however, to titanium-bearing magnetite, then it is one of the most widely diffused of accessory rock constituents in the State.[1]

As a rock constituent menaccanite is often in too small particles to be distinguished by the naked eye; when the particles are sufficiently large, however, they are seen to be characterized by a metallic luster and iron black color. As seen in the thin section, menaccanite is characterized by its complete opacity, black color, metallic luster in reflected light, its hexagonal outlines when in distinct crystals, its rod-like and club-like forms under other circumstances, and its tendency to decompose more or less completely into a grayish cloudy amorphous substance. Titanium-bearing magnetite may present all of these characters except the hexagonal outlines.[2]

22. Magnetite. Magnetic Iron Ore. ($Fe_3O_4=FeO+Fe_2O_3=$oxygen 27.6, iron 72.4=100; or Fe_2O_3 68.97, FeO 31.03=100. The iron is often replaced, however, by some titanium and in small part by magnesium.) Magnetite occurs in Wisconsin both as the principal ingredient of certain rock beds and masses— which, when sufficiently rich, constitute iron ores — as an accessory rock ingredient, and in the shape of a fine sand on the beaches of the great lakes. As instances of the occurrence of magnetite in quantity may be mentioned the great beds of magnetitic quartz-schist on the Penokee iron range of Ashland county;[3] the Menominee river region of Marinette county;[4] and the Black river region of Jackson county.[5] No titanium has been detected in any of these magnetites.

As an accessory rock constituent, magnetite, in both titanium-bearing and titanium-free varieties, is widely diffused in Wisconsin, occurring both in the basic crystalline rocks of eruptive origin and in the crystalline schists. It is also met with in the red sandstones of the vicinity of Lake Superior. When the particles of magnetite are large enough they may be recognized by their black color and metallic luster. In the thin section magnetite is frequently beautifully crystallized, the crystals showing the various forms that may be produced by sections in various directions through the characteristic octahedra; the more common section in the case of single crystals being of a square or rhombic shape. Often the crystals are grown together and then present very peculiar and characteristic zigzag or notched outlines. Magnetite is entirely opaque in the thin section, appearing perfectly black in transmitted light, and of a metallic luster in reflected light. Besides occurring as an original rock constituent, it is often found in thin rock sections under conditions that show its secondary production by the oxidation of the iron protoxide of augite and hornblende.[6] A good idea of the appearance of the crystalline-outlined magnetite may be obtained in Fig. 2, Plate XIII A, Vol. III. Irregularly outlined titanium-bearing magnetite is shown in Figs. 1, 2 and 4, Plate XV D, Vol. III.

23. Rutile. ($TiO_2=$oxygen 39, titanium 61=100.) Rutile is known among Wisconsin minerals only as a microscopic inclusion in the quartz of gneiss,

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[1] Dr. Lapham in his list of Wisconsin minerals (Vol. II, p. 28) speaks of the occurrence of menaccanite in the quartzites of the Baraboo region of Sauk county; but the statement lacks confirmation.

[2] Vol. III, pp. 37, 624, etc.

[3] Vol. III, pp. 118–136, 152–163, 248–301.

[4] Vol. III, pp. 437–506, 616–617, 667–689.

[5] Vol. II, pp. 493–499.

[6] Vol. III, pp. 38, etc.; Vol. IV, Part VII.

granite, and similar rocks. This rutile presents itself in the shape of delicate black needles of relatively great length.[1]

24. PYROLUSITE. (MnO_2=manganese 63.2, oxygen 36.8=100.) Pyrolusite has been noticed in small quantities, only occasionally well crystallized, in the magnetitic schists of the Penokee range of Ashland county.[2]

25. LIMONITE. BROWN IRON ORE. ($H_6Fe_4O_9=Fe_2O_3$ 85.6, water 14.4=iron 59.90, hydrogen 1.60, oxygen 38.50=100.) Limonite is, as usual elsewhere, widely spread in Wisconsin, occurring in the shape of nests and concretions in the various limestone and sandstone formations, in which shape it is commonly the result of the alteration of iron sulphide; as the principal constituent of deposits of "bog iron ore;" as a prominent constituent of the so-called "soft hematites" of the Menominee region, and as an accessory rock constituent. The limonite nests of the Potsdam sandstone reach occasionally a sufficiently large size to give them importance;[3] they commonly, as already stated,[4] contain a considerable proportion of hematite. Bog iron ore is known to exist underneath many of the numerous peat marshes of the State, but whether it will prove to occur in sufficient quantity to be used as an ore, remains to be seen. This bog ore is occasionally quite pure limonite, and is again largely mixed with sand brought into the shallow lake during the deposition of the iron oxide.[5]

The "soft hematites" of the Menominee region are much the most important of forms of limonite met with in the State. Whether they owe their origin to an alteration of the prevalent magnetic or specular ores, or to a direct replacement of some of the other mineral ingredients of the schists in which they occur, has not yet been determined.[6]

The hydrated oxide of iron is a common accessory rock constitutent. As the result of an original deposition, however, it is known in the fragmental rocks, such as conglomerates and sandstone, the yellow and brown colors which so often characterize these rocks being invariably due to the presence of this oxide. Yellow and brown sandstones are common in Wisconsin in the Potsdam and St. Peters sandstones.[7] In the crystalline rocks limonite is nearly always plainly the result of the alteration of some of the constituent minerals. As seen in the thin section, limonite presents itself as a pale yellow transparent substance, when exceedingly thin, from which condition it grades through various shades of brown and yellow, and various degrees of translucency to a nearly black color and complete opacity.

The minute black and brownish-black particles which occur in the thin sections of many rocks, in which there is a felsitic or otherwise imperfectly individualized matrix, are apparently often composed of hydrous oxide of iron. These particles appear often also to be of anhydrous or red oxide of iron, but all are commonly included under the general name of ferrite.[8]

26. TURGITE. ($H_2Fe_4O_7=Fe_2O_3$ 94.7, H_2O 5.3=100=iron 66.27, oxygen 33.14, hydrogen 0.59=100.) Brooks mentions turgite as occurring in the "soft" or

[1] Vol. IV, pp. 651, 655–656, 687, etc.
[2] Vol. III, pp. 121, 132, 134, 135.
[3] Vol. IV, pp. 49–56.
[4] This Vol., p. 314.
[5] Vol. II, pp. 635, 636.
[6] Vol. III, pp. 500, 501, 502, 506, 610, 618, 634.
[7] Vol. II, pp. 259, 286, 287, 540, 546, 557, 669, 675, etc.
[8] Vol. IV, pp. 649, 665, 667, 676, 679.

brown ores of the Menominee region.[1] I am not aware of its occurrence elsewhere.

27. WAD. BOG MANGANESE. Strong mentions the occurrence of a brownish black oxide of manganese as light as cork in crevices in the Trenton limestone of the lead region.[2] According to Lapham the cobaltiferous variety of wad or asbolite occurs also in Wisconsin, but he does not mention the place.[3]

28. QUARTZ. (SiO_2=oxygen 53.33; silicon 46.67=100.) Quartz is, of course, the most widely diffused mineral in Wisconsin, occurring as a prominent constituent of the crystalline schists of the northern part of the State; as the chief and often only constituent of quartzite, of the Potsdam and St. Peters sandstones, and of the sand of the drift, besides occurring often as a vein constituent. In the shape of chert this mineral is also widely diffused in the limestones of the southern and eastern parts of the State. In the crystalline condition the only very noteworthy occurrence of quartz in Wisconsin is among the quartzites of the Baraboo region of Columbia and Sauk counties, especially in the vicinity of Devil's lake and at the Upper Narrows of the Baraboo river.[4] Most of the crystals of the Baraboo region are small, though of great clearness and beauty; occasionally, however, they reach several inches in diameter.

Quartz as a rock constituent, when the grain is sufficiently coarse, is recognized by its very light color or complete lack of color — the colors of the other minerals showing through it — its great hardness and its complete lack of cleavage. As seen in the thin section quartz is characterized by its great clearness and freedom from decomposition, by its brilliant colors when examined between crossed nicol prisms, and by its lack of cleavage. Although belonging to the hexagonal system of crystallization, it does not, when cut parallel to the basal plane, become dark between the crossed nicol prisms of the polarizing microscope; but in a well-made rock section the quartz is of such great thinness that this peculiar property need not be taken note of. Very characteristic indeed of quartz in rock sections, unless these are of extreme thinness, are the colored bands forming the edges of the particles. These bands are due to the increasing thickness of the particle from without inwards. For the most part the quartz particles of crystalline rocks are irregularly outlined, their boundaries being formed either by those of previously crystallized minerals, or by the mutual interruptions of the quartz particles themselves. The quartziferous porphyries, however, carry the porphyritic quartz in the shape of distinctly outlined crystals. These crystals present the ordinary form of quartz, that is, are hexagonal prisms terminated at either end by right and left rhombohedra. But the terminal planes in these quartzes commonly predominate greatly over the prismatic, and not unfrequently the latter are entirely wanting. In the latter case the section is one of a rhombohedron only, that is, is foursided, and, since the rhombohedral angle is not far from 90° (94° 15′), is often not far from a square. When the section is sufficiently thin, these square or diamond-shaped areas will become dark between the crossed nicol prisms, when either diagonal of the square corresponds with the cross hair of the microscope; that is, with a nicol plane.

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[1] Vol. III, p. 500.
[2] Vol. II, p. 693.
[3] Vol. II, p. 28.
[4] Vol. II, pp. 506, 509, 516.

The particles of the quartz of the various rocks of which it forms a constituent are often plentifully supplied with microscopic inclusions. Most common among these inclusions are minute cavities, which are either empty or partially or completely filled with some liquid or gas. The liquid seems often to be pure water, while in other cases it is water holding carbonic acid in solution, or is simply liquid carbonic acid, or again is a supersaturated solution of chloride of sodium or potassium, in which case minute transparent cubic salt crystals may sometimes be seen with a high power. In these liquids, bubbles are sometimes perceptible, and these are often movable, being displaced by turning or heating the section, while at other times they have a spontaneous motion.[1] These liquid-filled cavities are commonly oval in outline, but often they are very irregular, and even branching; other very common inclusions are colorless needles of apatite,[2] leaves of mica,[3] hematite,[4] crystals of magnetite,[5] and needles of rutile.[6] The quartz crystals of the quartziferous porphyries also often include particles of the felsitic or devitrified matrix, and also particles of pure glass, or only partially devitrified glass. The glass inclusions have often a quite perfect crystalline outline corresponding in boundaries and axial position with the crystals in which they occur.[7]

The chert of the various Silurian and Cambrian limestones in the southern and eastern parts of the State is silica or quartz in an amorphous and concretionary form. Presumably it is of organic origin, but microscopic observations are needed to prove its character. The silica of these concretions is more or less completely dehydrated colloid silica. A similiar silicious material is met with among some of the schists of the Huronian of the Menominee region. The amorphous forms of silica are more widely distributed among the crystalline schists than is commonly supposed, and need further investigation.

Illustrations of the appearance of quartz as a rock constituent, in the thin section, are given at Fig. 2, Plate XII A; Fig. 2 of Plate XIII A; Figs. 5 and 6 of Plate XV A; Figs. 1 and 2 of Plate XV C; and Figs. 5 and 6 of Plate XIX A — all in Vol. III of this series.

29. ENSTATITE. BRONZITE ($Mg\ SiO_3$=silica 60, magnesia 40=100; but the magnesia is often in part replaced by iron protoxide). This mineral is known in Wisconsin only as a constituent of some unusual rocks of the Upper Wisconsin valley, and even in them has not been certainly distinguished from hypersthene. Externally these two minerals are much like one another and the resemblance remains in the thin section. Both are orthorhombic in crystallization, and both commonly present sections in which one cleavage is very strongly pronounced. When this cleavage is laid parallel to either cross-hair of the polarizing microscope, sections of enstatite and hypersthene are always dark between the crossed nicols. Hypersthene is somewhat less strongly dichroic than enstatite, and this property helps sometimes to distinguish between them. Externally enstatite is recognized in rocks of which it forms a constituent by its olive-green to brown color, its easy cleavage, the peculiar metalloidal luster of the cleavage surfaces in some varieties, and its considerable hardness. Sections of enstatite examined in the ordinary light present usually a pale brownish or greenish color.

[1] Vol II, pp. 639, 641 etc.; Vol. III, pp. 224, 249, 255, 268, 600, etc.
[2] Vol. III, pp. 96, 647, etc.; Vol. IV. pp. 628, 631, 635, 662, 685, etc.
[3] Vol. III, p. 614; Vol. IV, p. 685.
[4] Vol. III, p. 635.
[5] Vol. III, pp. 109, 614, etc.
[6] Vol. IV, pp. 651, 655–656, 687, etc.
[7] Vol. IV, p. 666.

30. HYPERSTHENE. ($(Mg\ Fe)SiO_3$. If Fe:Mg::1:2, the formula requires silica 54.2, ferrous oxide 21.7, magnesia 24.1=100.) Hypersthene is a rare mineral in Wisconsin, being known only as a constituent of some unusual rock varieties. It forms a large proportion of a norite which occurs on the lower part of the Eau Claire river in Marathon county.[1] Hypersthene is recognized macroscopically by its dark brownish-green to greenish-black color; its strong single cleavage and its considerable hardness. In the thin section hypersthene ranges from nearly colorless to grayish-green, and even deep yellow; the color varying with the thickness of the section, with the direction of the section, and in hypersthenes of different sections. Placed between the nicol prisms of the polarizing microscope, hypersthene is always dark when its principal cleavage lines are parallel to either cross-hair. The hypersthene from the typical region in Labrador shows in thin sections immense numbers of minute brownish scales laid parallel to the principal cleavage. The true nature of these scales is yet unknown. They are found also in the Wisconsin hypersthene above referred to.

31. PYROXENE. ($R\ Si\ O_3$. R=two or more of Ca., Mg., Fe., Mn., and these are also often replaced by Al_2, Fe_2, Mn_2, one or all.) Pyroxene is known in Wisconsin only as a rock constituent, in which shape it is, however, one of the most important of Wisconsin minerals, presenting itself in the three varieties of *augite*, *diallage*, and *sahlite*, the two former being the most important.

Augite. Aluminous lime-magnesia iron pyroxene. The most important augite-bearing rock in Wisconsin is diabase, which is basic in composition; but augite also occurs in acidic rocks in Wisconsin, as well as elsewhere, and as will be seen subsequently, is even often associated with quartz. Such an association was supposed formerly never to occur. When coarse enough to be seen with the naked eye, augite as a rock constituent is of a black or greenish-black color with cleavage surfaces nearly at right angles to one another; but commonly these cleavages cannot be seen with the naked eye, when it becomes very difficult and often impossible to distinguish augite from hornblende. In the thin section, however, the distinction is one of the most easily made. In the Wisconsin augitic rocks this mineral is only very rarely provided with distinct crystalline outlines, occurring either in irregularly rounded particles or in areas whose linear contours are determined by the previously crystallized mineral. In color the thin section of augite varies from almost entirely colorless to a deep reddish-violet, but it usually presents some shade of violet or pinkish-violet.[2] Augite is without dichroism, and hence, when revolved on the stage of the polarizing microscope with only the lower nicol attached, sections of augite present no change in color. The cleavage lines of augite as seen in a section parallel or nearly parallel to the basal planes cross one another nearly at right angles (87½° and 92½°). When the section is parallel or nearly parallel to the vertical axis, the cleavages present themselves only in parallel lines. In general the sections of augite show the cleavage much less prominently than those of hornblende, and often the section is traversed only by a few irregular rifts. When augite occurs in distinctly outlined crystals, or presents the cleavage lines very prominently, so that the crystallographic axial directions may be readily determined, its monoclinic crystallization is easily perceived. Sections containing the orthodiagonal present a dark field between the crossed nicols when that axis is placed parallel to a cross-hair,[1] whilst all other sections,

[1] Vol. IV, p. 667.

[2] I am aware that in works on lithology, augite sections are spoken of as commonly of a greenish color, but so far as my experience has gone, this color is always connected with a beginning molecular change to the uralitic condition.

in order to become dark, must be revolved away a certain distance from that position in which the crystallographic axis would be parallel to a cross-hair. Except in those few positions in which it is dark, the section of augite when viewed between the crossed nicols gives brilliant interference colors. Twinned particles of augite, recognizable as such by their giving different colors on opposite sides of a straight division line, are often met with in thin rock sections.

Augite has often undergone much alternation. There are two principal forms of alteration, the one to a soft green hydrous mineral which is some kind of chlorite, and the other to hornblende. The latter of these alterations, both of which are often found almost or quite complete throughout great masses of rock, is the most important and interesting of the two. This change is a molecular one only, being unaccompanied by any change in chemical composition. It has long been known that hornblende material existed with the external form of augite, from which mineral it was plainly altered. This substance Rose called *uralite*, from its being found in some of the rocks of the Ural mountains. The application of the microscope to the study of rock sections soon showed that this change is far more widespread than was at first supposed. The generalization has already been advanced, in fact, that all the hornblende of the plainly eruptive rocks is in the nature of uralite. From my own experience with the eruptive rocks and the crystalline schists of the Lake Superior region and Northern Wisconsin, I am led to conclude that none of the hornblende of these rocks is original, but all is merely altered augite. There are three phases which this alteration of augite into hornblende presents. In one the hornblende, as seen in the thin section, is a faint-greenish, delicately fibrous, not very strongly dichroic material. In another it is of a deeper green color, more strongly dichroic, without the fibrous structure, and affected by a very pronounced prismatic cleavage. In the third phase the hornblende section appears of a deep brown color, and is more intensely dichroic than either of the others. In other words all of the three kinds of hornblende found in rock sections occur at times with augite cores. The hydration of augite, above mentioned, by which is produced a chlorite mineral, has often been preceded by the simple molecular change into hornblende.

Augite is represented rather unsatisfactorily in Figs. 4, 5 and 6, Plate XV D, Vol. III, exhibiting in the last-named figure a partial change to a chloritic or viriditic material. At Fig. 1, Plate XV E, in the same volume, augite is represented in the shape of cores of uralite, which substance is still further altered to greenish chlorite. The most prominent augitic rocks of Wisconsin are the eruptive diabases of the Keweenawan[1] and Huronian[2] series.

Diallage. Foliated Augite. Diallage is an augite in which there is developed, in addition to the ordinary prismatic cleavage, a much more perfect one parallel to the clino-axis, as a result of which its sections are seen to be traversed by exceedingly strong parallel rifts. Another peculiarity which is often presented by diallage is the peculiar pearly or metalloidal — sometimes even brassy — luster, which marks the surface of its characteristic cleavage. Otherwise diallage is much like ordinary augite, and the remarks already made with regard to the appearances presented by altered and unaltered augite apply equally well to diallage. In fact there are passage forms between the two phases which would indeed be hardly worthy of separate notice here, but that the diallage forms a prominent constituent of a type of rock which has received a special name of

[1] Vol. III, pp. 8–10, 31–35, 37–49, 183–193, 336–349, 391, 400–428, etc.
[2] Vol. III, pp. 518–521, 621–627, 691, 704.

its own. This rock is the one known as gabbro. In it the diallage is associated commonly with a basic feldspar, and also at times with olivine or chrysolite. This rock, which is nearly always strongly characterized by its coarse grain, has a great development among the Keweenawan rocks of the northern part of the State.[1] The appearance of diallage in the thin section is represented in Fig. 2, Plate XV E, Figs. 1 and 2, Plate XV D, and (largely altered to uralite) Fig. 6, Plate XV C, all of Vol. III.

Sahlite. *Lime-Magnesia-Iron Pyroxene* ((CaMgFe) SiO_3. If Ca : Mg : Fe :: 4 : 3 : 1, the formula corresponds to silica 53.7, magnesia 13.4, lime 24.9, iron protoxide 8.00=100). It is this variety of pyroxene which is especially apt to occur in the crystalline schists.[2] At several places in the Upper Wisconsin valley dark-colored schists are found in which the only prominent constituents are sahlite and quartz. Many of the hornblende schists of the same region contain more or less sahlite, and it may be confidently asserted that in all of the hornblende schists of this region the hornblende is but altered augite or sahlite. Sahlite macroscopically is often not distinguishable from augite, though commonly affected by somewhat paler color. Sahlite in the thin section is frequently colorless, or at most of a pale green color. It is entirely without absorption or dichroism, but produces brilliant colors in the polarized light. Its particles are commonly very irregularly shaped. Not unfrequently they are drop-like in form. In sahlite there are also often recognizable peculiar cleavages parallel to the basal and orthopinacoidal planes.

32. AMPHIBOLE ($RSiO_3$. R may correspond to two or more of Mg. Ca. Fe. Mn. $Na_2K_2H_2$; it is also sometimes replaced by $Al_2Fe_2Mn_2$; the Al_2 and Fe_2 also in part replacing Si). The amphibole species are very widely spread in Wisconsin, as rock constituents, the three common varieties of *hornblende, actinolite* and *tremolite* all being met with. Of these the first named is very much the most important, while the tremolite is but rarely met with.

Hornblende. Aluminous magnesia-lime-iron amphibole. As a rock constituent hornblende appears in black particles, usually possessed of a strong luster. When very fine the macroscopical distinction between hornblende and black mica is a difficult one, while that between hornblende and augite is impossible, unless the particles are sufficiently large for the characteristic prismatic cleavage to be readily seen. In augite the cleavage angle is 87°, 5', while in hornblende it is 124°, 36. As a rule, however, cleavages cannot be seen, and the distinction between these two minerals is possible only with the microscope, and so true is this that all conclusions based upon macroscopic distinction between these minerals as rock constituents, made before the day of microscopic lithology, must be taken as worthless. It was formerly supposed that augite was the rarer, hornblende, the more common constituent. But it is now known that exactly the reverse is true, while of the hornblende which has been shown certainly to exist, a notable proportion is known to be merely a secondary product from the alteration of augite. This matter of the alteration of augite into hornblende has been referred to in the immediately preceding paragraphs. It must be taken as an open question whether any of the hornblende found as a rock constituent is of primary origin, and not merely the result of the alteration of augite.

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[1] Vol. III, pp. 10, 35, 168–183.
[2] Wichmann, Vol. III, p. 606.

Two phases of hornblende are recognized by lithologists, the basaltic and common varieties. The basaltic hornblende, so called from its common occurrence in eruptive rocks, is highly ferruginous, and yields sections which are of a deep brown color, and are very absorptive and dichroic. The commoner hornblende sections are usually of some shade of green, varying from deep green to yellowish-green and bluish-green, according to the position of the section in regard to the crystallographic axes. The dichroism of the common hornblende varies with the depth of its color. The common hornblende also as a rule is made up of more or less imperfectly aggregated microliths, the edges of the particles being usually ragged, and not frequently supplied with well completed crystalline outlines. It might be supposed that of these two varieties the common hornblende would be more likely to have resulted from the alteration of augite, but I have met with numbers of cases in which the basaltic hornblende also has evidently had this secondary origin. Like augite, hornblende is monoclinic in crystallization, and is never dark when a crystallographic axis falls together with the cross hair of the microscope except when the section holds the orthoaxis. The interference colors of hornblende sections are not so brilliant as those of augite.

Hornblende is liable to hydration, and a change to a soft greenish mineral, but the change is not so common as with augite. Connected with this change is often a separation of iron oxide in the shape of magnetite. As prominent instances of hornblende-bearing rocks in Wisconsin may be mentioned the hornblendic gneisses[1] and schists[2] and the so-called "diorites"[3] of the Menominee region; the hornblendic schists and gneisses of the Upper Wisconsin valley,[4] and the hornblende granite of Wausau,[5] in which the hornblende is of the basaltic variety. The common greenish hornblende is figured at Fig. 1, Plate XII A, of Vol. III.

Actinolite. Magnesia-lime-iron amphibole. Actinolite is less ferruginous than hornblende. It appears macroscopically in long, pale greenish prisms which in the thin section are colorless, or nearly so, and are without the strong dichroism characterizing the more ferruginous and aluminous amphiboles. Sections cut perpendicularly to the main axes of the prisms show at times the same strong prismatic cleavage that is observed in hornblende, but oftener there is no trace of this cleavage apparent. Actinolite is not a very common rock-constituent among the Wisconsin rocks, but enters into the composition of three types of rock which are of peculiar interest, because of their association with the iron ores of the Huronian. These are actinolite-schist proper,[6] actinolitic magnetite-schist[7] and garnetiferous actinolite-schist or eclogite-schist.[8]

Tremolite. Magnesia-lime amphibole. ((CaMg) SiO_3^{ii}; Ca : Mg :: 1 : 3; silica 57.70, magnesia 28.85, lime 13.35=100.) Tremolite is of only rare occurrence in Wisconsin as a rock constituent, being found only as an accessory ingredient in certain crystalline limestones of the Huronian series.[9] Macroscopically tremolite differs from the more ferruginous varieties of amphibole in completely

[1] Vol. III, p. 631.
[2] Vol. —, pp. 640–645.
[3] Vol. III, pp. 627–630.
[4] Vol. IV, pp. 629, 637, 654, 692, 694, 702, etc.
[5] Vol. IV, pp. 661–663.
[6] Vol. III, pp. 577, 587, 639, 691, 698, 699.
[7] Vol. III, pp. 482, 118–136, often noted 617.
[8] Vol. III, pp. 105, 118, 123, 151, 649.
[9] Vol. III, pp. 106–108, Fig. 1, Plate XIII A, p. 612.

lacking the dark coloring, ranging from white to transparent or colorless; but in the few Wisconsin rocks in which its presence has been noted, it is too fine to be observed without the aid of the microscope. Tremolite occurs macroscopically, both in short stout crystals or in aggregations of long thin fibrous ones. The latter is the common microscopical mode of occurrence, the crystals being quite without any color.[1]

33. CHRYSOLITE. OLIVINE. PERIDOTE. ($(MgFe)SiO_4$. Mg: Fe:: 12:1 or as 9:1 or as 6:1, and in the variety hyalosiderite as 2:1. If Mg: Fe:: 12:1, the formula requires silica 41.39, magnesia 50.90, iron protoxide 7.71=100; but the Wisconsin chrysolites appear to be commonly more ferruginous than this.) Chrysolite or olivine is known in Wisconsin only as the constituent of certain very basic eruptive rocks. When its particles are coarse enough to be seen with the naked eye and are unaltered — neither of which conditions is often filled in the Wisconsin rocks — they present themselves in the shape of small, yellowish-green, glassy, imbedded grains. In the thin section unaltered chrysolite appears in almost colorless, or at most in very pale greenish-tinted areas, which only rarely show any distinct crystalline outlines. There is no dichroism, but the interference colors are brilliant. Olivine yields polished surfaces with much greater difficulty than other rock constituents, its sections presenting an appearance something like that of ground glass. Olivine sections only rarely show any cleavage lines, but are usually traversed by strong irregular fissures.

Along the lines of these fissures decomposition has in most cases been set up. Of all rock constituents which are true individualized minerals, olivine is the most readily decomposed; this ease of decomposition resulting from the large content of iron-protoxide and relatively very low content of silica. So easy is this decomposition that rocks in which all other minerals are still unscathed will often have their olivine completely changed. Nevertheless, there are numbers of cases among the Wisconsin rocks in which the olivine is almost or completely fresh. The most common result of the decomposition of olivine is the formation of yellowish-green, finely fibrous serpentine along the fissures, the fibers lying at right angles to the surfaces from which they originated. As the alteration proceeds, this fibrous structure extends further inwards, until the whole crystal is converted into a mass of interlacing and contorted, or radially disposed fibers of serpentine.[2]

The change from olivine to serpentine consists not only in the hydration of the original silicate, but also in the more or less complete removal from the combination, by the agency of percolating carbonated waters, of the iron protoxide. Often this oxide has left no trace of its former presence, having been completely leached out, but frequently it has in part separated out in the form of the peroxide of iron, either the anhydrous red peroxide or the brown hydrated peroxide, and cases are not wanting in which the magnetic or protosesquioxide has resulted from this process.

With the more highly ferruginous olivines the deposition of iron peroxide has been greater, and often, instead of the greenish serpentine, the decomposition-result bordering the fissures or completely replacing the original olivine is the oxide of iron. In fact this form of alteration is more common among the Wisconsin olivine-bearing rocks than the change into serpentine, though marked

[1] In Vol. III, tremolite is mentioned in several places as a constituent of certain magnetite schists (pp. 121, 226, etc.), but what was taken for tremolite in these rocks should more properly be regarded as actinolite which commonly also presents colorless sections.

[2] The Study of Rocks, by Frank Rutley, p. 118.

instances of the latter change are met with.[1] Other forms of the alteration of olivine occur among the Wisconsin rocks. In the melaphyrs[2] of the Keweenaw series of Lake Superior region, for instance, the olivine is often in large measure replaced by a soft greenish substance, in the nature of a chlorite; while in some of the coarse gabbros of the same region a change into biotite, viridite, talc, and magnetite has been observed, first by Julien.[3]

As instances of olivine-bearing rocks in Wisconsin may be mentioned the black olivine-diabase intersecting gneiss at Grand Rapids on the Wisconsin river;[4] the peridotite — almost wholly altered to serpentine — of the upper Wisconsin, a short distance below the mouth of Copper river,[5] and the melaphyrs[6] and gabbros[7] of the Lake Superior region. Olivine, in a fresh condition, is represented in Figs. 1 and 2 of Plate XV D of Vol. III; altered to a greenish substance, at Fig. 4 of the same plate; altered to a greenish substance and magnetite, at Fig. 6 of the same plate; partly fresh and partly altered to oxides of iron, and surrounded by a shell of talc scales, at Fig. 2, Plate XV E, and altered to oxide of iron, biotite, viridite, and talc, at Fig. 1, Plate XXII, Vol. III.

34. GARNET ($R_3Si_3O_{12}$. R=Ca, Mg, Fe, or Mn). Garnet is not a common mineral in Wisconsin, cccasionally occurring as an adventitous constituent of certain gneisses,[8] and as an essential constituent of some unusual schists of the Huronian[9] series. When large enough to be perceptible to the naked eye, garnet particles are recognized by their red color, common translucency and regularly outlined crystalline forms, the forms being the dodecahedron and tetragonal trisoctahedron of the hexagonal system. In the thin sections garnet forms grains which, though sometimes almost colorless, generally show a very characteristic pale red or pinkish color. This peculiar color, together with their isotropic behavior — i. e., their remaining dark in all positions between the crossed nicols of the polarizing microscope — make the recognition of garnet sections a very simple matter. The garnet grains are often only irregularly outlined, but at times the microscopic garnet particles show the same crystalline forms that are evident macroscopically in the larger crystals. Garnet sections are frequently charged with minute inclusions — especially magnetite, actinolite and quartz — and are commonly strongly fissured in irregular rifts. Cleavage cracks, however, are entirely wanting in garnet. The garnet material is usually without sign of decomposition, but a very interesting change of garnet into chlorite and magnetite has been observed in the Huronian schists of Michigan,[10] and the same change might be expected in Wisconsin. At Figs. 1 and 2, Plate XV A, Vol. III, are represented sections of garnet from a schist occurring at Penokee Gap, in Ashland county. In the second one of these figures, the garnet is penetrated by needles of actinolite.

35. ZIRCON ($ZrSiO_4$=silica 33, zirconia 67=100). Zircon is known in Wisconsin only in the shape of a microscopic accessory constituent in certain actinolite-

[1] Vol. IV, pp. 702, 711.
[2] Vol. III, p. 32.
[3] Vol. III, p. 235.
[4] Vol. IV, b. 638.
[5] Vol. IV, pp. 702, 711.
[6] Vol. III, pp. 32-35.
[7] Vol. III, pp. 168-183.
[8] Vol. IV, pp. 590, 597, 606.
[9] Vol. III, pp. 105, 118, 123, 151, 649.
[10] R. Pumpelly, Am. Jour. Sci., III, Vol. X, p. 17.

schists and other rocks from the Menominee river region, its existence in these rocks having been first detected by Dr. Wichmann.[1] In the thin section zircon is recognized chiefly by its almost invariable occurrence in sharply outlined crystals belonging to the tetragonal system and its extraordinary power of refracting light. The crystals are square prisms terminated by the square pyramid, and in section are recognized as tetragonal by their giving square transverse sections, and always remaining dark between crossed nicols, and by the fact that all other sections are dark only when the edges of the prism coincide in direction with either cross-hair of the microscope. The very strong refractive power of zircon is shown by the peculiarly brilliant colors which it gives in polarized light. The color of a section of zircon is very variable, as is the case also of the external color of large sized crystals. The deeper colored crystals show strong dichroism, while the lighter colored ones are without this property. According to Wichmann zircon occurs microscopically in twin crystals, and also in crystals which have interrupted one another in such a way as to obscure the crystalline outlines.[2]

36. EPIDOTE ($H_2Ca_4(Al_2Fe_2)_3Si_6O_{26}O$). Epidote is not an uncommon mineral in Wisconsin, especially in the Lake Superior region. It occurs chiefly in the form of an alteration-product of some of the constituents of the diabases of the Keweenaw series, and sometimes large bodies of rock have been replaced almost entirely by this mineral. In this form it is never in distinct crystals. Crystals of epidote, however, do occur lining the cavities of some of the amygdaloids of the Keweenaw series. Macroscopically epidote is easily recognized by its peculiar yellowish-green, or pistachio-nut color. In the thin section it forms pale yellowish-green to nearly colorless, irregularly outlined grains, which occupy the places of some of the original rock constituents, especially augite. A cleavage in one direction is often marked by numerous cracks. Epidote sections polarize with very brilliant colors, and since there is little or no dichroism observable, may sometimes be mistaken for sections of sahlite, but the cleavage lines of epidote, and their relation to the optical axes, and more especially the universal occurrence of epidote as a secondary product, make the distinction between these two minerals easy on close inspection.[3]

37. BIOTITE. BLACK MAGNESIA-IRON MICA. UNIAXIAL MICA. (R_2SiO_4. $R = K_2Na_2Li_2$ Fe. Mg. Ca., and is also replaced by Al_2Fe_2, silica 36 to 44.50; alumina 11.50 to 21.50; iron peroxide 2.50 to 27.00; iron protoxide 00 to 21.00; magnesia 5.00 to 26.00; lime 00 to 3.00; potash 1.00 to 11.50; soda 00 to 3.00.) Biotite is a wide-spread mineral in Wisconsin, occurring as an essential constituent of many granites, gneisses and mica-schists, and as a frequent accessory in many other kinds of rocks. It is a far more abundant mica than muscovite in Wisconsin. Macroscopically biotite is easily recognized by its deep-black color, and eminent basal or micaceous cleavage. When present at all plentifully it produces a dark shade in the rock, being one of the three minerals — biotite, hornblende, augite — which commonly produce dark-colored rocks. Biotite is never observed in distinctly outlined crystals in Wis consin rocks, but forms ragged edged folia. In the thin section it is characterized by its peculiar yellowish to dark-brown color; strong cleavage rifts in one direction, and very marked dichroism and absorption. The cleavage cracks being parallel to the basal plane are not ap-

[1] Vol. III, p. 609.
[2] Vol. III, pp. 609, 634.
[3] For descriptions of rock sections containing epidote, see Vol. III, pp. 37, 41, 43, 421, 623.

parent in a basal section, which section moreover is without dichroism. Since biotite is optically uniaxial, sections which show the basal cleavage will be dark between the crossed nicols only when the cleavage directions correspond with either cross-hair, while basal sections remain dark throughout the entire revolution; these optical properties, along with the lack of cleavage in the basal sections, serving to distinguish it from brown or "basaltic" hornblende which it at times somewhat resembles. Biotite is so wide-spread a mineral among Wisconsin rocks that it is not possible to list here its principal occurrences. A number of sections containing it will be found described in Vols. III and IV. Figures of thin sections of biotite are given at Figs. 1, 2 and 6 of Plate XV D, Vol. III.

38. MUSCOVITE. POTASH MICA. BIAXIAL MICA. ($K_2Al_2Si_2O_8$, but with the alumina generally replaced by some iron peroxide, and the potash by a little magnesia, lime, and soda.) Muscovite occurs in Wisconsin as an essential constituent of certain granites, gneisses and mica-schists, but almost invariably along with and subordinate to biotite. Macroscopically muscovite is characterized by its pale color, which ranges from white through various shades of yellow and brown, its deeper brown and yellow colors accompanying a certain amount of decomposition. In the thin section muscovite forms thin colorless folia and scales, which polarize brilliantly, and are generally strongly characterized by abundant basal cleavage-cracks. As instances of muscovite-bearing rocks may be mentioned certain mica-schists of the Menominee region,[1] and certain granites and gneisses of the Upper Wisconsin valley.[2]

39. WERNERITE. SCAPOLITE. ($(CaNa_2)\ Al_2Si_2O_8$.) Foster and Whitney report the existence of scapolite at the Twin falls of the Menominee river.[3] It has not been observed elsewhere.

40 to 44. FELDSPARS. The feldspars are of course of the very first importance among the crystalline rocks of Wisconsin. The following list includes all of the feldspar species whose existence in Wisconsin has been certainly proven:[4]

NAMES.	FORMULÆ.	PERCENTAGE COMPOSITIONS.	CRYSTALLIZATION.
Anorthite....	$CaAl_2Si_2O_8$............	SiO_2 43.1, Al_2O_3 36.8, CaO 20.1=100.........	Triclinic.
Labradorite..	$(CaNa_2)\ Al_2Si_3O_{10}$. ...	SiO_2 52.9, Al_2O_3 30.3, CaO 12.3, Na_2O 4.5=100	Triclinic.
Oligoclase....	$(CaNa_2)\ Al_2Si_5O_{14}$.....	SiO_2 61.9, Al_2O_3 24.1, CaO 5.2, Na_2O 8.8=100	Triclinic.
Microcline....	$K_2Al_2Si_6O_{16}$..........	SiO_2 64.7, Al_2O_3 18.4, K_2O 16.9=100.........	Triclinic.
Orthoclase....	$K_2Al_2Si_6O_{16}$..........	SiO_2 64.7, Al_2O_3 18.4, K_2O 16.9=100.........	Monoclinic.

The species are all silicates of alumina, along with one or two of lime, soda and potash. The relation of bases to silica varies in the different species, which thus

[1] Vol. III, p. 634.
[2] Vol. IV, pp. 628, 631-635.
[3] Geology of the Lake Superior Land District.
[4] In Dr. Lapham's list (Vol. II, p. 28), albite is mentioned as common in Wisconsin, but while it not improbably does exist here, microscopic researches have failed to establish its existence.

naturally group themselves into the basic and acid species, and those which are intermediate in composition. Most of the species are triclinic in crystallization, orthoclase only being monoclinic. Nevertheless there is throughout a close isomorphism, and a general resemblance in the systems of occurring crystalline forms.[1] The tabulation shows also the relations of the feldspars as to composition and crystallization.

Macroscopically the feldspars are recognizable in rocks by their pronounced cleavage, pale color — white, gray, flesh-pink, flesh-red, rarely brick-red — and considerable hardness. In cleavage the several species strongly resemble one another, all possessing two easy cleavages inclined to each other at an angle of 90° or very near 90°. In the triclinic species, one of these cleavages is commonly marked by exceedingly fine striations, due to a repeated twinning process, as the result of which the crystal is made up of innumerable thin laminæ, each one of which occupies a position which is crystallographically 180° from the position of the adjoining ones. Since these laminæ are parallel to the second cleavage, the faces produced by that cleavage are without striations. Orthoclase, on the contrary, never presents these striations, although it is often affected by a single twinning, when each crystal is made up of two parts, the one removed 180° from the position of the other. Often the cleavage surfaces of orthoclase imbedded in granite or similar rocks will show plainly by the way in which the light is reflected that the crystal is made up of two distinct parts.

But commonly the distinction between the triclinic and monoclinic feldspars, unless the rock is tolerably coarse-grained, is macroscopically very difficult, or in fact impossible. In the thin section, however, the optical properties of orthoclase make its separation from the triclinic species an easy matter. The peculiar laminated structure of the triclinic species due to repeated twinning, as already explained, becomes especially marked and prominent in the polarized light, for now each crystal appears as if made up of numerous alternating bands of different colors. The colors of these bands will depend on the thickness of the sections and the position of the crystals with regard to the planes of the nicol prisms attached to the microscope; but a thoroughly good section will show the bands without color, but with merely different shades of light and dark. Since the twinning is parallel to one of the prominent cleavages of the feldspar — the brachypinnacoidal — sections parallel to this cleavage will show no banding; but such sections will be but few in a random section of the rock, and since all other sections show the banding, the triclinic feldspars are very readily distinguished from orthoclase. Since all of the triclinic feldspars except microcline show this banding, the distinction between these species is not always easy to make, and the triclinic feldspars are often referred to in rock descriptions under the general term of plagioclase.[2]

A very beautiful and simple method of separating the plagioclase species has been devised by Des Cloizeaux. This method is based upon the optical properties of the twinned feldspars, and requires sections made parallel to the easiest or basal cleavage; but such sections can be made only when the crystals are of a certain size, a condition not attainable with rocks of ordinary coarseness of grain. Pumpelly has, however, devised a modification of Des Cloizeaux's method, which makes it applicable to random sections. It is not possible in this

[1] Text-Book of Mineralogy, E. S. Dana, p. 297.

[2] i. e., feldspars with inclined cleavages in contradistinction to orthoclase, or the feldspar with rectangular cleavages. The term plagioclase has, however, been used to cover only the species labradorite, andesite and oligoclase.

place to explain the optical principle upon which the methods of Des Cloizeaux and Pumpelly depend. The practical application of the latter method, however, is so simple that it may be given here. The first requisite in making the determination is to find sections of the feldspars which are cut in the zone between the plane of the basal cleavage and a plane parallel to the orthoaxis of the crystal. That a section is in this zone is determined as follows: the lines between the alternating twinned bands of the feldspar are first placed parallel to one of the cross-hairs of the polarizing microscope, the nicols prisms being adjusted exactly in place. The position of the index on the graduated table of the microscope is then read off. The stage of the microscope is next turned, until one set of bands becomes perfectly dark.[1] The angle being read off, the stage is turned in the other direction, until the other set of bands becomes dark. Should the two angles thus obtained be equal or nearly so, the section is in the zone required. A number of such sections having been found and measured, should the whole angle between the two positions at which the alternate bands become dark never exceed 36°, the feldspar may be taken as oligoclase; should they never exceed 62°, as labradorite; and as anorthite should they exceed 62°.

The only defects of this method are that it fails to discriminate between two kinds of feldspar should they be in the section, and that since in some sections the feldspars may all be cut so as to give the lowest angles of their species, the determination may in that way be rendered imperfect. So far as my experience has gone the latter one of these defects has not proved to be of much account. It has also been my experience that only one kind of plagioclase is usually present, though that cases exist in which more than one kind is present has been certainly proved. I have also found that certain peculiarities of appearance are apt to characterize sections of the different plagioclase species. Oligoclase for instance is characterized by very narrow regular lineations. It is also much more apt to be altered than is the case with labradorite or anorthite. Labradorite on the other hand presents less regular and broader banding than oligoclase, whilst in anorthite the irregularity and frequent great breadth of bands reach a maximum. Both labradorite and anorthite frequently show one set of bands very broad and the alternate ones exceedingly narrow. As far as my experience has gone labradorite and anorthite are far less liable to change than oligoclase, anorthite being especially apt to occur in clear unaltered crystals.

A peculiar change sometimes affecting anorthite and labradorite is to a grayish non-translucent aggregate sometimes called saussurite.[2]

Orthoclase sections are without the repeated twinning characteristic of the triclinic species. They not unfrequently show, however, a twinned structure, each crystal or crystalline particle presenting in polarized light two differently colored bands. When the section approximates to parallelism with the orthopinnacoid, these bands occupy each a half of a crystal; while sections parallel, or nearly so, to the clinopinnacoid show no banding. Sections of such twins in all other directions, however, will show two bands of unequal size. Orthoclase has two well-marked cleavages, one parallel to the basal and one to the clinopinnacoid plane. Basal sections will become dark between the nicols when the cleavage is parallel to the cross-hair of the microscope. This behavior results, of course, from the monoclinic crystallization, and sometimes serves as a means of distinction from triclinic feldspars, in which the positions of maximum dark-

[1] The use of the quartz plate in these measurements, as ordinarily recommended, I do not find at all necessary; the eye quickly becoming able to detect very slight changes in degree of darkness.

[2] Vol. III, p. 563.

ness and parallelism of cleavage to the cross-hair never correspond. Orthoclase is sometimes met with interlaminated with a triclinic feldspar in a very regular manner. Such an interlamination with albite was long since shown to be true of the so-called perthite from Perth in Canada East, and I have noticed something of the same kind microscopically in some of the gabbros of the Keweenaw series from Ashland county, in which case, however, the triclinic feldspar is labradorite, and the included orthoclase is present in but very small quantity.

Another very peculiar kind of interlamination in orthoclase, first described by G. W. Hawes[1] as occurring in the rocks of New Hampshire, is widespread in the orthoclases of the Wisconsin gneisses and granites. The orthoclase which is affected by this peculiar structure presents usually no peculiar appearance in the ordinary light, but between the crossed nicol's prisms, is seen to be made up of a great number of irregular laminæ of two different colors. These laminæ are without the very straight bounding lines which characterize the ordinary twinned laminæ of the triclinic feldspars, each little band commonly running to a point before traversing the width of the particle. This peculiar structure Mr. C. R. Vanhise has found affecting crystals which present at the same time to a greater or less extent the cross-hatched appearance characteristic of microcline,[2] and he thinks that he has found indications of a change from the irregularly laminated orthoclase to microline. But a satisfactory explanation of this structure has not yet been reached.

Orthoclase particles are commonly without good crystalline outlines except when occurring as porphyritic ingredients embedded in a fine ground-mass.

A marked characteristic of all of the orthoclase of the old crystalline rocks is its tendency to decompose. The decomposition results in the formation of minute scales of kaolinite, which cloud the sections of orthoclase, and, when the decomposition is carried far, rob it of all of its distinguishing optical properties. Accompanying this decomposition in some rocks is an infiltration of oxide of iron, as a result of which the sections are more or less completely red-stained. This staining, however, is not to be confounded with the pale flesh-red color which much orthoclase presents macroscopically, the latter color being due to the inclusion of iron oxide particles within the feldspar at the time of its crystallization.[3]

Microline was first fixed as a species by Des Cloizeaux[4] in 1876, the name having been previously used, however, by Breithaupt for a mineral which was afterward proved to be orthoclase. The so-called amazon-stone, commonly regarded merely as a green variety of orthoclase, is microline; but the microline occurring as a rock constituent is without this green color, presenting on the contrary the appearance of orthoclase. Microscopically, however, the sections of microcline are strongly characterized. In the first place, its sections are never dark when either of its cleavages correspond in direction with a cross-hair of the microscope. But its chief peculiarity, as seen in the thin section, consists in its double system of repeated twinning, the result of which is to produce, in the polarized light, the appearance of numberless laminæ running at right angles to each other. According to Hawes[5] this cross-hatched microcline occurs also

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[1] Geology of New Hampshire, Vol. III, Part IV, Mineralogy and Lithology, p. 101.

[2] Vol. IV, p. 662.

[3] Vol. III, p. 601.

[4] The microcline of Rosenbusch (Mikroskopische Physiographie de petrographisch wichtigen Mineralien, 1873, p. 333) is that of Breithaupt, and not that of Des Cloizeaux and of these reports.

[5] Op. cit. p. 102.

inter-grown with orthoclase, and this association has also been noticed in the Wisconsin rocks.

The several feldspars differ among themselves with regard to the minerals with which they occur associated as rock constituents. Thus anorthite, the most basic of the feldspars, associates with olivine, augite, or diallage and magnetite, to make the ultra-basic varieties of gabbro and diabase. It is rarely if ever associated with orthoclase — the most acid of the feldspars — or with quartz. The association of anorthite with secondary quartz, i. e., quartz resulting from the alteration of some of the rock constituents, is not really an exception to this rule. Labradorite follows much the same rale as anorthite, though not unfrequently occurring along with orthoclase. Oligoclase on the other hand is frequently associated with orthoclase and with quartz; while the association of orthoclase with quartz is the rule, and their separation the exception.

The feldspars are so widely spread in the Wisconsin rocks that only a very few instances of their occurrence can be mentioned here. Anorthite occurs, especially in the coarse gabbros [1] and melaphyrs [2] of the Keweenaw series, in the northern part of the State. Labradorite is found especially in some of the coarse gabbros of the same region. Oligoclase characterizes especially the fine-grained diabases [3] of the Keweenaw series, besides all of the gneisses of the Laurentian, for instance those of Grand Rapids.[4] Orthoclase is the chief constituent of all granites and gneisses and occurs besides as a subordinate constituent in many other kinds of rocks.

The appearance of the thin section of anorthite is figured at Fig. 2, Plate XV E; of labradorite at Fig. 3, Plate XV A, Figs. 1, 2 and 3, Plate XV D, and at Figs. 1 and 2, Plate 21; and of orthoclase at Figs, 1 and 2, Plate XII A, and Fig. 2, Plate XV C — all in Vol. III.

45. TOURMALINE ($(K_2Na_2H_2)(MgFe)_2\ (Al_2B_2)_3\ Si_4O_{20}$). Tourmaline is known in Wisconsin only as a microscopic accessory ingredient in certain rocks, although its presence on a larger scale in the gneissic and granitic regions of the State might well be suspected.[5] In the thin section it appears in the form of long or short crystals of a bluish gray color, possessing an extraordinarily strong dichroism. When such sections are examined in the polarizing microscope with only the lower nicol attached, inasmuch as tourmaline belongs to the hexagonal system, they will be light colored, when the longer axis of the crystal is parallel to the cross-hair which marks the plane of vibration of the lower nicol, and almost black when placed at right angles to it.[6] Basal sections of tourmaline between the crossed nicols will of course remain dark in all positions. Tourmaline is readily distinguished microscopically from other strongly dichroic minerals by its lack of cleavage.

Wichmann has detected tourmaline in thin sections of clay slate,[7] sericite-schist,[8] chlorite-schist,[9] mica-schist,[10] and talc-schist [11] — all from the Menominee river region.

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[1] Vol. III, pp. 168–183.
[2] Vol. III, pp. 32–35.
[3] Vol. III, p. 32.
[4] Vol. IV, p. 628, 631–635.
[5] In Lapham's list, tourmaline is mentioned as occurring at the outlet of Lac Flambeau, on Schoolcraft's authority (Vol. II, p. 29), but the statement lacks confirmation.
[6] G. W. Hawes, op. cit., p. 105.
[7] Vol. III, pp. 651–653.
[8] Vol. III, p. 637.
[9] Vol. III, p. 646.
[10] Vol. III, p. 634.
[11] Vol. III, p. 648.

46. ANDALUSITE (Al_2SiO_5=silica 36.9, alumina 63.1=100). Andalusite is known in Wisconsin only as an accessory in certain mica-schists of the Penokee Huronian belt.[1] The variety of andalusite here found is that known as chiastolite, which is characterized by the removal and replacement of more or less of the interiors of the crystals. These crystals, as seen in the rock from Bad river near Penokee Gap, in Ashland county, are from one-fourth to one-half inch in length, and, usually, one-sixteenth of an inch in width. When broken across they present a rhombic cross-section. When examined with a magnifying glass these chiastolite crystals are white or colorless, or somewhat yellow stained along the borders; while along the center they all present a decided black line. The black center occupies different proportions of the entire width of the crystal, often having the merest edging of undecomposed material; while many long dark colored spots on the surface of the rock plainly mark the positions of crystals which have heen entirely replaced. In the thin section these crystals present an appearance corresponding to that given to the naked eye. The replacing materials of the centers of the crystals are seen to be chiefly brownish biotite scales with a smaller quantity of carbon particles.[2]

47. CYANITE (Al_2SiO_5=silica 36.9, alumina, 63.1=100). Norwood reports cyanite at Lac Flambeau, near the sources of the Wisconsin river,[3] but none has been observed by any members of this survey.

48. DATOLITE ($H_2Ca_2B_2Si_2O_{10}$=silica 37.5, boron trioxide, 21.9, lime 35.0, water, 5.6=100). The porcelain like variety of datolite is met with occasionally in connection with the Keweenawan diabases of the Lake Superior region.

49. TITANITE. SPHENE. ($CaTiSiO_5$=silica 30.61, titanic oxide 40.82, lime 28.57 =100.) Titanite is a not very uncommon microscopic accessory of certain hornblendic rocks and gneisses in Wisconsin. It presents itself sometimes in rounded grains, but more commonly in regularly outlined crystals, which are not unfrequently of a wedge-like form. The color is greenish-yellow to yellowish-brown, the substance not being very transparent, though remarkably free from inclusions. Wichmann finds titanite in syenites from the Menominee region,[4] while Mr. Vanhise finds it quite often in the gneisses of the Upper Wisconsin valley.[5] In some cases it appears as the result of a molecular change of the peculiar white decomposition-product so often found accompanying titanic iron.

50. STAUROLITE ($H_2(MgFe)_3Al_{12}Si_6O_{34}$; if Mg : Fe :: 1 : 3=silica 30.37, alumina 51.92, iron protoxide 13.66, magnesia 2.53, water 1.52=100). Staurolite occurs in Wisconsin as an accessory constituent of certain mica-schists, being particularly characteristic of the mica-schists of the Huronian. Macroscopically the staurolite presents itself as minute brown crystals dotting the schist planes. It gives deep brown, highly dichroic sections which, if revolved over one nicol, change from deep brown to nearly white in color.[6] The staurolitic mica-schists of Wisconsin have not as yet been examined thoroughly in the thin section. Such rocks occur, according to Brooks, in the Huronian of the Menominee region,[7] and I have myself seen specimens of staurolitic mica-schist from the northern part of Shawano county.

[1] Vol. III, pp. 143, 229.
[2] A. A. Julien, Vol. III, p. 230.
[3] Geological Survey of Wisconsin, Iowa and Minnesota, D. D. Owen, p. 279.
[4] Vol. III, p. 620.
[5] Vol. IV, pp. 620, 632, 633, 634, etc.
[6] G. W. Hawes, op. cit. p. 111.
[7] Vol. III, p. 496, 526, 559, etc.

51. LAUMONTITE ($CaAl_2Si_4O_{12}$+4aq=silica 50.0, alumina 21.8, lime 11.9, water 16.3=100). Laumontite is a common and very characteristic mineral among the diabases of the Keweenaw series of the Lake Superior region, occurring in these rocks in vein fillings, in fillings of the steam-made cavities of the amygdaloids, and as a substitution-product for the body of the rock. It is in all cases, however, the result of the more or less complete alteration of some part of the rock with which it occurs. It is especially associated with the amygdaloids whose large content of glassy matter in the original condition has rendered them particularly liable to change. The Wisconsin laumontite is usually closely associated and interwoven with calcite. Numerous instances of the occurrence of laumontite will be found mentioned in Vol. III.[1]

52. CHRYSOCOLLA ($CuSiO_3$+2aq=silica 34.2, copper oxide 45.3, water 20.5=100). Chrysocolla is reported by Dana[2] as occurring with malachite near Mineral Point, although Strong in his list of minerals of the lead region[3] does not mention its occurrence.

53. CALAMINE. ELECTRIC CALAMINE (Zn_2SiO_4+aq=silica 25.0, zinc oxide 67.5, water 7.5=100). Strong reports calamine as occurring near Mineral Point in small, drusy, colorless, vitreous crystals, coating smithsonite.[4]

54. PREHNITE ($Ca_2Al_2Si_3O_{11}$+aq=silica 43.6, alumina 24.9, lime 27.1, water 4.4=100). Prehnite is a wide-spread mineral among the diabases of the Keweenaw series of the Lake Superior region, occurring in these rocks both as a filling of the amygdaloid cavities, and as a replacement of the feldspathic constituents of the mass of rock. Though not unfrequently appearing in the amygdaloid cavities of sufficient size to be readily seen with the naked eye, it is more wide-spread in particles of microscopic size. When large enough to be seen macroscopically, if pure, prehnite is characterized by its light-green colors, translucency and considerable hardness. In the thin section it transmits a whitish, grayish, yellowish, or greenish color, and is without dichroism or absorption. Its double refraction is very strong, the colors produced being often as brilliant as those of quartz. Numerous instances of the occurrence of prehnite will be found given in Vol. III.[5]

55 to 60. APOPHYLLITE (4 ($H_2CaSi_2O_6$+aq)+KF=silica 52.97, lime 24.72, potash 5.20, water 15.90, fluorine 2.10=100.89); NATROLITE ($Na_2Al_2Si_3O_{10}$+^{2}aq=silica 47.29, alumina 26.96, soda 16.30, water 9.45=100); ANALCITE ($Na_2Al_2Si_4O_{12}$+2aq=silica 54.47, alumina 23.29, soda 14.07, water 8.17=100); CHABAZITE ($(HK)_2CaAl_2Si_5O_{15}$+aq=silica 50.50, alumina 17.26, lime 9.43, potash 1.98, water 20.83=100); STILBITE ($H_4RAl_2Si_6O_{18}$+4aq); HEULANDITE ($H_4CaAl_2Si_6O_{18}$+3aq=silica 59.06, alumina 16.83, lime 7.88, soda 1.46, water 14.77=100). These are hydrous silicates which, having been found often in the copper mines of Michigan, may be expected to occur also among the Keweenawan rocks of Wisconsin, and this is especially true of analcite and stilbite, but none of them have as yet been recognized.

61. TALC ($H_2Mg_3Si_4O_{12}$=silica 63.49, magnesia 31.75, water 4.76=100). Talc is known in Wisconsin especially as a constituent of certain unusual schistose

[1] pp. 183-195, 336-350, 399-428.
[2] System of Mineralogy, 5th edition, pp. 404, 785
[3] Vol. II, p. 691.
[4] Vol. II, p. 693.
[5] pp. 31-49, 183-195, 336-350, 399-428.

rocks. Talcose schists were formerly supposed to be very abundant rocks, but as the schists so-called are more closely examined chemically and microscopically, more and more of them are found to be non-magnesian, and in fact, to be sericite schists, or hydro-mica schists. Instances of a genuine talcose schist are in fact very uncommon. According to Wichmann, Brooks, and Wright, they occur in the Marquette region of Michigan, and in the Menominee river region of Wisconsin,[1] but elsewhere they are unknown in Wisconsin.[2] Macroscopically, talcose rocks are characterized by a peculiar greasy feeling and softness, the talc presenting itself in minute whitish, grayish or pale greenish flakes, but all of these characters belong also to some of the sericite-schists and sericitic quartz-schists. In the thin section the talc scales are colorless, without distinct crystalline outlines, without dichroism or absorption, without cleavage, and usually fresh and undecomposed.

62. GLAUCONITE (approximate composition, silica 49.3, alumina 3.60, sesquioxide of iron 22.7, protoxide of iron 6.3, potash 8.3, water 9.60). Glauconite occurs in Wisconsin in the shape of green grains inbedded in certain layers of the Potsdam sandstone, and Lower Magnesian limestone, in which formations it is very widely spread through the central and western parts of the State. These glauconitic grains have not been examined under the microscope. Numerous instances of the occurrence of glauconite will be found mentioned in Vol. II.[3]

63. SERPENTINE ($Mg_3Si_2O_7 + 2aq$=silica 43.48, magnesia 43.48, water 13.04=100). Serpentine is known in Wisconsin only as an alteration-product of olivine. When the olivine is present in small quantity the serpentine becomes evident only upon the examination of the thin section with the microscope. But when it forms any considerable portion of the rock, it is evident macroscopically also; in which case it presents itself as a light to dark green, amorphous, greasy-lustered, rather soft mineral. In the thin section this serpentine shows all the characters of a secondary mineral, polarizing only as an aggregate of minute particles. Nearly always it presents some traces at least of the olivine from whose alteration it has resulted. The change of the olivine begins on the outlines of the particles and along the borders of the numerous fissures traversing them. In an early stage of this alteration then, we see the olivine particle or crystal edged and irregularly traversed by narrow bands of green serpentine, each band being made up of minute serpentine fibers. Later the alteration process extends further and further inwards from the fissures, until finally a network of serpentine fibers is produced with only here and there a minute remnant of the olivine, or without any such remnants. Most if not all serpentine has evidently originated from the alteration of olivine. The most prominent instance of the occurrence of serpentine in Wisconsin is that of the altered peridotite in the bed of the Wisconsin, a short distance below the mouth of Copper river.[4]

64. KAOLINITE ($H_2Al_2Si_2O_8$ +aq=silica, 46.4, alumina 39.7, water 13.9=100). Kaolinite is a wide-spread mineral in Wisconsin. It is the common result of the alteration of orthoclase, from which it is formed by the removal of all the alkali and some of the silica, and the addition of water. This decomposition is

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[1] Vol. III, pp. 566, 648, 695, 712.

[2] The talc mentioned by Lapham as occurring at Ableman's, in Sauk county (Vol. II, p. 29), is a non-magnesian clay; while the talc mentioned by Julien, as resulting from the change of olivine (Vol. III, p. 235), is possibly only fibrous serpentine or chrysolite.

[3] pp. 29, 259, 261, 536, etc.

[4] Vol. IV, p. 711.

effected especially by the percolation of atmospheric carbonated water. Where orthoclase-bearing rocks are thus altered on a large scale, deposits of the so-called kaolin or porcelain-clay are produced. In such a decomposition the resulting soluble substances — the carbonates and silicates of potash and soda, and the bicarbonate of lime — pass off with the infiltrating waters, and add to the solid contents of the drainage-waters of the region. In the thin sections of all ordinary orthoclase-bearing rocks, the minute scales of kaolinite are to be seen clouding the orthoclase particles. With a high power these scales are seen to be colorless, occasionally possessed of an hexagonal outline, and to give strong colors in the polarized light. The same minute scales form the body of the white clay known as "kaolin," in which they are mingled, however, with more or less of quartz, and mica particles and particles of undecomposed feldspar. It is yet an open question whether the same kaolinite scales do not make up the larger part of all ordinary clays. Instances of kaolinized feldspar in Wisconsin are too numerous to mention, being practically universal among the granites and gneisses of the northern part of the State. Kaolin occurs in quantity on the Wisconsin river, in the vicinity of Grand Rapids.[1]

65. SAPONITE (approximate composition, silica 45.60, alumina 4.87, iron sesquioxide 2.09, magnesia 24.10, lime 1.07, potash and soda 0.45, water 20.66=98.84).[2] A very clay-like soft saponite — the thalite of Owen[3] — occurs filling the cavities of many amygdaloids on the north shore of Lake Superior, between Duluth and Pigeon Point. The same mineral has been reported from Black river, in Douglas county, and may be expected to occur more widely in northern Wisconsin.

66. SERICITE (Composition of sericite from Nerothal near Wiesbaden, according to List, silica 49.00, alumina 23.65, iron protoxide 8.07, magnesia 0.94, lime 0.63, soda 1.75, potash 9.11, water 3.41, titanium oxide 1.39, fluoride of silicon 1.60). As already indicated, the larger part of the soft, greasy-surfaced schists formerly called talc-schists are now known to contain, instead of talc, a hydrous mica, in which magnesia is either wanting, or present in insignificant amount. Some of this hydrous mica seems to be merely partly altered muscovite, but the larger proportion of it is evidently a distinct mineral, or perhaps two or three different minerals. For this hydro-mica, List's name of sericite is commonly used by lithologists. Rocks carrying sericite in various proportions present externally a shining greasy surface. In the thin section the sericite is seen in the shape of minute transparent scales which are generally aggregated into a felt-like mass. As instances of sericite-schists in Wisconsin may be mentioned those of the Huronian of the Menominee river region[4] and the rock of formation III of the Penokee Huronian.[5]

67. CHLORITE. There are several minerals differing somewhat from one another chemically and crystallographically, and yet having so many properties in common, that the distinction of one from the other is often very difficult, which lithologists conveniently group under the general name of chlorite. All of the chlorite species are hydrous-silicates of magnesia, iron protoxide and alumina. They are all soft, are all foliated, and all of various shades of dark green. The three most common species are *ripidolite* ($Mg_5Al_2Si_3O_{14}+4aq$=silica 32.5, alumina 18.6, magnesia 36.0, water 12.9=100; but the Mg is commonly replaced

[1] Vol II, pp. 466–477; Transactions, Wis. Acad. Arts., Sci. and Letters, Vol. III, pp. 1–30.
[2] Dana, System of Mineralogy, 5th edition, p. 472.
[3] Owen's Geological Survey of Wisconsin, Iowa and Minnesota, pp. 600–603.
[4] Vol. III, p. 636.
[5] Vol. III, pp. 111–118.

partly by Fe), *peninite* (approximate composition, silica 33.07, alumina 9.69, iron protoxide 11.36, magnesia 32.34, water 12.58=99.08) and *prochlorite* (average composition, silica 26.8, alumina 19.7, iron protoxide 27.5, magnesia 15.3, water 10.7=100), the first of which is optically biaxial while the second and third are uniaxial. There are, however, at least one or two other species among rock-forming chlorites. It is sometimes possible in thin rock sections to distinguish between biaxial and uniaxial species, but often it is not possible to do so. Moreover, there are certain greenish alteration-products often met with in rock sections, which can only be inferentially referred to chlorite, and which are therefore commonly spoken of by lithologists under the general term of viridite. In the thin section the chlorite appears in folia or scales of a pale green or bluish green color, and varying considerably in the amount of absorption and dichroism shown.

Chlorite as a rock constituent may very commonly be shown to be of a secondary nature. It has most commonly been formed by a direct alteration of hornblende or augite, but is also met with as a replacer of some of the feldspars. Whether it is ever of an entirely original nature as a rock constituent may well be doubted. The chlorites are very widely spread among Wisconsin rocks. As instances we may merely mention the chloritic schists of the Huronian of the Menominee region,[1] many altered diabases of the Keweenaw series of the Lake Superior region,[2] the chloritic gneisses of the Laurentian of Ashland county,[3] and the chloritic gneisses and schists of the Rib river valley.[4] Illustrations of rock sections containing chlorite are given at Figs. 1 and 2 of Plate XII A, at Fig. 3, Plate XV A, Fig. 6 of Plate XV D, Fig. 1 of Plate XV E, and Figs. 1 and 2 of Plate XIX A — all in Vol. III.

69. APATITE ($3Ca_3P_2O_8 + CaCl_2$=phosphoric acid 40.92, lime 48.43, chlorine 6.81, calcium 3.84=100; or $3Ca_3P_2O_8 + CaF_2$=phosphoric acid 42.26, lime 50.00, fluorine 3.77, calcium 3.97=100; F. and Cl. replace one another in varying proportions). Apatite is known in Wisconsin only as an accessory rock constituent, but as such is of an extraordinarily wide distribution. It is only very rarely large enough, however, to be seen with the naked eye, when it appears in the shape of minute hexagonal prisms with pyramidal terminations. In the thin section it shows in two phases, presenting itself either as very minute, but relatively long, completely transparent and colorless needles, or as larger sized colorless to white crystals, in which there is commonly to be seen more or less dusty included matter. Cross-sections of both the smaller and larger crystals are hexagonal in outline and appear dark in all positions between the crossed nicol prisms. Other sections are dark whenever the longer axis of the crystal lies parallel to a cross-hair. The smaller apatite needles, which are the most commonly met with, are found included in the other mineral ingredients of all kinds of massive and schistose crystalline rocks. The instances of the occurrence of apatite in the crystalline rocks of Wisconsin are so numerous, that I mention only the chloritic hornblende gneiss from Penokee Gap in Ashland county, figured at Fig. 2, Plate XII A. Vol. III.

70. BARITE. HEAVY SPAR ($BaSO_4$=sulphur trioxide 34.3, baryta 65.7=100). Barite occurs in the lead region, commonly in massive, more rarely in lamellar and crested forms. The only place where it has been found in distinct crystals

[1] Vol. III, pp. 646-648.
[2] Vol. III, pp. 31-43.
[3] Vol. III, pp. 92-99, 224.
[4] Vol. IV, p. 694-696.

is in the railroad cut at Scales' Mound, in the extreme southwest part of the State; it is not a very abundant mineral.[1]

71. CELESTITE ($SrSO_4$=sulphur trioxide 43.6, strontia 56.4=100). Lapham reports celestite as occurring "in drift clay filling a crevice in limestone" at Wauwatosa, Milwaukee county.[2] It has not been noticed elsewhere in the State.

72. ANGLESITE ($PbSO_4$=sulphur trioxide 26.4, lead oxide 73.6=100). Anglesite is reported as occurring in small quantities lining cavities in galenite near Mineral Point, in the lead region.[3]

73. LEADHILLITE ($Pb_7C_4S_2O_{21}+2H_2O$). Lapham includes this mineral in his list as occurring at Mineral Point. The statement is made on the authority of D. D. Owen,[4] but Strong does not mention its existence there.

74. GYPSUM ($CaSO_4+2aq$=sulphur trioxide 46.5, lime 32.6, water 20.9=100). Gypsum is found in Wisconsin in fragments in the drift of the region about Sturgeon Bay,[5] to which region it seems to have been transported from some of the gypsum-bearing formations of Michigan. It is also met with in small crystals in the Cincinnati shales of the eastern part of the State.[6]

75. MELANTERITE. IRON VITRIOL. COPPERAS (Fe_2SO_6+7aq). A copperas is met with in the lead region — where it occurs as the result of weathering of marcasite — which may possibly belong to melanterite.[7]

76. CALCITE ($CaCO_3$=carbon-dioxide 44., lime 56.=100; part of the calcium is sometimes replaced by magnesium, iron or manganese). Calcite is, of course, one of the most wide-spread minerals in Wisconsin, occurring (*a*) in coarse crystallizations in the lead and zinc veins of the lead region;[8] in nests in limestone;[9] (*b*) as the fillings of gas pores of amygdaloids;[10] (*c*) as the replacer of some lime-bearing silicate among the crystalline rocks;[11] (*d*) as the chief constituent of the crystalline limestones of the Huronian;[12] (*e*) as a more or less prominent constituent of the paleozoic limestone formations of the State; (*f*) in the shape of the stalactite and stalagmite of various crevices and caves in limestone;[13] (*g*) as travertine;[14] and (*h*) as tufa or calcareous moss about certain springs.[15] The various paleozoic limestones of the State may often be seen to be impregnated with crystalline calcite, and the same is true of much of the upper layers of the Potsdam sandstone, but how far the lime and magnesium carbon-

[1] M. Strong in Vol. II, p. 693.
[2] Vol. II, p. 29.
[3] Vol. II, p. 29, 693.
[4] Geological Survey, Iowa, Wisconsin and Minnesota.
[5] Vol. II, p. 29.
[6] Vol. II, p. 315.
[7] Vol. II, p. 29.
[8] Vol. II, p. 693.
[9] Vol. II, p. 549, etc.
[10] Vol. III, pp. 31, 183–193, etc.
[11] Vol. III, pp. 31, 37–43, 183–193, etc.
[12] Vol. III, p. 106, Fig. 1, Plate XIII A, p. 225, 611.
[13] Vol. II, p. 29.
[14] Vol. II, p. 29, and Vol. IV, p. 96–98.
[15] Vol. II, p. 29.

ates of the limestones are in the condition merely of comminuted organic secretions, and how far they may be strictly classed as dolomite and calcite, is uncertain, these rocks never having as yet been studied with the microscope.

Macroscopically calcite is recognizable by its colorlessness or pale white color, its translucency, its moderate hardness, and its very pronounced rhombohedral cleavage (three equal cleavages oblique to one another). Even with the coarsely crystalline calcite, the rhombohedral cleavage surfaces may be seen with the naked eye to be crossed by a series of close, minute, parallel lines. These are due to a process of repeated twinning, the crystal being made up of a great number of minute laminæ, the alternate ones only of which have the same crystallographic position. In the thin section, this twinned structure is brought out very prominently in polarized light, the laminæ being alternately light and dark. The twinning, moreover, is much more common in the smaller particles met with in rock-sections, than in the more coarsely crystalline kinds. Besides the twin banding, the pronounced rhombohedral cleavage and the translucency are the properties by which calcite is principally recognized in the thin section. Calcite particles exhibit some little absorption, but are usually without any bright colors in the polarized light. Calcite is figured at Fig. 1, Plate XIII A, and Figs. 1 and 2, Plate XIX A.

77. DOLOMITE ($(MgCa)CO_3$=calcium carbonate 54.35, magnesium carbonate 45.65=100). Dolomite is known in Wisconsin as the principal ingredient of certain crystalline limestones of the Huronian series;[1] as a constituent of most of the paleozoic limestones of the State,[2] in which it is sometimes of sufficiently coarse crystallization to be perceptible to the naked eye; and, in rhombohedral crystals of some size in nests in the latter limestones. As already indicated, although crystalline dolomite is known to occur in the paleozoic limestones, the exact condition in which most of the magnesian carbonate of these rocks occurs is still uncertain. Dolomite is much like calcite in its physical characteristics. The separation of the two in the thin section is often very difficult, although the assertion is made in the books that microscopical calcite is always characterized by the repeated twinning above described, while dolomite is always without it.

78. SMITHSONITE.[3] CALAMINE. DRY BONE ($ZnCO_3$=carbonic acid 35.2, zinc oxide 64.8=100; but with part of the zinc oxide often replaced by iron protoxide or manganese protoxide). Under the name of "dry bone," given on account of its resemblance to partly decayed bone, a botryoidal and ferruginous smithsonite occurs largely in the lead region of the southwestern part of the State, where it is mined in quantity. Crystalline smithsonite is exceedingly rare, but very interesting specimens of rhombohedrons and scalenohedrons of smithsonite, pseudomorphons after calcite, are not unfrequently met with. These pseudomorphs are more or less hollow within, the calcite never having been entirely replaced by carbonate of zinc. Smithsonite also occurs pseudomorphous after sphalerite and galenite.[4]

79. CERUSSITE. WHITE LEAD ORE. ($PbCO_3$=carbonic acid 16,5, oxide of lead 83.51=00.) Cerussite is occasionally met with in small pieces in the lead region; but never in sufficient quantities to form an object for mining. The fragments are

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[1] Vol. III, p. 613.

[2] Vol. II, p. 268, 293, 306, 337, 345, 349, 351, 357, 360, 390, 395, 543, 549, 560, 671, 684.

[3] Lapham includes siderite in his list of Wisconsin minerals (Vol. II, p. 29), noting it as occurring upon the Penokee range of Ashland county; the statement, however, lacks confirmation.

[4] Vol. II, p. 694.

of an earthy texture and yellowish color. Small irregular crystals coating galenite are very rarely met with.[1]

80. HYDRO-ZINCITE ($3ZnCO_3+5ZnH_2O_2$=carbonic acid 15.2, zinc oxide 74.5, water 10.3=100). Hydro-zincite is met with at Linden and Mineral Point in the lead region, as a white finely crystalline fibrous incrustation on smithsonite; but it is of very rare occurrence.[2]

81. MALACHITE ($CuCO_3+H_3CuO_2$=carbonic acid 19.9, copper oxide 71.9, water 8.2=100). Malachite is met with at Mineral Point in small seams and incrustations resulting from the alteration of chalcopyrite.[3]

82. AZURITE ($2CuCO_3+H_2CuO_2$=carbonic acid 25.6, copper oxide 69.2, water 5.2=100). Azurite occurs at Mineral Point along with, and in the same manner as the malachite, occasionally, however, appearing in small handsomely crystallized specimens.[4]

83. HYDROCARBONS. The Cincinnati shales in the lead region are at times sufficiently impregnated with hydrocarbon to become inflammable. A solid hydrocarbon is met with occasionally in the Hamilton limestone near Milwaukee;[5] in the Lower Helderberg limestone in Freedonia, Ozaukee county;[6] and in the Niagara limestone east of Fond du Lac.[7] Fragments of lignite are met with in the drift of the St. Croix valley. Peat is widely spread underneath the marshes of the State.[8]

[1] Vol. II, p. 694.
[2] Vol. II, pp. 29, 694.
[3] Vol. II, pp. 26, 694.
[4] Vol. II, pp. 29, 694.
[5] Vol. II, p. 29.
[6] Vol. II, p. 393.
[7] Vol. II, p. 29.
[8] Vol. II, pp. 240, 664, and Vol. III, pp. 877, 887.

CHAPTER III.

LITHOLOGY OF WISCONSIN.

BY R. D. IRVING.

The rock species that have thus far been recognized in Wisconsin are as follows, most of the kinds named including several subordinate varieties, which receive special mention beyond:

MASSIVE ROCKS.

(Eruptive Rocks.)

Basic.
- Diabase.
- Melaphyr.
- Gabbro.
- Norite.
- Diorite.
- Peridotite.

Of Intermediate Acidity.
- Syenite.
- Quartzless Porphyry.

Acid.
- Granite.
- Granitic Porphyry.
- Felsitic Porphyries.

SCHISTOSE ROCKS.

- Gneiss.
- Mica-Schist.
- Hydromica-Schist.
- Actinolite-Schist.
- Tremolite-Schist.
- Hornblende-Schist.
- Augite-Schist.
- Chlorite-Schist.
- Talc-Schist.
- Magnetite-Schist.
- Hematite-Schist.
- Quartz-Schist.
- Quartzite (in part).
- Chert-Schist.
- Jasper-Schist.

HALF-FRAGMENTAL ROCKS.

- Quartzite (in part).
- Clay-Slate.
- Novaculite.

CALCAREOUS ROCKS.

- Limestones.

FRAGMENTAL ROCKS.

- Sandstone.
- Shale.

DIABASE, MELAPHYR AND GABBRO.

(Plagioclase-Augite and Plagioclase-Diallage rocks.)

The several kinds of Wisconsin rocks which belong under this heading are given in the following list, which at the same time gives their positions in Rosenbusch's classification, and the essential constituents of each. The gabbros are here included with the diabases, because diallage is merely a variety of augite, all sorts of gradation phases between the two minerals occurring in rock sections.

Plagioclase-Augite Rocks.

I. GRANULAR.

(1) Plagioclase + augite	Diabase.
(2) Plagioclase + augite + olivine	Olivine-diabase.
(3) Plagioclase + augite + orthoclase	Orthoclase-diabase.[1]
(4) The augite of (1) and (2) more or less altered to uralite	Uralitic diabase.

II. PORPHYRITIC AND "HALF GLASSY."

(5) Plagioclase + augite + non-resolvable base	Diabase-porphyrite.
(6) Plagioclase + augite + olivine + base	Melaphyr.
(7) Devitrified base + feldspar and augite microliths + steam holes filled with various amygdules	Amygdaloids.

Plagioclase-Diallage Rocks.

GRANULAR.

(1) Plagioclase + diallage	Gabbro.
(2) Plagioclase + diallage + olivine	Olivine-gabbro.
(3) Plagioclase + diallage + orthoclase	Orthoclase-gabbro.
(4) The diallage of (1) and (3), more or less changed to uralite.	Uralitic gabbro.
(5) The diallage of (1) and (3), more or less changed to basaltic hornblende	Hornblende-gabbro.

Diabases. The Wisconsin diabases are for the most part quite fine-grained rocks, of a dark color, varying from gray in more feldspathic kinds to black in more highly augitic. Alteration also produces brownish, purplish and greenish kinds, and kinds in which these colors are indefinitely mixed.

The plagioclase ingredient of these diabases varies from the acid oligoclase to the basic anorthite, to judge from the numerous measurements made according to Pumpelly's modification of Des Cloizeaux's method.[2] But the oligoclase is more especially prone to occur in the orthoclase-bearing diabases, while the anorthite, in turn, especially affects the olivine-bearing kinds. Thus labradorite is left as the characteristic plagioclase of the typical diabases. The augite of these rocks has nearly always crystallized out after the feldspars, since it is found filling sharply the spaces left between them; but in some phases the augite occurs in irregularly bounded or round particles, in which case it has crystallized so nearly simultaneously with the feldspars, or at all events, so rapidly, as not to fill their interspaces. In addition to these two ingredients, magnetite, often, if not always, titanium-bearing, is so common in the Wisconsin rocks that it might properly be regarded as one of the chief ingredients.

The diabases, as already indicated, are much prone to alteration, the liability to change varying directly with the closeness of aggregation of the crystalline particles. The plagioclase is often more or less replaced and permeated by a greenish chloritic substance, while the augite is much more prone than the feldspars to a viriditic change, which, when carried out to any considerable extent, produces more or less of a greenish color in the rock mass itself. Accompanying this change, which results from a hydration of the magnesian silicate of the augite, is a separation of the ferrous oxide of this mineral, which, oxidizing, forms particles of black magnetite, or gives a more or less diffused, reddish or brownish stain to the rock, from the formation of anhydrous or hydrous ferric

[1] The "quartz-diabase" of Wichmann, Vol. III, p. 626, is merely an altered orthoclase-diabase, and is therefore not provided for in this classification.

[2] Vol. III, p. 30.

oxide. Another very interesting change is the peculiar molecular one by which the augite becomes greenish uralite, or brown basaltic hornblende. This change is often carried so far that no remnants of the augite are to be seen. This change is farther noticed under uralitic diabase. Other more intricate forms of alteration of the diabase are met with, especially in the copper region of Lake Superior, but an account of them would be out of place here.[1]

Diabases are especially prominent in Wisconsin in the Copper Bearing or Keweenawan series of rocks, where they form numerous thin, but laterally extensive flows.[2] Diabases also occur frequently in the Huronian of the Menominee River region.[3]

Olivine-Diabase. Olivine-bearing diabase is not so common in Wisconsin as the olivine-free kinds, the presence of olivine being usually accompanied either by the presence of more or less of an unindividualized base — when the rock becomes a melaphyr — or of diallage, in place of the augite — when it becomes a gabbro. Some of the fine-grained rocks of the Keweenaw series, however, having all of the characters of the melaphyrs below described, are without interstitial unindividualized matter, and are therefore olivine-diabases.[4] Some of the olivine-gabbros of the Keweenaw series of Ashland county, again, run into fine kinds, in which the augite loses its diallagic character, and which therefore become olivine-diabases.[5] Black, fine grained, olivine-diabase, rich in magnetite, is occasionally met with in masses and dikes intersecting the gneiss in the Wisconsin valley.[6]

Orthoclase-Diabase. A number of the fine-grained, olivine-free diabases of the Keweenaw series contain oligoclase as the plagioclastic ingredient, and with this there is a general tendency for orthoclase to occur as an accessory constituent. There is in fact a gradation through kinds which are more and more rich in orthoclase, to rocks of an intermediate degree of acidity — the so-called non-quartziferous porphyries.[7] Orthoclase-bearing kinds have also been noticed by Wichmann among the diabases of the Menominee river region.[8]

Uralitic Diabase. The augite of diabase, as indicated on a previous page, tends often to pass, by a simple molecular change, into a greenish fibrous hornblende material, known as uralite. This change I have found, among the Wisconsin rocks, to be much more commonly characteristic of the orthoclase-bearing diabases, than of those kinds which are free from orthoclase. But uralitic gabbros are far more common than uralitic diabases.[9]

Diabase-Porphyrite. The fine-grained diabases of the Keweenaw series pass into aphanitic, very dense kinds, with more or less of a conchoidal fracture, and of a black to dark-brown color, in which there is present more or less of an unindividualized base, in which macroscopically distinguishable feldspars are gen-

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[1] See Vol. III, p. 31; also The Metasomatic Development of the Copper-Bearing Rocks of Lake Superior, R. Pumpelly. Proc. Am. Acad. Sci., Vol. XIII, 1878.

[2] Vol. III, pp. 8, 30, 37–43, 183–193, 336–350, 391–428.

[3] Vol. III, pp. 453, 470, 522, 569, 625–627, etc.

[4] Pumpelly (Vol. III, p. 32) has included these with the melaphyrs.

[5] Vol. III, pp. 168–183.

[6] Vol. IV, pp. 630, 637, 638.

[7] "The Copper Bearing Rocks of Lake Superior," by R. D. Irving. Monographs of the U. S. Geol. Surv., Vol. V.

[8] Vol. III, p. 623.

[9] Vol. III, pp. 31, 38, 627.

erally perceptible as porphyritic ingredients.[1] By a gradual increase in acidity these pass into the quartzless porphyries. The unindividualized base is a devitrified glass, commonly highly charged and colored by ferritic matter. Porphyritic augites also occur. According to Wichmann, a small quantity of unindividualized matter sometimes occurs in some of the diabases of the Huronian of the Menominee river region, to which cases the name of diabase-porphyrite should strictly be applied.[2]

Melaphyr. A very characteristic rock of the Keweenaw series is one which, in its fresh state, is fine-grained, of a dark-gray to black or greenish-black color, and in which on a fresh fracture are to be seen numerous relatively large-sized lustrous cleavage surfaces, of augite. Each one of these surfaces appears in all respects like the rest of the rock, except in the one position in which it reflects the light. To this peculiar effect Pumpelly has applied the term of "luster mottling."

The constituents of this rock are found on the study of the thin sections to be olivine, basic plagioclase (mostly anorthite), augite (each individual of which mineral includes hundreds of minute plagioclases), titaniferous magnetite, and a small quantity of an unindividualized substance. This substance is never present in any very considerable quantity, and often completely fails, when the rock becomes an olivine-diabase, as above stated.

These melaphyrs are very prone to alteration. "The first constituent to undergo a change is the olivine; and where this change has been accompanied, as is usual, by a change of the ferrous oxide to the ferric state, the rock presents a true color mottling, dark-greenish spots corresponding to the augite areas, which are surrounded by red or dark-brown alteration-products of the olivine, which abounded in the spaces between the augite crystals. In many instances the whole rock has been permeated with the red stain, when it presents a rich liver-brown color."[3] Numerous descriptions and references to these melaphyrs will be found in Vol. III.[4]

Amygdaloids. The amygdaloids are the porous, quickly cooled, steam-blown upper portions of the flows of the Keweenaw series. They are found with flows whose lower portions are any one of diabase, olivine-diabase, diabase-porphyrite, or melaphyr. The steam holes are commonly filled with one or more of calcite, chlorite, epidote, quartz, prehnite, laumontite, copper, orthoclase, or alteration-products of these. There are also often present, scattered through the ground-mass, macroscopically visible porphyritic crystals of feldspar, more rarely of augite.

The ground-mass itself is a devitrified glass, swimming in which are to be seen with the microscope numerous minute microliths of plagioclase, and thoroughly permeating which is the dark-brown or red ferritic product of devitrification. This matrix has, moreover, often undergone very extreme changes, having been replaced bodily by one or more of chlorite, calcite, laumontite, prehnite, epidote, quartz and copper.[5] Such is the nature of some of the beds worked for copper in the Lake Superior region. A still further and quite extraordinary complication in these amygdaloids has been produced by the inter-

[1] Much of Pumpelly's "ash-bed diabase" (Vol. III, p. 32) is diabase-porphyrite.
[2] Vol. III, pp. 624, 625.
[3] R. Pumpelly, Vol. III, p. 34.
[4] pp. 32, 37, 183–193, 336–350, 399–428.
[5] See Vol. III, p. 31.

mingling with the scoriaceous upper portions of the lava flows of the detrital material of the next succeeding layer of the series. This is the character of the miscalled "ash-bed" of Keweenaw Point. Numbers of such beds occur distributed through the Lake Superior region, and doubtless are to be found also in Wisconsin.

Gabbro. The gabbros or plagioclase diallage rocks are especially found in the Keweenaw or Copper-Bearing series.[1] They are, however, occasionally met with among the Huronian schists,[2] and even traversing the Laurentian gneisses.[3] They are all of them plainly of eruptive origin, which origin is, in my judgment, to be assigned without exception to all the diabases also. The gabbros have always a tendency to a coarser grain than is met with among the diabases; a gradually increasing fineness of grain being accompanied always by a loss of the diallagic character in the augite. The color of these rocks is usually from light-gray to dark-gray and even nearly black. As in the diabases, so also in those gabbros which are free from both olivine and orthoclase, the predominant plagioclase is labradorite, while an iron oxide ingredient, mostly in the form of titaniferous magnetite, is often present in such quantity as to constitute a prominent constituent.

Olivine-Gabbro. Gabbro proper, that is, gabbro free from both olivine on the one hand and orthoclase on the other, is much less common, however, than are the olivinitic and orthoclase-bearing kinds. The olivine-gabbros are peculiar, not only as carrying olivine as one of the chief constituents, but also in having the plagioclase for the most part anorthite. The olivine of these rocks is always in part fresh; but always also partly altered either to a greenish serpentine — along with which is also usually an abundance of separated iron oxide — or to biotite, viridite, talc, or ocher. Macroscopically the olivine-gabbros present no marked difference from the olivine-free kinds, except in those few instances where the olivine becomes a prominent and unusually coarse ingredient, in which case the alteration of this mineral has commonly produced much brown iron stain. Olivinitic gabbros are figured in Vol. III, Plate XV D, and Fig. 2, Plate XV E.

Orthoclase-Gabbro. In studying recently the Keweenaw series throughout its entire extent in the Lake Superior basin, I have found an orthoclase-bearing gabbro forming one of the best marked and most persistent types of the series.[4] This type had already been recognized in the Wisconsin reports as distinct from the other gabbros; but its nature was not fully understood. Macroscopically this rock is often distinguished by more or less of a reddish stain to the feldspars and by a greenish alteration of the diallage. The iron oxide ingredient, too, is apt to be especially prominent and abundant, and appears always to be much more highly titaniferous than in the orthoclase-free kinds.

Generally speaking, these gabbros are far more prone to alteration than the other kinds. They often reach also an extreme degree of coarseness, the feldspar crystals occurring sometime as much as one or two inches in length; as for instance, in the rock which forms the bluffs immediately behind the city of Duluth in Minnesota. In the thin section these orthoclase-gabbros are found to

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[1] Vol. III, pp. 35-43, 168–183.
[2] Vol. III, pp. 474, 522, 563.
[3] Vol. IV, pp. 702, 710.
[4] "Copper-Bearing Rocks of Lake Superior." Monographs of the U. S. Geol. Surv., Vol. V.
[5] Vol. III, p. 170. The "second variety" of gabbro found characterizing the gabbro belt of Ashland county.

contain oligoclase as the plagioclase ingredient, and to have more or less orthoclase among the feldspars. The augite is commonly somewhat altered to greenish uralite, while secondary quartz, apatite and infiltrated iron oxide are characteristic.

Uralitic Gabbro. The orthoclase-bearing gabbros are but very rarely found without at least a commencing change of the augite to uralite. When this change becomes at all pronounced — it being not unfrequently almost complete — the rock becomes a uralitic gabbro, which is thus merely an alteration form of the orthoclase-gabbro. The relation of augite and uralite in one of these uralitic gabbros is shown in Fig. 1, Plate XV E, Vol. III. Such rocks are quite common in the Keweenawan districts of Ashland and Douglas counties.[1]

Hornblende-Gabbro. In one phase of the gabbro of Ashland county,[2] brown basaltic hornblende is found to form a large proportion of the thin section. This rock Prof. Pumpelly has called an augite-diorite, he taking both the augite and hornblende as primary constituents; but a more extended study of the thin sections shows that this hornblende also is merely a paramorphic product of the augite.[3] The other constituents of this rock are oligoclase, orthoclase, titaniferous magnetite and biotite.

NORITE.

(Plagioclase-Enstatite and Plagioclase-Hypersthene Rocks.)

The norites are very rare rocks in Wisconsin, having been noticed only in a few small exposures in the Upper Wisconsin valley, where they appear as medium-grained, dark-gray, gabbro-like rocks.[4]

DIORITE.[5].

(Plagioclase-Hornblende Rocks.)

The term diorite is used by lithologists to cover all pre-Tertiary rocks in which hornblende and a triclinic feldspar are the chief constituents. It was formerly supposed that nearly all of the older, dark colored, basic, massive rocks were hornblendic, that is, were diorites; whilst augitic kinds were supposed to be relatively very rare. But the application of the microscope to the study of thin sections has shown that precisely the reverse of this is the case, the diabases in fact being the common kinds, while diorites are everywhere rare. Moreover, in many diorites entitled to be so called by their content of hornblende as a chief constituent, this mineral has been proved to be merely a secondary transformation of augite, remnants of which are here and there to be seen in little cores. The Wisconsin rocks form no exception to this rule, the diorites only rarely appearing. In the cases of all those diorites whose thin sections I have studied, I have found, moreover, that the hornblende is always merely altered augite; and I have little doubt that the same would be true of the hornblende of the few diorites from the Menominee Huronian described by Wichmann.[6]

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[1] Vol. III, pp. 37-43, 168-183, 346.

[2] Vol. III, p. 179.

[3] In the Geol. of New Hampshire, Vol. IV, Part IV, Mineralogy and Lithology, p. 206, and Fig. 1 Plate VII, Hawes describes a similar change of augite into brown hornblende.

[4] Vol. IV, pp. 661, 667, 680.

[5] The terms quartz-diorite and diorite-porphyry, used in Vol. III, are names of mere unimportant phases of ordinary diorite, and do not deserve any special mention here. Diorite-porphyrite ,that is, a rock of the composition of diorite with more or less of an unindividualized base, is not known in Wisconsin.

[6] Vol. III, p. 627.

If this is the case diorite as an original rock has not yet been found in Wisconsin.

The hornblende-bearing rocks described by Wichmann as diorites present macroscopically the same appearance as the fine-grained diabases above mentioned. In the thin section the plagioclase appears as in the diabases; the hornblende is of the greenish variety and often altered to viridite; orthoclase occurs in greater or less quantity; augite is met with occasionally as cores to the hornblende; while biotite, quartz, and apatite are common accessories. Apatite is especially abundant in these rocks; and its occurrence, along with the presence of augite cores in the hornblende and of secondary quartz, and the structural identity between these diorites and diabases of the same region strongly suggests that the diorites are but altered orthoclase-bearing diabases.

PERIDOTITE.

(Non-feldspathic Rocks.)

Rocks in which olivine is a chief constituent, in which the feldspars are nearly or completely lacking, and in which the remaining chief ingredient, if any, is any one of augite, diallage, enstatite or hypersthene, are included under the general name of peridotite. Only one locality for a rock of this class is known in Wisconsin, and that is the bed of the Wisconsin river near the mouth of Copper river, Lincoln county.[1] The rock seen here, in its fresher portions, is of a deep-black color, rough texture, and greasy luster, large sized lustrous cleavage surfaces of hypersthene or enstatite appearing here and there. In the thin section, olivine, almost entirely altered to serpentine, appears as the chief constituent of the rock. The crystals of enstatite and hypersthene are abundant, and though somewhat altered still retain their optical properties. Magnetite, hematite and limonite occur in abundant particles, and are plainly results of the change of olivine into serpentine. A few highly altered crystals of plagioclase are present.

SYENITE AND QUARTZLESS PORPHYRY.

(Quartzless Orthoclase Rocks.)

The following classification shows the nature and relations of the several kinds of massive rocks in which orthoclase is the most important ingredient occurring in Wisconsin. Quartz does not occur in these rocks, except in an altogether subordinate manner, or as a secondary substitution-product of the orthoclase.

Quartzless Orthoclase Rocks.

I. GRANULAR.

(1) Orthoclase + hornblende.................................... Syenite.
(2) Orthoclase + augite.. Augite-syenite.

II. PORPHYRITIC.

(3) Aphanitic groundmass + porphyritic orthoclases and plagioclases .... Quartzless porphyry.

Syenite. Rocks in which hornblende and orthoclase are the chief constituents, and in which the hornblende is not evidently a mere paramorphic product of augite, and which at the same time are non-schistose in texture, are very rare in Wisconsin, if indeed they do occur at all. The few instances mentioned by

[1] Vol. IV, pp. 702, 711.

Wichmann and Brooks from the Menominee region and the adjoining part of Michigan, are, to judge from the descriptions given, only special phases of diorite, or else are uralitic gabbros, or altered augite-syenites.[1] The so-called hornblende-rock of the several succeeding volumes of this report,[2] being in large part merely a phase of hornblende-schist, and in part uralitic gabbro or diorite, does not deserve any special place here as belonging to a separate rock species.

Augite-Syenite. In Volume III of these reports I have mentioned, under the name of granitic porphyry, a reddish granite-like rock as occurring among the Keweenawan rocks of Ashland county.[3] My more recent and more extended studies of the Keweenawan series have shown me that these reddish granite-like rocks constitute one of its most prominent features, and that they include kinds which may be referred to augite-syenite, granitic prophyry, and true granite. There is, in fact, as I have elsewhere shown, among the Keweenawan crystalline rocks a completely graduated series, from the ultra-basic olivine-gabbros, to highly acid granite; and among the porphyritic kinds of the series, from the basic diabase-porphyrites through the quartzless porphyries, to the highly acid quartziferous porphyries and felsites.

Those kinds which may be included under the name of augite-syenite have orthoclase as their chief constituent, along with which is generally found a notable proportion of oligoclase. Augite is the remaining chief constituent, but is always present in much smaller quantity than the feldspars. Only cores of the augite remain unaltered, its place being taken either by greenish uralite or — and this is a very pronounced characteristic of the augite of these rocks — by a mass of reddish or brownish ferrite. Another remarkable characteristic of these rocks is the secondary quartz with which they are always more or less saturated. This quartz affects especially the orthoclase, increasing in quantity with the increasing quantity of that ingredient.[4]

Quartzless Porphyry. The augite-syenites just mentioned are found chiefly as intersecting masses in the Keweenaw series. Corresponding to them, however, among the lava-flows of the same series are the quartzless porphyries. These present, macroscopically, a brownish, aphanitic, conchoidally fracturing matrix, in which are sprinkled rather sparsely small crystals of feldspar.

Under the microscope the matrix presents various mixtures of microcrystalline and cryptocrystalline material, the whole commonly stained by brown ferritic matter. Orthoclase and oligoclase are generally recognizable among the crystalline ingredients of the base, and more rarely augite in clusters of little points. Secondary quartz sometimes has infiltrated this base, but is much less prominent than in the more acid or true quartziferous porphyries. At the time of the preparation of the description of the rocks of the Keweenaw series, in Vol. III of these reports, the existence of these quartzless porphyries was not distinctly recognized. Such rocks are now known to occur in a few places in Ashland county, as for instance on the Gogogashugun river, near the north line of Sec. 8, T. 46, R. 2 E.[5]

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[1] Vol. III, pp. 523, 582, 620.

[2] Vol. II, pp. 463, 472, etc., and Vol. III, pp. 137, 288, 524, 640, 702, etc.

[3] Vol. III, p. 195.

[4] For a full description of these augite-syenites, with illustrations, see my memoir on "The Copper-Bearing Rocks of Lake Superior." Monographs of the United States Geological Survey, Vol. V.

[5] This rock is mentioned in Vol. III, p. 196, where it is included with the felsitic porphyries.

GRANITE, GRANITIC PORPHYRY, FELSITE AND QUARTZIFEROUS PORPHYRY.

(Quartz-bearing Orthoclase Rocks.)

The following classification shows the natures and relations of the several Wisconsin rocks which fall under this heading:

Quartz-Bearing Orthoclase Rocks.

I. GRANULAR (Granite family).

(1) Orthoclase + quartz	Granulite and Granitell.
(2) Orthoclase + plagioclase + quartz + muscovite	Muscovite-granite.
(3) Orthoclase + plagioclase + quartz + biotite	Biotite-granite.
(4) Orthoclase + plagioclase + quartz + muscovite and biotite	Muscovite-biotite Granite.
(5) Orthoclase + plagioclase + quartz + hornblende	Hornblende-granite.
(6) Orthoclase + plagioclase + quartz + hornblende + biotite	Hornblende-biotite Granite.
(7) Orthoclase + plagioclase + quartz + augite	Augite-granite.
(8) Granites in which there is a tendency towards a porphyritic development, and which thus present us with a transition towards the quartziferous porphyries, are included under	Granitic Porphyry.

II. PORPHYRITIC (Felsitic porphyry family).

(9) Felsitic matrix without prominent porphyritic ingredients	Felsite.
(10) Felsitic matrix with porphyritic quartzes and feldspars	Quartziferous Porphyry.
(11) Felsitic matrix with porphyritic feldspars only	Feldspar-Porphyry.

Granulite or Granitell. Both of these names have been applied to rocks which are essentially mixtures of orthoclase and quartz. Such rocks in the shape of veins traversing gneiss occur to a considerable extent in the vicinity of Grand Rapids and Stevens Point, on the Wisconsin river.[1] As developed here, the granitell is a fine-grained to coarse-grained, pinkish to red rock, in which the feldspar and quartz are both easily distinguishable to the naked eye. Under the microscope the orthoclase and quartz, in nearly equal proportions, are seen to be the chief ingredients. Oligoclase and microcline are commonly mingled in some little quantity with the orthoclase; while in a few slices the microcline was seen to equal the orthoclase in quantity. Minute quantities of biotite, augite, chlorite, limonite, magnetite, apatite, are found as accessories.

In the sandstone regions of Green Lake and Marquette counties a number of isolated mounds of massive rocks rise through the overlying sandstone. Some of these are composed of granite, whilst others are quartziferous porphyry. Some of the porphyries, as indicated below, tend more and more towards a completely and coarsely crystalline structure, thus approaching granitic porphyry or granitell in character. In the case of the rock of Pine Bluff, in the N. W. qr. Sec. 2, T. 17, R. 11 E., Green Lake county, the crystallization is so coarse that the rock can no longer be called felsitic, but on the contrary must be placed with the granitells. On study it is found to be an intimate mixture of quartz, orthoclase and microcline, along with which a few particles of mica

[1] Vol. IV, pp. 620, 636, 643; Vol. II, pp. 472, 481.

occur, while abundant apatite, with some magnetite, hematite, and chlorite, are the accessories.

Granites. The granites carrying mica to the exclusion of hornblende are less common in Wisconsin than those in which hornblende is an essential constituent, while of those carrying micas only, the muscovite-granites are hardly known. Moreover, granites of any kind that are not merely dependencies or phases of gneiss, are uncommon.

Macroscopically the granites are nearly always coarse enough to show the quartz, feldspars, and mica or hornblende to the naked eye, while some kinds have an extreme degree of coarseness, the feldspars reaching sometimes one to two inches in width. The common color is some shade of pink or red, from the predominance of reddish feldspars. The mica or hornblende ingredient is always in quite subordinate quantity, and often sinks out of sight altogether.

Under the microscope the quartz of granite is always seen in irregularly bounded grains which mould themselves around the feldspars in such a manner as to prove their subsequent deposition. These grains are frequently highly charged with cavities containing fluid inclosures, the liquid in which is at times liquid carbonic acid, at times water, and again is a saline solution. Other common inclusions in the quartz of granite are prisms of apatite, deep red folia of hematite, particles of mica, and long needles of rutile. The orthoclase particles of granite present no unusual characters beyond what have already been described in a previous chapter. Microcline is very common among the Wisconsin granites and gneisses, not unfrequently occurring in nearly as large quantity as the orthoclase. The plagioclase is always oligoclase. The micas present no unusual characters. The hornblende is commonly of the greenish variety, although in a few cases brown basaltic hornblende has been observed; as for instance in the coarse hornblende-granite of Wausau, in which both green and basaltic varieties occur. Several cases also have been noticed in which the hornblende is merely altered augite or even altered diallage. Contrary to the generally received view, augite — of the variety sahlite — is a frequent accessory in Wisconsin granites, while not a few varieties have been noted in which the augite is present to the entire exclusion of both hornblende and mica.

As prominent instances of granite in Wisconsin may be mentioned the biotite-granite which underlies a large area in the Huronian of the Menominee river region;[1] the coarse hornblende-biotite granite of the Eau Claire river, Marathon county,[2] the very coarse hornblende-granite of Wausau, Marathon county — in which the hornblende is plainly only a paramorphic product of diallage; the hornblende-granite of Little Bull falls on the Wisconsin river[3] — in which the hornblende again is only altered augite; the mica-granite of Montello in Marquette county, and Spring Lake in Waushara county;[4] the very coarse granite of the upper Wolf river; and the granite intersecting gabbro at Bad River falls north of the Penokee range, Ashland county.[5] A figure of the last named granite is given at Fig. 2, Plate XV C, Vol. III.

Granitic Porphyry. In the Keweenaw series of Lake Superior a rock is met with which is intermediate between the quartziferous porphyries on the one hand,

[1] Vol. III, p. 619.
[2] Vol. IV, pp. 686–688.
[3] Vol. IV, pp. 650, 655.
[4] Vol. II, pp. 521, 522.
[5] Vol. III, p. 174.

and the granitells and true granites on the other, and to which, on account of its tendency to a porphyritic development, the name of granitic porphyry has been applied.[1] As already indicated this is one of the three phases of granite-like rocks met with in the Keweenaw series, the other two being augite-syenite and true granite.[2]

Felsitic Porphyries. The felsitic rocks are acid rocks whose base is completely homogeneous to the naked eye, and whose composition shows that they have essentially the composition of orthoclase, with the addition of more or less superfluous silica. When the rock is without any porphyritic ingredients, it is known as a felsite; if quartz is at all prominent among the porphyritic ingredients, it is a quartz-porphyry, and if the feldspars alone appear among the porphyritic ingredients, it is a feldspar porphyry. All these varieties may, and frequently do, occur in the same rock mass, while those felsites in which there is no porphyritic quartz at all are often as acid as the true quartziferous porphyries.

The nature of the felsitic groundmass of these rocks has been the subject of much discussion in the past. Before the application of the microscope to its study, it was held by some to be a simple mineral, by others to be a crystalline granular mixture of quartz and orthoclase, and by yet others was looked upon as merely a sort of a residuum of crystallization, or a sort of a mother liquor. It appears now, however, to be thoroughly well established that the felsitic groundmass varies considerably in its nature in different cases. In some felsites not distinguishable from others macroscopically, the groundmass is certainly merely a fine-grained aggregate of the same minerals found constituting granite, especially quartz and orthoclase. These kinds are a step below the granitic porphyries above mentioned. Felsitic rocks in which the matrix is of this character are designated as *microcrystalline* by Rosenbusch. In other felsitic rocks again the groundmass, while made up completely by doubly refracting particles, yet has these particles so excessively fine that their mineralogical nature is no longer recognizable. Such groundmasses as this Rosenbusch calls *cryptocrystalline*, or hidden crystalline. In still other cases large portions, or even all, of the felsitic matrix, is perfectly isotropic, that is, does not doubly refract light. This material, according to Rosenbusch, may be of two kinds, which often occur together, and again occur interwoven with cryptocrystalline matter. One of these substances, whilst completely isotropic, is not absolutely structureless, appearing in excessively minute, colorless, grayish, yellowish, or brownish scales, fibres, granules, or aggregates of granules. This substance, which differs from perfect glass in not being completely structureless, is called the *microfelsitic base* by Rosenbusch. At times, however, there is present in minute films, stripes and particles interwoven with the microcrystalline or cryptocrystalline matter, a completely structureless substance, which may be either absolutely homogeneous, or may be clouded with dark hair-like particles or granules. This substance, since it is plainly of the nature of a true glass, Rosenbusch calls the *glass base*.

The felsitic rocks of Wisconsin are of especial importance in the Keweenawan rocks bordering Lake Superior,[3] but they occur also prominently associated with the quartzites of the Baraboo region,[4] and in isolated mounds rising through the superincumbent Cambrian sandstone of Marquette and Green Lake

[1] Vol. III, pp. 37, 195.

[2] See Copper-Bearing Rocks of Lake Superior; Monographs of the U. S. Geological Survey, Vol. V.

[3] Vol. III, pp. 195–198.

[4] Vol. II, pp. 513–515.

counties.[1] These rocks are quartziferous porphyries, and appear to belong to the Huronian. Other quartziferous porphyries, apparently belonging to the Huronian, are met with in the Wisconsin valley in the vicinity of Wausau,[2] while on Yellow river a quartz-porphyry is found cutting gneiss.[3]

The Lake Superior felsitic rocks include all three kinds named, the different kinds occurring distinct in separate beds and again in the same mass. The prevailing color is some quite bright shade of red. Frequently this red is blotched with lighter shades or even with white, and often the lighter colored material is arranged in waving or contorted lines or rows of spots. This peculiar banding, which at times becomes very pronounced, is plainly a result of a flowage of the rock when in a molten or semi-molten condition, and the same flowage structure is often emphasized by the linear arrangement of the porphyritic ingredients. Under the microscope the matrix of these rocks is found to be for the most part made up of cryptocrystalline and microfelsitic matter. Distinctly recognizable orthoclase and quartz particles in the matrix are only very rarely met with. In general, it may be said that the matrix of these rocks is not very far from the glassy condition, although it is uncertain that any true glass is contained. The flowage structure seen macroscopically is still more beautifully brought out in the thin section, in which red and white material are to be seen interbanded in wavy, non-continuous lines. Very characteristic are the deep brown and deep red to black, opaque, irregularly outlined to needle-shaped ferrites. These occur especially in the red bands, and are often arranged in flowage lines in a very pronounced manner. Though wholly absent from some sections, a highly characteristic feature of the matrices of many of these Lake Superior rocks, and more particularly of the non-porphyritic felsites, is a saturation by secondary quartz, which is arranged in an exceedingly delicate and often arborescent network.

Of the porphyritic ingredients in these rocks, the feldspars are the most commonly and abundantly present, appearing in regularly outlined crystals usually of a red color, though occasionally white and porcellanous, and ranging in size from very minute particles just visible to the naked eye, to those which are a quarter or even half an inch in length. They include both orthoclase and oligoclase, which occur either separately or together in the same rock. Except where corroded or eaten into by the fused matrix, they show very regular crystalline outlines, and even in this case some remnants of their outlines are commonly perceptible. In a number of sections the feldspars are seen to have been not only eaten, but also shattered, before the solidification of the surrounding magma. The porphyritic quartzes of these rocks present the usual characters of the quartzes of such rocks from other regions, showing macroscopically a glassy rough surface, a nearly black color — due to the dark back-ground against which they lie — and more or less evident crystalline outlines; while microscopically they are seen to be sections of doubly terminated crystals more or less eaten into and rounded by the matrix. The rhombohedral angle of quartz being only a few degrees over 90°, and the prismatic planes being commonly very subordinate, or entirely absent, these quartz sections often present a nearly square shape. The fused matrix has often corroded these crystals in such a manner as to reach far into their interior in club-shaped projections. The necks by which these projections are connected with the matrix, being often

[1] Vol. II, pp. 519–521.
[2] Vol. IV, pp. 661, 670–673.
[3] Vol. II, p 491, and Vol. IV, pp. 645, 649.

oblique to the plane of section, are entirely removed by the grinding process, when the misleading appearance is presented of the existence of isolated inclusions of the matrix within the mass of the quartz. Veritable glass inclusions, however, are seen in the shape of doubly terminated "negative crystals."[1]

The felsitic porphyries of the Baraboo region, and thence northward, differ from those of the Lake Superior region in their common dark color — dark red to black — in the completely crystalline nature of the matrix, and in their relatively large content of magnetite particles. Some of these rocks, in fact, have a so completely crystalline matrix as to approach near to the granitic porphyries.

The porphyries of the vicinity of Wausau are intermediate as to the nature of the matrix between those of the Lake Superior and Baraboo regions, the groundmass in them being composed in part of cryptocrystalline and in part of microcrystalline material, whilst some microfelsitic matter is not unfrequently found in them. They are gray to nearly black in color and contain the usual porphyritic quartzes and feldspars.

GNEISS.

The essential constituents of gneiss are the same as those of granite; that is to say, it is composed of quartz, orthoclase and plagioclase, as invariable constituents; and one or other — or more than one at a time — of muscovite, biotite, sericite, hornblende, augite and chlorite, as essential but variable constituents. Gneiss is distinguished from granite, however, by having a more or less completely parallel arrangement of its constituents, by which a stratified appearance is produced. This stratification or parallel arrangement of its ingredients is commonly believed to have been caused by the process of sedimentation, the crystalline texture now shown by gneiss and all other crystalline schists being regarded as the result of a peculiar process of molecular rearrangement known to geologists as "metamorphism." While it seems very probable that there is a great deal of truth in this view, the theories of metamorphism as they now stand are very unsatisfactory. Many rocks which have been called metamorphic are plainly of an eruptive origin, and it seems not improbable that the same origin is to be attributed to some rocks with a strongly developed schistose structure. One of the most difficult things to understand about gneiss and the other crystalline schists is the arrangement of the particles of the constituent minerals, especially mica and hornblende, with their crystallographic axes more or less thoroughly in a common direction. A section of gneiss, for instance, parallel to the lamination, will often show much the larger part of the mica in sections parallel to the base.

The following list includes the names and compositions of the most prominent varieties of gneiss met with in Wisconsin:

(1) Orthoclase + plagioclase + quartz + muscovite ..... Muscovite-gneiss.
(2) The same as (1) + biotite .... Muscovite-biotite-gneiss.
(3) Orthoclase + plagioclase + quartz + sericite .... Sericite-gneiss.
(4) Orthoclase + plagioclase + quartz + hornblende .... Hornblende-gneiss.
(5) Orthoclase + plagioclase + quartz + hornblende + biotite .... Hornblende-biotite-gneiss.
(6) Orthoclase + plagioclase + quartz + augite .... Augite-gneiss.
(7) Orthoclase + plagioclase + quartz + chlorite .... Chlorite-gneiss.

[1] I have devoted a proportionally large amount of space to the felsitic porphyries of the Keweenaw series, not only because of their great interest, but because they are not anywhere described microscopically in these reports. For a very complete description of them with figures, see my memoir on the Copper-Bearing Rocks of Lake Superior, already referred to.

Between these different types there are, of course, all sorts of gradation forms, which are distinguished in name by using adjectives made from the name of the less common ingredient; for instance, augitic biotite-gneiss, hornblendic biotite-gneiss, etc. Pure muscovite-gneisses may be said to be almost unknown, though not uncommon in other gneissic regions. The commoner kinds in Wisconsin are the biotite-gneiss, biotite-muscovite-gneiss, hornblende-gneiss and augite-gneiss. Augite (sahlite) had been occasionally noticed as an accessory constituent of gneiss from several regions,[1] but among the Wisconsin rocks it occurs not only as an almost universal accessory among the micaceous varieties, but enters into the composition of a widespread variety — here for the first time recognized under the name of augite-gneiss — as an essential constituent. Moreover, so far as the gneisses of the Wisconsin valley are concerned, the chlorite and hornblende contained in them are invariably alteration-products of the augite. That the same is true of all other hornblende-bearing gneisses in the state is probable.

As prominent instances of the occurrence of gneiss in Wisconsin may be mentioned the coarse-grained augitic and hornblendic biotite-gneisses at Grand Rapids and Stevens Point on the Wisconsin river;[2] the augite-gneisses and hornblende-gneisses of the valley of the Upper Rib river in Marathon county,[3] and on the Wisconsin river in the vicinity of Merrill, Lincoln county;[4] and the chloritic hornblende-gneisses immediately south of Penokee Gap, Ashland county.[5] Figures of the appearance of the thin sections of the last named gneiss are given in Plate XII A, Vol. III.

MICA-SCHIST.

Mica-schists are composed essentially of quartz and either one or both of the common micas. The quartz, in minute closely interlocked grains, forms the groundmass, in which are more or less thickly scattered the scales of mica. These scales lie for the most part with the basal cleavage parallel to the schist-plane. The groundmass usually contains in addition to the quartz more or less feldspar, principally orthoclase, which at times forms even the larger part of the base. Greenish hornblende is very frequently present as an accessory, and, as it increases in quantity, presents us with transition-forms towards the true hornblende-schists. In the same way through the introduction of chlorite and augite we have gradation-forms towards the chlorite-schists and augite-schists. Magnetite is a common accessory, appearing in sharply defined sections of octahedral crystals. Certain schists are characterized by the presence in abundance of andalusite or staurolite.

By varying coarseness of grain and of lamination the mica-schists grade on the one hand into gneiss, and on the other into aphanitic kinds. Some of these aphanitic kinds have a black color due to a minute quantity of carbonaceous matter. With the increasing fineness of grain there is also always a more perfectly developed slaty cleavage. By a hydration and molecular rearrangement of the mica particles, the mica-schists pass over into the so-called hydro-mica schists, described below under the name of sericite-schists, the mineral sericite being commonly, if not always, the hydro-mica present.

As typical instances of the occurrence of mica schists in Wisconsin, may be

[1] Vol. III, p. 606.
[2] Vol. IV, pp. 628, 631–635, 639–644.
[3] Vol. IV, pp. 692, 694–696.
[4] Vol. IV, pp. 702–708.
[5] Vol. III, pp. 92–99.

mentioned the black mica-slate forming Formations VII, XII and XIV of the Penokee Huronian;[1] the chiastolitic mica-slate composing XVI of the same series;[2] the light-gray to dark-gray, rather coarse-grained biotite-schist composing XXI of the same series;[3] the staurolitic and other mica-schists of the Menominee region;[4] and the biotite-schist of the Eau Claire river in Marathon county.[5] Mica-schists are figured at Figs. 4 and 5, Plate XV A, and 1 and 3, Plate XV C, Vol. III.

SERICITE-SCHIST (HYDRO-MICA-SCHIST).

Formerly all greasy-surfaced schists were looked upon as talcose. Since the application of the microscope, however, it is known that most of these schists are non-magnesian, and that true talc-schists are of comparatively rare occurrence. Some of the hydro-mica schists appear to be simply muscovite-schists, in which the muscovite has undergone a partial hydration, and decomposition; but in other cases the micaceous ingredient is plainly a mineral distinct from muscovite. This is the so-called sericite of List. The Wisconsin hydro-mica schists seem to be altogether of the nature of sericite-schist.

Two types of these schists are known among the Wisconsin rocks. In one of these the micaceous ingredient is especially prominent, being readily perceptible to the naked eye, while in the other it sinks to particles of microscopic size, its presence being indicated macroscopically only by a greasy sheen upon the schistose surfaces. By a decrease in the amount of sericite, schists of the latter type grade into true quartz-schist. There is also a gradation, by the introduction of argillaceous matter, into the clay-slates. This argillaceous matter is commonly regarded as the result of an original sedimentation, but it is certainly in the case of some of the sericitic schists merely a decomposition-result. Quartz is always one of the chief constituents of sericite-schist, forming the groundmass in which the scales of sericite are interwoven. Larger particles of quartz occur at times, and while these commonly have rounded contours, others are sections of rhombohedral crystals, such as occur in the felistic porphyries. Such porphyritic quartzes are very prominent in the sericite-schists of the iron region of Vermillion lake, in Minnesota, where other things occur to suggest their possible origin from the alteration of felsitic porphyry. As instances of sericite-schists in Wisconsin may be mentioned the greasy-surfaced aphanitic schist forming much of Formation III of the Penokee Huronian,[6] and the sericite-schists of the Menominee region, so fully described by Wichmann.[7]

AMPHIBOLITE-SCHIST.

(Including hornblende-schist and actinolite-schist.)

Hornblende-Schist. As already indicated, by the introduction of hornblende, the mica-schists pass over into hornblende-schists, the mica finally disappearing altogether. Macroscopically the hornblende-schists are not often to be distinguished from the biotite mica-schist, and the resemblance remains even in the thin section, save that hornblende takes the place of biotite. Apatite also is a much

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[1] Vol. III, pp. 139–141.
[2] Vol. III, p. 143.
[3] Vol. III, p. 145.
[4] Vol. III, pp. 526, 634.
[5] Vol. IV, pp. 686, 689–691.
[6] Vol. III, p. 3. The nature of the micaceous ingredient of this rock is not recognized in the descriptions in Vol. III.
[7] Vol. III, pp. 636–639.

more common accessory in the hornblende-schists than in the mica-schists. What has already been said of the groundmass of mica-schist applies equally well to hornblende-schist. Augite (sahlite) is a very common accessory, and may very frequently be seen passing over into hornblende. So far as my own examinations have extended, all of the hornblende of these augitic varieties is of a secondary nature, having resulted from the alteration of an augitic constituent, and I have no doubt but that the same will prove to be true of all other of the Wisconsin hornblende-schists. The common accessories in these hornblende-schists, in addition to apatite and sahlite, already mentioned, are magnetite, hematite, titanic iron, the characteristic gray alteration-product of titanic iron, titanite and biotite.

The hornblende-schists are very much more abundant in Wisconsin than the mica-schists, and indeed than any other kind of schistose rock, excepting gneiss. As typical instances may be mentioned the hornblende-schists of the Menominee region;[1] those interstratified with gneiss in the vicinity of Grand Rapids and Stevens Point on the Wisconsin river;[2] and those of the upper Rib river, in Marathon county.[3]

Actinolite-schist. In certain rather unusual forms of amphibolite-schist the amphibole is actinolite instead of hornblende. These forms embrace three types. In one of these the long actinolite needles form most of the rock, the groundmass in which they are imbedded being composed of quartz grains along with some chlorite. In another the quartz sinks nearly or quite out of sight, and is mingled with a large proportion of magnetite, mostly in clusters of well crystallized grains, while in the third the actinolite is associated with a large proportion of garnet. The actinolite-schists have been observed chiefly in the Menominee and Penokee regions, where they are associated with some of the lower magnetic ores.[4]

AUGITE-SCHIST.

Wichmann first showed the existence in Wisconsin of schistose rocks in which augite takes the place of the hornblende of hornblende-schist and of the mica of mica-schist.[5] I have since found that such rocks are quite common in the Upper Wisconsin valley, where they occur grading into hornblende-schist and interstratified with and grading into augite-gneiss. The groundmass of these rocks is chiefly quartzose, and entirely similar to that of the hornblende-schists and mica schists. The augite is always of the variety sahlite.

I have already indicated my belief that the hornblende-schists of Wisconsin are but altered forms of augite-schist. As typical instances of Wisconsin augite-schists may be mentioned those of Trapp river in Lincoln county,[6] and those of the Upper Rib river in Marathon county.[7]

CHLORITE-SCHIST.

Chlorite schists are dark-greenish, greasy-lustered rocks, in which chlorite, in closely aggregated or interwoven folia, is the chief constituent. Quartz is the principal groundmass mineral. It may sink nearly out of sight, or may pre-

[1] Vol. III, pp. 640–645.
[2] Vol. IV, pp. 629, 637, 644.
[3] Vol. IV, pp. 694–696.
[4] Vol. III, pp. 105, 119, 123, 151, 482, 487, 526, 545, 587, 639.
[5] Vol. III, p. 645.
[6] Vol. IV, p. 669.
[7] Vol. IV, pp. 694–696.

dominate over the chlorite in quantity. The feldspars, chiefly orthoclase, also often enter into the groundmass. Magnetite and biotite are the most constant accessories; more rarely muscovite, calcite, apatite, titanic iron, zircon, tourmaline, and actinolite are met with. The chlorite-schists grade into chloritic gneisses. There can, I think, be little doubt that all of the chlorite-schists, as well as the chloritic gneisses, are altered rocks. In large part they are a result of the change of the hornblende of hornblende-schist or gneiss, and since these are often secondary to augitic rocks, the chlorite-schists have often originally been augite-schists. Other chloritic rocks to which the term chlorite-schist has been applied are merely altered diabases, and therefore of eruptive origin.

Chlorite-schist is not very common in Wisconsin. It occurs to some extent in the Menominee region.[1]

TALC-SCHIST.

Talc-schist consists principally of minute folia of talc. There is sometimes present a quartzose groundmass. Small particles of magnetite and hematite occur as accessories. Talc-schist is a rock of rare occurrence anywhere. Wichmann, in his microscopic descriptions of the Menominee region rocks, mentions only two occurrences of talc-schist, and both of these are from the vicinity of Marquette in Michigan. The rock of the Big Quinnesec falls, described as talc-schist by Wright and others,[2] has been shown by Wichmann to be sericite-schist. The soft talc-like schists in the vicinity of Black River Falls in Jackson county,[3] have never been examined under the microscope, or chemically. They are probably sericite-schist. It thus remains doubtful whether true talc-schist occurs anywhere in Wisconsin.

MAGNETITE-SCHIST AND HEMATITE-SCHIST.

Schistose rocks, in which magnetite is the predominant constituent, are very prominent in the Huronian of the Penokee and Menominee regions. These schists are found of two principal varieties. In one of these the magnetite, usually in aggregated crystalline grains, is associated with a completely crystalline quartz groundmass. In some sections this groundmass appears to be entirely made up of quartzose particles, which lie where originally deposited; but in other cases there is a distinctly arenaceous or sandy texture, and the rock seems to be plainly of a fragmental origin. In the other type the magnetite is associated with tremolite or actinolite, either with or without the quartz. In both varieties specular hematite often takes in part the place of the magnetite. The hematite increasing in quantity, we have gradation types towards the hematite-schists, in which quartz and micaceous or scaley hematite are the essential constituents. By a lessening of the iron oxide constituent, these rocks become mere ferruginous quartz-schists; while in the other direction they grade into merchantable magnetic and specular ores.

Magnetite-schist and hematite-schist have their most prominent occurrence in Wisconsin in the so-called "magnetic belt" in Ashland, Bayfield and Lincoln counties.[4]

QUARTZITE AND QUARTZ-SCHIST.

These rocks are composed essentially of quartz, which may occur nearly or quite without accessories, or with varying amounts of foreign minerals. Quartzite includes those kinds which are more or less heavily bedded and of relatively

[1] Vol. III, pp. 456, 485, 486, 497, 518, 557, 565, 640, 646, 697, 708.
[2] Vol. III, pp. 515, 713.
[3] Vol. II, pp. 494, 497.
[4] Vol. III, pp. 118, 136, 257, 301.

coarse grain, and consequently without a marked schistose structure. The quartz schists, on the other hand, have this structure very strongly developed, are for the most part of comparatively fine grain, and are more apt to be less purely siliceous.

Almost any kind of schistose rock may graduate into quartzite or quartz-schist by the partial or complete loss of its characteristic minerals. Thus gneiss, mica-schist, hornblende-schist, magnetite-schist, clay-slate, chlorite-schist, augite-schist, etc., when followed in the direction of the strike, are often found to become more and more quartzose, and finally to run into kinds in which the quartz is the only prominent ingredient. Thus quartz-schists are characterized especially by mica, hornblende, actinolite, magnetite, chlorite, etc., as accessories. On the other hand, there is a distinct gradation into fragmental rocks. This fragmental character is not unfrequently evident to the naked eye, either by the arenaceous texture of the rock, or by the presence of larger or smaller rounded to angular pebbles. These pebbles may not unfrequently be seen in a rock whose matrix is the hardest and least arenaceous kind of quartzite. There is often also present a distinct banding, due to the original deposition of fragmental material. This banding may be brought out by a difference in the amount of iron stain in the alternate laminæ, or by a difference in the coarseness of the material in different bands. Not unfrequently this banding due to deposition is not accompanied by any tendency to cleavage, or is even traversed by the schistose cleavages.

In the thin sections the purer quartzites show two distinct types. In one of these the quartz grains completely interlock, are without any finer interstitial material, and present every evidence of having been wholly deposited in their present positions. When the quartz grains of such a rock are of a large size, they are precisely like those of a gneiss. In the second type of quartzite more or less of the quartz is present in the shape of rounded or completely detached grains, between which there is a finer interstitial quartz. But in the same sections that present this evidence of a fragmental origin for the rock there will be always a larger or smaller proportion of completely interlocked quartz grains, equaling in size the rounded particles first mentioned. Such rocks as these are then plainly but sandstones, which have passed through a certain amount of the altering process known as metamorphism.

Quartzites and quartz-schists are widely spread in Wisconsin, characterizing especially the Huronian series. As a prominent instance we may mention in the first place the quartzite which forms the Baraboo ranges. These ranges, as to their topography and geological structure are fully described in Vol. II.[1] The common rock here is a quartzite of a non-granular, usually flaky, texture, and of a color from nearly white, through gray, pink and amethyst to purplish-red and even brick-red, the gray and deep-red being the most common colors, the white the least so. Very rarely a distinct granular texture is seen; somewhat more commonly a slight tendency in that direction. The quartzite is frequently very distinctly marked by very thin bands, due to the original sedimentary deposition, which are alternatingly light and dark colored. There is never any cleavage parallel to these bands. In the thin section this quartzite is seen to belong to the class of half fragmental rocks, the rounded grains of quartz being in part imbedded in a finer interstitial material, and in part mingled with and surrounded by interlocking quartz particles plainly deposited where they lie. A small amount of hydrated iron oxide is occasionally to be seen, while in some sections appear little nests of broken leaves of muscovite.

[1] pp. 504–519.

Other instances of half fragmental quartzites in Wisconsin are the rock exposed in the vicinity of the village of Portland, Dodge county; the rocks of the layers numbered II, XV and XVII of the Huronian series of the Penokee range in Ashland county;[1] some of the quartzites of the Menominee Huronian;[2] and those of the Chippewa river.[3] As instances of quartzite in which there is no appearance of fragmental origin, even under the microscope, may be mentioned the rock of Rib and Mosinee hills, near Wausau, in Marathon county,[4] and that of the vicinity of Necedah, in Juneau county.[5] The last named rock is of interest in presenting us a quartzite which is simply a gneiss unusually rich in quartz; muscovite, biotite, feldspars, augite and chlorite all occurring as accessories. As a prominent instance of quartz-schist which is to be regarded as sericite-schist unusually rich in quartz, may be mentioned much of the rock of Formation III of the Penokee Huronian;[6] and as an instance of quartz-schist intermediate between a quartzite and clay-slate, the rock of Marshall Hill in the vicinity of Wausau.[7]

CHERT-SCHIST AND JASPER-SCHIST.

The peculiar flint-like concretionary form of silica to which the name of chert is given, is the chief ingredient in a widespread rock in the Huronian series. These rocks have not as yet been at all thoroughly examined with the microscope. So far as the examination has gone the chert has proved to be for the most part merely a very close aggregate of crystalline particles of quartz; but I have examined a few sections of chert-schist from the Thunder bay region on the north shore of Lake Superior in which chert is a wholly amorphous substance. The chert-schists are not very important in the Wisconsin Huronian, occurring especially in the Menominee region.[8]

Certain of the magnetite-schists and hematite-schists of the Lake Superior Huronian run into forms in which the siliceous material predominates over the iron oxides, which then appear simply in thin interstratified bands. The siliceous portion of these schists is often merely an ordinary quartzite, but in other cases it presents itself as a very dense, bright-red, jaspery looking material. So far as microscopic examination of this material has gone — the ground has as yet been but very imperfectly covered — it has proved to be a crystalline aggregate of minute quartz grains with red oxide of iron as the coloring matter.

CLAY-SLATE.

The name clay-slate is given commonly to all of those completely aphanitic slaty rocks of an argillaceous or clayey nature. Many rocks so called are merely very fine mica-slates or hydromica-slates. Typical clay-slate — between which and the mica slates and hydromica-slates there are all sorts of gradations — are without any recognizable micaceous ingredient, appearing to be entirely or almost entirely formed of consolidated clayey material. They are therefore in the nature of fragmental rocks; but microscopic researches have shown that in them there is always a certain proportion of crystalline particles, on which account,

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[1] Vol. III, pp. 108, 142.
[2] Vol. III, p. 508.
[3] Vol. IV, pp. 575–581.
[4] Vol. IV, pp. 669, 685.
[5] Vol. II, p. 523. Thin sections of this rock examined since the notice prepared in 1876 for Vol. II, failed to show any trace of the fragmental origin then suspected.
[6] Vol. III, p. 111.
[7] Vol. IV, pp. 668, 681.
[8] Vol. III, p. 613.

as also on account of their associations with the crystalline schists, they are properly classed with the half fragmental rocks. They occupy somewhat the same position in this respect as that taken by the semi-arenaceous quartzites above referred to. Clay-slate is not a very important rock in Wisconsin. It is met with to some extent in the Huronian of the Menominee region, where it contains,—as shown by Wichmann, a certain amount of crystalline quartz besides tourmaline as a characteristic accessory.

The pipestone of Barron county, and the closely allied material which is occasionally met with in Formation III of the Penokee Huronian, are apparently clayey half fragmental rocks near to the true clay-slates.

Novaculite. Hydromica-schists and clay-slates both tend to run into kinds which are rich in quartz, and are possessed of a very peculiar and characteristic fine grain, and sharp-edged fracture. This material is known commonly as oilstone and is valued for sharpening tools. Such material is met with associated with the sericite-schist of Formation III of the Penokee Huronian.

LIMESTONES.

Under the general name of limestone are included all rocks composed chiefly of carbonate of lime or of the carbonates of lime and magnesia. Two principal classes of such rocks are known in Wisconsin, which are distinguished from one another both by their geological associations and their lithological characters. One of these classes includes those crystalline limestones and dolomites occurring with the crystalline schists of the Huronian. Into the other class fall all of the Paleozoic limestones, which, with a total thickness of over a thousand feet, are spread so widely over eastern, southern and western Wisconsin.

Limestones and Dolomites of the Huronian. Crystalline limestones and dolomites are met with in the Huronian of the Menominee region as well as that of the Penokee region. In both regions they tend to run into quartzites through a gradual increase in the quartz content. The limestones are made up chiefly of irregularly bounded grains of calcite, which in the dolomites are replaced by similar ones of dolomite. The microscopic distinction given in the books as obtaining between these two minerals, which in all other respects are very closely similar, as seen in the thin section, is one which depends upon the presence of a repeated twinning in the calcite and the absence of any such twinning in the dolomite. I am satisfied, however, that the distinction is one which will not always hold. Inasmuch as tremolite is a very common and abundant microscopic accessory in these limestones, even a chemical analysis will often fail to settle the question whether we are dealing with a rock in which calcite is present alone, or in which it is associated with dolomite.

A tremolitic crystalline limestone from Penokee Gap, Ashland county, is figured on Plate XIII A Vol. III.[1]

Paleozoic Limestones. Unfortunately the paleozoic limestones of the State have not been microscopically examined, so that it is not possible to add materially to the macroscopic descriptions of the rocks of the several limestone formations given in Vols. II and IV of this series, and in the preceding pages of this volume. It may be said in a general way, that the foreign matter contained in these limestones, beyond what may have been contained in the organic secretions from which some of them are formed, is in the nature of clay or sand, or in

[1] For further descriptions of the crystalline limestones of the Penokee and Menominee regions, see Vol. III, pp. 106, 226, 511, 611.

other words, has been deposited as a sediment along with the calcareous material of which these rocks are made up. The calcareous material itself appears to be in large measure also in the nature of consolidated mud or detritus, presumably of organic origin. But there is also present in most of these limestones, more or less of crystalline calcite and dolomite. This much is generally evident to the unaided eye. How far their occurrence would be extended by the examination of the thin sections with the microscope, and how far evidence as to the organic origin of the more minute particles might accumulate, are points which must be left for future study. Most of these paleozoic limestones are strongly magnesian. The origin of the magnesian ingredient is one of the unsolved problems of geology.

SANDSTONES.

Sandstones are, as the name implies, simply more or less consolidated masses of sand. They may be composed of any sort of material, although much more commonly than not quartz is the chief ingredient. The materials of which the sandstones are made are, of course, the result of the comminution, by the various atmospheric agencies, of the pre-existing rocks. In the process of atmospheric rock degradation, quartz, by virtue of its superior hardness, its lack of cleavage, and its great power of resisting decomposition, remains in coarse particles much longer than any of the other rock-forming minerals. The sedimentation process, by which this rock detritus is arranged into new formations, is essentially a sorting process, the finer and coarser particles being separated from one another. Thus it comes that the quartz particles are sorted out from the finer, more clay-like material, and arranged in beds by whose subsequent consolidation have resulted the ordinary quartzose sandstones.

The most prominent quartzose sandstones of Wisconsin are those composing the Potsdam and St. Peters formations, which are so widely spread in the central and western part of the State. The Potsdam sandstone is throughout the greater portion of its thickness made up of rounded grains of quartz. Often the spaces between these grains are wholly unoccupied by any interstitial ingredient, but more commonly there is present a minute portion of hydrous iron oxide, which acts as a cement. In the upper portions of the formation more or less carbonate of lime, in the state of crystalline particles, occupies the interspaces between the grains. There is also often present in this portion of the formation a certain proportion of glauconite, whose round, green grains are often so plenty in certain layers, as to give them a pronounced greenish hue. Neither the calcite nor the glauconite is in the nature of fragmental material. Part of the calcite has been introduced by infiltration from above, while much of it, with perhaps all of the glauconite, may have been deposited chemically at the time of the formation of the rock. The St. Peters sandstone is also a purely quartzose rock, containing only now and then a minute proportion of hydrous iron oxide.

The red sandstones of the Lake Superior region are much less quartzose than those above described. The red sandstones forming portions of the Keweenaw series, for instance, always contain a considerable proportion of clayey or decomposed feldspathic material, as well as a notable proportion of macroscopically recognizable feldspar. A microscopic study of these sandstones has shown me that they are all composed chiefly of the detritus of the quartziferous porphyries occurring in the same great series of rocks. This detritus presents itself in the shape of fragments of the porphyritic quartzes and feldspars of these rocks, and of their aphanitic matrices, the latter being often more or less decomposed into clayey material

Still another and very interesting sandstone, occurring among the Keweenaw rocks of Ashland county, and thence eastward to Keweenaw Point, in Michigan, has mingled with and often entirely excluding the usual porphyry detritus, a material made up of the ruins of some of the diabases of the Keweenaw series. This rock has often been subsequently infiltrated by calcite, when its silica content runs at times as low as 50 per cent.

Plate XIX A of Vol. III shows the appearance of the thin sections of several Wisconsin sandstones as seen under the microscope.

SHALES.

The term shale includes all of those fragmental rocks composed of very fine detrital material. This finer material having been deposited more slowly and gently than the sandstones, is affected by a much finer lamination. The shales are for the most part of a clayey nature, grading, however, on the one hand, by the introduction of arenaceous material, into sandstones, on the other by the introduction of calcareous matter into the limestones. The shales are clay, not because they have all been formed from the detritus of the same original rock, but because, as already indicated, the sedimentation process is also a sorting process. The clayey matter of these shales represents especially the feldspathic portions of the original rocks. The feldspars, on account of their strong cleavages and of the ease with which they decompose, tend always to wear down into finer material than the quartz.

The shales are not very important among the Wisconsin rocks. Their only prominent occurrence is in the so-called Cincinnati group, in which they are associated with and graduate into limestones.[1] Less important occurrences of shale are met with interpolated with the Potsdam sandstone,[2] with the Lower Magnesian limestone,[3] and in the Keweenaw series of Ashland county.[4]

[1] Vol. II, pp. 315, 687.
[2] Vol. II, pp. 260, 535, 541, 542.
[3] Vol. II, p. 673.
[4] Vol. III. p. 199.

CHAPTER IV.

LIST OF WISCONSIN FOSSILS.

COMPILED BY R. P. WHITFIELD.

NAMES OF FOSSILS. FORMATIONS.

GENERA AND SPECIES.	Potsdam.	Lower Magnesian.	Trenton.	Galena.	Hudson River.	Niagara.	Guelph.	Lower Helderberg.	Hamilton.
PLANTÆ.									
Palæochordia, sp. undet	*								
Phytopsis tubulosa, Hall			*						
Cruziana, sp. und	*		*	*					
Palæophychus cæspitosum, Hall			*						
P. duplex, Hall?	*								
P. plumosus, Whitf	*								
P. simplex, Hall	*								
P. tubularis, Hall	*								
P. sp. undet	*		*		*				
Buthotrephis gracilis, Hall			*						
B. succulens, Hall			*	*					
B. sp. undet			*	*		*			
Fucoids, gen. and sp. undet		*							
Sphenothallus, sp. undet								*	
Sigillaria									*
PROTOZOA — PETROSPONGIA.									
Astylospongia, sp. undet			*	*					
Stromatopora concentrica, Goldf						*	*		
S. sp. undet		*				*			
FORAMENIFERA.									
Receptaculites globularis, Hall				*					
R. hemisphericus, Hall						*			
R. infundibuliformis, Hall						*			
R. Iowensis, Owen				*					
R. Oweni, Hall				*					
Ceryonites dactyloides, Owen's sp						*			
RADIATA — ZOOPHYTA.									
ALCYONARIA. *(Graptolitidæ.)*									
Oldhamia? sp. undis			*						
Buthograptus laxus, Hall			*						
Dendrograptus Hallianus, Prout	*								
Dictyonema Neenah, Hall			*						
Diplograptus Peosta, Hall			*						
Climacograptus typicalis, Hall?				*					
C. sp. undet				*	*				
Graptolitic bodies, gen. and sp. undet			*	*					

NAMES OF FOSSILS. FORMATIONS.

GENERA AND SPECIES.	Potsdam.	Lower Magnesian.	Trenton.	Galena.	Hudson River.	Niagara.	Guelph.	Lower Helderberg.	Hamilton.
ZOANTHARIA-TABULATA.									
Chætetes atritus, Nich					*				
C. briareus, Nich					*				
C. discoideus, James			*	*	*				
C. fusiformis, Whitf					*				
C. Jamesi, Nich					*				
C. lycoperdon, Say?			*	*	*				
C. pulchellus, Nich			*						
C. sp. undet			*	*	*				
Monticulipora Dalei, Ed. & H			*						
M. mammalata, D'Orb					*				
M. multituberculata, Whitf					*				
M. Ortoni, Nich					*				
M. pavonia, D'Orb					*				
M. punctata, Whitf					*				
M. rectangularis, Whitf					*				
M. ramosa, D'Orb					*				
M. rugosa, Ed. & H					*				
M. sp. undet					*				
Dekaya aspera? Ed. & H					*				
Favosites favosus, Gold						*			
F. Gothlandicus, Gold.?						*			
F. Niagarensis						*	*		
F. occidens, Whitf							*		
F. sp. undet			*			*			
Astrocerium constrictum, Hall						*			
A. venustum, Hall						*	*?		
Columnaria alveolata, Gold			*						
C. sp. undet			*						
Alveolites irregularis, Whitf					*				
A. sp. undet					*		*		
Cladopora reticulata, Hall						*			
C. reticulata? with finer cells						*			
C. sp. undet							*		
Heliolites macrostylus, Hall						*			
H. pyriformis, Guttard?						*			
H. spinopora, Hall						*			
Halysites agglomeratus, Hall						*			
H. catenulatus, Linn						*	*		
H. c. var. labyrinthicus, Goldf						*	*		
H. c. var. micropora, Whitf						*	*		
Thecia minor, Rominger						*			
T. major, Rominger						*			
Cœnites lunatus, Nich. & Hinds						*			
ZOANTHARIA-RUGOSA.									
Syringopora compacta, Billings						*			
S. Dalmani, Billings						*			
S. retiformis, Billings						*			
S. verticillata, Goldf						*			
Diphiphyllum cæspitosum, Hall						*	*		
D. sp. undet							*		
Eridophyllum, sp. undet						*			
Cystostylus infundibulus, Whitf						*			

NAMES OF FOSSILS. FORMATIONS.

GENERA AND SPECIES.	Potsdam.	Lower Magnesian	Trenton.	Galena.	Hudson River.	Niagara.	Guelph.	Lower Helderberg.	Hamilton.
ZOANTHARIA-RUGOSA — con.									
Cystostylus typicus						*			
Strombodes pentagonus, Goldf						*	*		
S. sp. undet						*			
Zaphrentis, sp. resemb. Z. gigantea						*			
Z. (Polydilasma) turbinata, Hall sp.						*			
Z. Racinensis Whitf						*			
Z. sp. undet			*	*		*	*		
Amplexus annulatus, Whitf							*		
A. fenestratus, Whitf						*			
A. Shumardi, Ed. & H						*			
A. sp. undet						*	*		
Omphyma Stokesi, Ed. & H., ?						*			
Aulacophyllum, sp. undet						*			
Cyathoxonia Wisconsensis, Whitf						*			
Chonophyllum magnificum, Bill							*		
C. Niagarense, Hall						*			
C. sp. undet						*	*		
Cystiphyllum Niagarense, Hall						*			
C. Niagarense?							*		
Cyathophyllum, sp. undet									*
Streptelasma calyculum, Hall						*			
S. corniculum Hall			*	*					
S. multilamellosum, Hall				*					
S. profundum, Conrad			*						
S. sp. undet			*	*	*	*			
Calceola? sp.?			*						
ECHINODERMATA									
CYSTIDEA.									
Pleurocystites squamosus, Bill				*					
Glyptocystites Logani, Bill				*					
Holocystites abnormis, Hall						*			
H. alternatus, Hall						*			
H. cylindricus, Hall						*			
H. ovatus, Hall						*			
H. scutellatus, Hall						*			
H. Winchelli, Hall						*			
Gomphocystites clavus, Hall						*			
G. glans, Hall						*			
Echinocystites nodosus, Hall						*			
Crinocystites ornatus, Hall						*			
C. sp.?						*			
Hemicosmites subglobosus, Hall						*			
Apiocystites imago, Hall						*			
A. sp. undet				*					
Amygdalocystis florialis, Billings				*					
CRINOIDEA.									
Cryptodiscus sp.?						*			
Platycrinus sp. undet						*			
Saccocrinus Christyi, Hall						*			

Names of Fossils. Genera and Species.	Formations. Potsdam.	Lower Magnesian.	Trenton.	Galena.	Hudson River.	Niagara.	Guelph.	Lower Helderberg.	Hamilton.
CRINOIDEA — continued.									
Saccocrinus semiradiatus, Hall						*			
Metocrinus verneuili, Troost						*			
Eucalyptocrinus cœlatus, Hall						*	*		
E. cornutus, Hall						*			
E. cornutus, var. excavatus, Hall						*			
E. crassus, Hall						*			
E. obconicus, Hall						*			
E. ornatus, Hall						*	*		
E. sp. undet						*			
Macrostylocrinus striatus, Hall						*			
Caryocrinus ornatus, Say						*			
Cyathocrinus Cora, Hall						*			
C. pisiformis, Rœmer						*			
C. Waucoma, Hall						*			
C. sp. ?			*						
Poteriocrinus, sp. undet			*	*					
Schizocrinus nodosus, Hall			*	*					
Homocrinus, sp. undet			*	*					
Rhodocrinus rectus, Hall						*			
Glyptaster occidentalis, Hall						*			
G. pentangularis, Hall						*			
Glyptocrinus armosus, McChes. sp						*			
G. nobilis, Hall						*	*		
Lampterocrinus inflatus, Hall						*			
Icthyocrinus subangularis, Hall						*			
Lichenocrinus, sp. ?.					*				
Stephanocrinus gemmiformis, Hall						*			
MOLLUSCA.									
MOLLUSCOIDEA.									
BRYOZOA.									
Alecto inflata, Hall					*				
Aulopora (?) arachnoidea, Hall					*				
Palæschara, sp. undes					*				
Lichenalia concentrica, Hall						*			
Sagenella membranacea, Hall						*			
S. sp. ?						*			
Cornulites-like tubes			*						
Constellaria polystomella, Nich					*				
Clathropora flabellata, Hall						*			
Fenestella elegans, Hall						*			
F. granulosa, Whitf					*				*
F. sp. undet						*			
Polypora incepta, Hall						*			
Retopora, sp. undes					*				
R. sp. undet			*		*	*			
Ptilodictya recta, Hall			*	*					
P. sp. undet			*	*					
Stictopora elegantula, Hall			*	*	*				
S. fragilis, Bill					*				
S. ramosa, Hall			*						

Names of Fossils. Genera and Species.	Formations. Potsdam.	Lower Magnesian.	Trenton.	Galena.	Hudson River.	Niagara.	Guelph.	Lower Helderberg.	Hamilton.
BRYOZOA — con.									
Stictopora sp. undet			*	*					
Heliopora sp. undet					*				
Fistulipora lens, Whitf					*				
F. rugosa, Whitf					*				
F. solidissima, Whitf					*				
F. sp. undes					*				
Trematopora, annulifera, Whitf					*				
T. granulata, Whitf					*				
T. sp.?			*	*	*	*			
BRACHIOPODA.									
Lingula ampla, Hall	*								
L. attenuata, Hall			*						
L. Maquoketa					*				
L. mosia, Hall	*								
L. quadrata, Eichwald?			*	*					
L. obtusa, Hall			*						
L. palæaformis, Hall									*
L. Winona	*								
L. sp. undes				*					
Lingulella aurora, Hall	*								
L. Stoneana, Whitf	*								
L. Iowensis, Owen				*					
Lingulepis pinnaformis, Owen sp	*								
Discina inutilis, Hall	*								
D. marginalis, Whitf									*
Trematis sp. undet			*			*			
Schizocrania filosa, Hall sp			*						
Obolella polita, Hall	*								
Pholidops truncata, Hall				*					
Crania antiqua, Hall					*				
C. scabiosa, Hall				*					
C. sp. undes			*						
Dinobolus Conradi, Hall						*			
Monomerella prisca, Bill							*		
M. sp. undet				*					
Trimerella grandis, Bill						*			
Orthis bellarugosa, Hall			*	*					
O. biloba, Linn						*			
O. borealis, Bill			*						
O. disparalis, Conrad			*						
O. elegantula, Dalman						*	*		
O. Ella, Hall			*						
O. equivalvis, Conrad			*	*					
O. flabellula, Sowerby						*			
O. hybrida, Dalman						*			
O. impressa, Hall									*
O. Kankakensis, McChes					*				
O. lynx, Eich			*	*	*				
O. oblata, Hall								*	
O occidentalis, Hall					*				
O. pectinella, Conrad			*	*	*				

NAMES OF FOSSILS. FORMATIONS.

GENERA AND SPECIES.	Potsdam.	Lower Magnesian	Trenton.	Galena.	Hudson River.	Niagara.	Guelph.	Lower Helderberg.	Hamilton.
BRACHIOPODA — con.									
Orthis plicatella, Hall			*	*					
O. perveta, Conrad			*	*					
O. Pepina, Hall.	*								
O. subcarinata, Hall								*	
O. subequata, Conrad			*						
O. subquadrata, Hall.			*		*				
O. testudinaria, Dalman			*	*	*				
O. tricenaria, Conrad			*	*	*				
O. sp. undet			*	*	*	*			
Hemipronites Americana, Whitf.				*					
Streptorhynchus cardinale, Whitf					*				
S. deflectum, Hall			*	*					
S. deltoideum, Conrad			*	*					
S. filitextum, Hall			*		*				
S. planoconvexum, Hall			*						
S. planumbonum, Hall			*		*				
S. sinuatum, Emmons			*						
S. subtentum, Hall			*						
S. subplanum, Conrad						*			
S. sp. new and undet			*		*	*			
Strophomena alternata, Conrad			*	*	*				
S. antiqua, Sowerby					*				
S. camerata, Conrad			*	*	* ?				
S. camura, Conrad			*						
S. incrassata, Hall?			*	*					
S. Kingi, Whitf.					*				
S. nitens, Bill					*				
S. patenta, Hall						*			
S. profunda, Conrad						*	?		
S. recta, Conrad					*				
S. rhomboidalis, Wahl							*		
S. semifasciata, Hall						*			
S. tenuistriata, Hall			*						
S. tenuilineata, Conrad			*						
S. Thalia, Bill					*				
S. unicostata, M. & W					*				
S. Wisconsensis, Whitf.					*				
S. new and undet. sp			*	*	*	*			
Strophodonta demissa, Conrad									*
S. inequistriata, Conrad									*
S. perplana, Conrad									*
S. striata, Hall						*			
Skenidium insignum, Hall?						*			
Leptæna Barabuensis, Winchell	*	*							
L. sericea, Sowerby			*	*	*				
L. tranversalis, Dalman						*			
Chonetes coronata, Conrad									*
C. deflecta, Conrad									*
Productella spinulicosta, Hall									*
Spirifera angusta, Hall									*
S. (Cyrtina?) aspera, Hall									*
S. audacula, Conrad=S. medialis, Hall.									

NAMES OF FOSSILS. FORMATIONS.

GENERA AND SPECIES.	Potsdam.	Lower Magnesian	Trenton.	Galena.	Hudson River.	Niagara.	Guelph.	Lower Helderberg.	Hamilton.
BRACHIAPODA— con.									
Spirifera euritunes var. fornacula, Hall									*
S. gibbosa, Hall						*			
S. granulifera, Hall									?
S. mucronata, Conrad									*
S. nobilis, Barr						*			
S. meta, Hall						*			
S. pennata, Owen									*
S. plicatella, Sowerby						*			
S. plicatella var. radiata, Sowr						*	*		
Cyrtina? aspera, Hall									*
C. Hamiltonensis, Hall									*
Spiriferina? zigzag, Hall									*
Trematospira hirsuta, Hall									*
Meristella (Charionella) Hyale, Bill							*		
M. nucleolata, Vanux								*	
Retzia sp. undet							*		
Atrypa hystrix, Hall									*
A. nodostriata, Hall						*			
A. reticularis, Linn						*			*
A. spinosa, Hall									*
A. sp. undet							*		
Zygospira modesta, Hall			*	*	*				
Z. recurvirostra, Hall			*	*					
Rhynchonella Anticostensis, Bill			*	*					
R. capax, Conrad			*	*	*				
R. cuneata, Dalman							*		
R. Indianensis, Hall						*			
R. Janea, Bill					*				
R. Neenah, Whitf			*	*	*				
R. neglecta, Hall						*	*		
R. perlamellosa, Whitf					*				
R. pisum, H. & W							*		
Leiorhynchus Kelloggi, Hall									*
Leptocœlia planoconvexa, Hall						*			
L. plicatula, Hall						*			
Triplesia primordialis, Whitf	*								
Eichwaldia reticulata, Hall						*			
Camarella hemiplicata, Hall's sp			*	*					
C. ops, Bill			*						
Pentamerus bisinuatus, McChes						*			
P. fornicatus, Hall						*			
P. oblongus, Murch						*	*		
P. pergibbosus, H. & W						*	*		
P. ventricosus, Hall						*	*		
P. sp. undet						*	*	*	
Gypidula multicostatus, Hall						*	*		
G. occidentalis, Hall						*	*		
Stricklandinia Galtensis, Bill						*			
S. multilirata, Whitf							*		
Anastrophia interplicata, Hall						*			
Rensellæria, sp. undet							*		

Names of Fossils. Genera and Species.	Formations. Potsdam.	Lower Magnesian.	Trenton.	Galena.	Hudson River.	Niagara.	Guelph.	Lower Helderberg.	Hamilton.
MOLLUSCA-VERA.									
LAMELLIBRANCHIATA.									
Pterinea aviculoidea, Hall								*	
P. brisa, McChes						*			
P. demissa, Conrad					*				
Pteronites, sp. undet									*
Ambonychia acutirostra, Hall						*	*		
A. attenuata, Hall			*						
A. lamellosa, Hall			*	*					
A. planistriata, Hall			*						
A. radiata, Hall			*?	*					
A. recta, Hall			*	*					
A. sp. undet			*						
Tellinomya alta, Hall			*						
T. Iphigenia, Bill			*						
T. levata, Hall			*						
T. nasuta, Hall			*						
T. ventricosa, Hall			*						
T. sp. undet			*	*					
Cypricardites Canadensis, Bill			*						
C. Niota, Hall			*						
C. megambonus, Whitf			*						
C. rectirostris, Hall			*						
C. rotundatus, Hall			*						
C. subtruncatus, Hall			*						
C. ventricosus, Hall			*						
C. sp. undet			*						
Cleidophorus neglectus, Hall					*				
Palæoneilo constricta, Conrad's sp									*
P. emarginata, Conrad's sp									*
P. fecunda, H. & W									?
P. nuculiformis, Stevens' sp									*
Leptodomus (Amphicœlia) Leidyi, Hall's sp						*			
L. (Amphicœlia) neglectus, McChes						*			
L. undulatus, Whitf						*			
Megalomus Canadensis, Hall							*		
Modiolopsis dictæus, Hall						*			
M. faba, Hall			*						
M. Nilesi, M. & W						*			
M. plana, Hall			*						
M. recta, Hall						*			
M. superba, Hall			*						
M. sp. undet			*			*			
Modiomorpha concentrica, Conrad's sp									*
Schizodus? sp. undet						*			
GASTEROPODA.									
Palæacmæa Irvingi, Whitf	*								
Metoptoma Barabuensis, Whitf		*							
M. patelliformis, Hall					*				
M. perovalis, Whitf			*						
M. recurva, Whitf		*							

NAMES OF FOSSILS. FORMATIONS.

GENERA AND SPECIES.	Potsdam.	Lower Magnesian.	Trenton.	Galena.	Hudson River.	Niagara.	Guelph.	Lower Helderberg.	Hamilton.
GASTEROPODA — con.									
Metoptoma retrorsa, Whitf.		*							
M. similis, Whitf.		*							
Platyceras primordialis, Hall	*								
P. Niagarensis, Hall						*			
Platyostoma Niagarensis, Hall							*		
Euomphalus macrolineatus, Whitf.						*			
E. Strongi, Whitf.		*							
E. vaticinus, Hall	*								
E. (Straparollus?) mopsis, Hall						*			
Straparollus Hippolyte, Bill.							*		
S. solaroides, Hall							*		
S. sp. undet		*							
Straparollina, sp.?						*			
Ophileta? (Raphistoma) primordialis, Winchell.	*								
O. uniangularis, Vanuxem		*							
O. sp.? (casts only)		*							
Helicotoma planulata, Salter			*						
H. sp. undet				*	*				
Holopea elevata, Hall							*		
H. Guelphensis, Bill							*		
H. harmonia, Bill							*		
H. magniventra, Whitf.							*		
H. obliqua, Hall			*	*					
H. paludinæformis, Hall			*	*					
H. (Pleurotomaria) turgida, Hall		*							
Holopea Sweeti, Whitf.	*								
H. sp?		*							
Cyclonema (?) elevatum, Hall						*			
C. pauper, Hall						*			
C. sp. resembling C. pauper							*		
C. percarinata, Hall			*	*					
C. sp. ?						*			
Raphistoma lenticularis, Sowr.			*	*					
R. Niagarensis, Whitf.						*			
R. Nasoni, Hall			*						
R. sp. ?			*	*					
Trochonema ambiguum, Hall			*						
T. Beachi, Whitf.			*						
T. Beloitense, Whitf.			*						
T. fatua, Hall						*	*		
T. lapicidum, Salter					*				
T. umbilicatum, Hall			*	*					
T. sp. undet			*	*					
Zenophora trigonostoma, Meek						*			
Loxonema Leda, Hall						*			
L. magnum, Whitf.							*		
Eunema (Murchisonia) pagoda, Salter?			*						
Subulites elongatus, Conrad			*	*					
S. ventricosus, Hall							*		
Clisospira occidentalis, Whitf			*						
Pleurotomaria advena, Winchell	*								
P. Axion, Hall						*	*		
P. depauperata, Hall			*						

NAMES OF FOSSILS. FORMATIONS.

GENERA AND SPECIES.	Potsdam.	Lower Magnesian.	Trenton.	Galena.	Hudson River.	Niagara.	Guelph.	Lower Helderberg.	Hamilton.
GASTEROPODA — con.									
Pleurotomaria Galtensis, Bill							*		
P. Halei, Hall						*	*		
P. Hoyi, Hall						*			
P. Idia, Hall						*			
P. Laphami, Whitf						*			
P. occidens, Hall						*			
P. niota, Hall			*						
P. Racinensis, Whitf						*			
P. perlata, Hall						*			
P. subconica, Hall			*						
P. sp. undet			*			*			
Murchisonia bellicincta var. major, Hall				*					
M. bicincta, Hall			*	*					
M. Boydi, Hall							*		
M. Chamberlini, Whitf							*		
M. Conradi, Hall						*			
M. gracilis, Hall			*	*					
M. helicteres, Salter			*						
M. Hercyna, Bill							*		
M. Laphami, Hall						*			
M. Logani, Hall							*		
M. longispira, Hall							*		
M. macrospira, Hall							*		
M. mylitta, Bill							*		
M. (Eunema) pagoda, Salter			*						
M. tricarinata, Hall			*						
M. turritiformis, Hall							*		
M. ventricosa, Hall			*						
M. sp. undet			*	*		*			
Fusispira elongata, Hall				*					
F. ventricosa, Hall				*					
F. sp. undes				*					
Maclurea Bigsbyi, Hall			*						
M. cuneata, Whitf				*					
M. subrotunda, Whitf				*					
HETEROPODA.									
Bucania bidorsata, Hall			*						
B. Buelli, Whitf			*						
B. trigonostoma, H. & W						*			
B. punctifrons, Hall			*						
Bellerophon antiquatus, Whitf	*								
B. bilobatus, Sowr			*						
B. Wisconsensis, Whitf			*						
Cyrtolites compressa, Conrad			*						
C. Dyeri, Hall				*					
Scævogyra elongata, Whitf		*							
S. obliqua, Whitf		*							
S. Swezeyi, Whitf		*							

Names of Fossils. Genera and Species.	Formations. Potsdam.	Lower Magnesian.	Trenton.	Galena.	Hudson River.	Niagara.	Guelph.	Lower Helderberg.	Hamilton.
PTEROPODA.									
Ecculiomphalus undulatus, Hall			*						
Pterotheca attenuata, Hall			*						
Hyolithes Baconi, Whitf			*						
H. primordialis, Hall	*								
Conularia Trentonensis, Hall				*					
CEPHALOPODA.									
Orthoceras abnorme, Hall						*	*		
O. alienum, Hall						*			
O. amplicameratum, Hall				*					
O. anullum, Conrad			*						
O. annulatum, Sowerby						*	*		
O. (Actinoceras) Beloitense, Whitf			*						
O. capitolinum, Safford			*						
O. Carltonense, Whitf							*		
O. columnare, Hall						*	*		
O. crebescens, Hall						*			
O. Hoyi, McChes							*		
O. junceum, Hall			*	*					
O. Laphami, McChes						*			
O. medulare, Hall						*			
O. Niagarense, Hall						*			
O. multicameratum, Hall			*						
O. planoconvexum, Hall			*	*					
O. primogenium, Hall		*							
O. verebrale, Hall						*			
O. Wauwatosense, Whitf						*			
O. sp. undet			*			*			*
Actinoceras (Orthoceras) Beloitense, Wh.			*						
Ormoceras tenuifilum, Hall (?)			*						
O. sp. undet			*			*			
Endoceras annulatum, Hall			*						
E. proteiforme, Hall			*						
E. (Cameroceras) subannulatum, Whitf			*						
E. sp. undet			*						
Huronia annulatum, Hall						*			
Discoceras (Gomphoceras) conoideum Hall						*			
Gomphoceras fusiforme, Whitf									*
G. breviposticum, Whitf									*
G. scrinium, Hall						*			
G. septoris, Hall						*			
G. sp. undet			*			*	*		
Cyrtoceras annulatum, Hall			*						
C. articameratum, Hall							*		
C. brevicorne, Hall						*			
C. camurum, Hall			*						
C. corniculum, Hall			*						
C. dardanum, Hall						*			
C. eugium, Hall			*						
C. infundibulum, Whitf						*			
C. laterale, Hall						*	*		
C. loculosum, Hall			*						

NAMES OF FOSSILS.	FORMATIONS.								
GENERA AND SPECIES.	Potsdam.	Lower Magnesian.	Trenton.	Galena.	Hudson River.	Niagara.	Guelph.	Lower Helderberg.	Hamilton.
CEPHALOPODA — con.									
Cyrtoceras macrostomum, Hall			*						
C. Neleus, Hall			*						
C. planodorsatum, Whitf.			*						
C. rectum, Whitf.							*		
C.? rigidum, Hall						*	?		
Oncoceras abruptum, Hall			*						
O. Alceus, Hall			*						
O. brevicurvatum, Hall			*						
O. Lycus, Hall			*						
O. mumiaformis, Whitf.			*						
O. Orcas, Hall						*			
O. Pandion, Hall			*						
O. plebium, Hall			*						
Gonioceras anceps, Hall			*						
G. occidentalis, Hall			*						
Phragmoceras Hoyi, Whitf.						*			
P. Hoyi, var. compressum, Whitf.						*			
P. labiatum, Whitf.						*			
P. Nestor, Hall						*			
Gyroceras convolvans, Hall			*						
G. duplicostatum, Whitf.			*						
G. Hercules, W. & M.						*			
G. sp. undet			*			*			
Nautilus occidentalis, Hall						*			
N. sp. undet						*			
Lituites multicostatus, Whitf.						*			
L. occidentalis, Hall			*						
L. Ortoni, Meek						*			
L. Robertsoni, Hall			*						
Trochoceras costatum, Hall						*			
T. Desplainense, McChes						*			
T. Gebhardi, Hall							*		
ARTICULATA.									
ANNELIDÆ.									
Arenicolites (Scolithus) Woodi, Whitf.	*								
Serpulites Murchisoni, Hall	*								
Ortonia, sp?						*			
Worm-like tubes		*	*						
CRUSTACEA.									
ENTOMOSTRACA.									
Leperditia alta, Conrad								*	
L. fabulites, Conrad			*						
L. fonticola, Hall						*			
Beyrichia, sp. undet			*		*				

NAMES OF FOSSILS. FORMATIONS.

GENERA AND SPECIES.	Potsdam.	Lower Magnesian.	Trenton.	Galena.	Hudson River.	Niagara.	Guelph.	Lower Helderberg.	Hamilton.
TRILOBITA.									
Pemphigaspis bullata, Hall	*								
Agnostus disparalis, Hall	*								
A. Josepha, Hall	*								
A. paralis, Hall	*								
Aglaspis Barrandi, Hall	*								
A. Eatoni, Whitf.	*								
Ellipsocephalus curtus, Whitf.	*								
Dikellocephalus Barabuensis, Whitf.		*							
D. Eatoni, Whitf.		*							
D. Lodensis, Whitf.	*								
D. Minnisotensis, Owen	*								
D. Minnisotensis, var. limbatus, Hall	*								
D. Miniscaensis, Owen	*								
D. Miniscaensis var., Hall	*								
D. misa, Hall	*								
D. Osceola, Hall	*								
D. Pepinensis, Hall	*								
D. spiniger, Hall	*								
Chariocephalus Whitfieldi, Hall	*								
Triarthrella auroralis, Hall	*								
Conocephalus (Agraulos) anatinus, H.'s sp.	*								
Conocephalus binodosus, Hall	*								
C. calymenoides, Whitf.	*								
C. diadematus, Hall	*								
C. (Arionellus) dorsalis, Hall's sp.	*								
C. eos, Hall	*								
C. (Ptychaspis) explanatus, Whitf.	*								
C. Hamulus, Owen	*								
C. iowensis, Owen	*								
C. minor, Shumard	*								
C. nasutus, Hall	*								
C. optatus, Hall	*								
C. Patersoni, Hall	*								
C. Perseus, Hall	*								
C. ? quadratus, Whitf.	*								
C. Shumardi, Hall	*								
C. Winona, Hall	*								
C. Wisconsensis, Owen	*								
Crepicephalus? Gibbsi, Whitf.	*								
C. onustus, Whitf.	*								
Arionellus bipunctatus, Shumard	*								
A. convexus, Whitf.	*								
A. sp. undet	*								
A. (Conoceph.) dorsalis, Hall	*								
Agraulos (Conoceph.?) anatinus, H.'s sp.	*								
A. (Bathyurus?) Woosteri, Whitf.	*								
Ptychaspis Barabuensis, Winchell	*								
P. (Conoceph.) explanatus, Whitf.	*								
P. granulosus, Owen	*								
P. Miniscaensis, Owen's sp.	*								
P. minuta, Whitf.	*								
P. striata, Whitf.	*								
P. sp. undet	*								

NAMES OF FOSSILS. GENERA AND SPECIES.	Potsdam.	Lower Magnesian	Trenton.	Galena.	Hudson River.	Niagara.	Guelph.	Lower Helderberg.	Hamilton.
TRILOBITA — con.									
Calymene Clintoni, Hall						*			
C. Niagarensis, Conrad						*			
C. senaria, Conrad			*	*	*				
Asaphus Barrandi, Hall			*						
A. gigas, D'Kay			*						
A. Iowensis, Owen			*						
A. Homalonotoides, Walcott			*						
A. Susæ, Calvin			*						
A. sp. undet			*		*				
Illænus armatus, Hall						*			
I. crassicauda, Wahl			*						
I. cuniculus, Hall						*			
I. Daytonensis, H. & W.						*			
I. imperator, Hall						*			
I. insignis, Hall						*			
I. Ioxus, Hall						*			
I. Iowensis, Owen				*					
I. Madisonianus, Whitf						*			
I. oratus, Conrad			*						
I. pterocephalus, Whitf						*			
I. taurus, Hall			*	*					
I. sp. undet			*	*	*	*			
Illænurus convexus, Whitf		*							
I. quadratus, Hall	*								
Harpes, sp. undet				*					
Ceraurus Niagarensis, Hall						*			
C. pleurexanthemus, Green			*						
C. sp. undet			*			*			
Encrinurus ornatus, H. & W.						*			
E. sp			*			*			
Sphærexochus Romingeri, Hall						*			
Sphærocephalus sp. undet.				*					
Dalmania callicephalus, Hall			*	*					
D. nicta, Hall			*						
D. vigilans, Hall						*			
D. sp.?			*						
Phacops rana, Green									*
P. sp. undet.						*			
Prœtus undet. sp				*					
Lichas phlyctonodes, Green						*			
Bronteus acamas, Hall						*	*		
B. Laphami, Whitf						*			
VERTEBRATA.									
PISCES.									
Rhynchodus excavatus, Newberry									*
Plate of Placoderm									*

CHAPTER V.

CATALOGUE OF THE PHÆNOGAMOUS AND VASCULAR CRYPTOGAMOUS PLANTS OF WISCONSIN.

By G. D. Swezey.

Note.—This catalogue is in part a compilation, and the author has not been able to follow the strict and perhaps the better rule of including only such species as have passed under his eye or are preserved in herbaria accessible to the botanist. The early lists from the State, published by Dr. I. A. Lapham and T. J. Hale, have been incorporated, although including some species not since reported, mostly from the less accessible parts of the State; some of these may possibly have disappeared from the localities where they were found.

The "*Catalogue of the Exogenous, Endogenous, and Acrogenous Plants of Wisconsin,*" compiled by the author, April, 1877, and published as a list preliminary to this report, has served as a basis for this catalogue. It has, however, been much enlarged, and a few species have been dropped which the author has reason now to believe were wrongly reported, such as *Polypodium incanum*, which had merely been introduced but never established, *Pinus mitis*, etc.; or of whose legitimacy there seemed to be some doubt.

While the author has depended much upon the identifications of others, great caution has been exercised in giving credit to species unless reported by those in whose carefulness and conscientiousness he could have entire confidence, and many species have been rejected where there seemed a possibility of mistake.

This is not intended to be a catalogue of localities, and it is not possible at present to give any such catalogue for Wisconsin, as only small parts of the State have been thoroughly studied. Localities have been given for some of the more interesting species, but it is not presumed that they are always limited to these localities; nor is it to be inferred that species for which no localities are given are common throughout the State. It is hoped, however, that this catalogue may serve as the basis for a more thorough study of our flora and a more complete and exhaustive catalogue in the future.

The author would like to know, with reference to future publication, of additional species that should be reported from the State, and of the localities through which the less abundant are distributed. For any such additions, if reported to him and accompanied by specimens (which will be returned if desired), due credit will be given.

In the arrangement of the species, genera and families, the order of Gray's Manual has for the most part been adhered to except in the case of *Ilex* and *Nemopanthes*, which are transferred to the Polypetalæ.

Goodwin D. Swezey.

Crete, Neb., July 1, 1882.

RANUNCULACEÆ.

Clematis verticillaris, D. C. Lake St. Croix.
Virginiana, Linn.
Anemone patens, Linn., var. Nuttalliana, Gray.
multifida, Poir. Lake Superior.
cylindrica, Gray.
Virginiana, Linn.
dichotoma, Linn. *(A. Pennsylvanica, Linn.)*
nemorosa, Linn.
Hepatica, Linn. *(Hepatica triloba, Chaix.)*
acutiloba, Lawson. *(Hepatica acutiloba, D. C.)*
Thalictrum anemonoides, Michx.
dioicum, Linn.
purpurascens, Linn.
Cornuti, Linn.
Ranunculus aquatilis, L., var. trichophyllus, Gray.
" var. stagnalis, D. C. *(R. divaricatus, Gray's Manual)*.
multifidus, Pursh.
alismæfolius, Geyer. Milwaukee county *(Th. A. Bruhin)*.
Cymbalaria, Pursh. Along Lake Michigan.
rhomboideus, Goldie.
abortivus, Linn.
var. micranthus, Gray. Whitewater *(G. R. Kleeberger)*.
sceleratus, Linn.
recurvatus, Poir.
Pennsylvanicus, Linn., f.
fascicularis, Muhl.
repens, Linn.
" var. hispidus, Torr. & Gr. *(G. M. Bowen)*.
ACRIS, Linn.
Isopyrum biternatum. Torr. & Gray.
Caltha palustris, Linn.
Coptis trifolia, Salisb.
Aquilegia Canadensis, Linn.
Delphinium azureum, Michx. Various points along the Mississippi.
Hydrastis Canadensis, Linn. Milwaukee county *(Th. A. Bruhin)*, Racine *(Mrs. McMurphy)*.
Actæa spicata, Linn., var. rubra, Ait.
alba, Bigel.
Cimicifuga racemosa, Nutt.

MENISPERMACEÆ.

Menispermum Canadense, Linn.

BERBERIDACEÆ.

Caulophyllum thalictroides, Michx.
Jeffersonia diphylla, Pers.
Podophyllum peltatum, Linn.

NYMPHÆACEÆ.

Brasenia peltata, Pursh.
Nelumbium luteum, Willd. Oshkosh; La Crosse; Upper Mississippi.
Nymphæa odorata, Ait.
Nuphar advena, Ait.
" var. variegatum, Engelm.

SARRACENIACEÆ.

Sarracenia purpurea, Linn.

PAPAVERACEÆ.

Papaver SOMNIFERUM, Linn.
Argemone MEXICANA, Linn.
Stylophorum diphyllum, Nutt.
Sanguinaria Canadensis, Linn.

FUMARIACEÆ.

Adlumia cirrhosa, Raf.
Dicentra Cucullaria, D. C.
Canadensis, D. C.
eximia, D. C., Grant county. *(Th. A. Bruhin.)*
Corydalis glauca, Pursh.
aurea, Willd.
Fumaria OFFICINALIS, Linn.

CRUCIFERÆ.

Nasturtium OFFICINALE, R. Brown.
sinuatum, Nutt., Grant county. *(Th. A. Bruhin.)*
sessiliflorum, Nutt.
obtusum, Nutt.
palustre, D. C.
" var. hispidum, Gray.
lacustre, Gray.
ARMORACIA, Fries.
Dentaria diphylla, Michx., Manitowoc county, and along the Mississippi. *(Th. A. Bruhin.)*
laciniata, Muhl.

Cardamine rhomboidea, D. C.
pratensis, Linn.
hirsuta, Linn.
Arabis lyrata, Linn.
petræa, Linn., Lake Superior.
dentata, Torr. & Gray.
hirsuta, Scop.
lævigata, Poir.
Canadensis, Linn.
perfoliata, Lam.
Drummondii, Gray. Lake Superior.
Thelypodium pinnatifidum, Wats. *(Arabis hesperioides, Gray.)*
Erysimum cheiranthoides, Linn.
Sisymbrium, OFFICINALE, Scop.
THALIANA, Gaud. Sauk county. *(W. F. Bundy.)*
canescens, Nutt.
Brassica SINAPISTRUM, Boissier.
ALBA, Gray.
NIGRA, Koch.
Draba arabisans, Michx. Fond du Lac county; Lake Superior.
Caroliniana, Walt.
Camelina SATIVA, Crantz.
Capsella BURSA-PASTORIS, Mœnch.
Lepidium Virginicum, Linn.
intermedium, Gray.
Cakile Americana, Nutt.

CAPPARIDACEÆ.

Cleome integrifolia, Torr. & Gray. Beloit.
PUNGENS, Willd. Milwaukee. *(Dr. Lewis Sherman.)*
Polanisia graveolens, Raf.

VIOLACEÆ.

Viola lanceolata, Linn. Columbus. *(G. M. Bowen.)* Milwaukee. *(Dr. Lewis Sherman.)*
blanda, Willd.
cucullata, Ait.
" var. palmata, Gray.
sagittata, Ait.
delphinifolia, Nutt.
pedata, Linn.
canina, Linn. var. silvestris, Regel.
striata, Ait.
Canadensis, Linn.
Viola pubescens, Ait.
" var. eriocarpa, Nutt.

CISTACEÆ.

Helianthemum Canadense, Michx.
Hudsonia tomentosa, Nutt. Lake Superior.
Lechea minor, Walt.

DROSERACEÆ.

Drosera rotundifolia, Linn.
intermedia, Drev. & Hayne, var. Americana, D. C. *(D. longifolia, L.)*
linearis, Goldie.

HYPERICACEÆ.

Hypericum pyramidatum, Ait.
Kalmianum, Linn.
prolificum, Linn.
sphærocarpon, Michx. Beloit.
ellipticum, Hook. Black River Falls.
PERFORATUM, Linn.
corymbosum, Muhl.
mutilum, Linn.
Canadense, Linn.
Sarothra, Michx.
Elodes Virginica, Nutt.
petiolata, Pursh.

CARYOPHYLLACEÆ.

Saponaria OFFICINALIS, Linn.
VACCARIA, Linn. *(V. vulgaris, Host.)*
Silene stellata, Ait. f.
nivea, D. C. Beloit.
ARMERIA, Linn.
antirrhina, Linn.
NOCTIFLORA, Linn.
Lychnis VESPERTINA, Sibth. Racine. *(J. J. Davis.)*
GITHAGO, Lam.
Arenaria SERPYLLIFOLIA, Linn.
stricta, Wats.
lateriflora, Linn.
Stellaria MEDIA, Smith.
longifolia, Muhl.
longipes, Goldie.
borealis, Bigel.

Cerastium VULGATUM, Linn.
VISCOSUM, Linn.
nutans, Raf.
oblongifolium, Torr. Beloit
arvense, Linn.
Spergula ARVENSIS, Linn.

PARONYCHIEÆ.

Anychia dichotoma, Michx.

PORTULACACEÆ.

Portulaca OLERACEA, Linn.
Talinum teretifolium, Pursh. Falls of the St. Croix.
Claytonia Virginica, Linn.
Caroliniana, Michx.

MALVACEÆ.

Malva ROTUNDIFOLIA, Linn.
SYLVESTRIS, Linn.
MOSCHATA, Linn.
Callirrhoe triangulata, Gray.
Napæa dioica, Linn.
Abutilon AVICENNÆ, Gærtn.
Hibiscus TRIONUM, Linn.

TILIACEÆ.

Tilia Americana, Linn.

LINACEÆ.

Linum sulcatum, Riddell.
rigidum, Pursh.
USITATISSIMUM, Linn.

GERANIACEÆ.

Geranium maculatum, Linn.
Carolinianum, Linn.
Robertianum, Linn.
Erodium cicutarium, L'Her.
Flœrkea proserpinacoides, Willd.
Impatiens pallida, Nutt.
fulva, Nutt.
Oxalis Acetosella, Linn.
violacea, Linn.
corniculata, L. var. stricta, Sav. *(O. stricta, L.)*

RUTACEÆ.

Zanthoxylum Americanum, Mill.
Ptelea trifoliata, Linn.

ANACARDIACEÆ.

Rhus typhina, Linn.
glabra, Linn.
venenata, D. C.
Toxicodendron, Linn.
aromatica, Ait. Potosi.

VITACEÆ.

Vitis æstivalis, Michx.
cordifolia, Lam. (?) Michx.
riparia, Michx. *(V. cordifolia. Michx. var. riparia, Gray.)*
Amphelopsis quinquefolia, Michx.

RHAMNACEÆ.

Rhamnus alnifolius, L'Her. Milwaukee.
Ceanothus Americanus, Linn.
ovatus, Desf. *(C. ovalis, Bigel.)* Beloit.

ILICINEÆ *(AQUIFOLIACEÆ.)*

Ilex verticillata, Gray.
Nemopanthes Canadensis, D. C.

CELASTRACEÆ.

Celastrus scandens, Linn.
Euonymus atropurpureus, Jacq.

SAPINDACEÆ.

Staphylea trifolia, Linn.
Æsculus HIPPOCASTANUM, Linn. Commonly planted.
Acer Pennsylvanicum, Linn.
spicatum, Lam.
saccharinum, Wang.
" var. nigrum, T. & Gr.
dasycarpum, Ehrhart.
rubrum, Linn.
Negundo aceroides, Mœnch.

POLYGALACEÆ

Polygala incarnata, Linn.
sanguinea, Linn.
cruciata, Linn.
verticillata, Linn.
Senega, Linn.
polygama, Walt.
paucifolia, Willd.

LEGUMINOSÆ.

Lupinus perennis, Linn.
Trifolium ARVENSE, Linn.
PRATENSE, Linn.

Trifolium REPENS, Linn.
PROCUMBENS, Linn.
Melilotus OFFICINALIS, Willd.
alba, Lam.
Medicago SATIVA, Linn.
LUPULINA, Linn.
Psoralea argophylla, Pursh. Columbus. *(G. W. Bowen)* and Falls of the St. Croix.
esculenta, Pursh.
Petalostemon violaceus, Michx.
candidus, Michx.
villosus, Nutt. St. Croix county.
Amorpha fruticosa, Linn.
canenscens, Nutt.
Robinia pseudacacia, Linn.
Tephrosia Virginiana, Pers.
Astragalus caryocarpus, Ker. Pierce and St. Croix counties.
Canadensis, Linn.
Cooperi, Gray. Milwaukee.
Glycyrrhiza lepidota, Pursh. Lake Pepin.
Desmodium nudiflorum, D. C. St. Croix river.
acuminatum, D. C.
canescens, D. C.
cuspidatum, Torr. & Gray. Chippewa river.
Dillenii, Darlington.
paniculatum, D. C.
Canadense, D. C.
Illinoense, Gray.
Lespedeza repens, Barton (including *L. procumbens, Michx.)*
violacea, Pers.
reticulata, Pers. *(L. violacea, Pers. var. sessiliflora, Gray).*
" var. augustifolia, Maxim. *(L. violacea, Pers. var. augustifolia, Gray).*
capitata, Michx.
" var. augustifolia, Gray.
Vicia TETRASPERMA. Loisel. *(Th. A. Bruhin.)*
Cracca, Linn.
Caroliniana, Walt.
Americana, Muhl.
Lathyrus maritimus, Bigelow.
venosus, Muhl.
ochroleucus, Hook.
Lathyrus paluster, Linn.
" var. myrtifolius, Gray
Apios tuberosa, Mœnch.
Phaseolus diversifolius, Pers.
pauciflorus, Benth.
Amphicarpæa monoica, Ell.
Baptisia australis, R. Brown.
leucantha, Torr. & Gray.
leucophæa, Nutt.
Cassia Marylandica, Linn.
Chamæcrista, Linn.
Gymnocladus Canadensis, Lam.
Gleditschia triacanthos, Linn.

ROSACEÆ.

Prunus Americana, Marshall.
SPINOSA, L., var. INSITITIA. Gray, Milwaukee Co. *(Th. A. Bruhin.)*
pumila, Linn.
Pennsylvanica, Linn. *f.*
Virginiana, Linn.
serotina, Ehrhart.
Neillia opulifolia, Benth. & Hook. *(Spiræa opulifolia, L.)*
Spiræa salicifolia, Linn.
tomentosa, Linn. Upper Wisconsin River.
Agrimonia Eupatoria, Linn.
Geum album, Gmelin.
Virginianum, Linn.
macrophyllum, Willd.
strictum, Ait.
rivale, Linn.
triflorum, Pursh.
Waldsteinia fragarioides, Tratt.
Potentilla Norvegica, Linn.
supina, Linn. *(P. paradoxa, Nutt.)*
Canadensis, Linn.
" var. simplex, Torr. & Gray.
argentea, Linn.
Pennsylvanica, Linn.
arguta, Pursh.
Anserina, Linn.
fruticosa, Linn.
tridentata, Sol. Lake Superior.
palustris, Scop.
Fragaria Virginiana, Duchesne, var. Illinoensis, Gray.
vesca, Linn.
Rubus odoratus, Linn.
Nutkanus, Mocino. Lake Superior.

Rubus triflorus, Richardson.
strigosus, Michx.
occidentalis, Linn.
villosus, Ait.
Canadensis, Linn.
hispidus, Linn.
Rosa setigera, Michx.
Carolina, Linn.
parviflora, Ehrhart. *(R. lucida, Ehrh. of Gray's Manual.)*
blanda, Ait.
RUBIGINOSA, Linn.

Crataegus, Linn.
coccinea, Linn.
tomentosa, Linn, var. pyrifolia, Gray.
" var. punctata, Gray.
subvillosa, Schrad. *(C. tomentosa, L. var. mollis, Gray).*
Pirus coronaria, Linn.
arbutifolia, Linn. f.
Americana, D. C.
Amelanchier Canadensis, Torr. & Gray. (Including *var. Botryapium).*
" var. (?) oblongifolia, Torr. & Gray.
" var. rotundifolia, Torr. & Gray.
alnifolia, Nutt. *(A. Canadensis, Torr. & Gray, var. alnifolia* of Gray's Manual.

SAXIFRAGACEÆ.

Ribes Cynosbati, Linn.
oxyacanthoides, Linn. *(R. hirtellum, Michx.)*
rotundifolium, Michx.
lacustre, Poir.
floridum, L'Her.
rubrum, Linn.
Parnassia parviflora, D. C.
palustris, Linn. Lake Superior.
Caroliniana, Michx.
Saxifraga Aizoon, Jacq. Racine *(Mrs. McMurphy).* Lake Superior.
Virginiensis, Michx. Lake Superior.
Pennsylvanica, L.
Sullivantia Ohionis, Torr. & Gray. Wisconsin River.
Heuchera Americana, Linn.
hispida, Pursh.

Mitella diphylla, Linn.
nuda, Linn.
caulescens, Nutt. Manitowoc county. *(Th. A. Bruhin.)*
Tiarella cordifolia, Linn.
Chrysosplenium Americanum, Schw.

CRASSULACEÆ.

Sedum TELEPHIUM, Linn.
Penthorum sedoides, Linn.

HAMAMELACEÆ.

Hamamelis Virginiana, Linn.

HALORAGEÆ.

Myriophyllum spicatum, Linn
verticillatum, Linn.
Proserpinaca palustris, Linn.
Hippuris vulgaris, Linn.

ONAGRACEÆ.

Circæa Lutetiana, Linn.
alpina, Linn.
Gaura biennis, Linn.
Epilobium angustifolium, Linn.
origanifolium, Lam. *(E. alpinum, Linn. var. majus, Wahl).*
palustre, Linn, var. lineare, Gray.
molle, Torr.
coloratum, Muhl.
Œnothera biennis, Linn.
" var. muricata, Lindl.
" var. grandiflora, Lindl.
Oakesiana, Robbins. *(Œ. biennis, Linn, var. Oakesiana, Gray.)*
rhombipetala, Nutt.
pumila, Linn. (Including *Œ. chrysantha, Michx.)*
serrulata, Nutt. Lake Pepin.
Ludwigia polycarpa, Short & Peter.
palustris, Elliott.

MELASTOMACEÆ.

Rhexia Virginica, Linn.

LYTHRACEÆ.

Didiplis linearis, Raf. *(Ammannia Nuttallii, Gray)* Black River.
Lythrum alatum, Pursh.
Nesæa verticillata, H. B. K. Upper St. Croix River.

CACTACEÆ.

Opuntia vulgaris, Haworth. St. Croix Falls.
Rafinesquii, Engelm. Baraboo.
fragilis, Haworth. Baraboo.
Missouriensis, D. C. New London *(L. C. Wooster).*

FICOIDEÆ.

Mollugo verticillata, L. (Included in *Order* CARYOPHYLLACEÆ *of Gray's Manual.)*

CUCURBITACEÆ.

Sicyos angulatus, Linn.
Echinocystis lobata, Torr. & Gray.

UMBELLIFERÆ.

Hydrocotyle Americana, Linn.
Sanicula Canadensis, Linn.
Marylandica, Linn.
Eryngium yuccæfolium, Michx.
Daucus CAROTA, Linn.
Polytænia Nuttallii, D. C.
Heracleum lanatum, Michx.
Pastinaca SATIVA, Linn.
Archemora rigida, D. C.
Archangelica atropurpurea, Hoffm.
Selinum Canadense, Michx. *(Conioselinum Canadense, Torr. & Gray.)*
Thaspium barbinode, Nutt.
aureum, Nutt.
" var. apterum, Gray.
trifolatum, Gray.
" var. apterum, Gray.
" var. atropurpureum, Gray.
Pimpinella integerrima, Benth. & Hook *(Zizia integerrima, D. C.)*
Bupleurum ROTUNDIFOLIUM, Linn.
Cicuta maculata, Linn.
bulbifera, Linn.
Sium cicutæfolium, Gmelin. *(S. lineare, Michx.)*
Berula augustifolia, Koch. *(Sium angustifolium, Linn.)*
Cryptotænia Canadensis, D. C.
Osmorrhiza longistylis, D. C.
brevistylis, D. C.
Conium MACULATUM, Linn.
Erigenia bulbosa, Nutt.

ARALIACEÆ.

Aralia racemosa, Linn.
hispida, Vent.
nudicaulis, Linn.
quinquefolia, Decaisne & Planchon.
trifolia, Decaisne & Planchon.

CORNACEÆ.

Cornus Canadensis, Linn.
circinata, L'Her.
sericea, Linn.
stolonifera, Michx.
paniculata, L'Her.
alternifolia, Linn., f.

CAPRIFOLIACEÆ.

Linnæa borealis, Gronov.
Symphoricarpus occidentalis, R. Brown.
racemosus, Michx.
" var. pauciflorus, Robbins.
vulgaris, Michx.
Lonicera sempervirens, Ait.
flava, Sims.
parviflora, Lam.
" var. Douglasii, Gray.
hirsuta, Eaton.
ciliata, Muhl.
cærulea, Linn.
oblongifolia, Muhl.
Diervilla trifida, Mœnch.
Triosteum perfoliatum, Linn.
Sambucus Canadensis, Linn.
racemosus, Linn., var. pubens, Wats. *(S. pubens, Michx.)*
Viburnum Lentago, Linn.
nudum, Linn.
dentatum, Linn.
pubescens, Pursh.
acerifolium, Linn.
pauciflorum, Pylaie.
Opulus, Linn.

RUBIACEÆ.

Galium Aparine, Linn.
asprellum, Michx.
concinnum, Torr. & Gray.
trifidum, Linn.
" var. latifolium, Gray.
triflorum, Michx.
circæzans, Michx.
lanceolatum, Torr.

Galium boreale, Linn.
Cephalanthus occidentalis, Linn.
Mitchella repens., Linn.
Houstonia purpurea, Linn., var. longifolia, Gray.
" var. ciliolata, Gray.
cærulea, Linn.

VALERIANACEÆ.

Valeriana sylvatica, Richards.
edulis, Nutt.
Fedia Fagopyrum, Torr. & Gray.

DIPSACEÆ.

Dipsacus SYLVESTRIS, Mill.

COMPOSITÆ.

Vernonia Noveboracensis, Willd.
fasciculata, Michx.
Liatris cylindracea, Michx.
punctata, Hook. St. Croix River.
scariosa, Willd.
spicata, Willd.
pycnostachya, Michx.
Kuhnia eupatorioides, Linn.
Eupatorium purpureum, Linn.
altisimum, Linn.
sessilifolium, Linn.
perfoliatum, Linn.
serotinum, Michx.
ageratoides, Linn.
Nardosmia palmata, Hook.
Adenocaulon bicolor, Hook.
Aster corymbosus, Ait.
macrophyllus, Linn.
sericeus, Vent.
concolor, Linn.
patens, Ait.
lævis, Linn.
azureus, Lindl.
Shortii, Boott.
undulatus, Linn.
cordifolius, Linn.
sagittifolius, Willd.
ericoides, Linn.
multiflorus, Ait.
dumosus, Linn.
Tradescanti, Linn.
miser, Linn., Ait.
simplex, Willd.
tenuifolius, Linn.
carneus, Nees.
Aster æstivus, Ait.
longifolius, Lam.
puniceus, Linn.
" var. vimineus, Gray.
prenanthoides, Muhl.
oblongifolius, Nutt.
amethystinus, Nutt.
Novæ-Angliæ, Linn.
ptarmacoides, Torr. & Gray.
Erigeron Canadense, Linn.
bellidifolium, Muhl.
Philadelphicum, Linn.
glabellum, Nutt.
annuum, Pers.
strigosum, Muhl.
Diplopappus linariifolius, Hook.
umbellatus, Torr. & Gray.
amygdalinus, Torr. & Gray.
Boltonia glastifolia, L'Her.
diffusa, L'Her.
Solidago bicolor, Linn.
" var. concolor, Gray.
latifolia, Linn.
cæsia, Linn.
puberula, Nutt.
stricta, Ait.
speciosa, Nutt.
Virga-aurea, Linn.
rigida, Linn.
Ohioensis, Riddell.
Riddellii, Frank.
Houghtonii, Torr. & Gray. Milwaukee. *(Dr. Lewis Sherman.)*
neglecta, Torr. & Gray.
patula, Muhl.
arguta, Ait.
" var. scabrella, Gray.
altissima, Linn.
ulmifolia, Muhl.
nemoralis, Ait.
Missouriensis, Nutt.
Canadensis, Linn.
serotina, Ait.
gigantea, Ait.
lanceolata, Linn
tennifolia, Pursh.
Chrysopsis villosa, Nutt.
Inula HELENIUM, Linn.
Polymnia Canadensis, Linn. Milwaukee.
Silphium laciniatum, Linn.
terebinthinaceum, Linn.

Silphium trifoliatum, Linn.
integrifolium, Michx.
perfoliatum, Linn.
Parthenium integrifolium, Linn.
Iva xanthiifolia, Nutt. Upper Mississippi river.
Ambrosia trifida, Linn.
" var. integrifolia, Gray
artemisiæfolia, Linn.
psilostachya, D. C.
Xanthium strumarium, Linn.
Heliopsis lævis, Pers. var. scabra, Gray.
Echinacea angustifolia, D. C.
Rudbeckia laciniata, Linn.
subtomentosa, Pursh.
hirta, Linn.
Lepachys pinnata, Torr. & Gray.
Helianthus annuus, Linn.
rigidus, Desf.
lætiflorus, Pers.
occidentalis, Riddell.
giganteus, Linn.
grosse-serratus, Martens.
strumosus, Linn.
" var. mollis, Gray.
divaricatus, Linn.
hirsutus, Raf.
tracheliifolius, Willd.
decapetalus, Linn.
doronicoides, Lam.
TUBEROSUS, Linn.
Coreopsis lanceolata, Linn.
palmata, Nutt.
aristosa, Michx.
" var. mutica, Gray.
trichosperma, Michx.
discoidea, Torr. & Gray.
Bidens frondosa, Linn.
connata, Muhl.
cernua, Linn.
chrysanthemoides, Michx.
Beckii, Torr.
Dysodia chrysanthemoides, Lag.
Helenium autumnale, Linn.
Anthemis COTULA, Linn. (*Maruta Cotula, D. C.*)
Achillea Millefolium, Linn.
Leucanthemum VULGARE, Lam.
PARTHENIUM, Godron.
Tanacetum VULGARE, Nutt.
var. crispum.
Huronense, Nutt.
Artemisia Canadensis, Michx.
caudata, Michx.
Ludoviciana, Nutt, var. gnaphalodes, Gray.
serrata, Nutt. Prairie du Chien.
VULGARIS, Linn.
biennis, Willd.
ABSINTHIUM, Linn.
frigida, Willd. Lake Pepin.
Gnaphalium decurrens, Ives.
polycephalum, Michx.
uliginosum, Linn.
Anaphalis margaritacea, Benth. & Hook. (*Antennaria margaritacea, R. Brown.*)
Antennaria plantaginifolia, Hook.
Erecthites hieracifolia, Raf.
Cacalia suaveolens, Linn.
reniformis, Muhl.
atriplicifolia, Linn.
tuberosa, Nutt.
Senecio VULGARIS, Linn.
palustris, Hook.
aureus, Linn.
" var. Balsamitæ, Gray.
tomentosus, Michx.
Conicus LANCEOLATUS, Hoffm. (*Cirsium lanceolatum, Scop.*)
Pitcheri, Torr. & Gray. (*C. Pitcheri, Torr. & Gray.*)
discolor, Muhl. (*C. discolor, Spreng.*)
altissimus, Willd. (*C. altissimum, Spreng.*)
Virginianus, Pursh. (*C. Virginianum, Michx.*)
muticus, Pursh. (*C. muticum Michx.*)
pumilus (*C. pumilum, Spreng.*)
arvensis, Hoffm. (*C. arvense, Scop.*)
Lappa officinalis, Allioni.
" var. major, Gray.
Cichorium Intybus, Linn.
Cynthia Virginica, Don.
Troximon cuspidatum, Pursh.
Hieracium Canadense, Michx.
scabrum, Michx.
longipilum, Torr.
Gronovii, Linn.
venosum, Linn.
" var. subcaulescens. Gray.

Nabalus albus, Hook.
racemosus, Hook.
asper, Torr & Gray.
Lygodesmia juncea, Don. St. Croix river.
Taraxacum Dens-leonis, Desf.
Lactuca Canadensis, Linn.
Floridana, Gærtn. *(Mulgedium Floridanum, D. C.)*
leucophæa, Gray. *(M. leucophæum, D. C.)*
Sonchus OLERACEUS, Linn.
ASPER, Vill.
ARVENSIS, Linn.

LOBELIACEÆ.

Lobelia cardinalis, Linn.
syphilitica, Linn.
inflata, Linn.
spicata, Lam.
Kalmii, Linn.

CAMPANULACEÆ.

Campanula rotundifolia, Linn.
aparinoides, Pursh.
Americana, Linn.
RAPUNCULOIDES, Linn. "Established in roadsides," Racine *(J. J. Davis)*.
Specularia perfoliata, A. D. C.

ERICACEÆ.

Gaylussacia resinosa, Torr. & Gray.
Vaccinium Oxycoccus, Linn.
macrocarpon, Ait.
stamineum, Linn.
cæspitosum, Michx. Racine *(Dr. Hoy)*, Kilbourn.
Pennsylvanicum, Lam.
Canadense, Kalm.
vacillans, Solander.
corymbosum, Linn.
Chiogenes hispidula, Torr. & Gray.
Arctostaphylos Uva-ursi, Spreng.
Epigæa repens, Linn.
Gaultheria procumbens, Linn.
Cassandra calyculata, Don.
Andromeda polifolia, Linn.
Kalmia glauca, Ait.
Ledum latifolium, Ait.
Pyrola rotundifolia, Linn.
" var. asarifolia, Hook.

Pyrola var. uliginosa, Gray.
elliptica, Nutt.
chlorantha, Swartz.
secunda, Linn.
Moneses uniflora, Gray.
Chimaphila umbellata, Nutt.
Monotropa uniflora, Linn.
Hypopitys, Linn.

ILICINEÆ *(AQUIFOLIACEÆ)*.

This order is now regarded as polypetalus and placed just before Celastraceæ.

PLANTAGINACEÆ.

Plantago major, Linn.
cordata, Lam.
Patagonica, Jacq., var. gnaphalioides, Gray.

PRIMULACEÆ.

Primula farinosa, Linn.
Mistassinica, Michx.
Androsace occidentalis, Pursh.
Dodecatheon Meadia, Linn.
Trientalis Americana, Pursh.
Lysimachia thyrsiflora, Linn.
stricta, Ait.
quadrifolia, Linn.
Steironema ciliatum, Raf. *(Lysimachia ciliata, Linn.)*
lanceolatum, Gray. *(L. lanceolata, Walt.)*
lanceolatum, var. hybridum, Gray.
" var. angustifolia, Gray.
longifolium, Gray. *(L. longifolia, Pursh.)*

LENTIBULACEÆ.

Utricularia vulgaris, Linn.
minor, Linn.
intermedia, Hayne.
purpurea, Walt.
cornuta, Michx.

OROBANCHACEÆ.

Epiphegus Virginiana, Bart.
Conopholis Americana, Wallr.
Aphyllon uniflorum, Gray.
fasciculatum, Gray.

SCROPHULARIACEÆ.

Verbascum THAPSUS, Linn.
BLATTARIA, Linn.

Linaria Canadensis, Dumont.
VULGARIS, Mill.
Scrophularia nodosa, Linn.
Collinsia verna, Nutt.
parviflora, Dougl.
Chelone glabra, Linn.
Pentstemon pubescens, Solander.
lævigatus, Solander, var. Digitalis, Gray. *(P. Digitalis, Nutt.)*
grandiflorus, Nutt.
Mimulus ringens, Linn.
Jamesii, Torr. & Gray.
Gratiola Virginiana, Linn.
Ilysanthes gratioloides, Benth.
Synthyris Houghtoniana, Benth.
Veronica Virginica, Linn.
Anagallis, Linn.
Americana, Schweinitz.
scutellata, Linn.
serpyllifolia, Linn.
peregrina, Linn.
ARVENSIS, Linn.
Buchnera Americana, Linn.
Seymeria macrophylla, Nutt.
Gerardia purpurea, Linn.
aspera, Dougl.
tenuifolia, Vahl.
flava, Linn.
quercifolia, Pursh.
Skinneriana, Wood. *(G. setacea of Gray's Manual, not of Walt.)*
grandiflora, Benth.
pedicularia, Linn.
auriculata, Michx.
Castilleia coccinea, Spreng.
sessiliflora, Pursh.
Pedicularis Canadensis, Linn.
lanceolata, Michx.
Melampyrum Americanum, Michx.

ACANTHACEÆ.

Dianthera Americana, Linn.
Ruellia ciliosa, Pursh.
strepens, Linn.

VERBENACEÆ.

Verbena angustifolia, Michx.
hastata, Linn.
urticifolia, Linn.
stricta, Vent.
OFFICINALIS, Linn.
Verbena xutha, Lehm. A form which Dr. Gray pronounces to be this southern species grows in Grant county, according to *Th. A. Bruhin.*
bracteosa, Michx.
Lippia lanceolata, Michx
Phryma Leptostachya, Linn.

LABIATÆ.

Teucrium Canadense, Linn.
Isanthus cæruleus, Michx.
Mentha VIRIDIS, Linn.
PIPERITA, Linn.
AQUATICA, Linn.
ARVENSIS, Linn.
Canadensis, Linn.
Lycopus Virginicus, Linn.
sinuatus, Ell. *(L. Europœus, Linn. var. sinuatus, Gray.)*
Pycnanthemum lanceolatum, Pursh.
Satureia HORTENSIS, Linn.
Calamintha Nuttallii, Benth. *(C. glabella, Benth., var. Nuttallii, Gray.)*
Hedeoma pulegioides, Pers.
hispida, Pursh.
Collinsonia Canadensis, Linn.
Monarda didyma, Linn.
fistulosa, Linn.
punctata, Linn.
Blephilia ciliata, Raf.
hirsuta, Benth.
Lophanthus nepetoides, Benth.
scrophulariæfolius, Benth.
anisatus, Benth.
Nepeta CATARIA, Linn.
GLECHOMA, Benth.
Dracocephalum parviflorum, Nutt.
Physostegia Virginiana, Benth.
Brunella vulgaris, Linn.
Scutellaria versicolor, Nutt.
parvula, Michx.
galericulata, Linn.
lateriflora, Linn.
Marrubium VULGARE, Linn.
Galeopsis TETRAHIT, Linn.
Stachys palustris, Linn. The forms reported as *S. palustris, Linn, var. cordata, Gray*, are probably this rather than *S. cordata,* Riddell.

Stachys aspera, Michx. *(S. palustris, var. aspera, Gray).*
Leonurus CARDIACA, Linn.
Lamium AMPLEXICAULE, Linn.

BORRAGINACEÆ.

Echium VULGARE, Linn. Sparingly established in roadsides.
Symphytum OFFICINALE, Linn. Sparingly established.
Onosmodium Virginianum, D. C.
 Carolinianum, D. C.
Lithospermum OFFICINALE, Linn.
 latifolium, Michx.
 hirtum, Lehm.
 canescens, Lehm.
 angustifolium, Michx. *(L. longiflorum, Spreng.*, which is only the long-flowered spring state of Michaux's species.)
Mertensia Virginica, D. C.
 paniculata, Don.
Myosotis palustris, Withering.
 verna, Nutt. Winnebago Co. (*K.*)
Echinospermum Lappula, Lehm.
 Virginicum, Lehm. *(Cynoglossum, Morrisoni, D. C.*)
Cynoglossum OFFICINALE, Linn.
 Virginicum, Linn.

HYDROPHYLLACEÆ.

Hydrophyllum Virginicum, Linn.
 Canadense, Linn.
 appendiculatum, Michx.
Ellisia Nyctelea, Linn. (including *E. ambigua, Nutt.)*

POLEMONIACEÆ.

Polemonium reptans, Linn.
Phlox paniculata, Linn. (Escaped from gardens.)
 glaberrima, Linn.
 pilosa, Linn.
 divaricata, Linn.

CONVOLVULACEÆ.

Convolvulus ARVENSIS, Linn.
 sepium, Linn. *(Calystegia sepium, R. Br.)*
 spithamæus, Linn. *(Calystegia, spithamœa, Pursh.)*
Cuscuta tenuiflora, Engelm.
Cuscuta inflexa, Engelm.
 chlorocarpa, Engelm.
 Gronovii, Willd.
 glomerata, Choisy.

SOLANACEÆ.

Solanum DULCAMARA, Linn.
 nigrum, Linn.
Physalis grandiflora, Hook. Sturgeon Bay.
 Philadelphica, Lam.
 pubescens, Linn.
 Virginiana, Mill. *(P. viscosa, Gray's Manual, not of Linn.)*
 " var. ambigua, Gray.
 lanceolata, Michx. *(P. Pennsylvanica, Gray's Manual.)*
Nicandra PHYSALOIDES, Gærtn.
Datura STRAMONIUM, Linn.
 TATULA, Linn.
Nicotiana RUSTICA, Linn.

GENTIANACEÆ.

Frasera Carolinensis, Walt.
Halenia deflexa, Grisebach.
Gentiana quinqueflora, Lam.
 " var. occidentalis, Gray.
 crinita, Frœl.
 serrata, Gunner. *(G. detonsa, Gray's Manual.)*
 alba, Muhl.
 Andrewsii, Griseb.
 Saponaria, Linn.
 linearis, Frœl. *(G. Saponaria, Linn., var. linearis, Gray.)*
 puberula, Michx.
Bartonia tenella, Muhl.
Menyanthes trifoliata, Linn.

LOGANIACEÆ.

Spigelia Marilandica, Linn.

APOCYNACEÆ.

Apocynum androsæmifolium, Linn.
 cannabinum, Linn. All the forms of Gray's Manual occur abundantly.

ASCLEPIADACEÆ.

Asclepias Cornuti, Decaisne.
 Sullivantii, Engelm.
 phytolaccoides, Pursh.
 purpurascens, Linn.

Asclepias variegata, Linn.
ovalifolia, Decaisne.
incarnata, Linn.
obtusifolia, Michx.
rubra, Linn.
tuberosa, Linn.
verticillata, Linn.
Acerates viridiflora, Ell.
lanuginosa, Decaisne.
longifolia, Ell.

OLEACEÆ.

Fraxinus Americana, Linn.
pubescens, Lam.
viridis, Michx. f.
sambucifolia, Lam
quadrangulata, Michx.

ARISTOLOCHIACEÆ.

Asarum Canadense, Linn.

NYCTAGINACEÆ.

Oxybaphus nyctagineus, Sweet.
hirsutus, Sweet. Western part of the state.
angustifolius, Sweet.

PHYTOLACCACEÆ.

Phytolacca decandra, Linn. Whitewater. *(G. R. Kleeberger.)*

CHENOPODIACEÆ.

Chenopodium ALBUM, Linn.
GLAUCUM, Linn.
URBICUM, Linn.
HYBRIDUM, Linn.
BOTRYS, Linn.
AMBROSIOIDES, Linn.
Blitum capitatum, Linn.
Atriplex patula, Linn.
" var. hastata, Gray
" var. littoralis, Gray.
Corispermum hyssopifolium, Linn. Racine. *(J. J. Davis.)*
Salsola Kali, Linn.

AMARANTACEÆ.

Amarantus HYPOCHONDRIACUS, Linn.
RETROFLEXUS, Linn.
" var. hybridus, Gray.
ALBUS, Linn.
Acnida cannabina, Linn.
tamariscina, Gray. *(Montelia tamariscina, Gray.)*
Frœlichia Floridana, Moquin.

POLYGONACEÆ.

Polygonum ORIENTALE, Linn.
Hartwrightii, Gray. Whitewater.
Pennsylvanicum, Linn.
incarnatum, Ell.
Persicaria, Linn.
Hydropiper, Linn.
acre, H.B.K.
hydropiperoides, Michx.
amphibium, Linn.
Muhlenbergii, Wats. *(P. amphibium, Linn., var. terrestre, Gray's Manual, not of Willd.)*
Virginianum, Linn.
articulatum, Linn.
aviculare, Linn.
erectum, Linn. *(P. aviculare, Linn, var. erectum, Roth.)*
ramosissimum, Michx.
tenue, Michx.
arifolium, Linn.
sagittatum, Linn.
CONVOLVULUS, Linn.
cilinode, Michx.
dumetordum, Linn.
Fagopyrum esculentum, Mœnch.
Rumex orbiculatus, Gray.
altissimus, Wood. *(R. Brittanica, Linn.)*
verticillatus, Linn.
CRISPUS, Linn.
obtusifolius, Linn.
maritimus, Linn.
ACETOSELLA, Linn.

LAURACEÆ.

Sassafras officinale, Nees.

THYMELEACEÆ.

Dirca palustris, Linn.

ELÆAGNACEÆ.

Shepherdia Canadensis, Nutt.

SANTALACEÆ.

Comandra umbellata, Nutt.

SAURURACEÆ.

Saururus cernuus, Linn.

CERATOPHYLLACEÆ.

Ceratophyllum demersum, Linn.

CALLITRICHACEÆ.

Callitriche verna, Linn.

EUPHORBIACEÆ.

Euphorbia polygonifolia, Linn.
Geyeri, Engelm.
serpyllifolia, Pers.
glyptosperma, Engelm.
maculata, Linn.
hypericifolia, Linn.
corollata, Linn.
heterophylla, Linn.
ESULA, Linn.
CYPARISSIAS, Linn.
commutata, Engelm.
Acalypha Virginica, Linn.
Croton glandulosus, Linn. *(D. S. Jordan.)*

EMPETRACEÆ.

Empetrum nigrum, Linn.

URTICACEÆ.

Ulmus fulva, Michx.
Americana, Linn.
racemosa, Thomas
Celtis occidentalis, Linn.
Morus rubra, Linn.
Urtica gracilis, Ait.
DIOICA, Linn.
Laportea Canadensis, Gaudichaud.
Pilea pumila, Gray.
Bœhmeria cylindrica, Willd.
Parietaria Pennsylvanica, Muhl.
Cannabis SATIVA, Linn.
Humulus Lupulus, Linn.

PLATANACEÆ.

Platanus occidentalis, Linn.

JUGLANDACEÆ.

Juglans cinerea, Linn.
nigra, Linn.
Carya alba, Nutt.
sulcata, Nutt.
porcina, Nutt.
amara, Nutt.

CUPULIFERÆ.

Quercus alba, Linn.
stellata, Wang. *(Q. obtusiloba, Michx.)*
macrocarpa, Michx.
Quercus bicolor, Willd.
Muhlenbergii, Engelm. *(Q. Prinus, Linn, var. acuminata, Michx.)*
prinoides, Willd. *(Q. Prinus, Linn, var. humilis, March.)*
imbricaria, Michx.
nigra, Linn.
coccinea, Wang.
" var. tinctoria, Gray.
rubra, Linn.
palustris, Du Roi.
Fagus ferruginea, Ait.
Corylus Americana, Walt.
rostrata, Ait.
Ostrya Virginica, Willd.
Carpinus Americana, Michx.

MYRICACEÆ.

Myrica Gale, Linn.
Comptonia asplenifolia, Ait.

BETULACEÆ.

Betula lenta, Linn.
lutea, Michx. f.
papyracea, Ait.
nigra, Linn.
pumila, Linn.
Alnus incana, Willd.
serrulata, Ait.

SALICACEÆ.

Salix candida, Willd.
tristis, Ait.
humilis, Marsh.
discolor, Muhl.
sericea, Marsh.
petiolaris, Smith.
PURPUREA, Linn.
VIMINALIS, Linn.
cordata, Muhl.
" var. myricoides, Gray.
glaucophylla, Bebb.
livida, Wahl., var. occidentalis, Gray.
lucida, Muhl.
nigra, Marsh.
" var. amygdaloides, Anderson.
FRAGILIS, Linn.
ALBA, Linn.
" var. vitellina, Gray.
longifolia, Muhl.
myrtilloides, Linn.

Populus tremuloides, Michx.
grandidentata, Michx.
monilifera, Ait. (Including *P. angulata, Ait.)*
balsamifera, Linn.
var. candicans, Gray.
DILATATA, Ait.

CONIFERÆ.

Pinus Banksiana, Lambert.
resinosa, Ait.
Strobus, Linn.
Abies nigra, Poir.
alba, Michx.
Canadensis, Michx.
balsamea, Marshall.
Larix Americana, Michx.
Thuja occidentalis, Linn.
Cupressus thyoides, Linn.
Juniperus communis, Linn.
" var. alpina, Linn.
Virginiana, Linn.
Taxus baccata, Linn., var. Canadensis, Gray.

ARACEÆ.

Arisæma triphyllum, Torr.
Dracontium, Schott.
Calla palustris, Linn.
Symplocarpus fœtidus, Salisb.
Acorus Calamus, Linn.

LEMNACEÆ.

Lemna trisulca, Linn.
perpusilla, Torr.
" var. trinervis, Austin.
minor, Linn.
" var. orbiculata, Austin.
Spirodela polyrrhiza, Schleid. *(Lemna polyrrhiza, Linn.)* Winnebago county. *(W. A. Kellermann.)*

TYPHACEÆ.

Typha latifolia, Linn.
Sparganium eurycarpum, Engelm.
simplex, Hudson.
var. angustifolium, Gray.
minimum, Fries.

NAIADACEÆ.

Naias flexilis, Rostk.
Zannichellia palutris, Linn.
Potamogeton natans, Linn.
rufescens, Schrader.
lonchitis, Tuckerm. Whitewater. *(G. R. Kleeberger.)*
gramineus, Linn.
lucens, Linn. Winnebago Co. *(W. A. Kellermann.)*
prælongus, Wulfen. *(D. S. Jordan.)*
perfoliatus, Linn.
" var. lancolatus, Gray.
compressus, Linn.
pauciflorus, Pursh.
pusillus, Linn.
pectinatus, Linn.

ALISMACEÆ

Triglochin palustre, Linn. Racine. *(J. J. Davis.)*
maritimum, Linn., var. elatum, Gray. Racine. *(Dr. Hoy.)*
Scheuchzeria palustris, Linn. Racine. *(Dr. Hoy.)*
Alisma plantago, Linn., var. Americanum, Gray.
Sagittaria variabilis, Engelm. In most of its widely varying forms.
calycina, Engelm.
heterophylla, Pursh.

HYDROCHARIDACEÆ.

Anacharis Canadensis, Planchon.
Vallisneria spiralis, Linn.

ORCHIDACEÆ.

Orchis spectabilis, Linn.
rotundifolia, Pursh. *(Habenaria rotundifolia, Richardson.)*
Perularia virescens, Gray. *(H. virescens, Spreng.)*
Habenaria tridentata, Hook.
viridis, R. Brown, var. bracteata, Reich.
hyperborea, R. Br.
dilatata, Gray.
Hookeri, Torr.
orbiculata, Torr.
leucophæa, Gray
lacera, R. Br.
psycodes, Gray.
Goodyera repens, R. Br.
pubescens, R. Br.

Spiranthes latifolia, Torr.
cernua, Richard.
gracilis, Bigelow.
Arethusa bulbosa, Linn.
Pogonia ophioglossoides, Nutt.
pendula, Lindl. *(D. S. Jordan.)*
Calopogon pulchellus, R. Br.
Microstylis monophyllos, Lindl.
ophioglossoides, Nutt.
Liparis liliifolia, Richard.
Lœselii, Richard.
Corallorhiza innata, R. Br.
multiflora, Nutt.
Macræi, Gray. Oconto Co. *(W. A. Kellermann.)*
Aplectrum hyemale, Nutt.
Cypripedium arietinum, R. Br.
candidum, Muhl.
parviflorum, Salisb.
pubescens, Willd.
spectabile, Swartz.
acaule, Ait.

AMARYLLIDACEÆ.

Hypoxys erecta, Linn.

HÆMODORACEÆ.

Aletris farinosa, Linn.

IRIDACEÆ.

Iris versicolor, Linn.
lacustris, Nutt.
Sisyrinchium Bermudiana, Gray.
" var. mucronatum, Gray.
" var. albidum, Gray.

DIOSCOREACEÆ.

Dioscorea villosa, Linn.

SMILACEÆ.

Smilax rotundifolia, Linn.
hispida, Muhl. Racine. *(J. J. Davis.)*
herbacea, Linn.
" var. pulverulenta, Gray

LILIACEÆ.

Trillium sessile, Linn.
recurvatum, Beck.
grandiflorum, Salisb.
erectum, Linn.
" var. album, Pursh.
" var. declinatum, Gray.
Trillium cernuum, Linn.
nivale, Riddell.
Medeola Virginica, Linn.
Zygadenus glaucus, Nutt.
Tofieldia glutinosa, Willd.
Uvularia grandiflora, Smith.
perfoliata, Linn.
Oakesia sessilifolia, Wats. *(Uvularia sessilifolia, Linn.)*
Streptopus roseus, Michx.
Clintonia borealis, Raf.
Convallaria majalis, Linn.
Smilacina racemosa, Desf.
stellata, Desf.
trifolia, Desf.
Maianthemum Canadense, Desf. *(Smilacina bifolia, Ker., var. Canadense, Gray.)*
Polygonatum biflorum, Ell.
giganteum, Dietrich.
Asparagus OFFICINALIS, Linn.
Lilium Canadense, Linn.
Philadelphicum, Linn.
superbum, Linn.
Erythronium Americanum, Smith.
albidum, Nutt.
Camassia Fraseri, Torr. *(Scilla Fraseri, Gray.)*
Allium tricoccum, Ait.
cernuum, Roth.
Canadense, Kalm.

JUNCACEÆ.

Luzula pilosa, Willd.
campestris, D. C.
Juncus effusus, Linn.
Balticus, Dethard.
marginatus, Rostk. Milwaukee. *(Dr. Lewis Sherman.)*
bufonius, Linn.
Gerardi, Loisel.
tenuis, Willd.
pelocarpus, E. Meyer.
alpinus, Vill., var. insignis, Fries. Manitowoc county. *(Th. A. Bruhin.)*
acuminatus, Michx.
var. debilis, Gray.
var. legitimus, Gray.
nodosus, Linn.
scirpoides, Lam.

Juncus Canadensis, J. Gay, var. longicaudatus, Gray.
" var. brachycephalus, Gray.
" var. coarctatus, Gray.

PONTEDERIACEÆ.

Pontederia cordata, Linn.
" var. angustifolia, Gray.
Schollera graminea, Willd.

COMMELYNACEÆ.

Tradescantia Virginica, Linn.

CYPERACEÆ.

Cyperus flavescens, Linn.
diandrus, Torr.
" var. castaneus, Muhl.
erythrorhizos, Muhl. Racine. *(J. J. Davis.)*
inflexus, Muhl.
phymatodes, Muhl.
strigosus, Linn.
Michauxianus, Schultes.
Engelmanni, Steud.
Schweinitzii, Torr.
filiculmis, Vahl.
Dulichium spathaceum, Pers.
Hemicarpha subsquarrosa, Nees.
Eleocharis obtusa, Schultes.
palustris, R. Br.
compressa, Sullivant. Milwaukee. *(Dr. Lewis Sherman.)*
intermedia, Schultes.
tenuis, Schultes.
acicularis, R. Br.
Scirpus pungens, Vahl.
Torreyi, Olney.
validus, Vahl.
debilis, Pursh.
fluviatilis, Gray.
atrovirens, Muhl.
lineatus, Michx.
Eriophorum, Michx.
" var. cyperinus, Gray.
Eriophorum alpinum, Linn.
vaginatum, Linn.
Virginicum, Linn.
polystachyon, Linn.
gracile, Koch.
Fimbristylis capillaris, Gray.
Rhynchospora alba, Vahl.
Cladium mariscoides, Torr. Milwaukee. *(Dr. Lewis Sherman.)*
Scleria triglomerata, Michx.
Carex polytrichoides, Muhl.
Backii, Booth.
bromoides, Schk.
siccata, Dew.
disticha, Huds.
teretiuscula, Good.
" var. major, Koch.
vulpinoidea, Michx.
Nuttallii, Schw. *(C. crus-corvi, Shuttleworth.)*
stipata, Muhl.
conjuncta, Boott.
alopecoidea, Tuck.
sparganioides, Muhl.
cephalophora, Muhl.
rosea, Schk.
chordorhiza, Ehrh.
tenella, Schk.
trisperma, Dew.
tenuiflora, Wahl.
canescens, Linn.
Deweyana, Schw.
stellulata, Linn.
var. scirpoides, Gray.
sychnocephala, Carey. St. Croix county.
Muskingumensis, Schk. *(C. arida, Schw. & Torr.)*
scoparia, Schk.
lagopodioides, Schk.
" var. mirabilis, Boott.
straminea, Schk. Occurs in most of its almost indistinguishable forms.
rigida, Good.
vulgaris, Fries.
aquatilis, Wahl.
aperta, Boott.
stricta, Lam.
var. strictior, Carey.
crinita, Lam.
limosa, Linn.
irrigua, Smith.
Buxbaumii, Wahl.
aurea, Nutt.
panicea, Linn. var. Meadii, Olney. *(C. Meadii, Dew.)*
" var. tetanica, Olney. *(C. tetanica, Schk.)*
microdonta, Dew. *(C. Crawei, Dew.)*

Carex granularis, Muhl.
grisea, Wahl.
Davisii, Schw. & Torr.
gracillima, Schw.
virescens, Muhl. Racine, *(J. J. Davis.)*
plantaginea, Lam.
platyphylla, Carey.
digitalis, Willd.
laxiflora, Lam.
var. intermedia, Boott.
var. blanda, Carey.
oligocarpa, Schk.
Hitchcockiana, Dew.
eburnea, Boott.
pedunculata, Muhl.
Pennsylvanica, Lam.
varia, Muhl.
Richardsonii, R. Br.
pubescens, Muhl.
miliacea, Muhl.
flava, Linn.
viridula, Michx. *(C. Œderi, Ehrh.)*
filiformis, Linn.
lanuginosa, Michx.
Houghtonii, Torr. Milwaukee *(Dr. Lewis Sherman)*, Lake La Biche.
riparia, Curtis.
comosa, Boott.
Pseudo-Cyperus, Linn.
hystricina, Willd.
tentaculata, Michx.
intumescens, Rudge.
lupulina, Muhl.
lupuliformis, Sartwell. *(Th. A. Bruhin.)*
folliculata, Linn.
squarrosa, Linn.
retrorsa, Schw.
utriculata, Boott.
monile, Tuck.
bullata, Schk.
oligosperma, Michx.
longirostris, Torr.

GRAMINEÆ.

Leersia Virginica, Willd.
oryzoides, Swartz.
lenticularis, Michx.
Zizania aquatica, Linn.
Alopecurus PRATENSIS, Linn.
aristulatus, Michx.
Phleum PRATENSE, Linn.
Vilfa aspera, Beauv.
vaginæflora, Torr.
Sporobolus junceus, Kunth.
heterolepis, Gray.
cryptandrus, Gray.
Agrostis perennans, Tuckerm.
scabra, Willd.
vulgaris, Withering.
alba, Linn.
Cinna arundinacea, Linn.
var. pendula, Gray.
Muhlenbergia sobolifera, Trin.
glomerata, Trin.
Mexicana, Trin.
sylvatica, Torr. & Gray.
Willdenovii, Trin.
Brachyelytrum aristatum. Beauv.
Calamagrostis Canadensis, Beauv.
longifolia, Hook.
Oryzopsis melanocarpa. Muhl.
asperifolia, Michx.
Canadensis, Torr.
Stipa avenacea, Linn.
spartea, Trin.
Aristida purpurascens, Poir. St. Croix county.
tuberculosa, Nutt.
Spartina cynosuroides, Willd.
Bouteloua oligostachya, Torr. St. Croix county.
hirsuta, Lagasca.
curtipendula, Gray.
Dactylis GLOMERATA, Linn.
Kœleria cristata, Pers.
Eatonia obtusata, Gray.
Pennsylvanica, Gray.
Melica mutica, Walt.
Glyceria Canadensis, Trin.
elongata, Trin.
nervata, Trin.
pallida, Trin.
aquatica, Smith.
fluitans, R. Br.
Poa annua, Linn.
compressa, Linn.
cæsia, Smith. Milwaukee *(Dr. Lewis Sherman)*, northward.
serotina, Ehrhart.
pratensis, Linn.
TRIVIALIS, Linn.
sylvestris, Gray.

Poa debilis, Torr.
alsodes, Gray.
Eragrostis reptans, Nees.
POÆOIDES, Beauv., var. megastachya, Gray.
Frankii, Meyer.
capillaris, Nees.
pectinacea, Gray.
var. spectabilis, Gray.
Festuca tenella, Willd.
ovina, Linn.
nutans, Willd.
Bromus SECALINUS, Linn.
Kalmii, Gray.
ciliatus, Linn.
var. purgans, Gray.
Uniola latifolia, Michx.
Phragmites communis, Trin.
Lolium PERENNE, Linn.
Triticum repens, Linn.
dasystachyum, Gray.
violaceum, Linn.
caninum, Linn.
Hordeum jubatum, Linn.
Elymus Virginicus, Linn.
Canadensis, Linn.
var. glaucifolius, Gray.
striatus, Willd.
mollis, Trin.
Gymnostichum Hystrix, Schreb.
Danthonia spicata, Beauv.
Avena striata, Michx.
Trisetum subspicatum, Beauv., var. molle, Gray.
Aira flexuosa, Linn.
cæspitosa, Linn.
Holcus LANATUS, Linn.
Hierochloa borealis, Roem. & Schultes.
Phalaris CANARIENSIS, Linn.
arundinacea, Linn.
Milium effusum, Linn.
Panicum GLABRUM, Gaudin.
SANGUINALE, Linn.
capillare, Linn.
autumnale, Bosc.
virgatum, Linn.
latifolium, Linn.
clandestinum, Linn.
xanthophysum, Gray.
pauciflorum, Gray. (Ell.?)
dichotomum, Linn.
depauperatum, Muhl.
Panicum CRUS-GALLI, Linn.
var. hispidum, Gray.
Setaria GLAUCA, Beauv.
VIRIDIS, Beauv.
ITALICA, Kunth.
Cenchrus tribuloides, Linn.
Andropogon furcatus, Muhl.
scoparius, Michx.
Sorghum nutans, Gray.

EQUISETACEÆ.

Equisetum Telmateia, Ehrh.
arvense, Linn.
pratense, Ehrh.
sylvaticum, Linn.
palustre, Linn.
limosum, Linn.
lævigatum, Braun.
hyemale, Linn.
variegatum, Schleicher.
scirpoides, Michx.

FILICES.

Polypodium vulgare, Linn.
Adiantum pedatum, Linn.
Pteris aquilina, Linn.
Cheilanthes lanuginosa, Nutt.
Pellæa gracilis, Hook.
atropurpurea, Link.
Asplenium Trichomanes, Linn.
angustifolium, Michx.
thelypteroides, Michx.
Filix-fœmina, Bernh.
Camptosorus rhizophyllus, Link.
Phegopteris polypodioides, Fee.
hexagonoptera, Fee.
Dryopteris, Fee.
Aspidium Thelypteris, Swartz.
Noveboracense, Swartz.
fragrans, Swartz.
spinulosum, Swartz.
var. intermedium, Gray.
var. dilatatum, Gray.
cristatum, Swartz.
Goldianum, Hook.
marginale, Swartz.
acrostichoides, Swartz.
aculeatum, Swartz., var. Braunii, Koch.
Cystopteris bulbifera, Bernh.
fragilis, Bernh.
Onoclea sensibilis, Linn.

Onoclea, var. obtusilobata, Torr.
Struthiopteris, Hoffm. *(Struthiopteris Germanica, Willd.)*
Woodsia obtusa, Torr.
Ilvensis, R. Brown.
Osmunda regalis, Linn.
Claytoniana, Linn.
cinnamomea, Linn.

OPHIOGLOSSACEÆ.

Botrychium Virginianum, Swartz.
ternatum, Swartz. *(B. lunarioides, Swartz.)*
Ophioglossum vulgatum, Linn.

LYCOPODIACEÆ.

Lycopodium lucidulum, Michx.
annotinum, Linn.
dendroideum, Michx.
var. obscurum, Gray.
clavatum, Linn.
complanatum, Linn.

SELAGINELLEÆ.

Selaginella selaginoides, Link.
rupestris, Spring.
apus, Spring.

CHAPTER VI.

A PARTIAL LIST OF THE FUNGI OF WISCONSIN, WITH DESCRIPTIONS OF NEW SPECIES.

BY W. F. BUNDY.

DIVISION I. SPORIFERA.

FAMILY I. HYMENOMYCETES.

ORDER I. AGARICINI.

SERIES I. LEUCOSPORI.

Genus 1, Agaricus.

Sub-Genus Amanita.

Agaricus (Amanita) vaginatus. *Bull.*
A. (Amanita) Ceciliæ. *B. & Br.*
A. (Amanita) adnatus. *Smith.*
A. (Amanita) vernus. *Bull.*
A. (Amanita) phalloides. *Fr.*
A. (Amanita) muscarius. *L.*
var. minor.
A. (Amanita) pantherinus. *D. C.*
A. (Amanita) asper. *Fr.*
A. (Amanita) lenticularis. *Lasch.*

Sub-Genus Lepiota.

A. (Lepiota) procerus. *Scop.*
A. (Lepiota) rachodes. *Vitt.*
A. (Lepiota) acutesquamosus. *Wm.*
A. (Lepiota) holosericeus. *Fr.*

Sub-Genus Amillaria.

A. (Amillaria) melleus. *Vahl.*

Sub-Genus Tricholoma.

A. (Tricholoma) sapidus. *Kalchl.*

Sub-Genus Clitocybe.

A. (Clitocybe) nebularis. *Batsch.*
A. (Clytocybe) Poculum. *Pk.*
A. (Clitocybe) infundibuliformis. *Schœf.*
A. (Clitocybe) phyllophilus. *Fr.*
A. (Clitocybe) laccatus. *Fr.*
A. (Clitocybe) giganteus. *Fr.*
A. (Clitocybe) geotrupus. *Bull.*

Sub-Genus Pleurotus.

A. (Pleurotus) ulmarius. *Bull.*
A. (Pleurotus) serotinus. *Schard.*
A. (Pleurotus) subpalmatus. *Fr.*

Sub-Genus Collybia.

A. (Collybia) dryophilus. *Bull.*
A. (Collybia) velutipes. *Curt.*
A. (Collybia) familia. *Pk.*
A. (Collybia) collinus. *Scop.*

Sub-Genus Mycena.

A. (Mycena) acicula. *Schœff.*
A. (Mycena) pelianthinus.
A. (Mycena) corticola. *Schum.*
A. (Mycena) galericulatus. *Scop*
A. (Mycena) tenuis. *Bolt.*
A. (Mycena) rugosus. *Fr.*
A. (Mycena) polygrammus. *Bull.*
A. (Mycena) atro-albus. *Bull.*
A. (Mycena) alcalinus. *Fr.*

Sub-Genus Omphalia.

A. (Omphalia) fibula. *Bull.*

SERIES II. HYPORHODII.

Sub-Genus Volvaria.

A. (Volvaria) bombycinus. *Schœff.*
A. (Volvaria) parvulus. *Weinm.*
A. (Volvaria) speciosus. *Fr.*

Sub-Genus Pluteus.

A. (Pluteus) cervinus. *Schœff.*
A. (Pluteus) admirabilis. *Pk.*
A. (Pluteus) leoninus. *Schœff.*
A. (Pluteus) chrysophæus. *Schœff.*
A. (Pluteus) umbrosus. *Pres.*

Sub-Genus Entoloma.

A. (Entoloma) sericellus. *Fr.*
A. (Entoloma) nidorosus. *Fr.*

Sub-Genus Clitopilus.

A. (Clitopilus) prunulus. *Scop.*

Sub-Genus Leptonia.

A. (Leptonia) chalybæus. *P.*

SERIES III. DERMINI.

Sub-Genus Pholiota.

A. (Pholiota) præcox. *P.*

Sub-Genus Hebeloma.

A. (Hebeloma) sinapizans. *Fr.*
A. (Hebeloma) fastibilis. *Fr.*
A. (Hebeloma) pyriodorus. *P.*
A. (Hebeloma) deglubens. *Fr.*
A. (Hebeloma) rimosus. *Bull.*
A. (Hebeloma) crustuliniformis. *Bull.*

Sub-Genus Naucoria.

A. (Naucoria) melinoides. *Fr.*
A. (Naucoria) semi-orbicularis. *Bull.*
A. (Naucoria) pediades. *Fr.*

Sub-Genus Galera.

A. (Galera) ovalis. *Fr.*
A. (Galera) tener. *Schœff.*
A. (Galera) hypnorum. *Batsch.*
A. (Galera) aleuriatus. *Fr.*

Sub-Genus Tubaria.

A. (Tubaria) furfuraceous. *P.*

SERIES IV. PRATELLÆ.

Sub-Genus Psalliota.

A. (Psalliota) campestris. *L.*
A. (Psalliota) sylvaticus. *Schœff.*
A. (Psalliota) naucinoides. *Pk.*

Sub-Genus Stropharia.

A. (Stropharia) semiglobatus. *Batsch.*

Sub-Genus Hypholoma.

A. (Hypholoma) lacrymabundis. *Fr.*
A. (Hypholoma) fascicularis. *Hud.*
A. (Hypholoma) perplexus. *Pk.*

Sub-Genus Psilocybe.

A. (Psilocybe) cernuus. *Müll.*
A. (Psilocybe) fœnisecii. *P.*

SERIES V. COPRINARII.

Sub-Genus Panæolus.

A. (Panæolus) retirugis. *Batsch.*
A. (Panæolus) campanulatus. *L.*
A. (Panæolus) solipides. *Pk.*
A. (Panæolus) fimicola. *Fr.*

Sub-Genus Psathyrella.

A. (Psathyrella) gracilis. *Fr.*
A. (Psathyrella) disseminatus. *Fr.*
A. (Psathyrella) atomatus. *Fr.*

Genus 2, Coprinus.

Coprinus comatus. *Fr.*
C. ovatus. *Fr.*
C. atramentarius. *Fr.*
C. picaceous. *Fr.*
C. apthosus. *Fr.*
C. niveus. *Fr.*
C. micaceus. *Fr.*
C. ephemerus. *Fr.*
C. plicatilis. *Fr.*
C. semilanatus. *Pk.*

Genus 3, Bolbitius.

Bolbitius fragilis. *Fr.*
B. titubans. *Fr.*

Genus 4, Cortinarius.

Cortinarius squamulosus. *Pk.*
C. violaceus. *L.*
C. alboviolaceus. *Fr.*
C. pholideus. *Fr.*
C. cinnamomeus. *Fr.*
var. semisanguinea. *Fr.*
C. hinnuleus. *Fr.*

Genus 5, Paxillus.

Paxillus involutus. *Fr.*

Genus 6, Hygrophorus.

Hygrophorus conicus. *Fr.*
H. coccineus. *Fr.*
H. cantharellus. *Schw.*
H. ceraceus. *Fr.*
H. chloraphanus. *Fr.*

Genus 7, Lactarius.

Lactarius insulsus. *Fr.*
L. zonarius. *Fr.*
L. pyrogalus. *Fr.*
L. chrysorrhæus. *Fr.*
L. piperatus. *Fr.*

Lactarius vellereus. *Fr.*
L. deliciosus. *Fr.*
L. theiogalus. *Fr.*
L. camphoratus. *Fr.*
L. distans. *Pk.*
L. villosus. *Fr.*
L. sordidus. *Pk.*
L. uvidus. *Fr.*
L. volemus. *Fr.*
L. affinis. *Pk.*

Genus 8, Russula.

Russula simillimus. *Pk.*
R. rubra. *Fr.*
R. fœtens. (Pers.) *Fr.*
R. integra. *Fr.*
R. emetica. *Fr.*
R. sardonia. *Fr.*
R. veternosa. *Fr.*
R. Mariæ. *Pk.*
R. decolorans. *Fr.*
R. virescens. *(Schæff.) Fr.*
R. depallens. *Fr.*
R. furcata. *Fr.*
R. sanguinea. *Fr.*
R. lactea. *Fr.*

Genus 9, Cantharellus.

Cantharellus cibarius. *Fr.*
C. minor. *Pk.*

Genus 10, Marasmius.

Marasmius erythropus. *Fr.*
M. rotula. *(Scop.) Fr.*
M. pulcherripes. *Pk.*
M. campanulatus. *Pk.*
M. androsaceus. *Fr.*

Genus 11, Lentinus.

Lentinus lepideus. *Fr.*
L. flabelliformis. *Fr.*

Genus 12, Panus.

Panus stypticus. *Fr.*
Panus tomentosus. sp. nov.

Pileus rather fleshy, becoming tough, depressed, nearly plane in some specimens, subinfundibuliform, dull yellowish, merging into purple, tomentous, outer zone densely covered with tawny hairs; margins incurved; gills narrow, decurrent, white, at first tinged with purplish; stipe eccentric, short, thicker below, densely covered with tawny hairs.

From 1 to 1½ in. high; pileus about as wide.

On oak logs. Ironton. July.

Genus 13, Schizophyllum.

Schizophyllum commune. *Fr.*

Genus 14, Lenzites.

Lenzites betulina. *Fr.*

ORDER II. POLYPOREI.

Genus 15, Boletus.

Boletus elegans. *Schum.*
B. flavus. *With.*
B. badius. *Fr.*
B. chrysenteron. *Fr.*
B. subtomentosus. *L.*
B. edulis. *Bull.*
B. felleus. *Bull.*
B. bicolor. *Fr.*
B. castaneus. *Bull.*
B. retipes. *B. and C.*
B. cyanescens. *Bull.*
B. scaber. *Fr.*
B. strobilaceus. *Scop.*
B. radicosus. sp. nov.

Pileus thin, wide, recurved, yellow tinged with brown; cuticle easily removed; flesh pale yellowish, tinged with pink, not changing color when bruised; tubes decurrent, large, uneven-mouthed, compound, angular, tinged with brown; stipe flexuous, yellow above, whitish below, rough with dark appressed scales, fibrous rooted.

Height 3′ to 4′, width of pileus 4′, stipe 5″. Baraboo Bluffs, July.

B. lateralis. sp. nov.

Pileus moderately thin, umber, lighter toward margin, viscid, lateral margins incurved; tubes wide, shallow, angular, bounded by prominent, vein-like lamellæ connected by less promigent anastomosing dissepiments; yellow; stipe lateral, short, reticulated by decurrent anastomosing lamellæ, brown or olive brown, sometimes tinged with red. Pileus 2′ wide, stipe, 5″ to 8″ long.

About old basswood stumps in swamps. Sauk City. Aug.
B. spectabilis. *Pk.*

Genus 16, Polyporus.

Polyporus brumalis. *Fr.*
P. perennis. *Fr.*
P. squamosus. *Fr.*
P. sulphureus. *Fr.*
P. fomentarius. *Fr.*
P. hirsutus. *Fr.*
P. purpureus. *Fr.*
P. salicinus. *Fr.*
P. betulinus. *Fr.*
P. varius. *Fr.*
P. elegans. *Fr.*

ORDER III. HYDNEI.

Genus 17, Hydnum.

Hydnum repandum. *L.*
H. niveum. *P.*
H. imbricatum. *L.*

Genus 18, Sistotrema.

Sistotrema confluens. *Pers.*

ORDER IV. AURICULARINI.

Genus 19, Craterellus.

Craterellus cornucopioides. *Fr.*

Genus 20, Auricularia.

Auricularia mesenterica. *Bull.*

ORDER V. CLAVARIEI.

Genus 21, Clavaria.

Clavaria cristata. *Holmsk.*
C. fusiformis. *Sow.*
C. vermiculata. *Scop.*
C. aurea. *Schæff.*
C. coralloides. *L.*
C. cinerea. *Bull.*
C. fragilis. *Holmsk.*
C. flava. *Fr.*
C. Kunzei. *Fr.*
C. stricta. *P.*
C. inæqualis. *Müll.*
C. ligula. *Fr.*

ORDER VI. TREMELLINI.

Genus 22, Tremella.

Tremella fimbriata. *Pers.*
T. lutescens. *Fr.*
T. mesentericus. *Retz.*
T. albida. *Hud.*

Genus 23, Exidia.

Exidia glandulosa. *Fr.*

Genus 24, Dacrymyces.

Dacrymyces stellatus. *Nees.*

FAMILY II. GASTEROMYCETES.

ORDER VII. PODAXINEI.

Genus 25, Podaxon.

Podaxon Warnei. *Pk.*

ORDER VIII. PHALLOIDEI.

Genus 26, Phallus.

Phallus impudicus. *L.*

ORDER IX. TRICHOGASTRES.

Genus 27, Geaster.

Geaster Bryantii. *Berk.*
G. hygrometricus. *P.*
G. striatus. *D. C.*

Genus 28, Bovista.

Bovista nigrescens. *P.*
B. plumbea. *P.*
B. ammophila. *Lev.*

Genus 29, Lycoperdon.

Lycoperdon giganteum. *Batsch.*
L. cælatum. *Fr.*
L. Wrightii. *B. & C.*
L. atropurpureum. *Vitt.*
L. cyathiforme. *Bosc.*
L. pusillum. *Fr.*
L. saccatum. *Vahl.*
L. gemmatum. *Fr.*
L. pyriforme. *Schæff.*
L. separans. *Pk.*

Genus 30, Scleroderma.

Scleroderma vulgare. *Fr.*
S. bovista. *Fr.*
S. verrucosum. *Pers.*

ORDER X. MYXOGASTRES.

Genus 31, Lycogala

Lycogala epidendrum. *Fr.*

Genus 32, Reticularia.

Reticularia umbrina. *Fr.*

Genus 33, Æthalium.

Æthalium septicum. *Fr.*

Genus 34, Spumaria.

Spumaria alba. *D. C.*

Genus 35, Stemonitis.

Stemonitis fusca. *Roth.*
S. ferruginea. *Ehrb.*

Genus 36, Arcyria.

Arcyria punicea. *P.*

ORDER XI. NIDULARIACEI.

Genus 37, Cyathus.

Cyathus striatus. *Hoffm.*
C. vernicosus. *D. C.*

Genus 38, Crucibulum.

Crucibulum vulgare. *Tul.*

Genus 39, Sphærobolus.

Sphærobolus stellatus. *Tode.*

FAMILY III. CONIOMYCETES.

ORDER XII. TORULACEI.

Genus 40, Torula.

Torula ovalispora. *Berk.*
T. herbarum. *Lk.*

Genus 41, Helicosporium.

Helicosporium pulvinatum. *Fr.*

ORDER XIII. PUCCINIÆI.

Genus 42, Phragmidium.

Phragmidium mucronatum. *Link.*

Genus 43, Puccinia.

Puccinia graminis. *Pers.*
P. xanthii. *Schw.*

Genus 44, Podisoma.

Podisoma juniperi. *Fr.*

ORDER XIV. CÆOMACEI.

Genus 45, Ustilago.

Ustilago carbo. *Tul.*
U. maydis. *Corda.*

Genus 46, Cystopus.

Cystopus candidus. *Lev.*
C. portulacæ. *D. C.*

Genus 47, Uredo.

Uredo potentillarum. *D. C.*

Genus 48, Lecythea.

Lecythea saliceti. *Lev.*

ORDER XV. ÆCIDIACEI.

Genus 49, Rœstelia.

Rœstelia lacerata. *Tul.*
R. cornuta. *Tul.*

Genus 50, Æcidium.

Æcidium œnotheræ. *Pk.*
Æ. berberidis. *Pers.*
Æ. grossulariæ. *D. C.*
Æ. violæ. *Schum.*
Æ. geranii. *D. C.*
Æ. podophylli. *Schw.*
Æ. compositarum. *Mart.*
Æ. erigeronatum. *Schw.*
Æ. ranunculacearum. *D. C.*
Æ. epilobii. *D. C.*
Æ. quadrifidum. *D. C.*
Æ. Mariæ-Wilsoni. *Pk.*

FAMILY IV. HYPHOMYCETES.

ORDER XVI. DEMATIEI.

Genus 51, Helminthosporium.

Helminthosporium folliculatum. *Corda.*
H. tiara. *B. & R.*

Genus 52, Macrosporium.

Macrosporium cheiranthi. *Fr.*

Genus 53, Helicoma.

Helicoma Mulleri. *Corda.*

ORDER XVII. MUCEDINES.

Genus 54, Aspergillus.

Aspergillus glaucus. *Lk.*
A. candidus. *Lk.*
A. virens. *Lk.*

Genus 55, Peronospora.

Peronospora infestans. *Mont.*
P. nivea. *Ung.*
P. gangliformis. *Berk.*
P. parasitica. *Pers.*
P. viciæ. *Berk.*

Genus 56, Penicillium.

Penicillium crustaceum. *Fr.*
P. candidum. *Lk.*

Genus 57, Sporotrichum.

Sporotrichum sulphureum. *Grev.*

Genus 58, Acremonium.

Acremonium fuscum. *Schm.*

Genus 59, Rhopalomyces.

Rhopalomyces pallidus? *B. & Br.*

ORDER XVII. LEPEDONIEI.

Genus 60, Lepedonium.

Lepedonium chrysospermum. *Lk.*

DIVISION II. SPORIDIIFERA.

FAMILY V. PHYSOMYCETES.

ORDER XVIII. MUCORINI.

Genus 61, Ascophora.

Ascophora mucedo. *Tode.*

Genus 62, Mucor.

Mucor mucedo. *L.*

Genus 63, Hydrophora.

Hydrophora stercorea. *Tode.*

Genus 64, Sporodinia.

Sporodinia dichotoma. *Corda.*

FAMILY VI. ASCOMYCETES.

ORDER XIX. ELVELLACEI.

Genus 65, Morchella.

Morchella esculenta. *Pers.*

Genus 66, Helvella.

Helvella crispa. *Fr.*
H. sulcata. *Afz.*

Genus 67, Verpa.

Verpa conica. *Sow.*

Genus 68, Leotia.

Leotia lubrica. *Pers.*

Genus 69, Geoglossum.

Geoglossum luteum. *Pk.*

Genus 70, Rhizina.

Rhizina undulata. *Fr.*

Genus 71, Peziza.

Peziza macropus. *Pers.*
P. scutellata. *L.*
P. floccosa. *Schw.*
P. aurantia. *Fr.*
P. coccinea. *Jacq.*
P. virginea. *Batsch.*
P. sanguinea. *Pers.*

P. echinosperma. *Pk.*
P. imperialis. *Pk.*
P. Warnei. *Pk.*
P. venosa. *P.*
P. melaloma. *A. & S.*

Genus 72, Nodularia.

Nodularia balsamicola. *Pk.*

Genus 73, Helotium.

Helotium citrinum. *Fr.*
H. claro-flavum. *Berk.*
H. macrosporum. *Pk.*
H. epiphyllum. *Fr.*

Genus 74, Bulgaria.

Bulgaria inquinans. *Fr.*
B. rufa. *Schw.*

ORDER XX. PHACIDIACEI.

Genus 75, Hysterium.

Hysterium fraxini. *Pers.*

ORDER XXI. SPHÆRIACEI.

Genus 76, Hypomyces.

Hypomyces lactifluorum. *Schw.*

CHAPTER VII.

THE CRUSTACEAN FAUNA OF WISCONSIN,

WITH

DESCRIPTIONS OF LITTLE KNOWN SPECIES OF CAMBARUS.

By W. F. Bundy.

ORDER DECAPODA.

FAMILY ASTACIDÆ.

GENUS CAMBARUS.

Cambarus acutus. *Gir.* Racine, Sauk City.

C. stygius. *Bundy.* Bulletin No. 1, Ill. Mus. Nat. Hist., 1876.

Rostrum long and pointed, smooth above, foveolate at base, cephalothorax slightly compressed, smooth or slightly punctate above, finely granulate on sides; areola narrow; lateral spine acute; antennal plates wide, truncate, with short apical teeth; epistoma rounded in front, twice as wide as long; third maxillipedes hairy on inner and lower aspects; chelæ short, smooth above, serrate on interior margins; fingers short, nearly straight, costate and punctate above, contiguous margins tuberculate, exterior one hairy; third joint of third (and fourth ?) thoracic legs of male hooked. (Of three males sent me by Dr. P. R. Hoy, not one had the fourth thoracic legs remaining.)

First abdominal of male short, truncate, with three short, obtuse teeth directed outward from the posterior margin at apex. A smooth groove passes up on the outside of the leg between these teeth and the anterior margin.

Ventral annulus of female flat, transversely elliptical, posterior margin slightly elevated.

This species is closely related to C. acutus, but may be at once separated by the shorter hands,— similar to those of C. propinquus,— and the non-tuberculated annulus of female.

Found by Dr. P. R. Hoy on the shores of Lake Michigan, having been washed ashore during a storm.

C. virilis. *Hagen.* One of our most abundant species, frequenting running streams.

C. propinquus. *Gir.* Abundant, in company with C. virilis.

C. cousii ? *Street.* A few specimens among the collections of Beloit College. I cannot distinguish from the above.

C. rusticus. *Gir.* Lake Superior (Hagen). Beloit (Swezey).

C. Wisconsinensis. *Bundy.* Bull. No. 1, Ill. Mus. Nat. Hist., 1876.

Resembles *C. virilis.* Rostrum somewhat narrowed in front, more or less excavated above (in some individuals nearly plane), anterior teeth short, acumen short, acute; cephalothorax wider than deep, punctate above, granulate and tuberculate on sides, especially in front, lateral teeth present with a tuft of hairs in front of them in transverse suture; areola distinct, narrow, wider behind; cephalic carinæ prominent, sulcate, obtuse anteriorly, thickened behind; antennal plates exceed rostrum; antennæ slender, reaching middle of abdomen;

epistoma transverse, truncate, or in some individuals emarginate, sides oblique; maxillipedes coarsely barbate on inner aspect, sparingly so below; chelæ much as in C. virilis, but somewhat more slender, fingers punctate and costate above with rounded tubercles on contiguous edges, outer one hairy at base; movable finger with two rows of serrate teeth on inner margin, inner margin of chelæ with two rows of teeth; carpus with one sharp spine on middle of lower anterior margin and a larger one at middle of interior margin; brachium with two rows of sharp teeth below; third joint of third thoracic legs hooked; first abdominal legs of male long, bifid, external part longer, both recurved, inner often somewhat enlarged near tip. These legs reach to base of first thoracic pair when the abdomen is flexed. Length of areola contained one and one-third times in line from cervical suture to tip of acumen. Racine, Ironton, Wis. Normal, Ill. Not common.

C. debilis. Bundy. Bulletin No. 1, Ill. Mus. Nat. Hist., 1876.

Rostrum wide, quadrangular, slightly concave above, teeth prominent, margins nearly parallel, acumen short and flat; cephalothorax slightly depressed, punctate above, granulate on sides; lateral teeth acute; areola narrow, widest behind; antennal plates slightly longer than rostrum; antennæ slender, reaching to base of telson; epistoma transverse; third maxillipedes bearded on inner and lower aspects; chelæ with two rows of teeth on interior margin; fingers tuberculate on contiguous margins, outer one hairy at base, both costate and punctate above; third joint of third thoracic legs of male hooked; first abdominal legs of male long, bifid, nearly straight, outer ramus longer, recurved; inner ramus more abruptly recurved near apex, not enlarged near apex as in the preceding species; tubercles on basal angle inconspicuous.

Ironton, in company with C. propinquus. A single individual found at Sauk City.

C. gracilis. Bundy. Bulletin No. 1, Ill. Mus. Nat. Hist., 1876.

Rostrum short, wide, depressed, toothless, concave above, nearly right-angled in front; cephalothorax laterally compressed, smooth above, granulated on sides; areola none, cephalic carinæ prominent, ending posteriorly in callosities; antennal laminæ small and narrow; eyes small; antennæ slender and short; epistoma rounded in front; third maxillipedes hairy on interior and posterior margins; chelæ large, smooth below, punctate above, strongly toothed on inner margins; fingers slender, gaping at base, depressed, contiguous margins irregularly tuberculate, outer one incurved, wide at base, movable one longer; carpus with one large and several small teeth on inner margin; brachium with two rows of sharp teeth on inferior margin; third joint of third thoraic legs of male hooked; first abdominal legs of male truncate, with several small apical teeth, of which the inner one is longest, slender, and directed obliquely outward; bases of these legs narrow and inserted in deep sinuses in the first abdominal segment; interpedal space long, narrow, reaching half way from basal tubercles to apex of legs.

Ventral annulus of female movable, small and round. It consists of two half rings, each of which embraces one end of the other. Two tubercles on the anterior border are separated by a slight furrow that widens behind, covering the posterior portion. The posterior border is notched.

Low prairies in the neighborhood of Racine (Dr. P. R. Hoy). Normal, Ill. (Prof. Forbes).

C. obesus. Hagen. One of our most abundant species, frequenting ponds and meadow ditches. It is pre-eminently our burrowing species. The preceding species, according to Dr. Hoy, has the same habit.

C. Bartonii. Erickson. Lake Superior (Hagen).

FAMILY MYSIDÆ.

Genus Mysis.

Mysis relicta. *Loven.* An inhabitant of the deep waters of the Great Lakes. Not found in the interior waters of the state.

ORDER AMPHIPODA.

FAMILY ORCHESTIDÆ. GENUS ORCHESTES.

Orchestes dentatus (Smith). *Faxon.* Abundant everywhere.

FAMILY LYSIANASSIDÆ. GENUS PONTOPOREIA.

Pontoporeia Hoyi. *Smith.* Lake Mich.

P. filicornis. *Smith.* Lake Mich.

FAMILY GAMMARIDÆ. GENUS GAMMARUS.

Gammarus fasciatus. *Say.* Common everywhere.

G. limneus. *Smith.* Racine. (Dr. P. R. Hoy.)

ORDER ISOPODA.

FAMILY ONISCIDÆ. GENUS ONISCUS.

Oniscus sp. Common sowbug. Abundant everywhere.

FAMILY ASELLIDÆ. GENUS ASELLUS.

Asellus intermedius. *Forbes.* Sauk City. Abundant.

FAMILY PHYLLOPODA. GENUS EUBRANCHIPUS.

Eubranchipus Bundyi. *Forbes.* Ponds in Jefferson county.

FAMILY ESTHERIADÆ.

Limnetis sp. Occasionally met with in ponds. Not common.

ORDER CLADOCERA.

FAMILY SIDIDÆ. GENUS SIDA.

Sida crystallina. *Müller.* Common. Madison. (Prof. Birge.)

FAMILY DAPHNIDÆ. GENUS MOINA.

Moina brachiata. *Jurine.* Madison. (Birge.)

GENUS CERIODAPHNIA.

Ceriodaphnia dentata. *Birge.* Madison. (Birge.)

C. consors. *Birge.* Madison. (Birge.)

GENUS SIMOCEPHALUS.

Simocephalus Americanus. *Birge.* Common.

S. vetulus. *Müller.* Common.

GENUS SCAPHOLEBERIS.

Scapholeberis mucronata. *Müller.*

S. nasuta. *Birge.*

GENUS DAPHNIA.

Daphnia pulex. *De Geer.* *var. denticulata.* *Birge.* Madison. (Birge.)

GENUS MACROTHRIX.

Macrothrix rosea. *Jurine.* Madison. (Birge.)

GENUS BOSMINA.

Bosmina longirostris. *Müller.* Madison. (Birge.)

FAMILY LYNCEIDÆ.

GENUS EURYCERCUS.

Eurycercus lamellatus. *Müller.* Common.

GENUS PLEUROXUS

Pleuroxus procurvus. *Birge.* Madison. (Birge.)

P. denticulatus. *Birge.* Madison. (Birge.)

P. unidens. *Birge.* Madison. (Birge).

GENUS CHYDORUS.

Chydorus sphœricus. *Müller.* Madison. (Birge.) Sauk City.

Ch. globosus. *Baird.* Madison. (Birge).

GENUS CREPIDOCERCUS. *Birge.*

Crepidocercus setiger. *Birge.* Madison.

GENUS GRAPTOLEBERIS.

Graptoleberis inermis. *Birge.* Madison.

GENUS ALONA.

Alona porrecta. *Birge.* Madison.

A. spinifera. *Schödler.* Madison. (Birge.)

A. oblonga. *Müller.* Madison. (Birge.)

GENUS ACROPERUS.

Acroperus leucocephalus. *Schödler.* Madison. (Birge.)

GENUS CAMPTOCERCUS.

Camptocercus macrurus. *Müller.* Madison. (Birge.)

ORDER COPEPODA.

FAMILY CALANIDÆ. GENUS DIAPTOMUS.

Diaptomus sanguineus. *Forbes.* Sauk City. Not common.

CHAPTER VIII.

I. A CATALOGUE OF WISCONSIN LEPIDOPTERA

BY P. R. HOY.

Insects, in a restricted sense, are six-footed articulates. Wisconsin is rich in insect life, among which are many southern forms. The presence of these southern insects may be satisfactorily accounted for, in part, by the warmer summers that occur west of the Great Lakes than are experienced in the same latitude east of these great bodies of water — a curving north of the summer isotherm. "Though small in size, insects are great by their infinite variety of form, prodigious numbers, wonderful organization, and astonishing metamorphoses." You will find the following catalogue of Wisconsin insects sadly deficient, yet when you reflect that nearly all of the following Lepidoptera were taken in the immediate vicinity of Racine, you will be surprised, rather than disappointed.

LEPIDOPTERA.

(Butterflies, Sphinxes, Moths, etc.)

To the order *Lepidoptera* belong those four-winged insects, the wings of which are broad, regularly veined, and covered with minute scales. The jaws are prolonged into a tube, called the tongue. Their transformation is complete. In the *larval* (caterpillar) stage, they are furnished with stout jaws for clipping the various vegetable substances on which they feed. In this stage many of them inflict heavy damage on various cultivated plants. In the second stage — that of *chrysalidæ* or *pupæ* — they eat nothing, and can scarcely move at all. At the close of the pupa stage, the perfect insect emerges, clothed in beauty, to spend a short, joyous existence, fitted only to sip the sweets of nature. In this last stage, Lepidoptera are rather beneficial than injurious, for the fertilizing of many flowers depends, partially or wholly, on the good work of these *summer flower inspectors.*

DIURNAL LEPIDOPTERA. BUTTERFLIES.

Butterflies may be readily known by their antennæ, which terminate in a knob, and are never either hair-like or pectinate. They are universally abroad during the bright sunlight, never moving at twilight. Butterflies charm us by their gay colors and graceful movements, thus adding beauty and interest to our summer season.

I follow Edwards in the following catalogue;

FAMILY PAPILIONINÆ.

PAPILIO. *Linn.*

Papilio Ajax, Linn. Common.
var. Marcellus, Boisd. & Le C.
P. Philenor, Linn. Not uncommon.
P. Asterias, Fab. Common.
P. Troilus, Linn. Not rare.
P. Turnus, Linn. Abundant.
var.
P. Glaucus, Linn. This black variety of the female is rare here.
P. Cresphontes, Cramer. Occasionally met as far north as Lake Winnebago. The food plant here is the prickly ash.

PIERINÆ.

PIERIS. *Schrank.*

Pieris Protodice, Boisd. & Le C. Common.

P. oleracea, Harris. Abundant,—found but little south of Racine. Food plant mustard mostly.

P. rapæ, Linn. This European cabbage pest came to Wisconsin May, 1879. Common.

NATHALIS. *Boisd.*

Nathalis Iole, Boisd. In Grant county numerous.

CALLIDRYAS. *Boisd.*

Callidryas Eubule, Linn. Some seasons quite common. I have taken at least 50 specimens at Racine.

COLIAS. *Fab.*

Colias Cæsonia, Stoll. Abundant.

C. Eurytheme, Boisd. Numerous. White individuals of this species are not rare.

C. Philodice, Godt. Common.

TERIAS. *Swains.*

Terias Nicippe, Cramer. Accidental. I have taken but two specimens.

T. Lisa, Boisd. Common.

DANAINÆ.

DANAIS. *Latr.*

Danais Archippus, Fab. Everywhere.

NYMPHALINÆ.

ARGYNNIS. *Fab.*

Argynnis Cybele, Godt. Common.

A. Aphrodite, Fab. Abundant.

A. Idalia, Drury. Common on prairies.

A. Alcestis, Edwards. Rather rare.

A. Atlantis, Edwards. Rare.

A. Myrina, Cramer. Common.

A. Bellona, Fab. One of the most abundant species.

EUPTOIETA. *Doub.*

Euptoieta Claudia, Cramer. Common.

MELITÆA. *Fab.*

Melitæa Phaeton, Drury. Rather rare.

PHYCIODES. *Doub.*

Phyciodes Harrisii, Scud. Not common.

P. Nycteis, Doub. Common.

P. Carlota, Reak. Not common.

P. Tharos, Drury. Abundant everywhere.

GRAPTA. *Kirby.*

Grapta Interrogationis, Fab. Common.

G. Comma, Harris. Not common.

G. Progne, Cramer. Abundant.

G. j-album, Boisd. Common.

VANESSA. *Fab.*

Vanessa Antiopa, Linn. Abundant, Common to Europe and America.

V. Milberti, Godt. Not rare.

PYRAMEIS. *Doub.*

Pyrameis Atalanta, Linn. Common.

P. Huntera, Drury. Abundant.

P. Cardui, Linn. Not rare.

JUNONIA. *Doub.*

Junonia Lavinia, Cramer. Not rare. A beautiful species.

LIMENITIS.

Limenitis Ursula, Fab. Common.

L. Proserpina, Edwards. Rare.

L. Arthemis, Drury. Rather rare.

L. Disipus, Godt. Common.

APATURA. *Fab.*

Apatura Celtis, Boisd. Thirty years since found.

A. Clyton, Boisd. Rather rare.

PAPHIA. *West.*

Paphia Andria, Scud. I have taken these specimens at Racine, 1855,—accidental.

SATYRINÆ.

NEONYMPHA. *West.*

Neonympha Eurytris, Fab. Common.

N. Canthus, Linn. Not rare.

DEBIS. *West.*

Debis Portlandia, Fab. Rather common.

SATYRUS. *West.*

Satyrus Nephele, Kirby. Common on prairies.

LIBYTHEINÆ.

LIBYTHEA. *Fab.*

Libythea Bachmanni, Kirt. Once common. Now rather rare.

ERYCININÆ.

CHARIS. *West.*

Charis Borealis, Gr. & Rob. Racine and Waukesha.

LYCÆNIDÆ.

THECLA. *Fab.*

Thecla Melinus, Hübn. Common.
T. Calanus, Hübn. Not rare.
T. Edwardsii, Saund. Common.
T. Acadica, Edwards. Common.
T. Irus, Godt. Rare.
T. Titus, Fab. Common.

LYCÆNINÆ.

CHRYSOPHANUS. *Doub.*

Chyrsophanus Thoe. Boisd. & Le C. Common and variable.
C. Americanus, D'Urban. Common.

LYCÆNA. *Fab.*

Lycæna Scudderii, Edwards. Not rare.
L. Pseudargiolus, Boisd. & Le C. Common.
L. var. Violacea, Edwards. Not rare.
L. Neglecta, Edwards. Abundant, variable.
L. Lucia, Kirby. Not rare.
L. Comyntas, Godt. Rather rare.

HESPERIDÆ. *Leder.*

ANCYLOXYPHA.

Ancyloxypha Numitor, Fab. Numerous in swamps.

THYMELICUS. *Speyer.*

Thymelicus Garita, Reak. Common on prairies.

PAMPHILA. *Fab.*

Pamphila Massasoit, Scud. Common.
P. Zabulon, Boisd. & Le C. Abundant.
P. Sassacus, Scud. Not rare.
P. Metea, Scud. Common.
P. Seminole, Scud. Not rare at Racine.
P. Uncas, Edwards. At Racine. (Prof. Peabody.)
P. Brettus, Boisd. & Le C. Rare.
P. Pontiac, Edwards. Common in a few localities.
P. Otho, Sm. & Abb. Rare.
P. var. Egeremet, Scud. Common form here.
P. Peckius, Kirb. The most abundant species.
P. Mystic, Edwards. Common.
P. Cernes, Boisd. & Le C. Abundant.
P. Metacomet, Harr. Common.
P. Viator, Edwards. Abundant.
P. Vitellius, Smith & Abbott. Rare. Have taken but three.
P. Osyka, Edwards. Rare.
P. Hiaanna, Scud. Common.

AMBLYSCIRTES. *Speyer.*

Amblyscirtes Samoset, Scud. Numerous.

PYRGUS. *West.*

Pyrgus Tessellata, Scud. Some years abundant.

THANAOS. *Boisd.*

Thanaos Icelus, Lint. Not rare.
T. Persius, Scud. Common.
T. Martialis, Scud. Common.
T. Juvenalis, Fab. Not rare.

PHOLISORA. *Speyer.*

Pholisora Catalus, Cramer. Common.

EUDAMUS. *Swains.*

Eudamus Pylades, Scud. Common.
E. Bathyllus, Sm. & Abb. Abundant.
E. Lyciades, Sm. & Abb. Not rare.
E. Tityrus, Fab. Common.

I have all of the above butterflies, taken within ten miles of Racine.

SPHINGIDÆ. *Humming-bird Moths.*

This section includes many large insects. They are stout in body and wing; tongue long, so that these insects can balance the body on wing, while the long tongues are rifling the flowers of their sweet nectar. In these acts the motions resemble the humming-bird's. They are nearly all crepuscular, that is, they fly during twilight. The larvæ are large, generally have sixteen feet, and are mostly ornamented with a conspicuous caudal horn, or an eye-like spot instead. These large worms do considerable damage. All are decidedly noxious.

The following have been taken in Wisconsin, nearly all at Racine:

MACROGLOSSINÆ.

SESIA. *Fab.*

Sesia diffinis, Harris.
S. tenuris, Grote.
S. marginalis, Grote.
S. gracilis, Gr. & Rob.
S. uniformis, Gr. & Rob.
S. Thysbe, Fab.
S. carneicorta, Strecher.

MACROGLOSSA. *Ochs.*

Macroglossa baltæta, Kirt. Rather rare.

THYREUS. *Swains.*

Thyreus Abbottii, Swains. Not rare.
T. Nessus, Cramer. Not common.

DEILEPHILA. *Ochs.*

Deilephila lineata, Harr. Common.
D. Chamænerii, Harr. Not rare.

PHILAMPELUS. *Harr.*

Philampelus satellitia, Harr. (Daphne pondorus, Hübn.)
P. achemon (Drury), Harr.

ARGEUS. *Hübn.*

Argeus labruscæ (Linn), Hübn. Specimens of this rare sphinx have been taken as far north as Green Bay.

METOPSILUS. *Duncan.*

Metopsilus tersa, Linn.

DRAPSA. *Walk.*

Drapsa chœrilus (Cramer), Walk.
D. Myron (Cramer), Walk.

PONIAS. *Hübn.*

Ponias excæcatus (Sm. & Abb.), Hübn.
P. Myops, Hübn.
P. astylus, Drury.

SMERINTHUS. *Latr.*

Smerinthus geminatus, Say.

LOATHŒ. *Fab.*

Loathœ modesta, Harr.

CRESSONIA. *Gr. & Rob.*

Cressonia juglandis (Sm. & Abb.), Gr. & Rob.

MANDUCÆ.

CERATOMIA. *Harr.*

Ceratomia quadricornis, Harr.

DAREMMA. *Walk.*

Daremma undulosa, Walk.

DILUDIA. *Gr. & Rob.*

Diludia jasminearum (Boisd.), Gr. & Rob.

MACROSILA. *Walk.*

Macrosila Carolina (Linn), Clemens.
M. quinquemaculata, Steph.
M. Cingulata (Fab.), Clemens.

SPHINX. *Linn.*

Sphinx drupiferarum, Sm. & Abb.
S. kalmiæ, Sm. & Abb.
S. cinerea Harr. (Lethia chersis, Hübn.)
S. gordius, Cramer.
S. luscitiosa, Clemens.

AGRIUS. *Hübn.*

Agrius eremitus, Hübn.

DOBLA. *Walk.*

Dobla hylæus (Drury), Walk.

DILOPHONOTA. *Brum.*

Dilophonota ello (Linn), Brum.

HYLOICUS. *Hübn.*

Hyloicus plebia (Fab.), Grote.

ELLEMA. *Clemens.*

Ellema Harrisii, Clemens.

ÆGERIDÆ. *Harr.*

ÆGERIA.

Ægeria caudata, Harr.
A. tipuliformis, Linn. Currant borer.

ZYGÆNIDÆ.

Sub-Family HESPERI-SPHINGES. *Latr.*

ALYPIA. *Kirby.*

Alypia MacCullochii, Kirby.
A. octomaculata, Hübn.

EUDRYAS. *Hübn.*

Eudryas unio, Boisd.
E. grata, Harris.

Sub-Family GLAUCOPES. *Walk.*

SCEPSIS. *Walk.*

Scepsis fulvicollis, Hübn.
Ctenucha Virginica, Carp.
Acoloithus falsarius, Clemens.
Harrisina Americana, Pack.
Pyromorpha dimidiata, Herr. Schæff.
Lycomorpha polus, Harris.

BOMBYCIDÆ.

The Bombycidæ include some of the largest and most exquisitely beautiful moths known. They can generally be known by the small sunken head, large stout bodies, short tongue, and pectinate antennæ. This order furnishes, in the larval state, several insects most destructive to our cultivated plants. The larvæ are thick and usually densely covered with hairs. They spin a silken cocoon, which, in some species, is of great economical value for the manufacture of silk goods.

Sub-Family LITHOSINÆ. *Steph.*

HYPOPREPIA *Hübn.*

Hypoprépia fucosa, Hübn.

CLEMENSIA. *Pack.*

Clemensia albata, Pack.

EUPHANESSA. *Pack.*

Euphanessa mendica, Walk.

CROCATA. *Hübn.*

Crocata ferruginosa, Walk.
C. brevicornis, Walk.
C. immaculata, Reak.

UTETHEISA. *Hübn.*

Utetheisa (Deiopeia) bella, Linn. One of the most beautiful of insects.

CALLIMORHPA. *Latr.*

Callimorpha interrupto-marginata, DeB.
C. LeContei, Boisd.
C. fulvicosta, Clem.

EUPREPIA. *Germ.*

Euprepia Americana, Harris.

ARCTIA. *Schk.*

Arctia Virgo, Harr.
A. phalerata, Harr.
A. Anna, Grote.
A. virguncula, Harr.
A. Arge, Harr.
A. Melsheimeri, Grote.
A. Michabo, Grote.

PYRRHARCTIA. *Pack.*

Pyrrharctia Isabella, Smith.

PHRAGMATOBIA. *Steph.*

Phragmatobia rubricosa, Saund.

SPILOSOMA. *Steph.*

Spilosoma Virginica, Walk.
S. Acrea, Drury.

HYPHANTRIA. *Harris.*

Hyphantria punctata, Fitch.
H. cunea, Fitch.

ESPANTHERIA. *Harris.*

Espantheria scribonia, Hübn.

HALSIDOTA. *Hübn.*

Halsidota tesselaris. *Hübn.*
H. caryæ, Harris.
H. maculata, Clemens.

EUCHÆTES. *Hübn.*

Euchætes elge, Harris.
E. Oregonensis.

Sub-Family DASYCHIRÆ. *Hübn.*

ORGYIA. *Oschen.*

Orgyia leucostigma, Harris.

EUCLEA. *Hübn.*

Euclea pænulata, Clemens.

HYGRANTHŒA. *Guen.*

Hygranthœa acifera, Guen.

CALLOCHLORA. *Pack.*

Callochlora vernata, Pack.

PHRYGANIDIA. *Pack.*

Phryganidia Californica, Pack.

THYRIDOPTERYX. *Steph.*

Thyridopteryx ephemæriformis, Steph.

PEROPHORA. *Harris.*

Perophora Melsheimerii, Harris.

ICHTHYURA. *Hübn.*

Ichthyura (clostera) inclusa, Hübn.
I. (c.) albosigma, Fitch.

APATELODES. *Pack.*

Apatelodes torrefacta, Smith.

DATANA. *Walk.*

Datana integerrima, Gr. & Rob.
D. ministra, Drury.
D. angusa, Sm. & Abb.
D. contracta, Walk.
D. perspicia, Gr. & Rob.

GLUPHISIA. *Hübn.*

Gluphisia trilineata, Pack. Racine. Wescott.

NADATA. *Walk.*

Nadata gibbosa, Walk.

NOTODONTA. *Aschen.*

Notodonta stragula, Grote.

EDEMA. *Walk.*

Edema albifrons, Walk.

NERICE. *Walk.*

Nerice bidentata, Walk. Racine. Wescott.

DASYLOPHIA. *Pack.*

Dasylophia anguina. Sm. & Abb.

CŒLODASYS. *Pack.*

Cœlodasys unicornis, Sm. Racine, Geo. Thomas.
C. biguttatus, Pack. Racine, Wescott.

HETEROCAMPA. *Doub.*

Heterocampa albicans, Grote. Racine, Geo. Thomas.

CERURA. *Schr.*

Cerura borealis, Harris.

PLATYPTERYX. *Lasp.*

Platypteryx arcuata, Walk.

DRYOPTERIS. *Grote.*

Dryopteris rosea. Grote.

Sub-Family BOMBYCIDÆ. *West.*

TELEA. *Hübn.*

Telea (Attacus) Polyphemus, Linn.

SAMIA. *Hübn.*

Samia (Attacus) Cecropia, Linn.[1]

CALLASAMIA.

Callasamia (Attacus) Promethia, Drury.[1]

TROPÆA. *Hübn.*

Tropæa (Attacus) luna, Linn.

Sun-Family CERATOCAMPADÆ. *Harris.*

EACLES. *Hübn.*

Eacles imperialis, Drury. Rare.

EUCHRONIA. *Packard.*

Euchronia (Saturnia) Maia, Drury.

HYPERCHIRIA. *Hübn.*

Hyperchiria (Saturnia) Io, Smith.

ANISOTA. *Hübn.*

Anisota (Dryocampa) rubicunda, Hübn.
A. (D.) bicolor.
A. (D.) senatoria, Smith.
A. (D.) bisecta, Lint. (Ms.) Rare.
A. (D.) stigma, Smith.

These two species are American silk-worm moths.

Sub-Family LACHNEIDES. *Hübn.*

GASTROPACHA. *Oschen.*

Gastropacha Americana, Harr

TOLYPE. *Hübn.*

Tolype valleda, Hübn.

CLISIOCAMPA. *Curtis.*

Clisiocampa Americana, Harr. Tent caterpillar.
C. sylvatica, Harris. Forest tent moth.

COSSUS. *Harr.*

Cossus robinæ, Peck.
C. populi, Walk.

GEOMETRIDÆ.

Body long and slender; thorax narrow and weak, never tufted; head small and free; eyes large; antennæ mostly pectinate, sometimes ciliate; wings large in proportion to the small body; legs long. The larvæ are loopers, sometimes called measuring worms,—hence the name *Geometra.* An extensive and interesting family of moths, among which are not a few that are pernicious.

I follow Packard's monograph of the geometridæ, published in Vol. X of Hayden's geological report, 1876—a monument to the author. When we have all insects treated and illustrated in a similar style, the entomology of the United States will stand first among nations.

The following species have all been taken at Racine:

Sub-Family LARENTINÆ. *Pack.*

EUPITHECIA. *Curtis.*

Eupithecia absynthiata, Linn.
E. miserulata, Grote.

PLEMYRIA. *Hübn.*

Plemyra fluviata, Hübn.
P. multiferata, Pack.

THERA. *Steph.*

Thera contractata, Pack.

HYDRIOMENA. *Kirby.*

Hydriomena trifaciata, Pack.

PETROPHORA. *Hübn.*

Petrophora truncata, Pack.
P. hesiliata, Pack.
P. cunigerata, Pack.
P. diversilineata, Hübn.

OCHYRIA. *Hübn.*

Ochyria ferrugaria, Hübn.
O. lacteata, Pack.

RHEUMAPTERA. *Hübn.*

Rheumaptera ruficillata, Pack.
R. intermediata, Pack.
R. lacrustrata, Pack.
R. lugubrata, Pack.
R. hastata, Hübn.

ANTICLEA. *Steph.*

Anticlea vasiliata, Guen.

PHIBALAPTERYX. *Steph.*

Phibalapteryx latirupta, Walk.
P. intestinata, Guen.

HYDRIA. *Hübn.*

Hydria undulata, Hübn.

TRIPHOSIA. *Steph.*

Triphosia dubitata, Steph.

LOBOPHORA. *Curt.*

Lobophora Montanata, Pack.

ODEZIA. *Boisd.*

Odezia albovittata, Guen.

HELIOMATA. *Pack.*

Heliomata infulata, Grote.

HETROPHELPS. *Herr-Schæf.*

Hetrophelps harveiata, Pack.
H. triguttato, Herr-Schæf.

Sub-Family OPEROPHTERINÆ. *Pack.*

OPEROPHTERA. *Hübn.*

Operophtera boreata, Hübn.

ASPILATES. *Treits.*

Aspilates dissimilaria. Guen.

ZERENE. *Treits.*

Zerene Catenaria, Guen.

HÆMATOPSIS. *Hübn.*

Hæmatopsis grataria, Guen.

EUFIDONIA. *Pack.*

Eufidonia notataria, Pack.

FIDONIA. *Treits.*

Fidonia truncataria, Walker.

EMATURGA. *Led.*

Ematurga Faxonii, Pack.

CARIPETA. *Walk.*

Caripeta divisaria, Walk.

LOZOGRAMMA. *Steph.*

Lozogramma defluata, Walk.

EUFITCHIA. *Pack.*

Eufitchia ribearia (Fitch.), Pack.

THAMNONOMA. *Led.*

Thamnonoma subcessaria, Pack.

PSAMMATODES. *Guen.*

Psammatodes eremiata, Guen.

SEMIOTHISA. *Hübn.*

Semiothisa granitata, Pack.
S. eneotata, Pack.
S. bisignata, Pack.
S. ocellinata, Pack.

CORYCIA. *Dup.*

Corycia vertaliata, Guen.
C. semiclarata, Walk.

EUDEILINIA. *Pack.*

Eudeilinia herminiata, Pack.

DEILINIA. *Hübn.*

Deilinia variolaria. Pack.

STEGANIA. *Guen.*

Stegania pustularia, Guen.

Sub-Family ACIDALINÆ. *Steph.*

CALOTHYSANIS. *Hübn.*

Calothysanis amaturaria. Pack.

ASTHENA. *Hübn.*

Asthena albogilvaria. Pack.

ACIDALIA. *Treits.*

Acidalia ossulata, Pack.
A. insulsaria, Guen.
A. nivosara, Guen.
A. inductata, Guen.
A. quadrilineata, Pack.
A. inucleata, Guen.

EPHYRA. *Dupon.*

Ephyra myrtaria, Guen.

Sub-Family GEOMETRINÆ. *Guen*

NEMORIA. *Hübn.*

Nemoria pistaciata. Guen.

SYNCHLORA. *Guen.*

Synchlora rubivoraria. Pack.
S. rubrifrontaria, Pack.

APLODES. *Guen.*

Aplodes rubrifrontaria, Pack.
A. mimosaria, Guen.

GEOMETRA. *Linn.*

Geometra iridaria, Guen.

Sub-Family BOARMINACE. *Guen.*

PHIGALIA. *Dupon.*

Phigalia strigataria, Pack.

HYBERNIA. *Latr.*

Hybernia tiliaria, Harr.

AMPHIDASIS. *Treit.*

Amphidasis guernaria, Sm. & Abb.
A. cognataria, Guen.

PARAPHIA. *Guen.*

Paraphia deplanaria, Guen.

TEPHROSIA. *Boisd.*

Tephrosia cognataria, Pack.
T. cribrataria, Pack.
T. canadaria, Guen.

CYMATOPHORA. *Hübn.*

Cymatophora plumosaria, Pack.
C. pampinaria, Pack.
C. Humaria, Pack.
C. larvaria, Guen.
C. umbrosaria, Hübn.

HEMEROPHILA. *Steph.*

Hemerophila unitaria, Herr-Schæf

CLEORA. *Curt.*

Cleora pulchraria, Minot.

BORMIA. *Walk.*

Bormia creposcularia, Guen.

Sub-Family ENNOMINÆ. *Guen.*

HYPERETIS. *Guen.*

Hyperetis nyssaria, Guen.

PLAGODIS. *Hübn.*

Plagodis phlogosaria, *Pack.*
P. fervidaria, Herr-Schæf.
P. Keutzingaria, Grote.

NEMATOCAMPA. *Guen.*

Nematocampa filamentaria, Guen.

ANGERONA. *Dupon.*

Angerona crocataria, Fab.

SICYA. *Guen.*

Sicya macularia, Harr.

ANTEPIONE. *Pack.*

Antepione sulphurata, Pack.

ANAGOGA. *Hübn.*

Anagoga pulveraria, Hübn.

METROCAMPA. *Latr.*

Metrocampa perlaria, Guen.

THERINA. *Hübn.*

Therina fervidaria, Hübn.

ENDROPIA. *Guen.*

Endropia apicirasia, Pack.
E. hypochraria, Herr-Schæf.
E. marginata, Pack.
E. armataria, Pack.
E. bilinearia, Pack.
E. effeetaria, Walk.
E. obtusaria, Guen.
E. serrataria, Pack.

AZELINA. *Guen.*

Azelina Hübnerata, Guen.

EUGONIA. *Hübn.*

Eugonia subsignaria, Pack.
E. alniaria, Hübn.

CABERODES. *Guen.*

Caberodes cayennaria, Pack.

METANEMA. *Guen.*

Metanema inatomaria, Guen.
M. quercivoraria, Guen.

TETRACIS. *Guen.*

Tetracis lorata, Grote.
T. crocallata, Guen.

EUTRAPELA. *Hübn.*

Eutrapela transversata, Pack.
E. clematata.

II. A LIST OF THE NOCTUIDÆ OF WISCONSIN.

BY P. R. HOY, M. D.

The moths of this large family may be known by their stout bodies, their rather narrow upper wings and broad secondaries. The palpi are well developed, the antennæ simple, rarely slightly pectinate. They all fly in the night, and are attracted by light. Their love of sweets enables us to attract them to their destruction. The larvæ of the Noctuidæ are smooth, or only slightly hairy. Many are very injurious to trees and plants. Several species of army worms, and a host of cut-worms belong to this section.

The moths of the three closely allied genera, Agrotis, Hadena, and Mamestra, are especially interesting to all, in consequence of their depredations on cultivated plants.

In order to enable almost anyone to know these moths, I append Grote's concise analysis of these genera. They differ as follows: "Eyes naked, without lashes; thorax without divided dorsal, longitudinal, or posterior scale tufts; abdomen untufted; middle and hind tibias always, fore tibia sometimes, with spines. AGROTIS.

"Eyes naked, without lashes. Thorax with divided dorsal, longitudinal, and posterior tufts; abdomen more or less distinctly tufted, all the tibia unarmed. HADENA.

"Eyes hairy; thorax with dorsal and posterior tufts; abdomen more or less distinctly or entirely tufted. All the tibia unarmed." MAMESTRA.

NOCTUO-BOMBYCINI. *Boisd.*

BOMBYCIA. *Hübn.*

Bombycia caniplaga. Walk.

LEPTINA. *Guen.*

Leptina dormitans. Guen.

PSEUDOTHYATIRA. *Grote.*

Pseudothyatira cymatophoroides. Guen.

P. expultrix. Grote.

THYATIRA. *Ochs.*

Thyatira pudens. Grote.

NOCTUA. *Linn.*

RAPHIA. *Hübn.*

Raphia frater. Grote. Racine, Wescott.

CHARADRIA. *Walk.*

Charadra devidens. Guen.

MOMA. *Hübn.*

Moma Orion. Esper. Racine, Geo. Thomas.

M. falax. Herr.

ACRONYCTA. *Ochs.*

Acronycta tritona. Hübn.

A. occidentalis. Gr. & Rob.

A. morula. Gr. & Rob.

A. lobeliæ. Guen.

A. lepusculina. Guen.

A. inotata. Guen.

A. Americana. Harris.

A. euteicoma. Gr. & Rob.

A. brumoso. Guen.

A. superans. Guen.

A. Clarescens. Guen.

A. ovata. Grote.

A. hamamelis. Guen.

A. noctivega. Grote.

A. dissecta. Gr. & Rob.

A. oblinita. Sm. & Abb.

A. Harveyana. Grote.

JASPIDEA. *Hübn.*

Jaspidea lepidula. Grote.

J. palliatricula. Guen.

J. fragilis. Guen.

J. diphteroides. Guen.

J. lepidrela. Grote.

LITHOCODIA. *Hübn.*

Lithocodia bellicula. Hübn.

CERENA. *Hübn.*

Cerema Cora. Hübn.

POLYGRAMMATE. *Hübn.*

Polygrammate hebraicum. Hübn.

AGROTIS. *Grote.*

Agrotis sigmoides. Guen.
A. triangulum. Hub.
A. baja. Sm. & Abb.
A. badinoides. Grote.
A. C-nigrum. Linn.
A. bicarnea. Guen.
A. herilis. Grote.
A. subgothica. Haw.
A. sexatilis. Grote.
A. plecta. Linn.
A. vittifrons, Grote.
A. decolor, Morris.
A. Laurea, Guen.
A? gladiora, Morris.
A. stigmata, Harvey.
A. fennica, Touscher.
A. pitychrous, Grote.
A. tessellata, Harris.
A. scandens, Riley.
A. clandestina, Harris.
A. brunneicollis, Grote.
A. lubricans, Guen.
A. alternata, Grote.
A. ingeniculata, Grote.
A. Cupida, Grote.
A. nepeilis, Grote.
A. Morrisonia, Riley.
A. Chenopodii, Morris.
A. saucia, Hübn.
A. velleripennis, Grote.
A. messoria, Harris.
A. incivis, Guen.
A. suffusa, S. & V.
A. venerabilis, Walk.
A. lubricans, Guen.
A. normanius, Guen.
A. ingeniculata, Grote.
A. Cochrani, Riley.
A. devartor, Harris.

GRAPHIPHORA. *Guen.*

Graphiphora incerta, Morrison.
G. oviduca, Morrison.
G. modipia, Morrison.

EUROIS. *Hübn.*

Eurois occulta, Hübn.
E. herbacea, Guen.
E. astricta, Morris.
E. pressa, Grote.

MAMESTRA. *Ochen.*

Mamestra parpurissata, Grote.
M. latex, Guen.
M. grandis, Boisd.
M. Chenopodii, Sh. V.
M. legitima, Grote.
M. adjuncta, Grote.
M. vicina, Grote.
M. trifolia, Grote.
M. detracta, Walk.
M. Atlantica, Grote.
M. distincta, Grote.
M. olivacea, Morris.
M. dysodea, Grote.
M. lorea, Guen.
M. imbiferra, Guen.
M. suffusca, Morris.
M. obliquata, Grote.
M. Rosea, Grote.

DIANTHŒCIA. *Boisd.*

Dianthœcia meditata, Grote.
D. modesta, Morris.

POLIA. *Hübn.*

Polia leucoscelis, Grote.
P. confragosa, Grote.
P. atricornis, Grote.

LAMPROSTICTA.

Lamprosticta Cora. Hübn.

HOMOHADENA. *Grote.*

Homohadena badistriga, Grote.

CHYTONIX. *Grote.*

Chytonix jaspis, Guen.

HADENA. *Schrank.*

Hadena Bridghami, Gr. & Rob.
H. arctica, Boisd.
H. atriplices, Guen.?
H. devastator, Brace.
H. impulsa, Guen.
H. adjuncta, Boisd.
H. apamiformis, Guen.
H. rurea, Fab.

Hadena sputator, Grote.
H. lignicolor, Guen.
H. verbascoides, Guen.
H. sectillis, Guen.
H. cariosa, Guen.
H. mactata, Guen.
H. modica, Guen.
H. miselioides, Guen.
H. fractilinea, Grote.
H. vulgaris, Grote.
H. suffusca, Morris.
H. gemina, Hübn.
H. vulgaris, Morris.
H. vultuosa, Grote ?
H. sera, Guen.
H. grandis, Grote.
H. miseloides, Guen. ?
H. arna, Guen.
H. herbimaculata, Guen.

PERIGEA. *Guen.*

Perigea fabrefactta, Morrison.
P. xanthioides, Guen.

DIPTERYGIA. *Steph.*

Dipterygia pinastri, Linn.
D. scrabensenta, Linn.

HYPPA. *Dup*

Hyppa xylinoides, Guen.

ACTINOTIA. *Hübn.*

Actinotia ramosula, Guen.
A. vomerina, Grote.

CALLOPISTRIA. *Hübn.*

Callopistria mollissima, Guen.

PRODENIA. *Guen.*

Prodenia flavimedia, Harvey.

EUPSEPHOPÆCTES. *Grote.*

Eupsephopæctes procinetus, Grote. Racine, Wescott.

PHLOGOPHORA. *Guen.*

Phlogophora periculosa, Guen.

EUPLEXIA. *Steph.*

Euplexia lucipara, Linn.

BROTOLOMIA. *Leder.*

Brotolomia iris, Guen.

NEPHELODES. *Guen.*

Nephelodes violans, Guen.

HELOTROPHA. *Leder.*

Helotropha reniformis, Grote.
H. atrata, Grote.

HYDRŒCIA. *Guen.*

Hydrœcia nictitans, Linn.
H. sera, Gr. & Rob.
H. cognita, Grote.
H. cognivaria, Guen.
H. metilans, Grote.

GORTYNA. *Hübn.*

Gortyna immanis, Guen.
G. limpida, Guen.
G. rutila, Guen.
G. nebris, Guen.
G. nitela, Guen.
G. cataphhracta, Grote.
G. cerussata, Grote.

TRICHOLATA. *Grote.*

Tricholata semiaperta, Grote.

ACHATODES. *Guen.*

Achatodes zeæ, Harris.

PLATYSENTA. *Grote.*

Platysenta atriciliata, Grote.

LEUCANIA. *Hübn.*

Leucania Henrici, Grote.
L. eranidum, Grote.
L. adonia, Grote.
L. pallens, Linn.
L. Harveyi, Grote.
L. rubripennis, Gr. & Rob.
L. commoides, Guen. Racine, Wescott.
L. unipuncta, Harr.
L. pseudargyria, Guen.

LAPHYGMA. *Guen.*

Laphygma frugiperda, Abb. & Sm. Autumn army worm.
L. var. autumnalis, Morris.

CARADRIA. *Och.*

Caradria fillicolaris, Morris.

PYROPHILA.

Pyrophila pyramidoides, Guen.

TÆNEIOCAMPA. *Guen.*

Tæneiocampa oviduca, Guen.
T. incerta, Hufnel.
T. modifica, Morris.

ORTHODES. *Guen.*

Orthodes infirma, Guen.
O. cynica, Guen.

ANOMIS. *Hübn.*

Anomis erosa, Hübn.

ALETIA. *Hübn.*

Aletia argillacea, Hübn. Cotton worm.

CALYMNIA. *Hübn.*

Calymnia orina, Guen.

ETETHMIA. *Hübn.*

Etethmia pampina, Guen.

ORTHOSIA. *Osch.*

Orthosia viatica, Grote.
O. inulta, Grote.
O. apiata, Grote.
O. nelra, Grote.
O. rufago, Hübn.
O. ferruginoides, Hübn.
O. togata, Esp.
O. aurantiago, Guen.
O. helva, Grote.

GLORIA. *Hübn.*

Gloria viatica, Grote.

GLÆA. *Hübn.*

Glæa postilicans, Morris.
G. inulta, Grote.
G. venustula, Grote.

SCAPELOSOMA. *Curt.*

Scapelosoma græflana, Gr. Geo. Thomas.
S. ceromatica, Grote. Geo. Thomas.
S. vinulenta, Grote.
S. Morrisoni, Grote.
S. Walkeri, Grote.
S. sidus, Guen.
S. tristigmata, Grote.

XYLINANA.

LITHOPHANE. *Hübn.*

Xylina petulca, Grote
X. ferrealis, Grote.
Xylina siguosa, Walk.
X. Bethunei, Gr. & Rob.
X. semiusta, Grote.
X. fagina, Morris.
X. disposita, Morris.
X. Thaxteri, Morris.
X. auriundum, Grote.
X. cinera, Riley.
X. laticinerea, Grote. Doubtful sp.
X. tepida, Grote. Doubtful sp.
X. querquera, Grote.
X. pexata, Grote.
X. sculptus, Grote.

SCOLIOPTERYX. *Germ.*

Scoliopteryx libatrix, Linn.

CALOCAMPA. *Steph.*

Calocampa nupera, Lint.
C. cineritea, Grote.
C. curvimacula, Morris.

XYLOMIGES. *Guen.*

Xylomiges confusa, Hübn.

CUCULLIA. *Schrank.*

Cucullia convexipennis, Gr. & Rob.
C. asteroides, Guen.
C. postera, Guen.
C. intermedia, Speyer.

CRAMBODES. *Guen.*

Crambodes talidiformis, Guen.

INGURA. *Guen.*

Ingura abrostoloides, Guen. Geo. Thomas.
I. occullatrix, Guen.

TELESILLA. *Ochs.*

Telesilla cinereola, Guen.

PLUSIA. *Fab.*

Plusia ærea, Hübn.
P. balluca, Geyer.
P. contexta, Grote.
P. Putnami, Grote.
P. biloba, Steph.
P. verruca, Fab.
P. precationis, Guen.
P. simplex, Guen.
P. ou, Guen.
P. gamma, Linn.

Plusia brassicæ, Riley.
P. festuca, Guen.
P. viridisigma, Grote.
P. dyans, Grote.
P. oxygramma, Geyer.
P. mortuorum, Guen.
P. 8-scripta, Sanborn.
P. ampla, Walker.
P. U-aureum, Boisd.
P. purpurigera, Walker.

PLUSIODONTA. *Hübn.*

Plusiodonta compressipalpis, Guen.

CALPE. *Treis.*

Calpe canadencis, Beth.

CHLORIDEA. *West.*

Chloridea subflexa, Guen.

ALARIA. *West.*

Alaria gauræ, Sm. & Abb.

RODOPHORA. *Guen.*

Rodophora florida, Guen.

LYGRANTHŒCIA. *Gr. & Rob.*

Lygranthœcia Spraguei, Grote.

MELICLEPTRIA. *Hübn.*

Melicleptria, Hoyi, Grote.

HELIOTHIS. *Hübn.*

Heliothis phlogophagus, Gr. & Rob.
H. armigera, Hübn.
H. lucida, Dome.

PYRRHIA. *Hübn.*

Pyrrhia exprimens, Walker.
P. angulata, Grote.

TARACHE. *Hübn.*

Tarache erastrioides, Guen.
T. candefacta, Hübn.
T. binoculata, Grote.

GALGULA. *Guen.*

Galgula hepara, Guen.
G. subpartita, Guen.

XANTHOPTERA. *Guen.*

Xanthoptera nigrofimbria, Guen.

ERASTRIA. *Guen.*

Erastria albidula, Guen.
E. carneola, Guen.
E. synochitis, Gr. & Rob.
E. nigritula, Guen.
E. muscosula, Guen.

CHAMYRIS. *Guen.*

Chamyris cerintha, Fr.

DRASTERIA. *Hübn.*

Drasterea erichtea, Cramer.
D. media, Sprague.

EUCLIDIA. *Hübn.*

Euclidia caspidea, Hübn.

PARALLELIA. *Hübn.*

Parallelia bistriaria, Hübn.

PHURYS. *Guen.*

Phurys vinculum, Guen.

CELIPTERA. *Guen.*

Celiptera frustulum, Guen.

STICTOPTERA. *Guen.*

Stictoptera divaricata, Grote.

SYNEDA. *Guen.*

Syneda limbolaris, Geyer.
S. graphica, Hübn.
S. Edwardsii, Behr.

BOLINA. *Dup.*

Bolina nigrescens. Gr. & Rob.

ALLOTRIA. *Hübn.*

Allotria elonympha, Hübn.

HYPOCALA. *Guen?*

Hypocala Hilli, Lint.

PARTHENOS. *Hübn.*

Parthenos nubilis, Hübn.

CATOCALA. *Schrank.*

Catocala Epione, Drury.
C. insolabilis, Guen.
C. residua, Grote.
C. obscura, Streck.
C. viduata, Guen.
C. desperata, Guen.
C. retecta, Gr.
C. flebilis, Gr.

Catocala relicta, Walk.
C. unijuga, Walk.
C. Meskei, Grote.
C. Briseis, Edwards.
C. Faustina, Streck.
C. parta, Guen.
C. coccinata, Grote.
C. ultronia, Hübn.
C. concubens, Walk.
C. amatrix, Hübn.
C. var. nurus, Walk.
C. cara, Guen.
C. Ilia, Cramer.
C. innubens, Cramer.
C. var. scintillans, Gr. & Rob.
C. cerogama, Guen.
C. neogama, Guen.
C. subnata, Grote.
C. piatrix, Grote.
C. palœgama, Guen.
C. var. phalanga, Grote.
C. habilis, Grote.
C. consors, Sm. & Abb.
C. abbreviatella, Grote.
C. ponderosa, Gr. & Rob.
C. muliercula, Guen. Prof. Peabody.
C. badia, Gr. & Rob.
C. abrevitella, Grote.
C. antinympha, Hübn.
C. Levettei, Grote.
C. Whitneyi, Grote.
C. serena, Edwards.
C. Clintoni, Grote.
C. nuptialis, Walk.
C. polygama, Guen.
C. formula, Gr. & Rob.
C. Grynea, Cramer.
C. fratercula, Gr. & Rob.
C. gracilis, Edwards.
C. androphilia, Guen.
C. lineella, Grote.

Forty-seven species, all taken within two miles of Racine. Is there another point equally rich in *Catocalas?*

PONOPODA. *Guen.*

Ponopoda rufimargo, Hübn.
P. carneicosta, Guen.

REMIGIA. *Guen.*

Remigia latipes, Guen.

ANTICARSIA. *Hübn.*

Anticarsia gemmatalis, Hübn.

EREBUS. *Latr.*

E. rebus odora, Linn.
E. Zenobia, Linn. Male and female taken at Racine, Sept. 6th and 15th, 1871. This magnificent insect is a native of Costa Rica, and this is the second time it has been taken in the United States — another evidence of the southern peculiarity of the insect-fauna of Wisconsin.

HOMOPTERA. *Boisd.*

Homoptera lunifera, Hübn.
H. lunata, Dewey.
H. Saundersii, Beth.
H. Edusa, Drury. These three species are probably one.
H. calycanthata, Abb. & Sm.
H. obliqua, Guen.
H. involuta, Walk.
H. unilinea, Grote.
H. Woodii, Grote.

YPSIA. *Guen.*

Ypsia æruginosa, Guen.
Y. undularis, Drury.
Y. coracias. Guen.

ZALE. *Hübn.*

Zale horrida, Hübn.

PSEUDAGLOSSA. *Grote.*

Pseudaglossa lubricalis, Geyer. Wescott.

EPIZEUXIS. *Hübn.*

Epizeuxis Americalis, Guen.
E. æmulalis, Hübn.

MEGACHYTA. *Grote.*

Megachyta deceptricalis, Zeller.

LITOGNATHA. *Grote.*

Litognatha nubilifacia, Grote.
L lithophora, Guen.

CHYTOLITA. *Grote.*

Chytolita morbidalis, Guen.

ZANCLOGNATHA. *Led.*

Zanclognatha lævigata, Grote.

PHILOMÊTRA. *Grote.*

Philometra serraticornis, Grote.
P. longilabris, Grote.

PHALÆNOPHANA.

Phalænophana rurigena, Grote
P. umbrifacia, Grote.

RENIA. *Guen.*

Renia discoloralis, Guen.
R. Belfragei, Grote.

BLEPTINA. *Guen*

Bleptina caradrinalis, Guen

RIVULA. *Guen.*

Rivula propinqualis, Guen.

BOMOLOCHA. *Hübn.*

Bombolochia scutellaris, Grote.
B. Baltimoralis, Guen.
B. abalinealis, Walk.
B. deceptalis, Walk.
B. profecta, Grote.
B. lactulus? Grote.
B. perangulata, Harvey.

HYPENA. *Schrank.*

Hypena evanidalis, Robinson.
H. humuli, Harris.
H. citata, Grote.
H. scabra, Feb.

MORRISONIA. *Grote.*

Morrisonia vomerina, Grote.

The Pyralidæ, Tortricidæ and the Teneidæ, found in Wisconsin, are in such a state that it was thought best not to catalogue these families of small moths at this time.

CHAPTER IX.

CATALOGUE OF THE COLD-BLOODED VERTEBRATES OF WISCONSIN.

By P. R. Hoy, M. D.

In presenting the following catalogues of the cold-blooded vertebrates of Wisconsin,— Reptiles, Amphibians and Fishes — I have followed nearly the classification adopted by Jordan in his recently-published "Manual of the Vertebrates of the Northern States." I do this because of the excellence of the work, which I believe will eventually occupy the place in zoölogy which "Gray's Manual" holds in botany. Where there is no name affixed as authority for a species occurring within the state, Hoy is to be understood.

I. REPTILES.

Reptiles are cold-blooded, air-breathing vertebrates, having an imperfect double circulation,— a three-chambered heart. All reptiles are covered either with scales or plates; lungs large; eyes protected by lids; eggs large, covered with calcareous or leathery shells, numerous, and deposited at one time. The young are never produced in water, and undergo no metamorphosis.

Reptiles are mostly inhabitants of hot countries, and are related to birds, sometimes being classed with them under the group *Sauropsida.*

TESTUDINATA. Turtles.

These animals are covered with a natural armor, which may be considered as a portion of the osseous frame-work thrown outside of the body so as to constitute a kind of box, enclosing and protecting the muscles and viscera. This box is composed of two parts, covered with plates or leathery shields.

CISTUDO. Fleming.

Cistudo ornata (Agassiz). Northern Box Turtle. Grant county; rare.

EMYS. Brogniart.

Emys meleagris (Ag.). Blanding's Tortoise. Abundant on prairies.

CHRYSEMYS. Gray.

Chrysemys marginata (Ag.). Western Painted Turtle. Abundant everywhere. Probably this is a western form of *C. picta* of the eastern states.

MALACOCLEMMYS. Gray.

Malacoclemmys geographicus (Le Sueur). Moss Turtle. Grant county; rare.
M. pseudogeographicus (Holbrook). Le Sueur's Moss Turtle. Grant county; not rare.

AROMOCHELYS. Gray.

Aromochelys odoratus (Latreille). Musk Turtle. Grant county; rare.

CHELYDRA. Schweigger.

Chelydra serpentina (Linnæus). Common Snapping Turtle. Abundant everywhere.

MACROCHELYS. Gray.

Macrochelys lacertina (Schw.). Loggerhead Snapper. This ferocious turtle is occasionally found in the Mississippi river as far north as the mouth of the Wisconsin.

ASPIDONECTES. Wagler.

Aspidonectes spinifer (Le Sueur). Common Soft-shelled Turtle. Western part of the state; not rare.

AMYDA. Agassiz.

Amyda mutica (Le S.). Leathery Turtle. All the tributaries of the Mississippi river within the state; common.

LACERTILIA. Lizards.

Body usually covered with overlapping scales; mouth not dilatable; jaws always with teeth; feet usually with five digits; tail long, and readily broken by a slight blow; vent, a cross slit. The great majority of lizards belong to tropical or sub-tropical countries. Lizards watch over their eggs until hatched.

EUMECES. Wiegmann.

Eumeces septentrionalis (Baird). Northern Blue-tailed Skink. Not uncommon as far north as Lake Winnebago.

SCELOPORUS. Wiegmann.

Sceloporus undulatus (Harlan). Pine Tree Lizard. I have one specimen, sent from Lafayette county in 1850, which is the only one I have seen from the state.

OPHEOSAURUS. Dandin.

Opheosaurus ventralis (L.). Glass Snake. The limbs of the Glass Snake are rudimentary, covered by the skin, giving this remarkable reptile a serpentine appearance, although it is a true lizard. In early days they were not uncommon near Kenosha. They occur in the western part of the state as far north as La Crosse.

OPHIDIA. Serpents.

Body greatly elongated; limbs wanting; mouth dilatable; jaws articulated by elastic ligaments, so that a snake can easily swallow a body of greater circumference than its own.

FAMILY COLUBRIDÆ. Non-venomous Snakes.

A large family, embracing eighteen species inhabiting Wisconsin.

They can be recognized by the plates being in two rows from the vent to the end of the tail. No poisonous snakes of North America have this characteristic.

HETERODON. Beauvais.

Heterodon platyrhinus (Latreille). Blowing Adder. Dry, sandy locations. Not uncommon in the southwestern counties. A serpent of threatening looks but harmless.

H. simus (L.). Hog-nosed Viper. Found in dry, sandy locations.

TROPIDONOTUS. Kuhl.

Tropidonotus sipedon (L.). Spotted Water Snake. Abundant; they destroy many fish.

T. leberis (L.). Striped Water Snake.

T. Grahami (Baird & Girard). Graham's Snake. Resembles the *leberis;* a small, active water snake.

TROPIDOCLONIUM. Cope.

Tropidoclonium Kirtlandi (Kennicott). Kirtland's Red Snake. One specimen taken on the border of Wisconsin, near Fox river.

STORERIA. B. and G.

Storeria occipitomaculata (Storer). Red-bellied Snake. Abundant.

S. Dekayi (Holbrook). De Kay's Brown Snake. Common.

EUTÆNIA. B. and G.

Eutœnia Faireyi (B. and G.). Fairie's Garter Snake. Grant county.

E. proxima (Say). Say's Garter Snake. Southern counties.

E. radix (B. and G.). Hoy's Garter Snake. Abundant in vicinity of Racine.

E. sirtalis (L.). Common Garter Snake. Abundant; found as far north as the shores of Lake Superior.

BASCANIUM. B. and G.

Bascanium constrictor (L.). Blue Racer. Occasionally met in southwestern counties.

PITYOPHIS. Holbrook.

Pityophis Sayi (Schlegel). Western Pine Snake. A large species. In early days it was common in the western part of the state; now rare. This species reaches six feet in length.

SCOTOPHIS. B. and G.

Scotophis Alleghaniensis (Holbrook). Black Snake. Inhabits heavy-timbered districts and is partly arboreal; destroys great numbers of young birds. It is the largest snake found in the United States, and attains a length of six and one-half feet. It can swallow squirrels and even rabbits.

S. vulpinus (B. and G.). Fox Snake. This species is frequently called Rattlesnake's mate, or Copperhead, and is ignorantly supposed to be poisonous. It is harmless and docile when tamed. Common on prairies.

LIOPELTIS. Fitzinger.

Liopeltis vernalis (De Kay). Green Snake. A common, beautiful species.

OPHIBOLUS. B. and G.

Ophibolus eximia (De Kay). Milk Sucker. Common.

FAMILY CROTALIDÆ. Poisonous Snakes.

Upper jaw destitute of solid teeth, but provided instead with erectile grooved fangs. All our venomous species are provided with rattles, and hence can be easily recognized. All are thick, sluggish snakes, and, so far as I can ascertain, ovoviviparous.

CROTALUS. L.

The genus *Crotalus* embraces the most deadly poisonous serpents known.

Crotalus durissus (Anct.). Yellow Rattlesnake. These rattlesnakes inhabit rocky ledges, in the crevices of which they seek a good retreat to hibernate. They were so numerous thirty years ago in the vicinity of Devil's Lake, that it was extremely hazardous to clamber among the rocks. On all the bluffs of the Wisconsin and Mississippi rivers they were formerly extremely numerous, and are still common.

CROTALOPHORUS. Laurenti.

Crotalophorus tergemina (Say). Massassauga. This species inhabits marshy, grassy prairies where meadow mice live, on which they almost exclusively subsist. Their bite is not fatal, but causes great swelling and irritation. They are becoming rare, but were once abundant.

II. AMPHIBIANS.

Cold-blooded vertebrates allied to fishes, sometimes considered jointly under the term *Ichthyopsida.* Amphibians with few exceptions undergo a complete metamorphosis. Body covered with smooth skin which is structurally fitted to assist in aerating the blood. The small, soft eggs are deposited in water. The young, tadpoles, begin life provided with branchia and a two-chambered heart like fishes. As they advance the gills are absorbed, lungs are developed, a third ventricle is added to the heart, and in their perfect condition they leave the water air-breathers.

ANURA. Tailless Batrachians, Frogs and Toads.

The tadpoles have covered gills. During their transformation the hinder feet are developed first. Hind legs large and muscular, organized for leaping. The tail of the tadpole is not dropped, as commonly supposed, but absorbed to the nourishment of the body.

FAMILY RANIDÆ. Frogs.

RANA. Linnæus.

Rana halecina (Kalm.). Leopard Frog. Common throughout the state.

R. fontinalis (Le Conte). Green Frog. A large, common species.

R. sylvatica (Le C.). Wood Frog. Abundant.

R. pipiens (Ant.). Bull Frog. Common and well known on account of his rich bass voice.

R. nigricans (Agassiz). Black Frog. Prof. Agassiz determined a specimen caught at Racine as the nigricans; rare.

FAMILY HYLIDÆ. Tree Frogs

HYLA. Laurenti.

Hyla versicolor (Le Conte). Common Tree Toad. Abundant.

H. Pickeringii (Holbrook). Pickering's Tree Toad. Abundant. The clicking made by this Tree Toad is like the striking of two pebbles together. He might well be called the Castanet Tree Toad.

CHOROPHILUS. Baird.

Chorophilus triseriatus (Wied.). Striped Tree Frog. Common.

C. maculatus (Agassiz). Spotted Tree Frog. Found on Lake Superior.

FAMILY. BUFONIADÆ. Toads.

BUFO. Laurenti.

Bufo Americanus (Le C.). Common Toad. A common and beneficial animal.

URODELA. *Salamanders.*

The tailed Batrachians have naked bodies; four legs organized for walking. Tail persistent. In the tadpole stage they have conspicuously fringed external gills, which they lose at maturity. During their metamorphosis the fore legs are developed first. The adults have no gills — are strictly pulmonates. They are generally sluggish, harmless animals, which inhabit damp and shady locations. They devour large numbers of worms and slugs and are mostly nocturnal in their habits.

FAMILY PLEURODELIDÆ.

DIEMYCTYLUS. Rafinesque.

Diemyctylus viridescens (Raf.). Spotted Triton. Found in ponds and brooks.
D. miniatus (Raf.). Red Evet. Found with above.

FAMILY PLETHODONTIDÆ.

HEMIDACTYLIUM. Tschudi.

Hemidactylium scutatum (Schlater). Four-toed Salamander. Found at Racine.

PLETHODON. Tschudi.

Plethodon glutinosus (Green). Viscid Salamander. Found at Racine.

SPELERPES. Rafinesque.

Spelerpes bilineatus (Green). Two-striped Salamander. Found at Racine.
S. longicandus (Green). Cave Salamander. Found at Racine.
S. ruber (Dandin). Red Triton. Found at Racine.

FAMILY AMBLYSTOMIDÆ.

AMBLYSTOMA. Tschudi.

Amblystoma opacum (Gravenhorst). Opaque Salamander. Found at Racine.
A. punctatum (L.). Large Spotted Salamander. Found at Racine.
A. Jeffersonianum (Green). Jefferson's Salamander. Found at Racine.
A. luridum (Sager). The Great Salamander. This is probably the largest Salamander found in the United States.

All the Uridellæ in the above catalogue I have taken within a few miles of Racine, and have in my cabinet. Thirty years ago, when I studied this group, we could hardly turn over an old log in the swamp and heavily-timbered district without disturbing some species of Salamander. Now but few are left.

PROTEIDA.

Tailed Amphibians, provided with bushy external gills, which are persistent during life. Lungs rudimentary. These curious animals resemble the tadpole of the Salamander, hence they are the lowest of the Amphibians, and close to fishes.

NECTURUS. Rafinesque. Mud Puppies.

Necturus lateralis (Say). Mud Puppy. Found in abundance in most streams and lakes of the state. They are ignorantly supposed to be poisonous and are the subject of many ridiculous newspaper accounts. The Mud Puppies do considerable damage by eating the spawn of various fishes. The Mud Puppy is strictly aquatic, never leaving the water; in fact, many fishes can survive longer when taken from their native element.

III. FISHES.

Fishes are cold-blooded vertebrates, having fins as organs of progression. They have a two-chambered heart, corresponding to the right side of the heart of warm-blooded animals. Their bodies are mostly covered with scales, yet a few are entirely naked, like the catfish. Others, again, as the sturgeons are covered with curious plates.

In most fishes there is a swimming bladder, situated near the back, which is homologous to the lungs in the higher vertebrates. When present it serves an important purpose by enabling the fish to vary its specific gravity and thus to float at any desired elevation in the water.

The sides of most fish exhibit a longitudinal row of scales, in each of which is a perforation.

This series of openings forms what is know as the *lateral line.* The researches of Prof. L. Agassiz have shown that these holes are openings into tubes, which, together with similar ones on the head, permeate all parts of the body, brain, muscles, bones and viscera, freely admitting water, thus equalizing the pressure without and within. Fishes have no external ear, and hence it is doubtful if they can hear at all. They are exceedingly prolific under favorable conditions. Fresh water fishes are more universally edible than those inhabiting salt water, and, as a rule, the cooler and purer the water the better the fishes.

Wisconsin has, perhaps, the best facilities for fish culture of any state in the union. There are not less than eighteen hundred lakes within the state. These lakes cover some fourteen hundred square miles. The state has on the east and north the greatest bodies of fresh water on the globe, and on the west the "Great River."

In addition there are many rivers traversing the state. In consequence of most of these being tributaries of the Mississippi, numbers of southern forms of fish find their way into Wisconsin.

It gives me pleasure to acknowledge my great obligations to Prof. David S. Jordan, as well as to the lamented Copeland, for valuable assistance in determining species.

SUB-ORDER ACANTHOPTERI. Spiney-rayed Fishes.

Family Etheostomidæ. Darters.

Fish of small size; body elongated, not compressed; a ground fish having no swimming bladder. They frequent clear, running water, with sandy and pebbly bottom, and move about with a jumping motion, frequently resting among the stones on their large pectorals and rigid ventral fins. Most of the species are remarkable for their beautiful display of colors.

PŒCILICHTHYS. Agassiz.

Pœcilichthys variata (Kirtland). Blue Darter. A beautiful fish. Found in several cool spring brooks in Racine county, and at Nine Springs, Dane county.

P. spectabilis (Agassiz). Striped Blue Darter. Found in cool brooks in Racine county. Somewhat rare.

P. punctulatus (Agassiz). Dotted Darter. Not uncommon at the rapids near Racine.

P. lineatus (Agassiz). Striped Darter. Common.

P. flabellatus (Rafinesque). Fan-tailed Darter. Found in Fox river.

P. punctulata (Putnam). Least Darter. Common in Racine county. This fish is, perhaps, the smallest spiney-rayed fish known.

BOLEICHTHYS. Girard.

Boleichthys exilis (Girard). Red-sided Darter. Rock and Fox rivers.

B. eas (Jordan & Copeland). Copeland's Darter. Abundant in Brown's lake, on the shores of Island Wild.

PLEUROLEPSIS. Agassiz.

Pleurolepsis pellucidus (Agassiz). Sand Darter. Rock river. This species is in the habit of burrowing in the sand, leaving only its eyes visible.

BOLEOSOMA. De Kay.

Boleosoma Olmstedi (Storer). Tessellated Darter. Abundant in cool, shallow streams.

B. atromaculata (Girard). Resembles the *Olmstedi*, excepting that the neck and throat are scaled. Not uncommon.

B. brevipinnæ (Cope.). Little Johnny. Common in Rock and Fox rivers.

B. maculata (Agassiz). Spotted Darter. Lake Superior.

ETHEOSTOMA. Rafinesque.

Etheostoma blennioides (Kirtland). Black-sided Darter. Lake Michigan; rare.

PERCINA. Haldeman.

Percina caprodes (Rafinesque). Large Darter. Abundant in most lakes.

P. Zebra (Agassiz). Lake Superior. This may prove to be a variety of Caprodes.

P. Manitou (Jordan). Jordan's Darter. Taken at Racine.

PERCIDÆ. Perch.

Spine-rayed fishes. Cone-like scales; body more or less compressed. A hardy and valuable class of fish, including the perch, bass and sunfish. They take the hook and are well worth cultivating in all our lakes.

PERCA. Linnæus.

Perca flavescens (Mitchill). Yellow Perch. Abundant everywhere. Variable in markings and color, but it is doubtful if there is more than one species.

LUCIOPERCA. Cuvier.

Lucioperca Americanum (Valen). Wall-eyed Pike. A large, excellent pan-fish. Common.

L. griseum (De Kay). Gray Pike Perch. May be a variety of the *Americanum.*

ROCCUS. Mitchill.

Roccus crysops (Rafinesque). White Bass. Common in Lake Michigan and some of the inland lakes.

MICROPTERUS. Lacepede.

Micropterus flavidanus (Le Sueur). Large-mouthed Black Bass. Common everywhere and a valuable fish.

M. salmoides (Lacepede). Small-mouthed Black Bass. Common and valuable.

POMOXYS. Rafinesque.

Pomoxys hexacanthus (C. & V.). Six-spined Bass. Not uncommon in grassy lakes. The most important of our bass. It can be known by the six dorsal spines. It feeds almost exclusively on crustaceans, which explains its excellent flavor. Its length is from six to ten inches, and its breadth nearly half as much.

AMBLOPLITES. Rafinesque.

Ambloplites rupestris (Raf.). Rock Bass. Common in the stony-bottomed lakes.

COPELANDÆ. Jordan.

Copelandæ eriarcha. Hoy's Sunfish. The typical specimen was caught by the writer in the Menominee river at Wauwatosa.

TELIPOMIS. Rafinesque.

Telipomis Cyanellus. Blue-spotted Sunfish. A pretty, small Sunfish, of little value except in the aquarium. Common.

LAPOMIS. Cope.

Lapomis megalotis (Raf.). Long-eared Sunfish. Fox river. Not common.
L. nitidus (Kirtland). Kirtland's Sunfish. Not common.
L. angallinus (Cope.). Red-spotted Sunfish. Fox river (Nelson).
L. occulatus (Cope.). Cope's Sunfish.
L. pallastes (Cope.). The small Sunfish are difficult to classify as they vary exceedingly, according to sex, season, and the quality or temperature of the water they inhabit.

POMOTIS. Rafinesque.

Pomotis aureus (Linnæus). Common Sunfish. Common.
P. vulgaris. Common Spotted Sunfish.

APHREDODERIDÆ.

APHREDODERUS. Le Sueur.

Aphredoderus sayannus (Gilliams). Pirate Perch. Found in Fox river. (This aberrant form is inserted on the authority of Copeland.)

SCIAENIDÆ.

HAPLOIDONOTUS. Rafinesque.

Haploidonotus grunniens (Raf.). Sheepshead. Great Lakes. Large, fine-looking worthless fish.

FAMILY COTTIDÆ.

Fresh water Cottoids are small, singular looking fishes, with great heads, large pectoral fins without distinct rays, ventrals situated under the insertion of the pectorals, no swimming bladder. They inhabit cold rocky streams, move by hops — in this particular resembling the Etheostomidæ. In my opinion, that classification is extremely artificial that does not place these fish in close relation.

PEGEDICHTHYS. Rafinesque.

Pegedichthys ictalurops (Raf.). Big Cottus. Found in Rock river (Copeland).
P. Richardsonii (Ag.). Richardson's Cottus. Lake Superior.
P. alvordi. Not uncommon in the Wisconsin and Rock rivers.
P. Bairdii (Girard). Baird's Bull-Head. Racine. Not uncommon.

URANIDEA.

Uranidea Franklini (Ag.). Franklin's Cottus. Lake Superior.
U. Hoyi (Putnam). Hoy's Bull-Head. Lake Michigan, in deep water.
U. Kumlienii (Hoy). Kumlien's Cottus. Lake Michigan, in deep water.
U. pollicario (Jordan). We procured this large Cottus in Lake Michigan.

COTOPSIS. Girard.

Cotopsis Ricii (Nelson). Rice's Blue Head. Lake Michigan, in deep water

TRIGLOPSIS. Girard.

Triglopsis Thompsoni (Girard). Deep Water Sculpin. Lake Michigan, in deep water. They are found in the stomachs of trout taken in water seventy fathoms deep.

SUB-ORDER ANACANTHINI.

FAMILY GADIDÆ.

LOTA. Cuvier.

Lota maculosa (Les.). Lawyer. Common in Lake Michigan. This fresh water member of the codfish family is nearly worthless. It takes the hook readily.

SUB-ORDER HEMIBRANCHII.

FAMILY GASTEROSTEIDÆ.

GASTEROSTENS. Linnæus.

Gasterostens nebulosus (Ag.). Lake Stickleback. Abundant in Lake Michigan.

G. inconslans (Kirtland). Brook Stickleback. Abundant in all muddy, sluggish streams.

G. pygmoea (Agassiz). Lake Superior Stickleback.

SUB-ORDER ISOSPONDYLI.

FAMILY PERCOPSIDÆ.

PERCOPSIS. Agassiz.

Percopsis guttatus (Agassiz). Trout Perch. This pretty little fish occupies an intermediate place between the perch and trout — an old-fashioned fish closely related to several fossil fishes. This is one of many evidences that America is the oldest country, geologically speaking.

FAMILY SALMONIDÆ.

Soft-finned fish, with an extra dorsal fin, without rays called the adipose fin. Head naked; body covered with scales; swimming bladder large and simple. This family includes by far the most valuable of our fishes, among them the trout, whitefish and grayling. The trout family inhabits northern countries. All spawn in the latter part of autumn or early winter.

SALMO. Linnæus.

Salmo fontinalis (Mitchill). Brook Trout. This celebrated fish inhabits most of the streams and small lakes of the northern half of the state. It is cultivated for market, and propagated artificially in the state hatchery, near Madison, to supply suitable public waters.

S. namaycush (Pennant). Mackinaw Trout or Salmon Trout. A large, noble fish, weighing from five to sixty pounds, and found in the Great Lakes. This trout is propagated at the Milwaukee hatchery, for the purpose of stocking the deeper and colder of the inland lakes of the state.

S. Siscowet (Agassiz). Siscowet. Nearly as large as the preceding, but not so good, the flesh being too oily. As yet, none of this species have been taken except in Lake Superior.

ARGYROSOMUS. Agassiz.

Abundant in Lake Michigan. All of this genus take the baited hook at certain seasons. They may be known by the projecting under jaw.

Argyrosomus clupeiformis (Mitchill). Lake Herring.

A. sisco (Jordan). Sisco. This small white fish is found in most of our deep interior lakes, and is a moderately good pan-fish.

A. nigripinnis (Gill). Black Fin. It has as yet been found only in the deepest water of Lake Michigan, where I had the pleasure of discovering it.

A. Hoyi (Gill). Hoy's Sisco. The smallest and most beautiful of the white fish. This small species is numerous in the deep water of Lake Michigan. It is the principal fish on which the salmon trout feeds. Too small to be of value as a food fish for man.

A. Tullibee (Linnæus). Tullibee Sisco. Lake Superior (Agassiz).

COREGONUS, Linnæus.

The true white fish, *coregonus*, can be distinguished from the genus *argyrosomus* by the short under jaw and square nose.

Coregonus albus (Le Sueur). Lake white fish. This fish is the most valuable of our fresh water fish. It is largely propagated at the hatchery in Milwaukee, for the purpose of stocking Lake Michigan.

C. quadrilateralis (Richardson). Round white fish. Lake Michigan. This species spawns about the first of December, in fifteen fathoms of water, just outside the stony ridge north of Racine.

SUB-ORDER PERCESOCES

FAMILY ATHERINIDÆ.

Small, carniverous fish; body elongated and more or less compressed, covered with cycloid scales.

LOBIDESTHES. Cope.

Lobidesthes sicculus (Cope.). Silver Skip-Jack. Found in Fox and Rock rivers.

SUB-ORDER HAPLOMI.

FAMILY CYPRINODONTIDÆ.

Teeth in both jaws; air-bladder simple; head flattened; dorsal fin far back.

ZYGONECTES. Agassiz.

Zygonectes olivaceus (Storer). Top Minnow. Found at Madison.

FAMILY UMBRIDÆ.

MELANURA. Agassiz.

Melanura limi (Kirtland). Mud Minnow. Numerous all over the state, in every muddy ditch or pond.

FAMILY ESOCIDÆ.

Voracious fish, armed with strong teeth; bodies long and cylindrical. They lie in wait for their prey, and dart upon it in a hawk-like manner.

ESOX. Linnæus.

Esox nobiliar (Thompson). Muskallunge. The largest of our Pickerel. Not rare. One was caught April 9, 1877, in Fox river, which weighed forty pounds. Its length was four feet; length of head, ten inches; circumference of body, twenty and one-half inches; circumference over the eyes, eighteen inches; depth, six inches.

E. estor (Le Sueur). Pickerel. The most common species, reaching a length of from three to four feet.

E. salmoneus (Raf.). Little Pickerel. Found near Racine. Seldom is more than one foot in length.

E. cypho (Cope.). Buffalo Pickerel. Caught in Fox river; rare. Can be known by its small size and arched shoulders.

Family Hyodontidæ.

HYODON. Le Sueur.

Hyodon tergisus (Le Sueur). Moon Eye. Racine river and Lake Michigan.

SUB-ORDER EVENTOGRATHI.

Family Cyprinidæ.

Small, soft-finned fish, without maxillary teeth. Air bladder divided into two compartments. This family includes a great part of our small fish, such as shiners, chubs, dace, etc. They all spawn in the spring or early summer. A few species are good pan-fish.

CAMPOSTOMA. Agassiz.

Campostoma anomalum (Rafinesque). Stone Lugger. Found at Brown's lake.
C. dubium (Kirtland). Not common.

PIMEPHALES. Rafinesque.

Pimephales promelas (Raf.). Fat Head.
P. melanocephalus (Abbott). Black Head. Rock river and small lakes.

HYBOGNATHUS. Agassiz.

Hybognathus muchalis (Ag.). Blunt-Jawed Minnow. Wisconsin (Copeland).
H. argyritis (Girard). Silvery Minnow. Grant county, Wisconsin.

HYBORHYNCHUS. Agassiz.

Hyborhynchus notatus (Raf.). Blunt-Nosed Minnow. Common. Copeland.

SEMOTILUS. Rafinesque.

Semotilus corporalis (Mitchell). Common Chub or Horned Dace. Common everywhere.

CERATICHTHYS. Baird.

Ceratichthys biguttatus (Kirtland). Common.
C. dissimilis (Kirtland). Common.
C. prosthenius (Cope.). Lake Superior (Cope.). Not uncommon.

RHINICHTHYS. Agassiz.

Rhinichthys nasutus (Ayres). Long-nosed Dace. Common.
R. marmoratus (Ag.). Marbled Dace. Common.
R. atronasus (Mitchell). Black-nosed Dace. Common.
R. maxellosus (Cope.). Lake Michigan.
R. nasutus (Ag.). Lake Superior.

HYBOPSIS. Agassiz.

Hybopsis Storerianus (Kirtland). Storer's Minnow. Lake Michigan.
H. tudinatus (Cope.). Lake Michigan.
H. volucellus (Cope.). Lake Michigan (Cope.).
H. darsalis (Ag.). Lake Superior.
H. stramineus. Fox river.
H. hœmaturus (Cope.). Red-tailed Minnow. Lake Michigan.
H. plumbeolus (Cope.). Great Lakes.

HEMITREMIA. Cope.

Hemitremia heterodon (Cope.). Northern Hemitreonia. Abundant.

CHROSOMUS. Rafinesque.

Crosomus erythrogaster (Raf.). Red-bellied Minnow. A beautiful fish for the aquarium.

PHOXINUS. Rafinesque.

Phoxinus neogœus (Cope.). New World Minnow. Abundant.

GILA. Baird & Girard.

Gila elongata (Kirt.). Red-sided Minnow. Abundant.

LYTHRURUS. Jordan.

Lythrurus diplœmius (Raf.). Red Fin. Not uncommon.
L. cyanocephalus (Copeland). Hoy's Red fish.
This fish has not certainly been found except in Racine river.

LEUCISCUS. Klein.

Leuciscus cornutus (Mitchell). Horned Dace. Common.
L. frontalis (Ag.). Lake Superior Horned Dace. Lake Superior.
L. gracilus (Ag.). Slim Dace. Lake Superior.

CYPRINELLA. Girard.

Cyprinella analostana (Girard). Wisconsin and Rock rivers.

PHOTOGENIS. Cope.

Photogenis spilopterus (Cope.). Spotted-finned Shiner. Lake Michigan.

MINNILUS. Rafinesque.

Minnilus dinemus (Raf.). Emerald Minnow.
M. rubrifrons (Cope.). Rosy-faced Minnow. Fox river.
M. rubellus (Ag.). Rosy Minnow. Lakes Superior and Michigan.

NOTEMIGONUS. Rafinesque.

Notemigonus Americanus (L.). Shiner. Abundant everywhere.

FAMILY CATOSTOMIDÆ.

Cyprenoid fishes of medium or large size; mouth toothless, with fleshy, projecting lips; head naked; air-bladder large, divided into two compartments; scales large.

CATOSTOMUS. Le Sueur.

Catostomus teres (Mit.) Common Mud Sucker. Abundant in streams.
C. Hudsonii (Le S.). Long-nosed Sucker. Lakes Superior and Michigan.
C. Fosterianus (Ag.) Northern Sucker. Lake Superior.
C. aurora (Ag.). Red-sided Sucker. Abundant in Lake Michigan.
C. nigricans (Le S.). Stone Roller. Frequents clear water.

ERIMYZON. Jordan.

Erimyzon oblongus (Mit.). Chub Sucker. Abundant in Great Lakes.
E. melanops (Raf.). Striped Sucker. Abundant in Wisconsin river.

TERETULUS. Raf.

Teretulus Duquesnei (Le S.). Red Horse. Abundant in larger rivers.
T. aureolum (Le S.). Lake Red Horse. Abundant in Lake Michigan and streams flowing into it.
T. carpio (Val.). Silvery Mullet. Fox river; not abundant.

CARPIODES. Rafinesque.

Carpiodes bison (Ag.). Buffalo Carp. Mississippi and Wisconsin rivers.
C. Thompsoni (Ag.). Lake Carp. A few taken at Racine.

BUBALICHTHYS. Agassiz.

Bubalichthys niger (Raf.). Buffalo Fish. Abundant in Mississippi and tributaries.

CYCLEPTUS. Rafinesque.

Cycleptus elongus (Le S.). Black Horse. Baraboo river.

ORDER NEMATOGNATHI.

(Skin naked, or with long plates, long barbels, maxillary bones rudimentary.)

FAMILY SILURIDÆ.

ICTALURUS. Rafinesque.

Ictalurus punctatus (Raf.). Blue Cat-fish. Abundant in Mississippi and Rock rivers.
I. nigricans. Great Lake Cat-fish.
I. gracilis (Hough.). Northern Silvery Cat. Great Lakes; not uncommon.

AMINURUS. Rafinesque.

Aminurus Americanus. Bull Head. Not rare.
A. confinis (Girard). Wisconsin Bull Head. Common.
A. Hoyi (Girard). Hoy's Bull Head. Racine river.
A. albidus (Le S.) Brown Cat-fish. Common in Wisconsin river.
A. Vulgarus (Thompson). Bull Pout. Not rare.
A. œlurus (Girard). Minnesota Cat-fish. Rock and Wisconsin rivers.
A. cupreus (Raf.). Great Yellow Cat-fish. Mississippi. (Some of the above are doubtful species.)

NOTURUS. Rafinesque.

Noturus exilis (Nelson). Stone Cat. Fox river (Nelson).

ORDER APODES.

FAMILY ANGUILLIDÆ.

ANGUILLA. Thunberg.

Anguilla vulgarus (Jordan). Western Eel. One caught at Burlington that measured two feet ten inches in length.

ORDER CYCLOGANOIDEI.

FAMILY AMIDÆ.

Body stout, covered with thick cycloid scales; tail heterocercal; teeth in two sets, strong and sharp; dorsal fin long; air-bladder cellular.

AMIA. Linnæus.

Amia calva (L.). Dog fish. Abundant. Worthless.

ORDER RHOMBOGANOIDEI.

FAMILY LEPIDOSTEIDÆ.

Body cylindrical; jaws elongated, beak-like, and armed with numerous teeth; scales enamelled, rhomboidal.

LEPIDOSTEUS. Lacepede.

Lepidosteus osseus (L.). Gar Pike. Numerous in southern half of state.

L. platystomus (Raf.). Broad-nosed Gar. Rare. A fine specimen has been taken from Lake Koshkonong.

L. adamantinus (Raf.). Alligator Gar. This Gar has been taken from the Mississippi within the state.

ORDER SELACHOSTOMI.

FAMILY POLYODONTIDÆ.

Body elongated; skin naked; minute teeth on lower jaw; upper jaw prolonged into a long spoon-like process. But two species known,— one in America, and one in China.

POLYODON. Lacepede.

Polyodon folium (Lacepede). Spoon Bill. Not uncommon in muddy streams, tributaries of the Mississippi.

ORDER CHONDORSTEI.

FAMILY ACIPENSERIDÆ.

ACIPENSER. Linnæus.

Acipenser maculosus (Le Sueur). Rock Sturgeon.

A. rubicundus (Le Sueur). Red Sturgeon. Large and numerous.

A. carbonarius (Ag.). Lakes Superior and Michigan. A doubtful species.

SCAPHIRHYNCHOPS.

Scaphirhynchops platyrhynchus (Raf.). Shovel-nosed Sturgeon. Mississippi, Rock and Wisconsin rivers.

CLASS MARSIPOBRANCHII.

ORDER HYPEROARTIA.

FAMILY PETROMYZONTIDÆ.

Body naked, eel-shaped; dorsal and anal fins continuous with caudal; mouth suctorial; alimentary canal straight.

PETROMYZON. Linnæus.

Petromyzon niger (Raf.). Small Black Lamphrey. Mississippi river and Great Lakes.

P. argenteus (Kirt.). Silvery Lamphrey. Found at Racine.

CHAPTER X.

LIST OF THE MAMMALS OF WISCONSIN.

BY MOSES STRONG.

NOTE.—In the following list of the Mammals of our state I have only endeavored to give the scientific and common name of each species, referring them to the author with whom they originated. A few remarks are also added, relative to the portions of the state where they are found, and their food and habits which render them injurious or beneficial to mankind. Much information that is interesting and useful, which is contained in all large works on natural history, for want of space is necessarily omitted.

The order followed in the list is that of Dr. Theodore Gill in his "Arrangement of the Families of Mammals," prepared for the Smithsonian Institution. I am also much indebted to Dr. P. R. Hoy, of Racine, for the completeness of the list, and for numerous additions to it, which his long experience as a naturalist in Wisconsin has enabled him to make.

FELIDÆ.

1. *Felis concolor.* Linnæus. Panther. Found rarely in the northern part of the state. Carnivorous. Injurious.

2. *Lynx Canadensis.* St. Hillaire. Canada Lynx. Found occasionally in unsettled districts. Carnivorous. Injurious.

3. *Lynx rufus.* Rafinesque. Wildcat. More common than the preceding. It is found frequently in the heavily timbered regions. Carnivorous. Injurious.

CANIDÆ.

4. *Canis lupus.* Linnæus. Gray Wolf. Occurs in timbered portions of the state. Carnivorous. Injurious.

5. *Canis latrans.* Say. Prairie Wolf. Found frequently in the prairie regions. Carnivorous. Injurious.

6. *Vulpes fulvus.* Desmarest. Red Fox. Occurs occasionally in nearly all parts of the state. Carnivorous. Injurious.

7. *Vulpes Virginianus.* Richardson. Gray Fox. Much more rare than the preceding. Carnivorous. Injurious.

MUSTELIDÆ.

8. *Mustela Americana.* Linnæus. Pine Marten. Found in the northern and central portions of Wisconsin. Carnivorous and insectivorous; also eats some kinds of berries and nuts. Valuable for its fur. Beneficial.

9. *Mustela Pennantii.* Erxleben. Fisher. Occurs in the same districts as the preceding. Food, small animals, fish, frogs, grouse, etc. Valuable for fur. Beneficial.

10. *Putorius noveboracensis.* De Kay. White Weasel. Found in nearly all parts of the state. Food, rats, mice, moles, gophers and other small animals destructive to crops, destroying large numbers of them annually. Beneficial.

11. *Putorius vulgaris*. Linnæus. Little Weasel. Its geographical distribution and habits and food are similar to the preceding. Beneficial.

12. *Putorius cicognanii*. Bonaparte. Small Weasel. Similar in food and habits to the preceding. Beneficial.

13. *Putorius Richardsonii*. Bonaparte. Richardson's Weasel.

14. *Putorius vison*. Brisson. Mink. Common in the uninhabited and thinly populated parts of Wisconsin. Food, fish, frogs, crabs, rats, mice, small animals and birds. Valuable for its fur. Beneficial.

15. *Mephitis mephitica*. Shaw. Skunk. Found in all parts of Wisconsin. Food, small animals and the eggs of birds which nest on the ground; also insects. Injurious.

16. *Lutra Canadensis*. Sabine. Otter. Found occasionally near the lakes and streams in the northern half of the state. Its food is chiefly fish. Fur valuable. Beneficial.

17. *Taxidea Americana*. Boddaert. American Badger. This animal, which figures conspicuously on the State Seal, was formerly abundant in all parts of the state, but is now found chiefly in the sandy and thinly inhabited regions. It is chiefly carnivorous, feeding on field mice, gophers and other small animals. Beneficial.

18. *Gulo luscus*. Linnæus. Wolverine. Occurs rarely in northern Wisconsin. Food, small rodents and dead animals. Beneficial.

URSIDÆ.

19. *Ursus Americanus*. Pallas. Black Bear. Found frequently in the northern and central parts of the state. Carnivorous. Eats also roots, berries, nuts, corn, etc. Injurious.

20. *Ursus cinnamomum*. Audubon and Bachman. Cinnamon Bear. This is a large and long-legged variety of the preceding, found very rarely in northern Wisconsin. Injurious.

PROCYONIDÆ.

21. *Procyon lotor*. Linnæus. Raccoon. Found in all parts of the state, in heavy timber and swamps. Food, frogs, clams, eggs, green corn. Injurious.

CERVIDÆ.

22. *Cervus alces*. Harlan. Moose. Found very rarely in the hardwood timber in northern Wisconsin. It is rapidly becoming extinct in this state. Food, grass, and the leaves, twigs and bark of the maple. Valuable for their flesh and hides. Beneficial.

23. *Cervus Canadensis*. Erxleben. Elk. Occurs very rarely in northern and central Wisconsin. It was formerly quite numerous, but is now almost extinct. Food, grass, branches of willow, buds, twigs and lichens. Beneficial.

24. *Cervus Virginianus*. Boddaert. Common Deer. The deer are still quite numerous in Wisconsin, especially in the uninhabited districts. Their food is quite similar to the preceding. They are valuable for their flesh and hide. Beneficial.

VESPERTILIONIDÆ.

Within the confines of Wisconsin, eight species of bats have been observed. They are all insectivorous and nocturnal in their habits. During the day they conceal themselves in barns and outbuildings, and in caves and clefts of the rocks, finding also congenial haunts in the dark recesses of the forest and swamps.

They are most frequently seen at evening in the vicinity of groves, and but seldom on the prairie. They are embraced in the following list:

25. *Vespertilio subulatus.* Say. Little Brown Bat.
26. *Vespertilio lucifugus.* Leconte. Blunt Nosed Bat.
27. *Lasiurus noveboracensis.* Tomes. Red Bat.
28. *Lasiurus pruinosus.* Say. Hoary Bat.
29. *Scotophilus fuscus.* Palisot. Brown Bat.
30. *Scotophilus Carolinensis.* G. St. Hilaire. Carolina Bat.
31. *Scotophilus noctivagans.* Leconte. Silvery Bat.
32. *Scotophilus Georgianus.* H. Allen. Georgia Bat.

TALPIDÆ.

33. *Scalops argentatus.* Bachman. Silvery Mole. Found in the prairie regions of southern and central Wisconsin. It feeds on the larvæ of insects, earthworms, grubs, slugs, and other worms which are injurious to growing crops. Beneficial.

34. *Condylura cristata.* Linnæus. Star-nosed Mole. Occurs in the same regions as the preceding. Its food and habits are also similar. Beneficial.

SORECIDÆ.

The shrews, by reason of their diminutive size and nocturnal habits, are animals which are seldom seen and concerning which it is difficult to procure reliable information. They are quite generally distributed throughout the state. They burrow much deeper than the moles, and unlike them seek their food at night on the surface of the ground. Their food consists of insects, the carcasses of small animals, and the seeds of various weeds. They are probably rather beneficial than injurious. They are comprised so far as known in the following list:

35. *Sorex Cooperi.* Bachman. Cooper's Shrew.
36. *Sorex platyrhinus.* De Kay.
37. *Sorex Richardsonii.* Bachman. Richardson's Shrew.
38. *Sorex Hoyi.* Baird. Hoy's Shrew.
39. *Blarina talpoides.* Gapper.
40. *Blarina brevicauda.* Say. Mole Shrew.

MURIDÆ.

41. *Jaculus Hudsonius.* Baird. Jumping Mouse. Found occasionally in nearly all parts of the state. Food, the seeds of various weeds, also nuts and grain. Probably less injurious than beneficial.

42. *Mus musculus.* Linnæus. Common Mouse. Found in all inhabited districts. It also lives in the fields in burrows. Omnivorous. Injurious.

43. *Mus rattus.* Linnæus. Black Rat. This rat is not of frequent occurrence, owing to the free occupation of our houses by the Brown or Norway Rat. It is omnivorous and injurious.

44. *Mus decumanus.* Pallas. Brown or Norway Rat. The habits and depredations of this house rat are well known. It exterminates the black rat. Omnivorous. Injurious.

45. *Hesperomys leucopus.* Wagner. White-footed Wood Mouse, Occurs frequently in the timbered portions of the state. Its food is grass seed, grain of all kinds, corn, nuts. Sometimes also it destroys fruit trees by gnawing the bark. It seldom burrows in the ground. Injurious.

46. *Hesperomys Bairdii.* Hoy and Kennicott. White-footed Prairie Mouse.

Found in the prairie regions of Wisconsin. Food, seeds, grain, insects. They are very injurious to prairie nurseries. Injurious.

47. *Hesperomys Michiganensis.* Audubon & Bachman. Prairie Mouse. Locality and habits similar to the preceding. Injurious.

48. *Arvicola austerus.* Leconte. Prairie Meadow Mouse. Quite abundant in the prairie regions of southern and central Wisconsin. It burrows and lays up stores of food. Its food consists of grasses and plants with their seeds and roots, grain, corn, hay, vegetables, and the bark and roots of fruit trees, to which they are very destructive. The arvicolas may be classed among our most injurious mammals. The habits and distribution of our other meadow mice are quite similar. They comprise the following species:

49. *Arvicola riparius.* Ord. Meadow Mouse.

50. *Arvicola pinetorum.* Leconte. Pine Mouse.

51. *Arvicola Gapperi.* Vigors.

52. *Fiber Zibethicus.* Cuvier. Muskrat. Found near lakes and streams in all parts of the state. Habits, aquatic and nocturnal. Food, roots of aquatic plants and mollusca. Valuable for its fur. Beneficial.

CASTORIDÆ.

53. *Castor fiber.* Linnæus. American Beaver. Occurs occasionally on some streams in the northern part of the state. Food, roots of aquatic plants, the bark of certain trees, especially the birch and willow, also berries and leaves and some kinds of herbage. It is valuable for its fur, and is rapidly becoming extinct in Wisconsin. Beneficial.

SCIURIDÆ.

54. *Sciurus Sayi.* Audubon and Bachman. Fox Squirrel. Found in the oak openings and groves in the southern and eastern parts of the state. Food, nuts of various kinds and corn. In the spring it eats the buds of trees, especially hickory and oak. Compared with other species they are not numerous. Injurious.

55. *Sciurus migratorius.* Audubon and Bachman. Gray Squirrel. Numerous in the southern and central portions of Wisconsin. Food, seeds and nuts of several kinds, also corn and grain when there is a deficiency of its natural food. Injurious.

56. *Sciurus niger.* Linnæus. Black Squirrel. Occurs rarely in the same localities as the preceding, of which it is a variety. Its food and habits are the same. Injurious.

57. *Sciurus Hudsonius.* Pallas. Red Squirrel. Found abundantly in the northern and central parts of the state, especially in the pine groves. Food, nuts and seeds of various kinds, especially those of the white pine. In the vicinity of cornfields it is sometimes quite injurious.

58. *Pteromys volucella.* Pallas. Flying Squirrel. Occurs occasionally in nearly all parts of Wisconsin. Food, nuts and seeds of various kinds. As it seldom or never leaves the timber, it can scarcely be considered injurious.

59. *Pteromys Hudsonius.* Gmelin. Northern Flying Squirrel. Found occasionally in northern Wisconsin. Its food and habits are similar to the preceding.

60. *Tamias striatus.* Linnæus. Chipmunk. Occurs in nearly all parts of Wisconsin, most numerous in thickets and groves, avoiding both the open prairie and the largest timber. Its food is nuts and seeds of several kinds, also grain. Not injurious unless very numerous.

61. *Tamias quadrivittatus.* Say. Four-Striped Squirrel. Found in northern and central Wisconsin. Food, nuts and the seeds of plants and grasses, also the seeds of the white pine. Its habits are generally similar to the preceding.

62. *Spermophilus tridecem-lineatus.* Audubon and Bachman. Striped Gopher. Very abundant in all the prairie regions of the state. Food, roots and seeds of many grasses and weeds, grasshoppers, insects, field mice. They are sometimes very destructive to cornfields and gardens in the vicinity of the uncultivated prairie, but it seems probable that this is more than counterbalanced by their destruction of injurious insects and weeds. Beneficial.

63. *Spermophilus Franklini.* Sabine. Gray Gopher. Occurs in all the prairie regions, but not so abundantly as the preceding. Food, plants, grasses, seeds and grain. It frequently inhabits cultivated fields. Injurious.

64. *Geomys bursarius.* Shaw. Pouched Gopher. Occurs rarely in the prairie regions. Food, insects, seeds and grain. Injurious.

65. *Arctomys monax.* Linnæus. Wood-chuck. Found in nearly all the timbered districts of the state. Food, roots, seeds, grasses, especially clover. It burrows in the ground, and is not injurious unless numerous.

HYSTRICIDÆ.

66. *Hystrix dorsata.* Audubon and Bachman. Canada Porcupine. Occurs frequently in the hardwood timber in the northern and central portions of Wisconsin. Food, bark of the hard maple, elm, hemlock, and basswood. It is not otherwise destructive.

LEPORIDÆ.

67. *Lepus Americanus.* Audubon and Bachman. Northern Hare. Found only in the northern and central parts of the state. Food, grass, leaves, buds, berries, and the bark of the willow, birch, poplar, hazel, and young pine. It turns white in the winter and gray in the summer. Valuable for food. Beneficial.

68. *Lepus sylvaticus.* Audubon and Bachman. Gray Rabbit. Abundant in the central and southern parts of the state. It is much smaller than the preceding, and does not change color in the winter. Its food is essentially the same. It is sometimes injurious to orchards and nurseries.

DIDELPHIDÆ.

69. *Didelphys Virginiana.* Shaw. Opossum. Found occasionally in the vicinity of Lake Michigan. Its habits are nocturnal. It is omnivorous, feeding on nuts, berries, grain, roots, vegetables, insects, worms, larvæ, birds, eggs, mice and other small animals.

CHAPTER XI.

ECONOMIC RELATIONS OF WISCONSIN BIRDS

BY F. H. KING.

PREFATORY LETTER.

RIVER FALLS, WIS., Nov. 6, 1882.

Prof. T. C. CHAMBERLIN,
Chief Geologist:

Herewith I transmit, in compliance with your request, a report on the Economic Relations of the Birds of Wisconsin, to be published under the auspices of the Wisconsin Geological Survey.

The field work, which forms the basis of this report, was commenced at your suggestion, as you are aware, in July, 1873, and was prosecuted, as time could be devoted to it, until October, 1877. The funds which could be appropriated to this work did not permit of the collection of materials from the various portions of the state, consequently the data presented were gleaned, very largely, from a collection of birds obtained in Walworth, Jefferson, Green Lake, Waushara, Waupaca and Price counties, a territory which lies well back from the main water routes, along which the strongest currents of the stream of purely migratory species are likely to be found. This fact will doubtless explain in part the conspicuous absence of personal observations relative to species which have been reported as abundant in contiguous territory. The same conditions which circumscribed the field of observation also limited the time which could be devoted to field work, to the months of July and August and the early part of September, and while an effort was made, with a degree of success, to secure specimens at other times of the year, yet the report has lost, in a measure, that roundness and fullness which could have been desired.

The facts recorded in the report were obtained from an examination of the contents of the stomachs of over eighteen hundred birds, sixteen hundred and eight of which contributed results which have been incorporated in the report.

The contents of one-half of the stomachs were examined under the hand-lens on the day they were obtained, while the contents of seven hundred and fifty were transferred at once to small apothecary phials containing alcohol, and were carefully labeled with a tag. This material I was permitted to study much more in detail through the kindness of Prof. J. H. Comstock, of Cornell University, who granted me a seat in the Entomological Laboratory, together with the free use of specimens and apparatus. I desire to express here, too, my appreciation of the personal assistance, besides that coming from a sojourn of six months in the sunshine of a warm heart, which Prof. Comstock was able to give me. He should in no sense, however, be held responsible for errors which may have occurred in the identification of insects found among the food of the birds.

The examination of the material which had been collected was completed in June, 1878, and the report essentially completed before the middle of the following August, but, knowing that it would not be needed for publication immediately, I preferred to retain the manuscript until the latest possible date in order to retouch it as might seem desirable. This has been done so far as practicable. The valuable results obtained by Prof. S. A. Forbes in regard to the food of birds of Illinois has been included, and the whole nomenclature has been made to conform with Dr. Coues' new "Check List of North American Birds."

Following my own notes on the food of each species examined, there have been given such other apparently authentic records of food as could be obtained. This supplementary information is far from being as complete as I had hoped to make it, and I fear not so accurately transferred as it should have been, for it has been impracticable to compare the transcript with the originals. I regret this the more, since the items were jotted down during the odd moments which fell between other absorbing duties.

The amount of specific information which it has been possible to present in regard to the food of our birds may seem unduly small compared with the amount of material which has been examined. Larger results might have been obtained had the materials, after having been classified in a general way, been subjected to a careful examination by entomologists expert in the various departments. Birds rarely swallow an insect of any size without taking especial care to severely mutilate it first, and I have no doubt that the bird has, in his own mind, the best of reasons for doing so. One may easily imagine the commotion which might come of introducing an able-bodied ground-beetle or a centipede grown expert in elbowing his way through all sorts of tortuous and impassable galleries. It is this fragmentary character of the food which has made it so difficult to classify the insects which had been eaten by the birds obtained. But had it been possible to identify specifically the 7,663 insects, etc., taken from the stomachs of the 1,608 birds, this would have been by far the smallest part of the task set, for then it would be required to command a full and broad knowledge of the economic relations of the insects eaten. But with this difficulty solved we must recognize still another of greater magnitude and higher degree.

Because of these great difficulties inherent in the task itself, and the ample grounds they present for difference of opinion in regard to final conclusions, it has seemed very desirable that there should be presented some of those general considerations which have served as guides to the classification adopted. These considerations are presented as an introduction to the body of the report.

There remains now the pleasant duty of thanking you for the privilege of having struggled with a difficult task, and, while the hopes you have entertained may find in this report but a faint realization, it is trusted that enough of real value may be found in it to repay the labor devoted to its preparation.

Very respectfully yours,

F. H. King.

INTRODUCTION.

The discordant views held by prominent ornithologists and entomologists, in regard to the value of birds as insect destroyers, and particularly in regard to the actual and comparative value of certain species, prove conclusively that some of them have reached their conclusions on insufficient or false data. For this reason, and because it appears that many more facts must be gleaned and collated before final conclusions in regard to the economic value of birds can be reached, it is deemed advisable to consider briefly, as introductory to what follows, some of the more important factors which should enter into the solution of the problems of economic ornithology.

The most difficult and intricate problem of economic ornithology is that of the food of birds. In the discussion of this question it will be most convenient to bring that which birds eat under the two heads, (1) *Vegetation and Vegetable Matter*, and (2) *Animals and Animal Matter.* The food of birds thus grouped must be further identified as belonging to one or the other of the following classes:

(1) *That, the consumption of which is, on the whole, a service to man.*

(2) *That, the consumption of which is, on the whole, an injury to man.*

To determine what birds do, or may under forced conditions, eat is certainly a very difficult question, and many of the problems which must be solved before their food can be properly classified as indicated embrace the extreme of intricacy. That this classification must be made before final conclusions can be reached, I think all will agree; that such a classification can ever be made complete and unquestionable, there are grave reasons for doubting; but that a desirable approximation to completeness is possible, we may feel confident.

So much is yet to be learned in regard to the real and potential industrial relations of the plants and animals affected by birds, that whatever may now be said upon the subject must be regarded as open to modification by more detailed and careful future work.

Beneficial services on the part of birds may be stated under the following propositions:

(1) *A bird renders a service when it is injurious or destructive to plants which are to be regarded detrimental.* This may occur when the bird consumes the foliage, buds, inner bark, blossoms or seeds of injurious plants.

The principal service which our birds render in this direction is in the consumption of the seeds of weeds; and the number which they destroy in the course of a season is very great. From the stomach and crop of one Carolina Dove were taken 4,016 seeds of the common pigeon grass, *Setaria glauca.* The service which a bird renders in this line, however, is not to be regarded as always proportionate to the number of seeds which it consumes, for the mere act of cultivation, necessary to many crops, so effectually controls these weeds that but little work is left for birds to do. Birds, therefore, which possess many very serious traits, and have only the habit of feeding upon the seeds of weeds in their favor, must be looked upon as of doubtful utility.

(2) *A bird renders a service when it feeds upon injurious mammals.* Squirrels, gophers, rats, mice, and hares are the principal ones, regarded as noxious, which are preyed upon by our birds. They are among the smallest, the most prolific, and the most destructive of mammals. All of them are largely herbivorous or frugivorous, but some of them are somewhat carnivorous. All are familiar with the havoc which rats often make among young chickens and ducks. The ground squirrels are said to feed occasionally upon insects and upon mice. Occasionally, at least, the little red squirrel plunders birds' nests of their eggs. In June of 1878, as Prof. W. A. Kellerman and myself were passing through the cemetery at Ithaca, N. Y., our attention was attracted to an evergreen, standing near the walk, by a pair of Robins, which were dashing wildly about among its branches. On examining the tree, the nest of the birds was discovered, and just below it sat a Chickaree eating one of the Robin's eggs.

An instance similar to the above is mentioned by Edgar A. Mearns, in the Bulletin of the Essex Institute, Vol. X, 1878. He says: "Among the Robin's worst enemies may be ranked the red squirrels *(Sciurius hudsonius)*, for, though their young are subject to the attacks of Crows, Jays, and particularly to the ravages of the black snake *(Rescaurion constrictor)*, yet none of these enemies inflict as much injury as the squirrels, because, not only do they seek out and devour the eggs, but the young are also eaten; and their numbers are in excess. . . . On the morning in question, a red squirrel came a considerable distance out of the woods, ascended to this nest, and would have destroyed all the young ones had not the parent returned just at the critical moment." The Robin succeeded in driving the squirrel away, but not until one of her young had been eaten.

In the spring of 1879 I placed the young of the Chipping Sparrow in the cage with a young pet flying squirrel *(Sciuropterus volucella)*. The bird was seized with energy and killed but not eaten.

How general this practice among squirrels may be I do not know; it suggests, however, that the little red squirrel and its nearer allies may be formidable enemies of nearly all our small woodland birds.

The fact, too, that rats and ground squirrels are carnivorous, to some extent, suggests that these may be destructive to birds which nest upon the ground in fields and on the prairies. Mice are preyed upon to a considerable extent by some of the Hawks, and Owls, and probably also by the Sand-hill Crane, but whether birds of prey are especially serviceable in destroying squirrels and gophers may be questionable.

(3) *A bird does us a benefit when it feeds upon injurious birds.* This head is introduced here, not because any of our birds are known at present to render a service in this direction, but because it suggests a field in which further observation is needed.

(4) *A bird assists us when it feeds upon injurious reptiles.* Of the reptiles preyed upon by birds, our larger snakes are the only ones to be regarded as noxious. Snakes that are not venomous have been classed among beneficial animals, because they feed to some extent upon mice and insects. This classification, however, so far as it includes the larger species of snakes, appears to be, at present, unwarrantable. The fact that snakes also eat small birds and birds' eggs, toads, frogs, salamanders, and some of them fish, is conclusive proof that they do some injury. While my own observations indicate that both insects and mice are eaten by them, yet frogs and toads appear to form by far the larger part of their food, at least, that of our common garter snake. From the stomach of a large striped snake *(Eutainia sirtalis)* were taken eleven ground beetles, two elaters, one lamellicorn beetle, three caterpillars, one millipede, and one large toad. Leaving out of this account the toad, it will be seen that, in this particular instance, the snake had done a greater injury than a service, for the ground beetles, usually regarded as beneficial, nearly double in number all the other insects combined. The fact that during the season when insects are abundant, snakes are often found with their stomachs entirely empty, suggests that, with some species, at least, insects are only make-shifts for food. It should be observed in this connection that all snakes are capable of enduring a long fast without apparently suffering any very great inconvenience. If, then, it is true that insects are only eaten in default of other food, the services of snakes in this direction must be much smaller than might otherwise be expected.

Our frogs and toads in the adult stage, so far as is known, are entirely insectivorous, and are, therefore, harmless, except so far as they may be destructive to useful insects. Toads are nocturnal in their habits and feed upon the ground in gardens and fields where there are few animals, except the shrews and moles, to take their place. Some of the frogs, too, spend the summer in fields and meadows where birds are few, and consequently have a special work to perform. Few birds, and certainly no snake, can be more serviceable, as insect destroyers, than these animals. The facility with which some snakes climb trees, and the stealthiness with which all may approach their prey upon the ground, give them great advantage over birds during the breeding season. That the common striped snake will devour even large mature birds, when it can obtain them, is proved by an instance which came under my observation last summer. On returning to camp, after a morning's excursion, a large striped snake was seen in the act of swallowing a Downy Woodpecker, which, with several other birds, had been thrown upon the ground after its stomach had been removed for examination. Only the tail feathers were protruding from the snake's mouth and all of the feathers were intact. The same snake had already swallowed a full-grown Catbird, with its entire plumage, and having only its stomach removed. The fact that a snake is sufficiently strong to seize and hold large toads and frogs indicates that they are abundantly able to hold any of our common birds, provided they come within their grasp.

Although ten or more species of our birds prey to some extent upon snakes, these birds are either destructive to other birds, or to frogs and toads, or to both; it does not follow, therefore, that their services should be retained simply because they are destructive to snakes. Snakes, owing to their slow movements, are much more easily controlled by direct means than most other animals.

(5) *A bird renders a service when it feeds upon insects which are injurious or destructive to useful animals, plants or materials, and which are not extensively destructive to noxious forms of life.* It is in the destruction of the members of this group that birds are chiefly serviceable, not only because insects are among the most prolific and the most destructive forms of life with which we have to contend, but because their small size and their habits make it very difficult to oppose them by any direct means. While, as entomologists have claimed, the most potent checks against these animals are among the members of their own class, yet, that these are not adequate to our needs, is conclusively proved by the results which have invariably followed from the wholesale slaughter to which birds have been subjected from time to time in different countries. Wherever the English Sparrow, the bird so much decried in our country of late, has been exterminated in Europe, noxious insects are said to have followed in such abundance that it has not only been gladly reinstated, but is now protected because it accomplishes what parasitic and predaceous insects are unable to do. When it is argued that birds feed indiscriminately upon beneficial and noxious insects, it should be observed that predaceous insects do the same, and that parasites have their parasitic foes.

Birds are insignificant in numbers when compared with the abundance of parasitic and predaceous insects, but their larger size, their active habits, their longer lives, the greater facility with which they move about, and the greater range of country over which they roam, go far toward compensating for smaller numbers. It should be added, also, that birds, either in one place or in another, are consuming insects throughout the year, while, in the temperate zones, predaceous and parasitic insects do nothing during one-half of that time. No insect is so large but that any bird may destroy it while it is passing through one or more of its stages, and few are so small as not to attract the attention of many of our birds. The White-Bellied Swallow captures on the wing plant-lice and flies, smaller than the wheat midge. The Purple Finch, and some of the Warblers, feed extensively upon plant-lice. Chalcidian and other parasitic flies, less than a tenth of an inch long, have been taken from the stomach of several of our birds, even from that of the Swamp Sparrow, a bird which rarely pursues its prey upon the wing and which is counted among the seed-eating forms.

The nocturnal habits, which so many insects possess, do not offer such absolute protection against birds as some appear to think. Lepidopterous insects, so many of which deposit their eggs under the cover of night, feed in the larval state, with some exceptions, during the day, and this is the longest and so the most dangerous period of their existence, as it is the most destructive. But even when hidden during the day, insects are not secure; birds have learned their hiding places and search them out, and some of them make this the business of their lives. The Woodpeckers, Nuthatches and Creepers capture those that have hidden beneath the bark and in the crevices on the trunks and branches of trees; Warblers, Vireos and Flycatchers destroy those that betake themselves to the undersides of leaves; and the Thrushes, Finches and Starlings pick up those that seek security upon the ground and among the grass. "Mimicry," though protective, doubtless, to some extent, does not lessen the service which birds render. It simply tends to throw the heaviest attacks upon the more conspicuous forms. But protective colors, forms and surfaces can hardly be as effectual against birds as against predaceous insects, for they survey their field from a more advantageous point of view, and they discriminate well objects both remote and close at hand. Besides, birds, and predaceous insects as well, learn to see as collectors learn to collect. They become experts in their business, and this is of as great an advantage to them as "mimicry" can be to other forms.

While many of our troublesome insects spend their larval states in the stems of plants, in various fruits or beneath the ground, feeding upon the roots of plants beyond the reach of most birds, yet even these, while searching for places in which to undergo their transformations, and in the winged state, are destroyed by birds in large numbers. If birds do not exterminate noxious insects, they nevertheless perform a serviceable mission by holding them within certain limits.

That an approximate estimate may be made of the amount of work which birds do in destroying insects, the table given below has been prepared. The first four columns are compiled from notes taken in Jefferson county, between July 31st and August 7, 1878; those in the last four columns are from notes taken in the vicinity of Ithaca, N. Y., in June of 1878. In each column, opposite the name of the species, is given the number of individuals which were observed in traveling the distance that is given near the foot of each column. The item, "Birds seen or heard, but not named," includes those individuals which were known to exist in the territory passed over, but which, for various reasons, could not be identified with certainty. The two series of observations are taken for the purpose of comparison in discussing another point. As will be seen further on, the different routes were chosen with reference to certain topographical features, in order that the combined results might include the peculiarities due to them. By referring to the table it will be seen that the average number of individuals observed per mile on the four trips in the two localities bear a remarkable closeness to one another, that for Jefferson being about 33 per mile, and that for the vicinity of Ithaca nearly 57 per mile. Since these results are so close to one another, they may be fairly assumed to represent a definite factor, for the respective localities, at the time the observations were taken.

Table of Observations on the Abundance of Birds.

Name.	Number Observed. I.	II.	III.	IV.	V.	VI.	VII.	VIII.
Turdus migratorius	11			3	20	13	31	44
Turdus fuscescens					2		2	4
Mimus carolinensis	2	8	3	2	12		25	7
Sialia sialis	1	2			2	8	5	17
Parus atricapillus							9	
Sitta carolinensis	3	7	2			1	2	3
Troglodytes ædon						1		5
Eremophila alpestris								3
Cistothorus stellaris	1							
Dendrœca æstiva					1	2	5	5
Geothlypis trichas			1	3				
Setophaga ruticilla	2	15	5		2			
Pyranga rubra	1	3						
Hirundo erythrogastra horreorum	5	5				12	7	20
Tachycineta bicolor		2						
Petrochelidon lunifrons					2	12	10	55
Cotyle riparia								13
Progne subis	2			1				
Ampelis cedrorum			8		4	7	12	4
Vireo olivaceus	1	13	13				1	
Vireo gilvus	1			3				
Vireo flavifrons			10	4				
Lanius ludoviciannus excubiteroides	1							
Astragalinus tristis	9	27	5	4	6	28	32	44
Poœcetes gramineus	5			10		16	19	18
Melospiza fasciata	6	5	8	17	7	33	23	73
Melospiza palustris			1					
Spizella domestica	3	1	1		7	33	17	36
Spizella agrestis (shot)				2				
Passerina cyanea		5				2	3	3
Pipilo erythrophthalmus		3	3					
Dolichonyx oryzivorus		18	3			5	22	52
Molothrus ater					2			10
Agelæus phœniceus		1			12		10	12
Sturnella magna	1	2			2	8	5	11
Icterus galbula					7	11	5	3
Quiscalus purpureus								2
Corvus frugiverous	1	2			3	10	8	28
Cyanocitta cristatus				1				
Tyrannus carolinensis	8			10	4	4		8
Sayornis fusca	2			4	2		22	11
Contopus virens	3	20	15	4			2	4
Empidonax minimus					1			
Chætura pelasgica					4	3	13	12
Trochilus colubris	1	5	1	1		1	1	
Ceryle alcyon	2	7						
Coccyzus erythrophthalmus					2		1	
Picus villosus	2		1					
Picus pubescens		1						
Sphyrapicus varius	1	2	4					
Melanerpes erythrocephalus	4	2				3		3
Colaptes aurates	7			6	2		2	1
Circus cyaneus hudsonicus				5				
Falco sparverius					1			
Hawk		2					2	
Zenaidura carolinensis	5						4	1
Bonasa umbella			10					
Ægialitis vociferus	17	2						
Tringoides macularius	1	11					4	3
Bartramia longicauda	2							
Ardea herodias	2							
Butorides verescens	2	3						
Rallus virginianus	1					1	1	
Podilymbus podicips	1							
Birds seen or heard, but not named	20	36	18	15	20	69	100	101
Total number of birds observed	137	141	112	95	127	282	405	616
Number of miles traveled	4	5	3	3	2¼	5	7	11
Average number of birds per mile	34	28	37	32	56	56	58	56
Total number of species	35	27	18	17	23	22	30	32

Total average per mile in Jefferson county is about 33.

Total average per mile in the vicinity of Ithaca, New York, is nearly 57.

It will probably be far within the limits of truth, if it is assumed that the average number of birds observed per mile represents only one-half the actual number which existed on each square mile at the time it was crossed. At this rate the bird population of Jefferson would be 66 per square mile, while that of the vicinity of Ithaca would be 114 per square mile. This would give for Jefferson county a total bird population of 30,096, and for an equal area in the vicinity of Ithaca, 51,984. At the rate of 66 per square mile, an area somewhat less than that of our state would have a population of 3,565,000.

From the stomach of a Passenger Pigeon were taken nine full-grown black crickets, and four grasshoppers over an inch long, together with two large caterpillars and one harvestman. From the stomach of a young Partridge, less than a week old, were taken thirteen caterpillars, seven harvestmen and one grub; from that of a Night-hawk were taken five small grasshoppers, eight large square-shouldered hemiptera, and ten scorpion bugs, none of which were less than three-fourths of an inch long. Nine grammes of insect debris were taken from the stomach of another Night-hawk. Three Golden-winged Woodpeckers had in their stomachs, respectively, 255, 220, and 200 ants. In the stomach of a Hairy Woodpecker were found the remains of eleven grubs of long-horned beetles and thirteen measuring worms. A Pewee, *Sayornis fuscus*, had in its stomach ten ichneumon flies, averaging over half an inch long, five small moths and one caddis fly. The actual amount of food which the above species eat during the day, if we except the Night-hawk, is probably more than three times that which was found in their stomachs. Fifty insects of the average size would certainly be a small daily allowance for the average bird. One hundred and twenty days is less than the time our summer residents are with us. At the rate assumed, each bird would consume 6,000 insects. This would give as the aggregate number of insects consumed by the birds calculated to occupy an area equal to that of our state, the enormous total of 21,384,000,000. Add to this amount the work which these birds do in their southern homes, and we have a low estimate of the influence they exert over insect life.

It should be borne in mind that less than half of our summer residents are included in the table, and that nothing whatever has been said in regard to the birds of passage which sweep the state twice every year. The insects which these birds eat will more than compensate for whatever other food those birds which have entered into our computation may consume.

(6) *A bird does us service when it feeds upon noxious mollusks.* In damp climates, such as exist in many parts of Europe, mollusks often become very abundant and very destructive to garden and field products. In the United States, however, but little injury from them appears to have been thus far realized; and in a climate like ours, but little apparently need be anticipated. The fact, however, that slugs have occasionally made destructive raids upon strawberry patches, should put us sufficiently on our guard to look into their possibilities for evil before we attempt to drive off or destroy their natural enemies. It may be remarked here, in passing, that a species of Limax, common in the grass at Ithaca, N. Y., has several times been seen feeding upon ripe cherries that had fallen from the trees. Whether, as many slugs are known to do, this species will in damp days ascend the trees to feed, is a question worthy of study.

Mollusks, and other animals as well, may be, at times, extremely injurious even when, so far as their food is concerned, they are practically harmless. That terrible disease known as "fluke-rot" or "water-rot," which has destroyed in a single locality in Europe, during one season, 300,000 sheep, and which has ruined large herds of cattle, and which, under favorable circumstances, has even attacked man, is due to a parasite, *Faciola hepatica.* This parasite is believed by those who have studied its habits, to pass through one stage of its transformations in the bodies of fresh-water mollusks. If these mollusks are a necessary habitat of the fluke-rot parasite, whatever destroys them lessens the liabilities of its attacks. Quite a large number of birds and fishes and some insects feed upon fresh-water mollusks, but whether in so doing they are benefiting us, we cannot at present say.

(7) *A bird may render service by feeding upon noxious crustaceans and worms.* Crawfish have been so little studied in regard to their habits that an economic position cannot be satisfactorily assigned them at present. Prof. W. F. Bundy writes me in regard to their habits as follows:

"Crawfish feed on worms, small mollusks, insects that fall in their way, small fish, and in general any kind of animal food, especially carrion. They are industrious scavengers. This latter item, with the additional ones that they form a not inconsiderable part of food for fish, and their damage to meadows by burrowing, indicate where they come in the most direct relation to human interests."

The river species he regards as beneficial. Those which burrow in meadows, building mud chimneys which become sun-baked and interfere quite seriously with mowing, he is in doubt in regard to, but inclines to the opinion that their services as scavengers more than offset the damage they do.

Crawfish are preyed upon to a considerable extent by various species of Herons and some other birds. The Cowbird is said to eat the intestinal worms voided by cattle and horses.

(8) *Birds are serviceable when they feed on carrion.* Ordinarily, in a country and climate like that of Wisconsin, there appears to be but little need for large carrion-eating animals. Birds of this class, therefore, which have other and very injurious tendencies, can hardly be tolerated in abundance merely for the purpose of consuming carrion.

The injurious relations of birds may likewise be stated in the following propositions:

(1) *A bird is harmful to us when it is injurious or destructive to useful plants.* This may occur when the bird feeds upon the inner bark, buds, foliage, blossoms, fruit, or seeds of useful plants.

It is in the destruction of cereals, either shortly after they are planted or when they are ripening, that our birds are chiefly injurious in this direction at present, but even here their injuries have rarely assumed alarming proportions. Quite a large number of birds feed upon small fruits, but those which do are in other respects almost exclusively insectivorous. Even the Cherry Bird and Baltimore Oriole, which horticulturists tell us should be exterminated in mid-cherry time, feed quite as much upon insects as upon fruits. The Yellow-bellied Woodpecker is said to feed upon the inner bark of orchard and ornamental trees. The Purple Finch and some other birds occasionally eat the buds of fruit trees; their injury, however, has thus far been trifling. In the forests, during the winter, buds form a large part of the food of quite a number of birds. From the stomach of a Partridge were taken, in October, 302 white birch buds. While the number of buds which this species consumes during the winter is doubtless very great, it is probable that its flesh will always amply compensate for the injury it does in this direction, to say nothing of the insects which it consumes during the summer.

It is only when forest-planting becomes a necessity that bud-eating birds, as such, can take the rank of enemies, unless, by any means, these birds should become very abundant. In any case, only the small bud-eaters, like the Purple Finch and some of the Linnets, whose small size render them valueless as food, and which, for this reason, would have to be controlled by the awarding of bounties or some similar means, need give us any apprehensions whatever.

(2) *A bird does us harm when it preys upon shrews, moles and bats.* These animals, owing to their insectivorous and nocturnal habits, and their, so far as known, inoffensive natures, are to be regarded as of great value. They are especially to be protected because they choose a time to feed when noxious insects are abroad in abundance and when their enemies are few. Birds, therefore, which are extensively destructive to them, unless they have some very desirable traits, are to be regarded as enemies.

Owls are the principal birds known to feed upon these animals.

(3) *A bird is harmful to us when it preys upon other beneficial birds and their eggs.* A species which makes a practice of preying upon birds' eggs or their young, or which has the ability and disposition to capture mature birds, must certainly do a very important work for us in compensation to be encouraged in agricultural districts, at least until after experience has proved that its services are needed to prevent an undue increase of certain birds. All of our Hawks, Owls, Shrikes and Crows are known to be, or may be suspected of being, more or less destructive to birds in one or more of their stages of development, but to what extent, observations, so far as they have been published, are too limited and indefinite to allow any very definite conclusions to be drawn.

(4) *A bird is harmful when it feeds upon lizards and perhaps our smallest species of snakes.* As the food of these animals probably consists almost entirely of insects, they are to be regarded as beneficial, until shown to be detrimental.

(5) *A bird is harmful when it feeds upon frogs, toads and salamanders.* Enough has already been said in regard to frogs and toads to show what their economic relations are, and how birds must be regarded which feed extensively upon them. Salamanders probably occupy a similar, though less important position.

(6) *A bird is detrimental when it feeds upon the parasites of noxious animals, and especially upon those of noxious insects.* Parasites are regarded as the most potent agents which serve to keep noxious insects within safe bounds, and that their influence is very great, there can be no doubt. This, however, is to be said in regard to them: Many, apparently, only become extremely abundant when the insects upon which they prey have assumed such numbers as often to commit wide-spread ravages. Their influence has a tendency toward spasmodic rather than steady action. They are, as it were, the last reserves which Nature holds back for those emergencies when favorable conditions of climate shall let loose upon the world such an abundance of insects as cannot be controlled by other means.

The fateful army-worm, whose history is so well given by Riley,[1] illustrates well what is meant. In spite of the combined action of its nine known parasites, this worm, at irregular intervals, marches its gigantic armies over fields of grass and grain, for a season, and then disappears.

Again, parasites do not stop the ravages of an insect at once as birds do. The larvæ which they infest are allowed to pass through the destructive period of their lives, apparently with appetites unimpaired. They save future rather than present crops, while birds do both.

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[1] Second Annual Report, p. 37.

How far birds are destructive to parasitic insects cannot be stated with certainty at present. The fact, however, that the contents of not more than thirty-two out of six hundred stomachs, examined carefully under the microscope, gave any evidence of parasitic hymenoptera, and that, if we set aside the probably exceptional case of the Pewee, already mentioned, usually but one, or occasionally two of these insects were found in a stomach, indicates that this group of parasites is not preyed upon by birds to the same extent that other insects are. It should be said, however, that some sixteen species of birds are proved to feed upon these insects to some extent, and that these species represent Thrushes, Titmice, Warblers, Swallows, Flycatchers and Finches as well as the Hummers. Large birds, like the Robin and Chewink, as well as the small Kinglets and the Humming Bird, eat these hymenopterous friends. Birds, doubtless, destroy large numbers of parasites with the insects which they infest, but such a destruction is admissible.

(7) *A bird may be classed as an enemy in so far as it feeds upon beneficial predaceous insects, spiders and myriapods.* It is in the destruction of these forms that we are to apprehend the greatest injury from our birds. They are large, conspicuous, and, as a rule, easily captured. They are extremely numerous, and frequent every situation which a bird may visit. The majority of them, to obtain food, are obliged to lead roving lives, and are thus more exposed and consequently more liable to be discovered by birds than many of the plant-eating insects are. In the directness of their effect upon insect life, they take the same rank with birds, for when they secure their prey its devastations are at an end. Like birds, too, they feed more or less indiscriminately upon whatever insects they may capture; nor does this trait detract so much from their general usefulness as might be expected. It is, in fact, this habit which enables them to maintain a somewhat steady abundance even when the caprices of climate or an over-abundance of parasites nearly exterminates certain insects upon which they commonly feed. A parasitic insect confined to one, or at most to but a few, species, must fluctuate in abundance with it, and no matter how abundant or how destructive another insect may become, it is powerless to destroy it, or to save itself. With predaceous forms, however, this case is quite different, and their general tendency, like that of birds, is to maintain a steady, rather than a vacillating, abundance. Many of the wasps, the Tiger and Ground beetles, the Lady-birds, a few moths (Report of Department of Agriculture for 1879), the Asilus and Syrphian flies, many of the true Bugs, the Dragon-flies and Lace-wings, nearly all of the Spiders and many of the Myriapods, are representatives of this group, and, as will be seen beyond, all of them are destroyed to a greater or less extent by very many of our birds.

(8) *A bird does us harm when it feeds upon carrion insects.* How much of health we owe to these scavengers we can only imagine, but that they do exert a great influence in checking malarial diseases we have no reason to doubt. Fortunately for us, birds do not appear to be very destructive to these insects, especially in their larval states.

(9) *A bird is harmful when it eats beneficial worms.* In the light of the investigations made by Charles Darwin on the "Origin of Vegetable Mould," angle-worms, or earth-worms, appear to render an important service in the accumulation of this most essential material to the growth of shallow-rooted vegetation. Not a small number of our birds feed on angle-worms to some extent.

Hair-worms (Gordii) and some other similar forms are other members of this group, some of which are parasitic on grasshoppers and other insects, including spiders, during their larval stages. In the adult stages they are found in the water and are there occasionally picked up by Snipes.

Considering some of the effects of entozoa in man in connection with Dr. Leidy's statement that "their (Gordii) bulk and weight are frequently greater than all the soft parts, including the muscles, of their living habitation; nevertheless, with this relatively immense mass of parasites, the insects jump about almost as freely as those not infested," there may be a chance for error in deciding just which species of these worms are beneficial and which are detrimental. If, in the case of the grasshoppers, the parasites do not kill their hosts nor prevent them from laying perfect eggs, they must be classed as detrimental, for their presence in the insect must have the effect of increasing the amount of food consumed by it. It amounts to the same thing as hair-worms eating vegetation; but the reverse of this would be true of species infesting spiders, for they would be required to kill more insects than if not infested.

It will be observed that in the foregoing classification nothing has been said of what are commonly known as "neutral" plants and "neutral" insects. Notwithstanding such statements as[1] "Birds destroy insects enormously, but these are in the great part neutral," it is doubtful if any such insects exist, at least when life is considered in its broadest relations to man. What noxious insect or plant have we which, when judged by the usual standard of neutrality, was not once neutral? Nineteen years ago the Colorado potato beetle, feeding in its original habitat upon a wild species of *Solanum*, would have been classed as neutral, and yet it only needed the encroachment of civilization upon its home to enable it to march eastward and take possession of the whole potato growing region of the United States, which it now holds with a tenacity that baffles all opposition. There are now feeding upon the potato beetle between twenty-five and thirty insects, all of which, until their possibilities of usefulness became known, would have been classed with the beetle upon which they prey as neutral. Now they are acknowledged friends, while the beetle is a pronounced enemy. All those insects which may feed upon plants under cultivation, or upon those which are yet to come under cultivation, are, with the utmost consideration for them, to be looked upon as but latent enemies, and guarded as such, while those animals which hold them in check should be looked upon as latent allies, to be held in reserve for future needs. But when vegetation not under cultivation, and not to be regarded as weeds, is considered with reference to its soil-producing function, to its influence upon climate, and to the production of lumber and fuel, the insects which feed upon it are injurious, and the birds and insects which hold them in check are beneficial. Viewed in this light, the life of the Rocky Mountains and that of the wilds of the British Possessions are as directly connected with human interests as the winds and the waters which flow from them. The food of birds cannot, therefore, be said to consist of insects which are, in the great part, neutral.

When it is proposed to utilize birds as insect destroyers, to increase the abundance of certain species and to exterminate or hold in check others, to encourage the breeding of certain birds in given places and to prevent others from doing so; or, when it is proposed to introduce into a country a foreign species, other questions than those of food simply must be considered.

Some of the more important of these are the following:

(1) *The relations which the bird holds to different industries.* The failure to recognize the dissimilar relations which various birds sustain to different indus-

[1] Nature's Means of Limiting the Number of Insects. Am. Nat., Vol. VIII, p. 270.

tries has led to much of the diversity of opinion in regard to the value of birds as destroyers of insects, and to much of their needless persecution. The Bobolink, considered with reference to rice-culture, has been regarded as a scourge in the Carolinas, where almost countless numbers of them have been slaughtered. But all through the Northern States, where it spends the summer, and where it is almost exclusively insectivorous, few birds are more needed than it. Here it occupies the grassy meadows, both damp and dry, where grasshoppers, crickets, cutworms, and other noxious insects abound and upon which it may feed. To the dairying interests of its summer home, then — and these are by far the greater and more important — it is as beneficial as it is destructive to the rice-crops of the South. Shall we ask our Southern friends to guard their plantations and spare the birds? Before we can do this with consistency we must know more definitely than we do now what injury and service they render in the South, what work they do in the West Indies, whither they take themselves for the winter, and what is to be the mission of the large number that pass by us in summer to the fast opening Saskatchewan country to breed.

(2) *The food and habits of the bird in different localities.* That these elements must be taken into consideration is sufficiently evident from what has been said in regard to the Bobolink under the last head.

(3) *The food of the bird during different seasons.* There are very many of our birds which, if judged alone by their food during a particular season, would be classed as injurious, when in reality they are very beneficial. The Red-winged Blackbird during the month of August is, in many localities in Wisconsin, very injurious, and for this reason has often been declared a nuisance. It is, however, far from being such. During the months of May, June and July, its home is in the sloughs, wet meadows and low pastures, and from these it often visits the adjoining dry fields. In all of these places it feeds, like the Bobolink, very largely upon insects. After the corn has hardened in the fall, it is again beneficial, feeding almost exclusively upon insects and the seeds of weeds, which it obtains in cultivated fields.

(4) *The food of the bird when young and when mature.* We probably have no bird except the Carolina Dove, Passenger Pigeon, possibly the Thistle Bird, and perhaps some of the birds of prey, whose young are not largely or entirely fed upon insects. The first few weeks of a bird's life (during which time the majority of our species attain their full size) is the most voracious period of its existence. Dr. Bradley has estimated that a pair of Sparrows, with a brood to feed, will consume 3,360 caterpillars in the course of a week. A pair of Thrushes are said to have carried to their young, in the course of an hour, 100 insects, principally caterpillars. A young Robin, reared by Prof. Treadwell, required not less than sixty earth-worms a day. A Wood Pewee was observed by the writer to carry, to her brood of three, forty-one insects in three-fourths of an hour.

In view of these facts, it is evident that there can be but few of our birds, unless it be some of those which plunder the nests of other birds, which are not beneficial during one period of their existence at least.

(5) *When and how long the bird is with us.* The birds that are with us longest, other things being equal, are, of course, capable of rendering the greatest service or the greatest injury; and they are the birds, viewed from an economic standpoint, which should interest us most. But the service which birds of passage render is far from being so insignificant as to be overlooked. On the contrary, the services of these birds are so great that we have a right to demand their protection when they are in lands not our own.

The assertion,[1] "Birds are only united in troops more or less considerable at the times of migrations of autumn and spring, that is when insects are infinitely less numerous than during the summer"— however true the impression which it conveys may be for Europe, is wholly untrue for the United States both in reference to summer residents and to birds of passage. During an average of two weeks in the spring and for the same length of time in the fall, the birds of passage are probably double the number per square mile of our summer residents. They are with us then nearly one-fifth as long and in double the abundance, consequently they should do, if we leave out of the account the rearing of young, nearly two-fifths as much work. We should expect them to eat more, relatively, for they are working harder. Many of them have been flying all night and not quietly sleeping among the branches as resident birds do.

Because the insects are infinitely less numerous during the seasons when birds are migrating, does not signify that the actual number of insects destroyed is necessarily so much less. The hungry and exhausted birds must be fed before they can resume their journey, and if they do not find food in abundance they only search the more diligently and scrutinize the more closely until their wants are supplied. Although most of the insects upon which they feed in the fall have nearly or quite passed through the period of their destructiveness, yet many of them are the ones which are to hibernate in one state or another, and from which the next season's ravages are to come. Those which are consumed during the spring are the forms which have survived the severities of winter, and from which far more of destruction than is actually realized would come if they were left to multiply during the coming summer. It can hardly be said, then, that in the insects which they do destroy, they render a less service than do other birds. They supplement the work of our summer residents, as it were, at both extremities, and they do it well. Let us see to it that they are properly protected.

Some of our birds of passage are quite destructive to some crops in the fall. The Tennessee Warbler, called, by some, with us, the Grape-sucker, occasionally does serious injury to vineyards by probing with its sharp bill the ripe grapes, apparently to obtain the juice. It might be inferred that as this bird is with us so short a time, its services in destroying insects can hardly compensate for the injury which it may do to vineyards, and, consequently, that it is a fit subject for extermination. The very fact, however, that it is with us so short a time should make us all the more careful in regard to what steps are taken in respect to it. For, if ours is the only injury it does, and so far as is now known it is, it must lead a long life of usefulness in other places where it may do what other birds are not able to accomplish. It is, indeed, one of those small active species which feeds quite extensively upon plant-lice and other very small insects which are said to be overlooked by most birds. From the stomachs of four specimens examined collectively, thirty plant-lice, and thirty small heteropterous insects, nine-hundredths of an inch long, were taken.

(6) *The place in which the bird nests.* Wherever a bird builds its nest (except the forms whose young run about as soon as hatched), there or in the immediate vicinity, as a rule, its labors are confined until after the young are able to feed themselves. In consequence of this, those birds which breed in cultivated grounds and in the vicinity of dwellings are generally the most valuable. It should be observed, however, that cultivated grounds are not the only places where the insects which ravage them are bred. The army-worm

[1] Nature's Means of Limiting the Number of Insects. Am. Nat., Vol. VIII, p. 270.

has for its natural abode the wild grass swamps so common in many parts of the country, and from there, when it becomes excessively abundant, it marches out upon fields of grass and grain in such vast columns as to sweep everything green before it. The army-worm year of 1861 will long be remembered. The Rocky Mountain Locust is another insect of the same kind.

Viewed in the light of such facts as these, insectivorous birds which rear their young in such uninviting places, and where they appear to lead useless lives, shine with a new interest to us; and even though they may be somewhat destructive, they should be protected until careful study proves that they do not feed upon the army-worm or other pests. Some of the birds which frequent these situations are the Marsh and Short-billed Wrens, the Swamp Sparrow, several of the Blackbirds, the Bobolink, the Rails, as well as other birds.

The situation in which the nest is placed has much to do in determining the abundance of the species, especially in cultivated districts, and consequently its general usefulness. The Short-billed Wren often builds in our low, wet meadows, but its breeding season is not fully past when haying-time begins, and many a nest freighted with eggs or young is mown down and its contents destroyed. The result is, that it is far less abundant than its cousin, which selects more secure breeding places. The Short-billed Wren cannot, therefore, be offered as a substitute for the troublesome Redwing, or for the Bobolink, both of which breed in similar situations, but which get their young upon the wing before the grass is ready to cut.

Birds, like plants, may be out of place, and so more injurious than they would be if confined to their proper spheres. Blue Jays and Shrikes have no right in orchards and about dwellings during the breeding season, unless more useful birds cannot be induced to tarry there.

(7) *The haunts of the birds.* The places which a bird frequents during the season, though always including the place where it nests, are often much more varied and extensive. Upon these haunts, as upon the breeding places, depend much of the bird's usefulness or injury. All of our Thrushes, so far as food and method of obtaining it are concerned, have essentially the same habits as the Robin, but none of them are, at present, as useful to agricultural or horticultural interests as it is. Should any of them in the future become as familiar as the Robin, they will doubtless approximate it in usefulness.

(8) *The time of day at which the bird obtains its food.* Nocturnal insectivorous birds and those which feed in the early twilight are especially to be encouraged, not because they are necessarily more destructive to insects than other birds, but because they feed at a time when insects are abroad in abundance and when they have but comparatively few enemies with which to contend. Rapacious birds, however, which obtain their food at night are to be regarded with more suspicion, perhaps, than those which fly by day. All the Owls, provided with their peculiar plumage, are able to move so noiselessly, that, under the cover of night, when other birds are in repose, they may be expected to exert a powerful influence in reducing the abundance of birds, especially of the woodland species.

(9) *The method by which the bird obtains its food.*

(10) *The situation in which the bird obtains its food.*

(11) *Whether or not the bird does an important work which other birds are not fitted to do.*

These are questions of extreme importance, especially if it is proposed to extirpate a species, or to reduce its abundance. There is such a division of labor among birds, that, as has been said, there are very few insects indeed which may not, in one or more stages of their existence, become a prey to them. And this division of labor which birds have assumed, in the face of the profusion of life from which they may choose their food, is conclusive evidence to me that the power which they exert over the abundance of insect life is far from being inappreciable. The utility of birds as a whole, judged by that of a particular species, without reference to the points under consideration, would undoubtedly lead to an unfavorable, but equally false conclusion. What we need to aim at in regulating the bird-fauna of agricultural districts, is to make it combine, in sufficient abundance, all of those species which do peculiar but important work. We need, in fact, to adopt those divisions of labor which nature has been so long in working out, and perhaps without modification, except so far as changing conditions and industries make it necessary that new relations should be established.

To expect the Robin, with an unlimited abundance, to do the work of the Kingbird and Pewee, or that these birds can do the work of the Vireos, is absurd. Neither can the slow-winged and short-flighted Pewee and Kingbird, although they are fly-catchers, be expected to do what the Swallows are able to accomplish with their long, swift, gyratory and zig-zag flights. Each species has fitted itself by long practice for its own peculiar work, and does it more effectually than another species can. Viewed in this light, it is evident that some birds, even though they may be somewhat destructive to particular crops, must, nevertheless, be protected, simply because they do an important work which other birds do not.

The Baltimore Oriole has been consigned to extirpation because it is somewhat destructive to grapes, destroying at times, it is said, more than it needs to eat; and yet this bird does an important work, which, so far as I have observed among birds, is peculiar to itself. It is that of feeding upon leaf-rollers in the larval state. These are a large and destructive group of moths. They infest nearly all our fruit trees, our strawberries and cranberries, as well as many of the trees of the forest. Those which do not infest the fruit protect themselves either by folding one side of a leaf over them, or by tying a number of leaves securely together, thus forming a strong house in which they feed secure, I fear, from the majority of birds. But the Oriole has learned their habits, and, with its strong bill, is able to demolish their houses and devour the inmates. I have seen a whole family of these birds working together in a grove devouring leaf-rollers, and making such a noise as to lead me to suspect at first that some large animal was stripping the leaves from the trees. Prof. J. H. Comstock informs me that he has seen the same bird thrust its head through the web of the tent-caterpillar, and eat the larvæ which courted security within.

When a bird which is injurious does a special work, that work must be an important one in order that it may be urged as a reason for protecting the bird. The tent-caterpillar, although it is very destructive, is easily and completely under our direct control. Its tent makes it so conspicuous that it cannot be overlooked, while every worm in a colony may be easily removed at once and destroyed. When it is said that this evil sometimes becomes so great that even the best farmers have despaired of counteracting it, the statement only speaks disparagingly of the energy and shrewdness of the farmers. It is not in the destruction of such pests as these that birds render their greatest service, but rather in the destruction of those that are small, though prolific, of those that do not betray their existence until after their hurtful mission is performed, and of those that feed singly and do not congregate under tents for a season of rest and security.

(12) *Size and activity of the bird.* The larger and the more active a bird is the greater will be the amount of food which it requires, and, consequently, other things being equal, the more beneficial, or the more injurious, it will be. It is by no means, however, the largest bird which is the most serviceable. Diminutive proportions are, in many cases, quite as desirable as their opposites. It is the smallness of the Tennessee Warbler which makes it profitable for it to feed upon plant lice; and it is the same quality, together with its agility, that enables the Chickadee to hang back downwards from the leaves of the outermost sprays of trees, that it may feed upon those small larvæ and other insects which can only be obtained by the larger and more clumsy species with difficulty. These small and agile birds perform, therefore, a distinct work in protecting the terminal foliage of forest trees.

(13) *Whether the bird is or is not gregarious in its habits.* It is not necessary that birds should be "united in troops more or less considerable" that they may be of material service. On the contrary, insectivorous birds can hardly be gregarious, at least to any considerable extent, for feeding purposes, while it is the gregarious habits of many graminivorous birds which lends to them their chief noxious quality. Not that they would eat any less grain if they did not unite in such large troops, but that their injury would be more evenly distributed, causing each man to bear his share of the expenses incident to bird life, as he has received his share of the profits. Did our Blackbirds spread out over the country at large instead of uniting in such large troops, the amount of grain which they would consume, though just as great as it is at present, would be drawn from so many sources that the quantity taken from each would be so small as to be almost inappreciable. Birds having gregarious habits, unless they perform some special and important work, should not be encouraged to an equal extent with other birds; and this point should be looked to especially, when it is proposed to introduce a foreign species.

(14) *The swiftness and dexterity of the bird upon the wing.* The swifter and the more dextrous an insectivorous bird is, which captures prey upon the wing, the more efficient it is, provided other things are equal. If it feeds extensively upon parasitic insects, it becomes more dangerous, as it is better able to capture its prey. Among rapacious birds the swiftest winged Hawks are to be looked upon as the most dangerous; and, if any of these birds are to be extirpated, those which are best able to capture mature birds should succumb first. Extreme swiftness of flight is not necessarily possessed by those Hawks which are to hold in check injurious mammals.

(15) *The disposition of the bird.* When different species of birds are to be associated closely together, as is the case in many cities, and as we hope will be more extensively the case in orchards, and in the vicinity of dwellings, only those, as a rule, which will live together in harmony should be encouraged. At least, a tyrannical, overbearing bird should not be permitted to drive away from our dwellings more useful species.

(16) *The value of the bird as food for man.* Birds whose size and flesh make them valuable as food for man have that much in their favor to offset whatever injury they may do. But birds may be too valuable as insect-destroyers to justify their being killed as game. The Prairie Chicken and Quail should be stricken from our list of game birds, at least for the present, and the Meadowlark, Killdeer, and Field Plover should not be destroyed under any consideration, until after they assume an abundance far beyond what they have with us at present. The last three species are almost exclusively insectivorous throughout their stay with us, and they affect meadows, pastures, and cornfields where

their services are much needed. The Quail and Prairie Chicken are also largely insectivorous until after the middle of August, when the grain is harvested and out of danger from them, and as they live in uncultivated fields and meadows their services are very valuable.

(17) *Whether the bird is or is not a necessary habitat for troublesome parasitic entozoa.* As many fishes are infested with parasites, some of which pass through one stage of their development in Herons and other piscivorous birds, it becomes a question worthy of study to determine whether these birds may become detrimental to fish-culture by breeding parasites which will destroy the fish or render their flesh unfit for food. This question is the more important since fish-culture has become a national enterprise.

(18) *The number of broods the bird rears each season.* Those birds which rear more than one brood during the season, if they are not injurious, are likely to be of greater service than those which are single-brooded, not only because they must be more destructive to insects directly, but because they are capable of becoming more numerous than single-brooded species are likely to become.

OTHER CONSIDERATIONS.

(1) *The changing habits of birds.* Two hundred years have been sufficient to produce such marked changes in the habits of many American birds as to have caused them to assume entirely new relations to human interests. In virtue of these changes many birds have become more useful, some have become more injurious. Many, like the Swallows, now build their nests in situations whose surroundings are so entirely different from those of their original haunts that the character of their food must have undergone quite as marked a change as have the situations in which they build their nests. Since all of our native birds, which are so familiar about dwellings and farms, once inhabited exclusively wild tracts, it is but fair to presume that many which are now shy and retiring will in time become as confiding as those which have already taken up their homes with us. Indeed, these changes are being noted almost every year. When these changes of habits do take place, with them must come new and important relations. Some of these birds will then be more useful, others may be more injurious. The practical question arising from this is, how can we best hasten these changes?

(2) *Can birds ever become abundant in thickly settled districts?* The facts which have thus far been recorded in regard to the abundance of different species of birds in different localities at different times, are so meager and indefinite, that it is impossible to draw any very satisfactory conclusions in regard to this point at present. To throw some light upon this question the statistics on page 447 have been prepared They are too limited to be of very great value by themselves, and are offered here simply as a beginning. The two localities in which the statistics were taken are not as similar in some respects as could have been wished. Due allowance must be made for this fact. The salient features of the two localities, briefly sketched, are these: In the vicinity of Ithaca, there is a long, deep and narrow valley, having somewhat rolling, glen-cut sides. In it lies Cayuga lake, deep and weedless, stretching, like a broad river, to the northward. Its east and west banks are abrupt and rocky and cut at intervals by deep, wooded glens. A small grass swamp, bearing a few trees, at the south end of the lake, and running up into the city is about the only low land in the vicinity. Formerly a mixed deciduous and evergreen forest covered the hills. Now, mere remnants stand near together upon small, close-packed farms on both sides of the valley. The houses are numerous, the orchards large,

and there are few fields but what have at least a few trees standing in them. In the portion of Jefferson county where the notes were taken, the country is nearly level, with gentle undulations, and is traversed by Rock and Bark rivers. These streams draw a sharp line between prairie and openings on one side, and heavy maple timber on the other. Marshes trend along the streams, and shallow, reedy ponds are common. Compared with the vicinity of Ithaca, the farms are larger, the houses less numerous, the orchards smaller, the woods larger, and few trees stand in the cultivated fields.

Route I led from a point about one-half a mile north from Bark river out and across cultivated fields, through two small groves, across a marsh near Cold-spring Pond, and then again across cultivated fields. Routes II and III each led east from Rock river, north of Jefferson, alternately through pieces of heavy timber, and across dry cultivated fields. Route IV led from the Crawfish west, upon the prairie southwest of Aztalan, traversing dry treeless fields, and leading through two small oak groves. Route V extended from the buildings of Cornell University west across the valley, leading through a pasture, through the north end of the city, through the swamp, and up the railroad, bordered by cultivated fields on one side and by tangled thickets on the other. Route VI led directly east from the campus to Varna, and then southwest along the line of the railroad. On this trip only cultivated fields were crossed and one small piece of woods passed through. Route VII led up the valley from Ithaca along the east side, and then across to Enfield Falls. On this tramp we passed in turn along the railroad, bordered with small scattered thickets on both sides, across the Inlet, through low fields, and then past cultivated fields and small pieces of woods. Route VIII lay ten miles east of Ithaca, and led from McLean off to the southeast of Dryden, and then through Dryden to Freeville. A branch of Fall Creek was crossed twice, and with the exception of a small marsh near Freeville, only dry cultivated fields and small pieces of woods were passed.

It should be observed that the notes taken in Jefferson county were obtained after the breeding season, while those taken at Ithaca were made during the breeding season before the young birds had, to any extent, left the nests. The difference in the times of observation in the two localities will doubtless compensate largely for the difference in topographical features. For instance, the Bobolinks observed on trip VIII were, with two exceptions, all males, so that the figures probably show but about one-half the actual number of birds of this species which were there at the time.

The table, as it stands, indicates that notwithstanding the fact that the vicinity of Ithaca has been much longer under cultivation, and that it is more thickly settled, its bird population is more than a third larger, so far as the number of individuals is concerned, than that of Jefferson county. Whether this greater abundance is due more to the influence of man than to natural topographical features, the table does not appear to prove, for it is deceptive in regard to this point in several respects.

(3) *What birds, if left to themselves, are likely to become most abundant as the country grows older.* Before we can safely interfere with the restraints which nature has imposed upon bird-life, we must know the facts in regard to this point, because it can hardly be supposed that the different species will continue to hold the same relative proportions to one another that they now do if their enemies should be removed. If the birds in the table to which we have had occasion to refer are classified under the four heads, Fruit-eaters, Fly-catchers, Seed-eaters and Insect-eaters, the average number of individuals observed per mile during the eight trips, considered collectively, will be found to be approximately as follows:

FRUIT-EATERS.

For the vicinity of Ithaca.

Number of species observed	3
Number of individuals observed	179
Average number per mile	7+

For Jefferson county.

Number of species observed	3
Number of individuals observed	37
Average number per mile	3−

SEED-EATERS.

For the vicinity of Ithaca.

Number of species observed	16
Number of individuals observed	576
Average number per mile	23+

For Jefferson county.

Number of species observed	12
Number of individuals observed	141
Average number per mile	9+

FLY-CATCHERS.

For the vicinity of Ithaca.

Number of species observed	10
Number of individuals observed	255
Average number per mile	10+

For Jefferson county.

Number of species observed	8
Number of individuals observed	106
Average number per mile	7+

INSECT-EATERS.

For the vicinity of Ithaca.

Number of species observed	8
Number of individuals observed	69
Average number per mile	3−

For Jefferson county.

Number of species observed	14
Number of individuals observed	116
Average number per mile	8−

These figures appear to indicate that the greatest difference between the two localities exists among the Fruit-eaters, the Seed-eaters, and the Insect-eaters, the first two classes being much more abundant at Ithaca, while the Insect-eaters are much more abundant in Jefferson county. Much less weight can be given to these figures than to those considered under the last head. They simply indicate a direction in which observation needs to be made.

(4) *Some birds may be injurious to a locality which they seldom or never visit.* The migratory movements which characterize most birds subject them to a great variety of enemies. The boreal birds of prey, which live in the summer homes of all our birds of passage, and of all our winter visitants, are as injurious to us, so far as they destroy the members of these classes, as though they did the work of destruction in our midst. The same is to be said of those

birds of prey whose residence is in latitudes south of our own, for there both our summer residents and birds of passage may be destroyed by them.

(5) *Do birds of prey perform a necessary work by holding in check certain birds and noxious animals?* "Hawks and the larger Owls should be exterminated" is the verdict of many, and yet we are far from having that knowledge of their relations to our needs which will justify the execution of such a verdict. We need a greater abundance of insectivorous birds than we have at present, but it has not been demonstrated that a wholesale destruction of all our birds of prey will not withdraw such a restraint from our vegetable-feeding species as to cause them all to become nuisances by their excessive abundance. Nearly all of them feed upon seeds or insects, at their pleasure. There are but few of them which are not known to feed to some extent upon grains and useful seeds. These facts appear to indicate that no bird is so likely to become excessively abundant in agricultural districts as they. It would appear that, so far as they are capable of doing the work of insectivorous birds, they might even become injurious by simply crowding them out. Until these questions are securely settled, we must retain most of our birds of prey. We may experiment with them by reducing their abundance for a period, and carefully noting the effect which it has upon the abundance of other birds and upon that of noxious mammals. Since a bird once extirpated can never be reclaimed, no matter how much its services may be needed, the most guarded action in this direction can alone be justifiable.

(6) *Parasitism among birds.* Birds which possess the habit of imposing their duties of incubation upon other species are to be ranked with Hawks and Owls, so far as their influence in regulating the abundance of birds is concerned. Out of nine Pewees' nests, which were visited in the spring of 1878, at Ithaca, N. Y., by my friend F. H. Severance and myself, two contained a single Cowbird each, and two contained Cowbirds' eggs. Mr. C. N. Pennock informs me that three out of five Pewees' nests visited by him contained one or two Cowbirds' eggs each. These facts indicate that seven out of fourteen families of Pewees would, if their nests had not been disturbed, have had their own broods destroyed, and that instead of some 28 or 35 Pewees which they would have reared, only seven Cowbirds could have taken their places as insect destroyers. Such is the influence which this bird exerts over the abundance of the Pewee.

A long list of other birds, similarly affected, has been determined, and the majority of the members are among the most exclusively insectivorous birds we have.

(7) *The scientific, educational and æsthetic value of birds.* This, though mentioned last, is not the least consideration which should challenge the thoughtful and influential whenever a bird is proposed for extermination. Prof. Alfred Newton, in an article on the extermination of species (Am. Jour. of Sci., Dec., 1876), has pointed out, in a general way, the dangerous tendencies in this direction, and justly calls upon men of science to take a stand in behalf of posterity.

In view of the many important unsolved problems relating to life and its phenomena, the first factors of whose solution we already have, it is certain that the living species are too few to supply the much needed data, and that stuffed skins and dry bones can, in no adequate way, answer such questions as should be put to animated tissues. These, in my judgment, are sufficient reasons for not now recommending the absolute extirpation of any bird.

In the light of educational needs, the case of the detrimental bird appears still stronger. It is certain that, as our methods of instruction improve, the student will be led more and more into intimate personal contact with the forms of living, feeling and thinking nature to supplement and vivify, with his own perceptive faculties, the suggestions from teacher and text-book. The amount of illustrative material needed in the shape of living forms must increase year by year as long as our educational methods are progressive; while, with the most careful husbanding of resources, the number of living species must diminish in given localities. The time has already come when the least beneficial animals should be sacrificed for anatomical and physiological demonstrations, whenever they will answer the purpose, and the more beneficial forms, in other ways, spared. Here are grounds for a legitimate demand for the preservation of animals to some extent detrimental, and every parent can well afford to contribute a not inconsiderable sum for their maintenance as educational material simply.

There is another aspect of the educational phase of this question. The amount of information unconsciously imbibed by the inevitable contact with living forms is very large as regards both variety and value, and this must increase continually as long as there is progress, and the objects for personal contact remain. Viewed in this light, the very viciousness of the Blue Jay and Shrike gives to them a kind of intrinsic educational value which is not small.

A TEMPORARY CLASSIFICATION OF WISCONSIN BIRDS ON AN ECONOMIC BASIS.

In view of the fact that so little careful study has been devoted to the food of American birds, and that the subject, considered in all its important bearings, is so difficult, intricate and important, it is deemed advisable, for present purposes, to arrange our birds under the groups following. In this classification, only Wisconsin interests will be especially considered, not because the interests of other states are regarded as unimportant, but because each state, so far as its industries are peculiar, must solve its own questions.

GROUP I.

Birds whose habits, so far as they are known, render them, on the whole, beneficial.

Under this group are placed those birds whose ability to render service appears to exceed their known injurious tendencies. It may be divided into three classes:

(a) *Birds whose known habits render them beneficial at all times.*

While it is probable that, after a careful and exhaustive study of the habits of our birds has been made, none of them will be found wholly beneficial, it is better to regard them innocent until they are proved guilty.

(b) *Birds which are known to be to some extent injurious, but whose known services exceed their known injuries.*

It is probable that all of our useful birds will ultimately fall into this class.

(c) *Birds whose flesh is valuable for food, and whose present abundance and slight usefulness as insect destroyers make it proper to permit their destruction as game.*

Birds of this class belong properly in one of the two preceding classes, but this classification is made for an obvious special purpose.

Group II.

Birds whose habits, so far as they are known, make it doubtful whether they are, on the whole, beneficial or injurious.

This group is necessitated partly by conflicting evidence, partly by the absence of evidence, and partly by evidence which seems to indicate that the destructiveness and usefulness of the birds are nearly balanced. As in the first group, this may be divided into three classes:

(a) *Birds whose relations of structure and habits ally them to Group I, but which in the absence of data, or on account of conflicting data, cannot be placed there at present.*

(b) *Birds whose known beneficial and injurious results appear to balance.*

(c) *Birds whose relations of structure ally them to Group III, but which in the absence of data, or on account of conflicting statements, cannot be placed there at present.*

Group III.

Birds whose habits, so far as they are known, render them, on the whole, injurious.

In this group are placed those birds whose ability to do injury appears to exceed their beneficial agencies. It is divisible into two classes:

(a) *Birds whose known habits render them injurious at all times.*

As in the first class of Group I, it is probable that, ultimately, the members of this class will all be placed in the next.

(b) *Birds which are known to be to some extent beneficial, but whose known injuries exceed their known services.*

How shall a bird's food account be expressed numerically in terms of debit and credit? This is at once the most difficult and the most important of all the questions requiring solution in order to express the *specific* economic relations of any bird.

Nothing can be more certain than that, after the food of a bird has been classified under the heads "Elements Beneficial" and "Elements Detrimental" to man, neither the relative volumes nor the relative weights of these two classes of materials can express the true economic relations of the bird.

If we compare the corn plant-louse, the gall stage of the grape phylloxera, the plum-curculio, the small parasitic military microgaster, which lays its eggs in several kinds of cut worms, the potato-beetle and the chinch-bug, with the large coral-winged grasshopper, bulk for bulk, the ratios will appear about as follows:

1 coral-winged grasshopper = 12,000 military microgasters.
1 coral-winged grasshopper = 3,000 phylloxera.
1 coral-winged grasshopper = 1,500 corn plant-lice.
1 coral-winged grasshopper = 750 chinch bugs.
1 coral-winged grasshopper = 60 plum curculios.
1 coral-winged grasshopper = 7 potato-beetles.
1 coral-winged grasshopper = 1,000 young potato-beetles.

By a system of gauging bulk for bulk, it is evident from the table that one coral-winged grasshopper eaten by a bird would give it a credit which would offset completely the destruction of 12,000 military microgasters, a proposition sufficiently absurd. The same system of gauging would also count the destruction of seven adult Colorado potato-beetles as the full equivalent of 1,000 very young beetles of the same species, while, as a matter of fact, the destruction of seven very young beetles should be counted a greater service than the destruction of an equal number of adult forms, since not only is the food required to mature the young beetles saved, but the possibility of a deposition of seven thousand eggs (it is estimated that one female may lay one thousand eggs), is effectually precluded.

The fragmentary condition, also, of the contents of a bird's stomach renders any purely quantitative system of gauging as fruitful of false values as does the inequality of size and weight among insects. A single maxilla, a bit of elytron, or a small wing would count for almost nothing in the account by such a system, while each is positive proof of the destruction of a whole insect of some kind, no matter how small the fragment may be.

But when insects are estimated bulk for bulk with grains, weed seeds and fruits, the diversion from true relations reaches the maximum.

A peck of plums and a peck of curculios, a peck of wheat and a peck of chinch-bugs, or a peck of corn and a peck of cut-worms, are manifestly not to be considered as equivalent values on opposite sides of any account.

Even in those cases where the individuals are nearly equal in bulk and weight, there is often little justice in offsetting one with the other, for then no account will be taken of the relative service or injury of the two species, or of the different rates of reproduction.

In view of the fact that we have no standard of insect values, and that, in the present state of progress of entomological science, a satisfactory one can hardly be furnished, the simplest and, I believe, all things considered, the most reliable method of exhibiting the results of observations on the food of birds, as well as one which will leave the materials accumulated in the most available form for subsequent more critical examination, is to exhibit the number of individual forms of life which a bird can be proved to have eaten in as systematic a form and as specifically as possible. In the tables which follow under the various families of birds, an effort has been made to do this. The second table in each case exhibits the details as far as they could be shown in the space allowed, and the first table exhibits the same facts brought together under the heads "Elements Beneficial," "Elements Detrimental," and "Elements whose Economic Relations are Unknown." There are two general tables introducing the body of the report which exhibit the same results for all of the birds examined, brought together under the families to which they belong.

Tabular summary of the results of an examination of the contents of the stomachs of 1,608 birds.

THE NAMES OF THE FAMILIES TO WHICH THE BIRDS EXAMINED BELONG.	Whole number of birds examined.	Number eating animal food.	Number eating vegetable food.	Number eating adult forms.	Number of adult forms eaten.	Number eating pupæ.	Number of pupæ eaten.	Number eating larval forms.	Number of larval forms eaten.	Number eating eggs.	Number of eggs eaten.	Number eating beneficial forms.	Number of beneficial forms eaten.	Number eating noxious forms.	Number of noxious forms eaten.	Number eating forms of unknown economic relations.	Number of forms of unknown economic relations eaten.
Thrushes	105	93	46	66	159	2	6	34	72	3	15	12	18	46	96	67	163
Bluebirds	27	26	1	24	40	..	...	6	9	2	10	3	5	20	42	11	22
Sylvias	16	16	...	14	65	1	1	3	9	..	...	2	2	3	9	14	64
Pitmice	12	12	1	12	42	..	...	7	14	1	5	2	2	8	17	10	37
Nuthatches	29	27	10	26	87	1	1	2	4	..	...	2	2	5	10	27	80
Creepers	3	2	...	2	6	..	...	...	...	..	...	...	...	...	...	2	6
Wrens	27	27	2	27	108	..	...	5	9	1	5	2	2	13	23	20	87
Larks	6	...	6	...	...	..	...	...	...	..	...	...	...	...	...	...	...
Wagtails	2	2	..	2	6	..	...	...	...	..	...	...	...	...	...	2	6
American Warblers	246	241	19	218	1,118	1	1	60	184	6	133	14	28	72	323	218	942
Tanagers	29	29	4	27	120	1	1	8	26	..	...	7	15	10	38	25	94
Swallows	32	32	...	32	281	..	...	...	...	..	...	13	67	16	124	17	109
Waxwings	15	5	13	5	18	..	...	...	...	1	50	2	7	2	7	3	4
Greenlets	87	85	14	62	301	1	1	47	114	7	88	7	9	61	113	51	184
Shrikes	15	15	...	15	75	..	...	4	6	..	...	7	8	13	49	10	24
Finches	339	156	266	102	484	..	...	35	67	5	16	13	18	62	241	110	328
American Starlings	150	74	99	56	194	..	...	19	71	4	65	9	12	37	119	50	139
Crows, Jays, etc	35	28	28	23	51	..	...	8	11	..	...	2	5	10	15	22	42
American Flycatchers	119	119	5	118	659	..	...	11	23	5	328	32	53	41	126	113	601
Goatsuckers	7	7	...	7	118	..	...	...	...	1	162	1	1	4	18	7	97
Chimney Swifts	3	1	...	1	2	..	...	...	...	..	...	...	...	...	...	1	2
Humming-Birds	5	5	...	5	17	..	...	...	...	..	...	4	4	1	1	5	12
Kingfishers	6	...	...	...	...	..	...	...	...	..	...	...	...	...	...	...	...
Cuckoos	14	14	...	11	62	..	...	11	83	..	...	3	3	12	102	4	31
Woodpeckers	110	102	41	84	1,864	8	285	30	166	..	...	6	22	41	354	87	1903
Owls	8	3	1	2	9	..	...	1	10	..	...	...	...	3	19	...	...
Hawks	15	13	...	12	102	..	...	2	3	..	...	3	3	8	60	2	10
Pigeons	16	2	16	2	26	..	...	1	2	..	...	1	1	1	15	2	12
Grouse	8	5	5	4	13	..	...	2	25	1	5	1	7	7	30	...	...
Plover	16	16	...	14	78	..	...	7	15	1	52	2	7	9	33	13	61
Phalaropes	5	4	...	4	16	..	...	3	10	..	...	...	...	...	...	4	20
Snipe, etc	45	38	5	23	150	..	...	7	13	..	...	5	17	3	6	35	164
Herons	15	15	...	11	39	..	...	4	21	..	...	8	47	1	1	7	53
Rails	16	9	14	3	12	..	...	...	...	..	...	...	...	1	2	9	58
Ducks	13	7	9	1	2	..	...	1	3	..	...	1	2	...	...	6	69
Gulls	6	6	...	5	28	..	...	3	6	..	...	...	...	3	6	5	26
Grebes	6	6	...	5	24	..	...	2	15	..	...	...	...	2	15	5	32
Totals	1,608	1,243	605	1,021	6,376	15	296	323	991	38	934	164	367	515	2,018	964	4392

Tabular summary of the results of an examination of the contents of the stomachs of 1,608 birds.

The Names of the Families to which the Birds Examined Belong.	Number of hymenoptera eaten.	Number eating hymenoptera.	Number of lepidoptera eaten.	Number eating lepidoptera.	Number of diptera eaten.	Number eating diptera.	Number of hemiptera eaten.	Number eating hemiptera.	Number of coleoptera eaten.	Number eating coleoptera.	Number of orthoptera eaten.	Number eating orthoptera.	Number of neuroptera eaten.	Number eating neuroptera.	Number of spiders eaten.	Number eating spiders.	Number of myriapods eaten.	Number eating myriapods.
Thrushes	73	34	45	24	1	1	2	2	93	44	22	13	...	...	5	5	1	1
Bluebirds	2	1	10	6	...	...	1	1	13	8	22	17	...	...	2	2	...	...
Sylvias	2	2	9	3	12	2	...	...	14	6	...	...	...	...	1	1	...	...
Titmice	...	...	10	5	...	...	3	1	13	7	...	...	...	...	2	2	...	...
Nuthatches	5	2	6	3	4	2	...	...	47	17	...	...	...	...	1	1	...	...
Creepers	3	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Wrens	4	2	14	10	7	3	7	2	33	10	3	3	2	2	...	...	...	...
American Warblers	45	23	167	55	175	59	79	15	221	80	6	4	10	7	4	3	...	...
Tanagers	4	4	26	8	6	3	6	3	47	17	7	4	1	1	11	3	...	...
Swallows	21	9	16	9	57	11	44	7	85	19	2	2	40	10	1	1	...	...
Waxwings	5	1	...	...	4	1	...	...	3	2	3	1	3	1	...	...	...	...
Greenlets	21	5	114	48	26	8	76	10	56	26	10	9	5	4	2	2	...	...
Shrikes	...	...	12	4	4	2	...	...	18	9	24	7	6	3	...	...	...	...
Finches	10	7	67	25	11	7	138	12	96	41	28	23	4	3	4	4	1	1
American Starlings	2	2	79	26	15	6	2	1	80	30	42	22	2	2	...	...	...	...
Crows, Jays	1	1	3	3	...	...	...	...	30	15	8	5	...	...	...	...	...	...
American Flycatchers	97	26	48	24	114	28	9	7	48	24	18	13	29	21	...	...	...	...
Goatsuckers	...	...	13	3	...	...	23	2	33	5	5	1	4	2	...	...	...	...
Chimney Swift	...	...	...	...	2	1	...	...	...	...	...	...	...	...	...	...	...	...
Humming-birds	1	1	...	...	...	...	1	1	...	...	...	...	...	...	3	3	...	...
Cuckoos	13	2	77	10	...	...	...	...	10	2	26	6	...	...	2	2	...	...
Woodpeckers	1449	61	24	12	2	2	222	5	215	48	2	2	...	...	2	2	...	...
Owls	...	...	10	1	...	...	...	...	...	...	6	1	...	...	...	...	...	...
Hawks	...	...	7	2	...	...	...	...	6	3	69	11	...	...	...	...	...	...
Pigeons	...	...	2	1	...	...	...	...	...	...	13	1	...	...	1	1	...	...
Grouse	...	...	24	2	...	...	...	...	5	3	3	2	...	...	7	1	...	...
Plover	15	4	9	5	1	1	...	...	32	11	13	7	...	...	3	1	...	...
Phalaropes	...	...	...	...	...	...	...	...	6	3	...	...	...	...	...	...	...	...
Snipe, etc	6	1	1	1	3	3	...	...	45	14	5	3	3	2	...	...	...	...
Herons	...	...	...	...	...	...	32	4	11	4	...	...	26	4	1	1	...	...
Rails	...	...	...	...	...	...	5	2	2	2	...	...	...	...	...	...	...	...
Ducks	...	...	...	...	...	...	...	...	...	...	...	...	2	1	...	...	...	...
Gulls	...	...	...	...	...	...	6	3	...	...	...	...	6	3	...	...	...	...
Grebes	...	...	...	...	...	...	15	4	...	...	...	...	15	2	...	...	...	...
Grand Totals	1,779	189	793	290	444	140	671	82	1,262	430	337	157	158	68	52	35	2	2

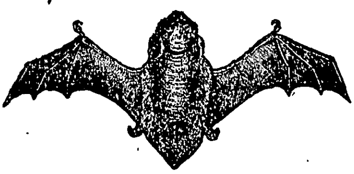
FIG. 103.

TYPES OF THE PRINCIPAL GROUPS OF BENEFICIAL AND DETRIMENTAL ANIMALS PREYED UPON BY BIRDS.

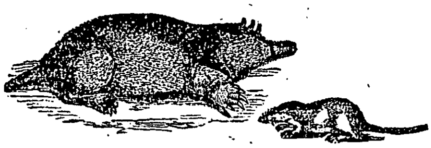
MAMMALS.

(*Beneficial.*)

Those preying upon night-flying insects;—Bats. Those eating terrestrial and underground insects;—Shrews and Moles.



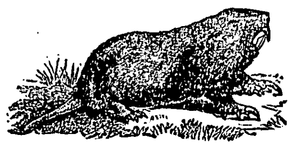
HOARY BAT.



COMMON MOLE. THOMPSON'S SHREW.

(*Detrimental.*)

Those eating grains, birds or their eggs; Rats, Mice, Gophers and Squirrels.



POCKET GOPHER.

WHITE-FOOTED MOUSE.

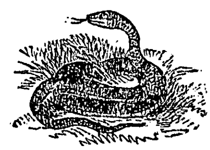
BATRACHIANS. (*Beneficial.*)

Those preying upon detrimental insects;—Toads, Tree-Toads. Frogs and Salamanders.

LEOPARD FROG.

SNAKES. (*Detrimental.*)

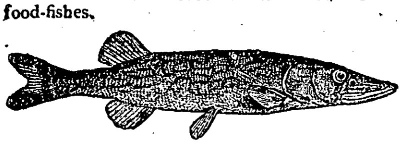
Large ones preying upon frogs toads, birds and their eggs;—most snakes over 18 or 20 inches long.



BLACK SNAKE.

FISHES. (*Beneficial.*)

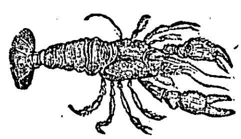
Those suitable for food or for the food of food-fishes.



PICKEREL.

CRUSTACEANS. (*Detrimental.*)

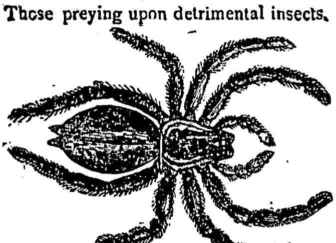
Those building clay chimneys in meadows.(??)



CRAY-FISH.

SPIDERS. (*Beneficial.*)

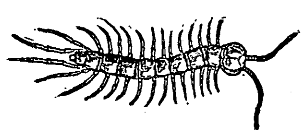
Those preying upon detrimental insects.



SPIDER.

MYRIAPODS. (*Beneficial.*)

Those preying upon detrimental insects.



AMERICAN EARWIG.

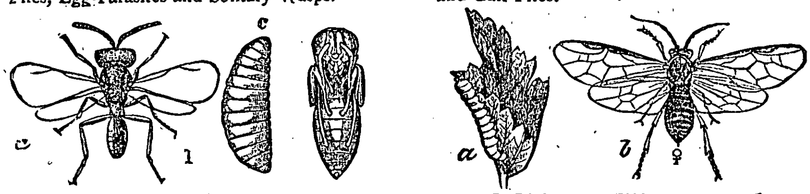
FIG. 104.

TYPES OF THE PRINCIPAL GROUPS OF BENEFICIAL AND DETRIMENTAL ANIMALS PREYED UPON BY BIRDS.

(*Beneficial.*) HYMENOPTERA. (*Detrimental.*)

Those that are parasitic or predaceous on noxious insects;—Ichneumon and Chalcis Flies, Egg-Parasites and Solitary Wasps.

Those eating leaves, boring stems, or producing galls;—"Slugs," Saw-Flies, Horntails, and Gall-Flies.

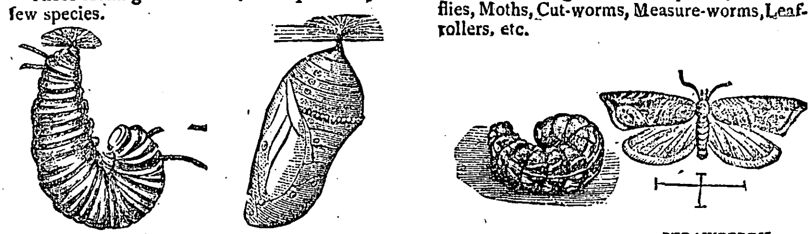


CHALCIS FLY. LARVE. PUPA. LARVE. CURRANT SAW-FLY

(*Beneficial.*) LEPIDOPTERA. (*Detrimental.*)

Those feeding on weeds;—comparatively few species.

Those feeding on useful plants;—Butterflies, Moths, Cut-worms, Measure-worms, Leaf-rollers, etc.

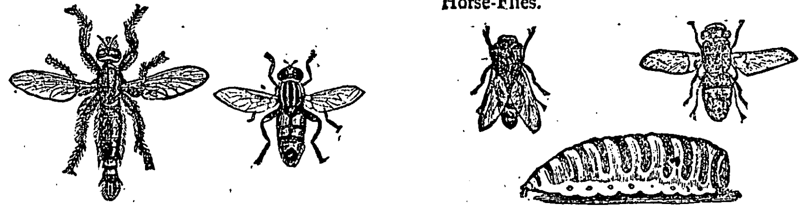


MILKWEED CATERPILLAR. PUPA. W-MARKED CUT-WORM. STRAWBERRY LEAF-ROLLER

(*Beneficial.*) DIPTERA. (*Detrimental.*)

Those preying upon detrimental insects and carrion;—Asilus, Syrphian and Meat-Flies.

Those feeding on useful plants and animals;—Gnats, Gall-Gnats, Crane-, Bot- and Horse-Flies.

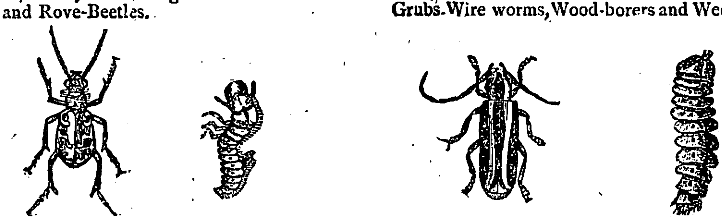


ASILUS FLY. SYRPHUS FLY. SHEEP BOT-FLY.

(*Beneficial.*) COLEOPTERA. (*Detrimental.*)

Those preying upon detrimental insects and carrion;—Lady-Birds, Tiger- Ground- Carrion- and Rove-Beetles.

Those feeding on useful plants;—Click Long-horned, Lamellicorn, and Leaf-Beetles Grubs. Wire worms, Wood-borers and Weevils.



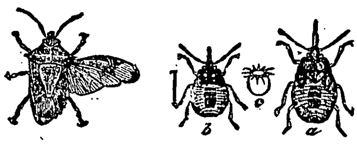
TIGER BEETLE. LARVE. APPLE TREE BORER. LARVE.

FIG. 105.

TYPES OF THE PRINCIPAL GROUPS OF BENEFICIAL AND DETRIMENTAL ANIMALS PREYED UPON BY BIRDS.

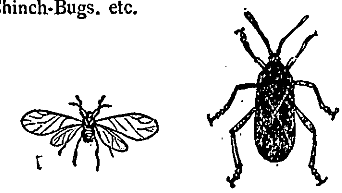
(*Beneficial.*) **HEMIPTERA.** (*Detrimental*)

Those sucking the blood of detrimental insects;—Reduvian and some Corisian Bugs.



SPINED SOLDIER-BUG. EGG AND LARVE.

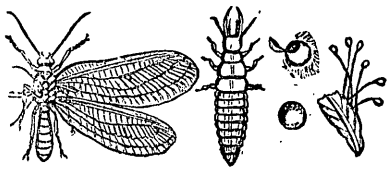
Those sucking the juice of useful plants;—Harvest-Flies, Leaf-Hoppers, Plant-Lice. Chinch-Bugs. etc.



PLANT LOUSE. SQUASH BUG.

NEUROPTERA. (*Beneficial.*)

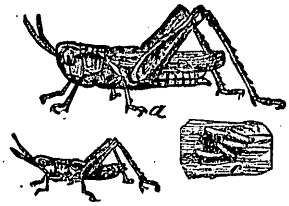
Those preying upon detrimental insects;—Dragon-Flies, Lace-Wings, and Ant-Lions.



LACE-WING FLY. LARVE. COCOON. EGGS.

ORTHOPTERA. (*Detrimental.*)

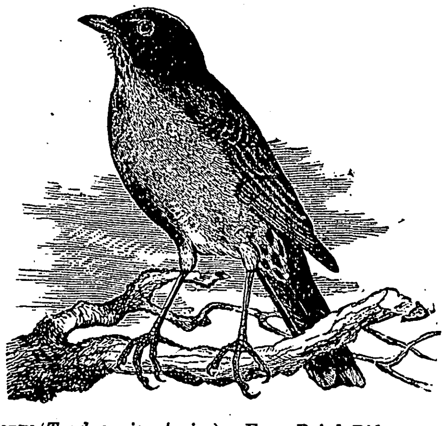
Those feeding on useful plants;—Grasshoppers Locusts, Crickets, Cockroaches.



GRASSHOPPER. LARVE AND EGGS

FAMILY TURDIDÆ: THRUSHES.

FIG. 106.



COMMON ROBIN (*Turdus migratorius*). From Baird, Ridgway and Brewer.

Table showing the number of birds which had eaten (1) vegetal and (2) animal food, and the economic character of the latter (mostly insects) under the heads Beneficial, Detrimental and Unknown Relations.

Number and Name of Specimens Examined.				Classification of Food.	Ratios Represented by Lines.
Of thirty-seven Robins examined	34	Contained		Animal food	
	13			Vegetal food	
	29		60	Detrimental	
	6		10	Beneficial	
	17		56	Unknown	
Of two Wood Thrushes examined	2	Contained		Animal food	
	1			Vegetal food	
				Detrimental	
				Beneficial	
	2		4	Unknown	
Of nine Hermit Thrushes examined	9	Contained		Animal food	
	3			Vegetal food	
	5		7	Detrimental	
				Beneficial	
	9		28	Unknown	
Of eighteen Olive-backed Thrushes examined	16	Contained		Animal food	
	6			Vegetal food	
	4		10	Detrimental	
	1		1	Beneficial	
	13		26	Unknown	
Of seven Wilson's Thrushes examined	5	Contained		Animal food	
	3			Vegetal food	
	2		4	Detrimental	
	2		2	Beneficial	
	4		10	Unknown	
Of twenty-two Cat-birds examined	17	Contained		Animal food	
	13			Vegetal food	
	3		8	Detrimental	
	2		2	Beneficial	
	15		28	Unknown	
Of ten Brown Thrushes examined	10	Contained		Animal food	
	7			Vegetal food	
	3		7	Detrimental	
	1		3	Beneficial	
	7		11	Unknown	

Table showing the kind and amount of animal, mostly insect, food eaten by the Thrushes.

Number and Name of Specimens Examined.			Classification of Food.		Ratios Represented by Lines.
Of thirty-seven Robins examined	3	Contained	14	Hymenoptera	
	13		26	Lepidoptera..	
	19		53	Beetles	
	6		9	Grasshoppers.	
	2		2	Spiders	
	1		1	Millepede	
	2		2	Angle-worms.	
	24		67	Adult forms..	
	2		6	Pupæ.........	
	19		47	Larvæ........	
	2		9	Insect eggs...	
Of two Wood Thrushes examined	1	Contained	2	Ants..........	
	1		1	Caterpillar ...	
	2		2	Beetles	
	2		4	Adult forms..	
	1		1	Larva	
Of nine Hermit Thrushes examined.........	1	Contained	20	Ants..........	
	6		6	Beetles	
	3		3	Caterpillars ..	
	2		3	Grasshoppers.	
	6		26	Adult forms..	
	3		4	Larvæ........	
Of eighteen Olive-backed Thrushes examined...............	4	Contained	11	Ants..........	
	4		10	Lepidoptera..	
	5		9	Beetles	
	1		1	Plant-louse ..	
	1		1	Spider	
	13		24	Adult forms..	
	4		10	Larvæ........	
	1		6	Insect eggs...	
Of seven Wilson's Thrushes examined.	1	Contained	2	Ants..........	
	4		9	Beetles	
	1		1	Harvest-man .	
	4		7	Adult forms..	
	1		4	Larvæ........	

Table showing the kinds and amount of animal, mostly insect, food eaten by the Thrushes — continued.

Number and Name of Specimens Examined.			Classification of Food.		Ratios Represented by Lines.
Of twenty-two Catbirds examined	6	Contained	24	Ants..........	
	1		1	Caterpillar ...	
	1		1	Tipulid	
	3		3	Beetles	
	1		1	Heteroptera..	
	3		6	Orthoptera ...	
	1		1	Spider	
	10		15	Adult forms..	
	8		3	Larvæ	
Of ten Brown Thrushes examined	2	Contained	4	Lepidotera...	
	5		11	Beetles	
	2		4	Orthoptera ...	
	2		2	Snails	
	7		16	Adult forms..	
	3		3	Larvæ........	

1. Turdus migratorius, Linn. **COMMON ROBIN.** Group I. Class b.

The Robin is the largest and the most abundant of the Thrushes, as it is the most confiding and familiar. With us, it frequents, by preference, agricultural districts, and is especially attracted to towns and villages and to the suburbs, parks and cemeteries of large cities. Not less than a hundred pairs of Robins reared their young, in 1878, within the city limits of Ithaca, N. Y.

In its method of obtaining food, and in the situation from which its food is gleaned, the Robin performs a very important work, and one for which few other birds are so well adapted. So important is this work that the quantity of small fruits which it consumes is but a stingy compensation for the services which it renders, and I know of no bird whose greater abundance is likely to prove of more service to the country. Its eminently terrestrial habits, its fondness for larvæ of various kinds, and its ability to obtain those which are hidden beneath the turf, give it a usefulness in destroying cut-worms, in the larval state, which no other bird possesses in the same degree, and for this feature of its economy alone its greater abundance should be encouraged.

Early in the morning and towards the close of the evening, the Robin may often be seen searching after cut-worms in lawns, pastures and meadows, and when thus engaged, it hops about apparently gazing more at distant objects than searching for something near at hand; then, suddenly, it commences tearing up the old grass and turf with its bill; and, in another instant, it stands triumphant with its wriggling prize in its bill, for it rarely digs in vain. I have seen a Robin capture, in this manner, five cut-worms in less than ten minutes; and five other birds, within view, were doing the same work.

Almost invariably the larvæ were beaten upon the ground and more or less mangled before they were eaten; and by taking advantage of the Robin when she lays her prey upon the ground, by throwing something at her she can usually be driven away and whatever she has captured obtained. How the Robin discovers these cut-worms is not easily explained. It is possible, however, that the larvæ while gnawing at the bases and roots of the grass stems, while secreting themselves after their night's raids, or while, toward evening, they grow restless and hungry, the slight movements which they produce among the grass are sufficient to betray their hiding places to the Robin. It should be observed in regard to these cut-worms, that large numbers of them are destroyed by various birds just after showers and during cool, drizzly and lowery days, when the absence of the scorching rays of the sun enables them to feed with quite as much comfort as during the night. Facts like these should weigh heavily against such *a priori* reasoning in regard to the general utility of birds, as "many (insects) are nocturnal and hide by day, with that instinct of self-preservation which is as much developed in them as in larger animals." It may be added here, that possibly the greater activity which birds evince at the approach of and during stormy weather may find a partial explanation in a corresponding activity of insect-life, which would enable them sooner to obtain a meal.

While the Robin obtains a greater part of its food upon the ground, it does not reject those insects which it meets while passing among the branches of trees and shrubbery; and its ability to discover these insects is quite remarkable. I have seen it throw itself from the boughs of an oak tree into a grape vine standing three rods distant, and, without stopping, seize and bear to the ground a hog-caterpillar-of-the-vine which had attained about two-thirds its full size. The expedition with which this capture was made convinced me that the Robin must have marked its prey before it left the tree, and that, after all, "mimicry" of colors does not furnish that protection to insects against birds which appears to be supposed.

All are familiar with the situations in which the Robin builds her nest, and in this connection it need only be added that it is always located out of the way, where nothing but wilful hands and marauding cats are likely to disturb it. The two or three broods of from three to five individuals each indicate how destructive to insects it must be, and how abundant it may become if properly protected and encouraged. It is generally amicable in its relations with other birds, and allows those whose haunts are similar, but whose work is different, to associate with it. Should this species become excessively abundant, it may be easily reduced without resorting to fire-arms — instruments whose murderous use has made them terrifying to birds of all kinds,— for their nests are easily discovered and reached.

The results obtained from an examination of thirty-seven stomachs of the Robin are indicated, in a general way, in the two tables introducing the family. Of these specimens one was taken in March, one in April, eleven in June, thirteen in July, five in August, six in September and one in October.

Five birds had eaten eleven cut-worms; three, five wire-worms (Elaters); five, six grub-worms; two, two caterpillars (Arctians); one, a hog-caterpillar-of-the-vine (Chœrocampa pampinatrix); five, eight scarabeans; two, two curculios (Brevirostres); one, a click-beetle (Elater); one, an ichneumon-fly (Anomalon?); two, two spiders; one, a millepede; two, two angle-worms; six, nine grasshoppers; two, eight grasshopper eggs; one, a moth; three (young birds), pellets of grass; one, choke cherries; two, black cherries; one, raspberries; one, grapes one, sheep berries; and one, berries of Indian turnip.

From the stomach of one Robin were taken seven cut-worms, 1.25 inches long, six other caterpillars, varying from three-fourths to one inch long, two small curculios and five grape seeds.

From the stomachs of three young Robins — all of the same brood — were taken respectively, (1) one wire-worm, one grub-worm, one caterpillar, several beetles, and a pellet of grass; (2) one wire-worm, three larvæ, one ground beetle, one lamellicorn beetle, and a small pellet of grass; (3) one grub-worm, one caterpillar, several small seeds and a pellet of grass.

The food of the Robin, as indicated by others, is as follows:

"Its principal food is berries, worms and caterpillars; berries, those of the sour gum and poke berry" (Wils.); "Chiefly insects — especially worms — and berries" (Cooper); "Worms, insects, berries, and fruits" (De Kay); "Grubs and caterpillars, crickets, grasshoppers, grubs of locusts, harvest-flies, and of beetles, the apple-worm when it leaves the apple, cut-worms, silk-worms" (Samuels); "Larvæ of Bibionidæ" (Packard); "Larvæ of *Dryocampa senatoria*" (A. J. Cook). Prof. S. A. Forbes concludes, from an examination of the contents of 41 stomachs, that 78 per cent. of the food was insects; 2 per cent. myriapods and spiders, and 28 per cent. grubs. Twelve per cent. were caterpillars, 7 per cent. beneficial beetles (Harpalinæ), 6½ per cent. noxious beetles, 8 per cent. orthoptera and 1½ per cent. noxious myriapods. This record, he concludes, indicates fully as much injury as good done by these forty-one birds.

2. Turdus mustelinus, Gm. WOOD THRUSH. Group I. Class b.

This rich-voiced songster, though a summer resident, is far from being common at present, even during the migrations. Its favorite haunts are the osier and alder thickets which embrace the winding streams of our low, deep woods, but during the fall and spring, more open woods and groves are visited by it. Like the Robin it is terrestrial in its habits, and appears to obtain its food in a similar manner; but its secluded retreats forbid any direct relation to agricultural interests at present. There are indications, however, that its habits are changing, and that it is becoming more familiar.

In the Germantown (Pa.) Telegraph for May 8, 1878,[1] occurs the following from the pen of its editor:

"But within the last five years it (Wood Thrush) has appeared in our gardens, builds its nest and rears its young. Last year they had considerably increased upon our premises, notwithstanding much of the cover had been cut away; and already this season they have made their appearance quite numerously and have begun to entertain us with their charming song. They have also become quite tame, fully as much so as the Robin or Catbird. This, too, in the very face of our colony of House Sparrows." If these are facts, by due encouragement and protection we may hope to have the Wood Thrush much more abundant and familiar than it now is.

Of two specimens examined, one had eaten two ants, fragments of beetles, and one caterpillar; the other had eaten fruits and beetles.

Its food, according to Wilson, consists of lichens, berries, caterpillars and beetles. Audubon states that it eats berries, small fruits, and occasionally insects and various lichens.

Prof. S. A. Forbes says of the contents of the stomachs of twenty-two birds which he examined, that "seventy-one per cent. of their food consisted of in-

[1] From an article clipped from a Boston paper and kindly sent me by Dr. Brewer.

sects and twenty per cent. of fruit, a small ratio of spiders and an unusually large percentage of myriapoda making up the remainder. Blackberries, strawberries, cherries and gooseberries appear among the fruits. The twelve per cent. of myriapoda were mostly Palydesmus and Inulus. Harvest-men were among the two per cent. of arachnida, orthoptera were six and hemiptera one per cent. Wire-worms and snout-beetles make up thirteen per cent. and the carabidæ amount to six per cent. The coleoptera make eighteen per cent. and the diptera twelve per cent. Lepidoptera were taken in about the same amount, one-third being recognized as cut-worms, while ants reached the unusual average of fifteen per cent.

3. Turdus unalascæ nanus (Aud.), Coues. EASTERN HERMIT THRUSH. Group I. Class b.

The Hermit Thrush, occasionally at least, occurs in our state during the summer, where I believe it also breeds, although it is regarded by Dr. Coues, "on the whole, a more northern bird than any of its allies." Two specimens of this species were obtained July 22, 1876, near Waupaca. Both were males. The first was perched near the top of a dead tree standing in a small opening in an unfrequented piece of upland woods, and singing merrily when taken. Four other birds similarly situated in the immediate vicinity, and just as joyous, hushed their voices and fled when their comrade fell; the other was surprised on the shore of a small lake in the edge of a grove of young tamaracks. During the fall migrations of this species, which begin the last of September, it is common in timbered districts where pieces of woods are bordered by open fields. In the spring nearly all have passed us to the northward by the 10th of May. Nelson states that this, and the two varieties of the Olive-backed Thrush, frequent vacant lots and grounds containing shrubbery in Chicago, in large numbers during the migrations — a fact which bespeaks for them a growing familiarity. As with all of the Thrushes, it obtains most of its food from the ground. Of nine specimens examined, one had eaten twenty ants; three, a caterpillar each; two, three grasshoppers; six, as many undetermined beetles; and one, a wire-worm. One had eaten wild grapes, and one, berries of the Indian turnip.

Of eighteen specimens examined by Prof. Forbes, thirteen per cent. of their food was ants, eighteen per cent. lepidoptera, twelve per cent. carabidæ (including *Dischirius globulosus*, *Platynus*, *Evarthrus*, *Pterostichus*, *Amara*, *Anisodactylus*, *Bradycellus* and *Stenolophus*), five per cent. dung-beetles, two per cent. curculios, two per cent. plant beetles, nine per cent. hemiptera (including three per cent. Reduviidæ), eighteen per cent. grasshoppers, and a single lace-wing. A few of the caterpillars were measuring-worms. Eighty-seven per cent. of the food was insects proper, four per cent. arachnida and nine per cent. herbivorous myriapods.

4. Turdus ustulatus Aliciæ (Bd.), Coues. ALICE'S THRUSH; GRAY-CHEEKED THRUSH.

5. Turdus ustulatus Swainsoni (Cab.), Coues. OLIVE-BACKED THRUSH. Group I. Class b.

Considering both varieties of Swainsoni together, this Thrush, aside from the Robin, is the most abundant member of its genus. Neither form, so far as known, nests in the state; Nelson, however, mentions var. Swainsoni as a rare summer resident in Northern Illinois. The fall migration occurs earlier than that of the last species, and I have taken both varieties on the same day — September 1st; from this time until the end of the month it is abundant. During their stay, the greater number spend their time in groves of small trees, but woods bordered by fields are also visited by them, and occasionally they glean along fence-rows. Rarely one enters an orchard for a taste of grapes.

Of eighteen specimens examined, three had eaten seven caterpillars; five, nine beetles; four, eleven ants; one, four moths; one, an aphis; one, a spider, and one the grub of a carab beetle. One had eaten wild grapes, one black cherries, and one berries of Indian turnip.

From the stomach of one specimen were taken four ants, four small moths, one aphis, one spider, and six eggs of some insect, apparently those of some moth, and probably from one of the moths which the bird had eaten. Birds are often mentioned as destroying the eggs of insects; in my own observations, however, I have never found eggs in the stomach of any bird which did not appear most likely to have come from a fecundated insect which the bird had eaten, and it is my opinion that birds rarely make a practice of hunting insect eggs.

Prof. Forbes found eight stomachs of the variety Alice's Thrush, taken in May, to contain seven per cent. of mollusks, forty-two per cent. (of every bird) ants, thirteen per cent. of caterpillars, eight per cent. of crane flies and two per cent. of predaceous beetles. One had filled itself with scavenger beetles. All had eaten small curculios amounting to two per cent.

The stomachs of six specimens of Swainson's Thrush, one taken in April and five in May, contained twenty-two per cent. crane flies, twenty-eight per cent. ants, five per cent. predaceous beetles (Harpalidæ), several curculios, and in one stomach was found a mass of short-horned borers, *Scolytus muticus*, Say.

6. Turdus fuscescens, Steph. VEERY; TAWNY THRUSH: WILSON'S THRUSH. Group I. Class b.

The Veery, though a summer resident, is common with us only during its migrations. Its haunts are among the shrubbery of low deep woods, where it is oftener heard than seen. Like the Wood Thrush it is apparently becoming reconciled to man, and is beginning to assume more familiar relationships with him. In the immediate vicinity of Ithaca, N. Y., it is one of the commonest birds. In the cemetery, and in the glens of Cascadilla and Fall Creeks — both of them are close by the campus and are visited by students every day,— all through the spring its subdued song has been one of the most attractive features of those beautiful scenes. The breeding habits of this Thrush are not such, at present, as to ensure it a very great abundance in agricultural sections of the usual topography, for it builds upon or close to the ground, where it is more likely to be disturbed unintentionally and where situations suited to its present tastes are rare. Mr. F. H. Severance found a nest of this species placed in a little opening near the banks of Fall Creek, upon a small bunch of flood-grass, and only hidden by the tall grass which grew around the spot. He simply looked into the nest, without touching it, and came away; but when, two days afterwards, we visited the nest together, we found that the suspicious pair had forsaken it. Such facts as this show how cautiously we must deal with these timid birds, if we wish to retain their services in any but their secluded retreats. Nuttall mentions an instance of a pair of these birds breeding in a garden near Boston. At Ithaca, I have seen them passing from the fields back to glens and thickets which adjoin them, and I have no doubt that they had been searching for food.

Of eight specimens examined one had eaten two ants; one, a large lamellicorn beetle; one, three wire-worms *(Elater)*; one, a larve of a ground beetle; one, a harvest-man; two, dogwood berries; and one, raspberries.

Insects (Samuels). Beetles, berries, and, in Labrador, blossoms of several dwarf plants (Aud.). Canker-worm (Maynard).

7. MIMUS POLYGLOTTUS (L.), BOIE. **MOCKINGBIRD.** GROUP II. CLASS a.

This is a southern species which occurs irregularly in the state, and is said to nest occasionally near Racine.

8. MIMUS CAROLINENSIS (LINN.), GRAY. **CATBIRD.** GROUP II. CLASS b.

Known to almost everybody, looked upon by children as a peevish, snarling bird, and regarded by the farmer and gardener as a sly, sneaking robber, the poor Catbird has but few friends. Although not one of the best birds, he renders a far greater service and does much less injury than many give him credit for. Extremely abundant in his favorite resorts, with us the whole summer, of good size and active habits, his aggregate consumption of food is large. Loving best willow, osier, and alder thickets, where woods slope into marshes, the brush piles and brambles about old clearings, the hazel patches fringing groves, and the tangled hedges that often grow along fences, the Catbird can do but little harm while in these haunts. On the contrary, he must render there material service, for such places are the nurseries of hosts of insect forms. It is only when he intrudes upon orchards, gardens and vineyards for small fruits that he can be looked upon as injurious; this, however, he rarely does unless his favorite haunts are near at hand. Occasionally he nests in those gardens where much shrubbery grows along the fences, and his familiar feline "mew" is sometimes heard in our villages.

Of twenty-two specimens examined, six had eaten twenty-four ants; two, three grasshoppers; one, three crickets; three, three beetles; one, sheep berries; two, dogwood berries; one, blueberries; one, choke cherries; one, raspberries, and one, black cherries. From the stomach of one bird were taken three crickets and two grasshoppers, and from that of another were taken one ground beetle *(Harpalini ?)*, one tipulid, one heteropterous insect and one larva (caterpillar?). Its food, according to others, consists of strawberries, cherries and pears (Wils.); insects, worms, fruits and berries (Cooper); berries, worms. wasps and other insects (De Kay); canker worms (Maynard). Prof. Forbes, in discussing the economic relations of the Catbird, after having examined the contents of seventy stomachs, concludes that the beneficial, injurious and neutral elements eaten by the birds stand in the relation of 41 to 15 to 44. Among injurious insects he finds the birds had eaten saw-flies one per cent., lepidoptera seven, leaf-chafers two, snout-beetles one, plant-beetles one, chinch-bugs one, and orthoptera three, making a total of sixteen per cent.; while among beneficial insects he finds predaceous beetles five per cent., predaceous hemiptera one, and arachnida two, making a total of eight per cent. Deducting the eight per cent. of beneficial insects from the forty-one per cent., it is seen that thirty-three per cent. of the food consisted of garden fruits, while fifty-two per cent. represents the amount of fruits of all kinds eaten by the birds.

9. Harporhynchus rufus (Linn.), Cab. **BROWN THRUSH; SANDY MOCKINGBIRD; THRASHER.** Group I. Class b.

Although a common and familiar bird, the Thrasher is not as abundant as the last species. Its haunts, too, are similar, but it prefers to choose them in opening and prairie sections rather than in heavy timbered districts, where the Catbird exists in greater abundance. In proportion to its numbers, it also makes more frequent visits to the vicinity of dwellings. The Brown Thrasher is eminently terrestrial in its habits, and obtains much of its food beneath the fallen leaves and mould of its favorite haunts, and for this work the strong decurved beak serves its owner admirably.

Of ten specimens examined, one had eaten two crickets; one, two grasshoppers; five, eleven beetles — among which were two species of Harpalus; three, three larvæ — among them caterpillars and a grub of a tiger beetle; two, two mollusks; five, seeds; one, wheat; and one, wild grapes.

"Its food consists of worms, which it scratches from the ground, particularly a dirty-colored grub more pernicious to corn than nine-tenths of the birds, 'wasps' and beetles. It is accused of scratching up corn" (Wils.). "It eats insects, worms, berries of all sorts, ripe pears, and figs" (Aud.). "Worms, insects and various kinds of berries" (De Kay). Prof. Forbes has examined the contents of the stomachs of sixty-four of these birds, and estimates the beneficial, noxious and neutral elements to stand in the relation of 33 to 26 to 41. Among the injurious insects eaten were seven per cent. lepidoptera, ten leaf-chafers, two spring-beetles, two snout-beetles, one chinch-bugs and four orthoptera; while among the beneficial insects were six per cent. carabidæ, two predaceous hemiptera, one spider and one of predaceous thousand-legs. From this it is seen that twenty-six per cent. of the insects eaten were injurious and ten per cent. beneficial, including the spiders and myriapods. Twenty-one per cent. of the food consisted of small fruits.

Family SAXICOLIDÆ: Stonechats and Bluebirds.

Fig. 107.

Eastern Bluebird (*Sialia sialis*). From Baird, Brewer and Ridgway.

Tabular Summary of Economic Relations showing the number of specimens containing animal and vegetable food, and the number of insects and spiders taken from the stomachs, classified as to economic relations under the heads Beneficial, Detrimental and Unknown Relations.

Number and Name of Specimens Examined.			Classification of Food.		Ratios Represented by Lines.
Of twenty-seven Bluebirds examined	26	Contained		Animal food......	
	1			Vegetal food.....	
	20		42	Detrimental......	
	3		5	Beneficial........	
	11		22	Unknown.........	

Table showing the kinds and number of insects and spiders eaten by the Bluebird.

Number and Name of Specimens Examined.			Classification of Food.		Ratios Represented by Lines.
Of twenty-seven Bluebirds examined	1	Contained	2	Ants.............	
	6		10	Lepidoptera......	
	8		13	Beetles..........	
	1		1	Heteroptera......	
	17		22	Orthoptera.......	
	2		2	Spiders..........	
	24		40	Adult forms......	
	6		9	Larvæ............	
	2		10	Grasshopper eggs.	

10. Sialia sialis (Linn.), Hald. **EASTERN BLUEBIRD.** Group I. Class b.

The Bluebird has so many excellent qualities that it promises to become, under proper management, one of the most readily utilizable insect-destroyers which we have among birds. It is, with us, almost exclusively insectivorous, and is especially destructive to grasshoppers. It captures its prey upon the wing and upon the ground, giving it a wide range of food, from which it may be expected to maintain, under favorable conditions, a steady and considerable abundance. Its long summer residence, its rearing of two, sometimes three, broods each season, its fondness for cultivated fields, and its willingness to breed in bird-houses protected from the ordinary enemies of birds, and beyond the disturbance of the machinery and live-stock of the farm, are other qualifications which tend to place it in the front rank of usefulness.

How to cause this bird to take and maintain a greater abundance than it now has is a question of great practical importance to all classes of farming. The fact that its familiar and confiding nature has not made it more numerous among us, appears to be readily explained by its breeding habits. In its unmodified condition, its nest is usually placed in some hollow limb or tree; and as a natural consequence the Bluebird is driven away when its nesting places are destroyed. But as Bluebirds accept so gladly the houses which are sometimes provided for them, I can see no reason why, if sufficient and suitable breeding places were put up, they might not in a few years become far more numerous than they are now; and I would earnestly recommend that our farmers generally should put up cheap bird-houses, or even small boxes provided with suitable openings, in convenient places about their premises. Not one, simply, but several. Let them be put up in the trees which stand out in the fields and along the fences, so that the birds may be induced to live where their services are most needed.

Of the twenty-seven birds examined, one had eaten two ants; two, three moths; four, seven caterpillars; one, two tiger beetles; one, a ground-beetle; sixteen, twenty-one grasshoppers; one, one cricket; and two, a spider each. One bird ate a few raspberries.

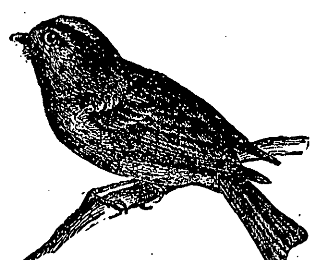
Others record its food as follows: Principally insects, among which are large beetles and spiders. In the fall, berries of sour gum; in the winter, those of red cedar (Wils.). Numerous insects, among these, grasshoppers (Samuels). Beetles, caterpillars, spiders; in autumn, grasshoppers and various kinds of ripe fruits (Aud.). Multitudes of noxious insects; in autumn, cedar berries and wild cherries (De Kay).

Prof. Forbes, after examining one hundred and eight stomachs of the Bluebird, finds them to contain, among noxious insects, twenty-six per cent. lepidoptera; three per cent. leaf-chafers, and twenty-one per cent. orthoptera, making a total of fifty per cent.; and among beneficial insects, three per cent. ichneumons; carabidæ, seven per cent.; soldier-beetles, one per cent.; soldier-bugs, three per cent., and spiders, eight per cent.—making a total of twenty-two per cent. Seventy-eight per cent. consisted of insects, eight per cent. of spiders, and one per cent. of myriapods, making, with thirteen per cent. of vegetable food, the whole amount.

NOTE.—*Sialia arctica*, Arctic Bluebird. A single specimen of this species is said to have been observed in a collection at Dubuque, Iowa, which was taken late in the fall, upon the east side of the Mississippi river, near that place. (Birds of Northeastern Illinois, p. 95, by E. W. Nelson.)

FAMILY SYLVIIDÆ: SYLVIAS.

FIG. 108.



GOLDEN-CRESTED KINGLET (*Regulus satrapa*). After Baird, Brewer and Ridgway.

Tabular Summary of Economic Relations, showing the number of specimens containing animal and vegetable food, and the number of insects and spiders taken from the stomachs, classified as to economic relations under the heads Beneficial, Detrimental and Unknown Relations.

Number and Name of Specimens Examined.				Classification of Food.	Ratios Represented by Lines.
Of seven Ruby-crowned Kinglets examined......	7	Contained		Animal food	
				Vegetal food	
	2		2	Beneficial	
	2		4	Detrimental.	
	6		24	Unknown.........	
Of nine Golden-crowned Kinglets examined......	9	Contained		Animal food......	
				Vegetal food	
				Beneficial	
	1		5	Detrimental	
	8		40	Unknown.........	

Table showing the kinds and number of insects and spiders eaten by the Kinglets.

Number and Name of Specimens Examined.				Classification of Food.	Ratios Represented by Lines.
Of seven Ruby-crowned Kinglets examined......	2	Contained	2	Hymenoptera ..	
	2		4	Caterpillars	
	3		5	Beetles...........	
	1		1	Spider............	
	6		26	Adult forms......	
	2		4	Caterpillars	
Of nine Golden-crowned Kinglets examined......	1	Contained	5	Caterpillars	
	2		12	Diptera...	
	3		9	Beetles...........	
	8		39	Adult forms......	
	1		1	Pupa.............	
	1		5	Larvæ...........	

Our representatives of this family are among the pigmies of the forest, and feed upon insects of proportionate size. From the stomach of a Ruby-crowned Kinglet were taken a chalcis-fly .08 of an inch, and two beetles only .07 of an inch long. In their method of obtaining food, they combine with the habits of the Fly-catchers, those of the Nuthatches and Warblers; but while they frequent similar haunts and feed upon the same grounds as the birds whose habits they imitate, their diminutive size and great agility enable them to perform a *special* work by feeding more extensively upon the smaller insects. How destructive they may be to parasitic insects cannot be said at present. That their whole make-up fits them for such work, and that they do occasionally destroy them, is certain, but that they feed as extensively upon these insects as upon other forms is far from probable.

11. Regulus calendula (Linn.), Licht. **RUBY-CROWNED KINGLET.** Group I. Class b.

Of our two Kinglets, *Satrapa* is perhaps the most abundant. Both are migrants, and during their journeyings through the settled districts, they tarry in orchards, among the village shade-trees, in groves, in thickets bordering marshes and streams, and occasionally in more open woods.

Of seven specimens examined, two had eaten four small caterpillars; three, five beetles; one, an ant; one, a chalcis-fly, and two, bits of insects not identified.

According to others, its food embraces maple blossoms, pear, apple, and other fruit-tree blossoms — particularly the stamens. In November, it feeds upon numerous black-winged insects which infest orchards (Wils.). Insects, chiefly gnats and other *diptera* (Cooper). Seeds, insects and their larvæ (De Kay). Minute flying insects, their eggs and larvæ (Samuels). A single specimen examined by Prof. Forbes gave indications of a taste for lepidoptera, scarabæidæ, lady-bugs, heteroptera and spiders. I believe that Wilson was mistaken in regard to this species eating blossoms. It was probably catching insects among them.

12. Regulus satrapa, Licht. **GOLDEN-CRESTED KINGLET.** Group I. Class a.

This species passes us earlier in the spring and returns later in the fall than the last. The 15th of October, 1877, it was abundant in the heavy timber along the Flambeau river. Of nine specimens examined two had eaten twelve small *diptera;* three, nine small beetles; one, five caterpillars; one, a small chrysalid, and three, very small bits of insects, too fine to be identified.

According to others their food embraces larvæ, various kinds of small flies, and a small black-winged insect which infests orchards (Wils.). Insects, which it takes upon the wing and from the crevices of the bark on trees (De Kay).

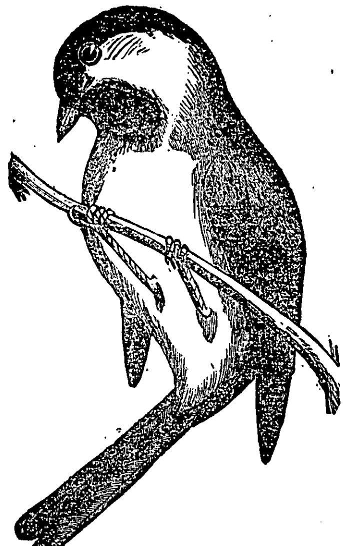
13. Polioptila cœrulea (Linn.), Scl. **BLUE-GRAY GNAT-CATCHER.** Group II. Class a.

This species is said to be not uncommon in Wisconsin and to breed in the state; Mr. Trippe mentions its occurrence in Iowa but not in Minnesota; and Mr. Nelson states that it is a common migrant in Northeastern Illinois. I have, however, never met with it. Indeed, it appears to prefer on the whole more southern latitudes than ours. Audubon says: it prefers the skirts of woods along damp, swampy places, and the borders of creeks and pools to the interior of forests.

Food: Winged insects, particularly mosquitoes (De Kay). Seizes insects on the wing (Aud.).

FAMILY PARIDÆ: TITMICE.

FIG. 109.



BLACK-CAPPED CHICKADEE (*Parus atricapillus*). After Coues.

Tabular Summary of Economic Relations showing the number of specimens containing animal and vegetable food, and the number of insects and spiders taken from the stomachs, classified as to economic relations under the heads Beneficial, Detrimental and Unknown Relations.

NUMBER AND NAME OF SPECIMENS EXAMINED.			CLASSIFICATION OF FOOD.		RATIOS REPRESENTED BY LINES.
Of twelve Black-capped Chickadees examined...	12	Contained		Animal food......	
	1			Vegetal food	
	2		2	Beneficial	
	8		17	Detrimental......	
	10		37	Unknown.........	

Table showing the kinds and number of insects and spiders eaten by the Black-capped Chickadee.

NUMBER AND NAME OF SPECIMENS EXAMINED.			CLASSIFICATION OF FOOD.		RATIOS REPRESENTED BY LINES.
Of twelve Black-capped Chickadees examined...	5	Contained	10	Caterpillars	
	7		13	Beetles...........	
	1		3	Heteroptera......	
	2		2	Spiders...........	
	12		42	Adult forms	
	7		14	Larvæ............	
	1		5	Insect eggs	

14. PARUS ATRICAPILLUS, LINN. **BLACK-CAPPED CHICKADEE; TITMOUSE.** GROUP I. CLASS b.

The Titmouse, with its sympathy-enlisting "chick-a-dee-dee," is one of our abundant, hardy residents and most useful little foresters. During the breeding season it is principally confined to larch and pine tracts; but at other times it searches for food wherever trees may be found—along fences, in orchards, about dwellings and among village shade-trees, as well as in groves and woodlands. At Ithaca, N. Y., it has been a frequent visitor to the University campus all through the spring and summer. Its small size, its method of feeding, and its great agility enable it to perform a very useful and special work. In feeding it searches most diligently among the outermost branches of the trees, where it often hangs back downward from the leaves to obtain those small larvæ and insects which are accessible only with difficulty to larger and more clumsy birds. The habit which it has of picking open buds for insects which they often contain has led some to infer that it is injurious. Whatever injury it may do in this manner must certainly be trifling when compared with the service it renders. If the Chickadee is as destructive to insect eggs as it is said to be, its winter residence and its searching habits must lend great additional value to its services. Evidently if this bird could be induced to so change its breeding habits as to nest commonly in orchards and about dwellings, it would become one of the most valuable aids in destroying noxious insects. It does not appear improbable, in view of the fact that these birds build in sheltered situations, even though usually excavated by themselves, that they might not come, in time, to nest in houses like Bluebirds and Wrens, if they were properly encouraged to do so. Could such change be induced, we might then bring them readily into closer relationship with us; for they are already becoming familiar in cultivated districts out of the breeding season. I believe that an experiment worthy of thorough trial in this connection would be to put up in their breeding haunts some sort of cheap houses, perhaps imitating interiorly their own excavations, to ascertain whether it is not possible to induce them to nest in such places. If such a change could be brought about, first in their breeding haunts, we might then expect to bring them about our dwellings. No very marked immediate results could be expected from such a course; but future prosperity is not the last consideration with which we should deal.

Of twelve specimens examined, seven had eaten fourteen larvæ, ten of which were caterpillars; seven, thirteen beetles; two, two spiders; one, three heteropterous insects related to the genus *Tingis;* and one, five eggs of some insect. One individual of the twelve had in its stomach a few seeds.

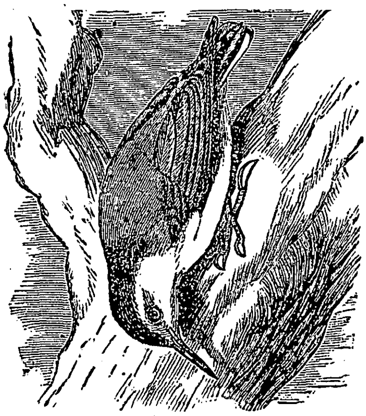
Food according to others: Pine seeds, sunflower seeds, insects and their larvæ (Wils.). Nuts, numerous insects and their larvæ (De Kay). Eggs of the moth of the destructive leaf-rolling caterpillar and of the apple-tree moth and cankerworm; larvæ which infest buds, caterpillars, flies and grubs (Samuels). Though omnivorous, they prefer insects to all other food. Destroys the chrysalis of the woolly-bear, *Leucarctia acræa* (Brewer). Insects,—their larvæ and eggs—berries, fruit, acorns, seeds of pine and sunflower, and poke-berries (Aud.). Cankerworms (Maynard). Caterpillars and plant-lice (Forbes).

15. PARUS HUDSONICUS, FORST. **HUDSON'S BAY TITMOUSE.** GROUP II. CLASS a.

This species is introduced in this connection on the authority of Dr. Hoy, who says: "A small party of this northern species visited Racine during the unusually cold January of 1852." Mr. Nelson states that Dr. Velie has since observed it at Rock Island, Illinois.

FAMILY SITTIDÆ: NUTHATCHES.

FIG. 110.



WHITE-BELLIED NUTHATCH (*Sitta Carolinensis*). After Baird, Brewer and Ridgway.

Tabular Summary of Economic Relations showing the number of specimens containing animal and vegetable food, and the number of insects and spiders taken from the stomachs, classified as to economic relations under the heads Beneficial, Detrimental and Unknown Relations.

Number and Name of Specimens Examined.			Classification of Food.		Ratios Represented by Lines.
Of twenty-five White-bellied Nuthatches examined	23	Contained		Animal food .	
	10			Vegetal food .	
	2		2	Beneficial	
	5		10	Detrimental ..	
	23		56	Unknown.....	

Table showing the kinds and number of insects and spiders eaten by the Nuthatches.

Number and Name of Specimens Examined.			Classification of Food.		Ratios Represented by Lines.
Of twenty-five White-bellied Nuthatches examined	1	Contained	2	Ants..........	
	3		6	Lepidoptera..	
	2		4	Diptera.......	
	14		32	Beetles	
	1		1	Spider.........	
	22		63	Adult forms..	
	1		1	Pupa	
	2		4	Larvæ	
Of four Red-bellied Nuthatches examined	4	Contained	24	Adult forms..	
	1		3	Ants	
	3		15	Beetles	

16. SITTA CAROLINENSIS, GM. **WHITE-BELLIED NUTHATCH.** GROUP I. CLASS b.

This species is another of those birds whose possibilities for usefulness appear to be among the highest; but it is one which can hardly attain, under present management, that abundance in thickly settled districts which could be desired. It has conclusively proved its desire to assume familiar relations with man, and this with only the slightest encouragement. The orchard, ornamental, and shade trees, as well as the groves and scattered patches of woods of thickly settled districts, offer it an ample supply of food and need its protection: but few yet appear to realize that if these birds are to become abundant and of service, they must have places in which to rear their young. They usually place their nests in holes in trees and stumps, which they find ready formed, or excavate for themselves. It is usually regarded as in harmony with thrifty husbandry, in gathering the year's fuel, to select from the woods those trees which give evidence of decay. Such an economy, however, if carried to an extreme, will ultimately leave the Nuthatches and Woodpeckers, and all of those species which breed in hollow trees, without nesting places, and will necessarily extirpate them from sections so modified, and deprive the country of their services, except so far as some of these birds may be able to form new habits which are more in harmony with the altered conditions. The practical questions which these facts suggest are these: Are the services of this class of birds sufficiently great to justify the preservation of their nesting places? Is it probable that these birds can so modify their habits as to place themselves in harmony with the new features which our country is assuming so rapidly? That this Nuthatch gathers its food from a field where some of our most destructive insects abound, there can be no question. In proof of this, it need only be said that almost its whole time is spent searching about and upon the trunks and larger branches of trees in quest of insects, and that in such situations as these the wingless female of the canker-worm, the larvæ and pupæ of the codling moth, the adults of the round-headed and flat-headed apple-tree borers, and a host of nocturnal moths and other insects may be destroyed by it. That the particular insects which have been mentioned are so destroyed cannot be asserted positively at present, yet it is highly probable that they are, for its record of food, meagre as it is, proves that it does feed upon closely allied forms.

In regard to the other question little can be said at present. The fact, however, that the Nuthatch does not always excavate the holes for its nest indicates that it is not very particular, and gives some grounds for the hope that it may yet be induced to breed commonly in groves and orchards. Wilson states that it sometimes nests in hollow rails in fences, and in the wooden cornice under the eaves of houses. When an old tree is cut down, whose branches are hollow and have been occupied by these or other birds, it would be very desirable, by way of experiment, to fasten the perforated portions of the limbs in other trees to ascertain whether they might not in those conditions still be used by birds as breeding places. The same experiment might be tried in orchards. Should they prove acceptable to the birds there would then be no need of allowing all decaying trees to stand for this purpose.

Food: Of twenty-five specimens examined, fourteen had eaten thirty-two beetles — among which were three elaters, one long-horn and a lady-bug (?); one, two ants; one, two caterpillars; one, two grubs of a beetle; one, a spider; one, a chrysalid; one, small toad-stools; five, acorns; and one, corn.

According to others: Ants, bugs, insects and their larvæ, spiders (Wils.). Larvæ and eggs of insects (Samuels). Insects are its favorite food at all times.

It seems to break open acorns and chestnuts for the included insects (Aud.). Prof. Forbes records finding in the stomachs of four birds of this species evidence that it eats many beetles, Nitiduliddæ, Cetoniidæ and lady-bugs. One had eaten corn.

17. SITTA CANADENSIS, LINN. **RED-BELLIED NUTHATCH.** GROUP I. CLASS a.

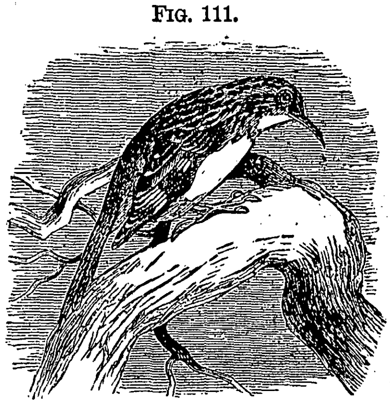
This species, so far as I know it personally, is only a migrant of a somewhat meagre and irregular abundance. A few, however, are said to nest near Racine, and a greater number in the northern portion of the state. Mr. Nelson mentions it as a rare summer resident in Northeastern Illinois. It was not observed in the woods of Oconto county during the month of August, 1875, nor during a trip of a week, from Worcester to Wisconsin Valley Junction, the last of July, 1876. In October of 1877, it was observed several times in the woods along the Flambeau river. I have taken but four specimens — September 12, 1876,— and except those mentioned above, these are the only ones which I have observed. It is said to build its nest in low dead stumps, seldom more than four feet from the ground. Mr. Rice[1] is said to have observed a pair feeding their unfledged young the last of April, 1874, in an excavation in a tree, standing on one of the principal streets of the town of Evanston. The similarity, in habits and haunts, of this species to its more familiar congener, renders it probable that it does a similar, though less important work. Its more northern habitat suggests that it can hardly be of much service to us except during its migrations.

Food: The four specimens examined had in their stomachs fifteen beetles, three ants and six other small insects.

Insects and their larvæ and fine seeds (Wils.). Insects and the seeds of evergreens (De Kay). Insects and their larvæ which are caught in the crevices of bark and under it (Aud.).

FAMILY CERTHIIDÆ: CREEPERS.

FIG. 111.



BROWN CREEPER (*Certhia familiaris*). After Baird, Brewer and Ridgway.

[1] Birds of Northeastern Illinois, by E. W. Nelson.

18. CERTHIA FAMILIARIS, LINN. **BROWN CREEPER.** GROUP I. CLASS b.

The Brown Creeper is another of those birds, which, like the Nuthatches, scrambles about the trunks and larger branches of trees in quest of food, using its long, slender, decurved bill to remove those small insects that hide in the crevices of the bark and under it. In the northern portions of the state it is resident throughout the year. In the fall it spreads southward, to return again in the spring. Its favorite haunts are the deep, heavy woods, but during its migrations it ventures near the abodes of man and is often seen in cities. Mr. Nelson states that he has seen as many as a dozen of these birds upon the sides of a house at once, in Chicago, searching after small spiders.

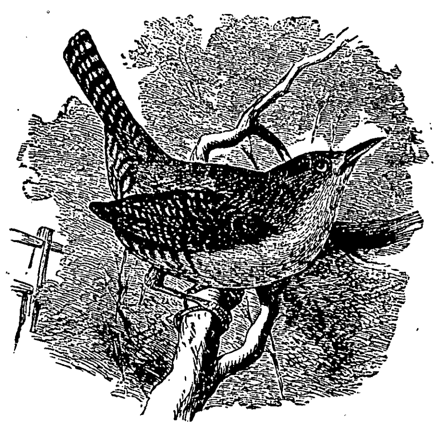
Enough has been said, in the introduction, to indicate the value of the kind of work which this bird does, and that it should be more abundant. It is difficult to explain why birds which lay as many eggs as this and the Black-capped Titmouse do, and in places apparently so secure from the plunderers of birds' nests, as we know them, do not become more numerous. The subject is one which needs careful investigation. It may be added, in connection with what has already been said of squirrels robbing birds' nests, that the chipmunk has been known to capture and carry away young chickens, and that this fact suggests that it may also be a dangerous enemy to small birds. If so, its small size enables it to enter almost any nest which is built in hollow trees, and, hence, only the ability of the bird to ward off its attacks remains as a safeguard against it. I make these statements not as an accusation against the little striped squirrel, but as indicating a field in which careful observation is needed. The flying squirrel, too, as I have shown in another place, is fond of birds' eggs, and might rob the nests of these and other birds in their absence. The little red squirrel, in many cases, might also enter the nests of this species.

Food: Only three stomachs of this species have been examined; one was empty, one contained three small beetles, and one three small insects.

Bugs, pine seeds and fungi (Wils.). Insects and the seeds of pines (De Kay). Spiders (E. W. Nelson).

FAMILY **TROGLODYTIDÆ**: WRENS.

FIG. 112.



HOUSE WREN (*Troglodytes domesticus*). After Baird, Brewer and Ridgway.

Tabular Summary of Economic Relations showing the number of specimens containing animal and vegetable food, and the number of insects and snails taken from the stomachs, classified as to economic relations under the heads Beneficial, Detrimental and Unknown Relations.

Number and Name of Specimens Examined.			Classification of Food.		Ratios Represented by Lines.
Of six House Wrens examined	6	Contained		Animal food	
				Vegetal food	
				Beneficial	
	4		8	Detrimental	
	6		25	Unknown	
Of three Winter Wrens examined	3	Contained		Animal food	
				Vegetal food	
	1		1	Beneficial	
	1		1	Detrimental	
	3		12	Unknown	
Of fourteen Long-billed Marsh Wrens examined	14	Contained		Animal food	
	1			Vegetal food	
	1		1	Beneficial	
	6		11	Detrimental	
	10		45	Unknown	
Of four Short-billed Marsh Wrens examined	4	Contained		Animal food	
	1			Vegetal food	
				Beneficial	
	2		3	Detrimental	
	1		5	Unknown	

Table showing the kind and number of insects and snails eaten by the Wrens.

Number and Name of Specimens Examined.			Classification of Food.		Ratios Represented by Lines.
Of six House Wrens examined	3	Contained	7	Caterpillars	
	2		9	Beetles	
	1		1	Grasshopper	
	6		26	Adult forms	
	3		7	Larvæ	
Of three Winter Wrens examined	1	Contained	3	Ants	
	1		1	Caterpillar	
	1		3	Beetles	
	1		1	Dragon-fly	
	3		13	Adult forms	
	1		1	Larve	

Table showing the kind and number of insects and snails eaten by the Wrens — continued.

Number and Name of Specimens Examined.			Classification of Food.		Ratios Represented by Lines.
Of fourteen Long-billed Marsh Wrens examined...........	1	Contained	1	Ant................	
	4		4	Lepidoptera......	
	1		3	Diptera...........	
	7		21	Beetles...........	
	2		7	Hemiptera.......	
	2		2	Grasshoppers....	
	1		1	Dragon-fly........	
	1		1	Snail............	
	14		51	Adult forms......	
	1		1	Larvæ............	
	1		5	Grasshopper eggs.	
Of four Short-billed Marsh Wrens examined..............	2	Contained	2	Moths............	
	2		4	Diptera..........	
	4		18	Adults............	

19. Thyothorus ludovicianus (Gm.), Bp. CAROLINA WREN. Group II. Class a.

The habitat of this Wren is so peculiarly southern that it can only be regarded, at present, as a rare straggler in Wisconsin.

20. Troglodytes domesticus (Bartr.), Coues. HOUSE WREN. Group I. Class b.

The House Wren is a common summer resident, but at present, with us, a bird of heavily timbered districts rather than of openings and prairie sections. In the older Eastern and Middle States it has assumed much more familiar and intimate relationship with man than with us; there it is common about dwellings and nests in bird-houses, in the cornice of buildings, under the eaves, and in hollow cherry trees. Habits similar to these are being assumed by our birds, but at present they are most abundant in woods where the upturned roots and tangled branches of trees are common. It is very destructive to insects, feeding almost entirely, if not wholly, upon them, and is, therefore, a bird which any abundance cannot make destructive to grains or fruits. It rears a large family, and often two each season.

No pains should be spared in attracting these birds to our dwellings and in establishing their homes along the fence-rows of cultivated fields. The accusation that is brought against them in the East, of their driving Bluebirds out of their houses and appropriating them to their own use, is no great objection. Houses enough and to spare should be gladly provided for both species. This, however, is to be said in regard to the disposition of these two species upon the farm. The size of the Bluebird, its method of obtaining food, and its haunts, fit it best for work in the open fields, where it should be especially encouraged; the House

Wren is especially fitted to do work among the shrubbery of orchards, gardens and yards, and these, particularly, should be the foci of its labors.

Food: From three specimens were taken seven caterpillars; from two, nine beetles; and from one, a grasshopper.

Insects and their larvæ (Wils.). Insects, their larvæ, and spiders (Samuels).

Four specimens examined by Prof. Forbes contained only beetles and hemiptera. The beetles were ground-beetles and Hydrophilidæ.

21. Anorthura troglodytes hyemalis (Wils.), Coues. **WINTER WREN.**
Group I. Class b.

In the northern portion of the state among the heavy timber, where this species is common, it is a summer resident. In this region it frequents the line of the Wisconsin Central Railroad, and often affects the large piles of slabs that are drawn out from the saw-mills. In the southern portion of the state it only occurs during its migrations.

Food: Of three specimens examined one had eaten three ants; one, a geometrid caterpillar; one, three beetles; and one a dragon-fly.

Insects and their larvæ (Wils.). Prof. Forbes found in one stomach evidence of ants, moths, caterpillars, ground-beetles, rove-beetles, diptera, day-flies and spiders.

22. Telmatodytes palustris (Bartr.), Cab. **LONG-BILLED MARSH WREN.**
Group I. Class b.

As the name of this species implies, it is a denizen of marshy tracts, and in all of these places it is an abundant summer resident. Its broods are two; and its eggs six or eight in number. It loves best the swampy borders of streams, lakes, and ponds, where coarse sedges, reeds and wild rice abound, but it also frequents the adjoining wet meadows.

Food: Of fourteen specimens examined one ate one ant; one, a caterpillar; one, three beetles; three, three moths; one, a small grasshopper; one, five grasshopper eggs; one, one dragon-fly; and one a small snail.

According to others, flying insects and their larvæ, and a small green grasshopper which inhabits the reeds (Wilson). Aquatic insects and diminutive mollusks (Audubon). Entirely insects captured at rest (Cooper).

23. Cistothorus stellaris (Licht.), Cab. **SHORT-BILLED MARSH WREN.**
Group I. Class b.

This Wren is a common summer resident with us, but far less abundant than its long-billed cousin. Although it affects situations similar to those of the last species, it is, on the whole, a more upland bird. I have never found its nest in wet sloughs, but always in low damp meadows, where no water stands during the summer. It rears two broods each season. The second, which appears late in July, or early in August, is often unavoidably destroyed when the grass is cut, and this fact doubtless accounts, in part, for its less abundance with us than the last species.

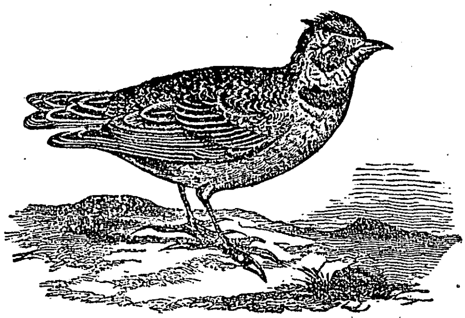
The Short-billed Wren is smaller than the last species, but its place of nesting lends to its services a greater comparative value. It is almost wholly insectivorous, and the smallest bird which frequents meadows. For this reason it is especially to be encouraged. Late haying in their breeding haunts would probably tend to make them more abundant, but it is doubtful whether their services will compensate for the injury that would result to the hay crop by allowing it to stand so long.

Food: Of four specimens examined, two had eaten four moths; two, four diptera, among which was one tipulid.

Insects and spiders (Samuels).

Family ALAUDIDÆ: Larks.

Fig. 113.



Horned Lark (*Eremophela alpestris*). After Coues.

24. Eremophela alpestris (Linn.), Boie. **HORNED LARK; SHORE LARK.**
Group I. Class b.

Without reference, in the present connection, to the varieties of this species which have been designated, except to state that *leucolæma* is probably the only form that breeds in the state, it may be said that this highly terrestrial and graminivorous bird is rather common in suitable places during most of the year, but that it is only abundant late in the fall and early in the spring. Except during the breeding season, it is gregarious in its habits, and its usual haunts are dry, open fields. Fields of newly sowed grain are sometimes visited by these birds both in the spring and fall, but the little injury that they do in picking up grain at present is slight when compared with the immense amount of seeds of various weeds which they consume during the year. Although it rears two broods each year, the exposed situations in which its nest is located appears to preclude any very considerable abundance.

Food: Five out of six specimens examined had eaten only the seeds of weeds, among which were those of the black bind-weed, the pigeon-grass and pig-weed; the remaining specimen had in its stomach winter wheat.

Small black seeds, buckwheat, oats, buds of sprig birch and larvæ of certain insects (Wilson). Seeds and insects which it finds among the grass (Cooper). Seeds of grasses, insects and mollusks (Samuels). Of seven specimens examined by Prof. Forbes, one had eaten ground-beetles; one, a fungus-beetle (Cryptophagidæ); one, a rove-beetle; two, leaf-chafers; one, a predaceous hemiptera (Reduviidæ); and six, seeds of weeds.

Family MONTACILLIDÆ: Wagtails.

25. Anthus ludovicianus (Gm.), Licht. **TITLARK; PIPIT; WAGTAIL.**
Group I. Class a.

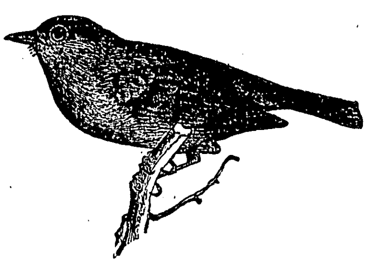
This gregarious and highly terrestrial species is only a migrant in Wisconsin. It passes us southward in October and returns again in April and May, and during these times it is probably common, although I have met with but a single flock. Its haunts are plowed fields, pastures, meadows, the banks of streams and the shores of lakes.

Food: The two specimens which were examined had in their stomachs several small beetles and heteropterous insects.

Various small seeds (Wilson). When along shores, minute shells, small shrimps, and insects found among drift-weeds; when in meadows and plowed fields, insects and seeds (Audubon). Seeds and insects (Cooper). On the beach, small mollusks and animalculæ; in pastures and fields, insects, spiders, and seeds of grasses and weeds (Samuels).

Family SYLVICOLIDÆ: American Warblers.

Fig. 114.

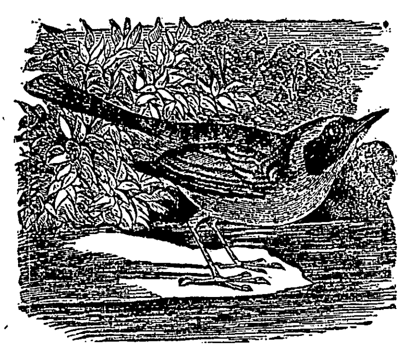


Orange-crowned Warbler (*Helminthophaga celata*). After B., B. and R.

Fig. 115.

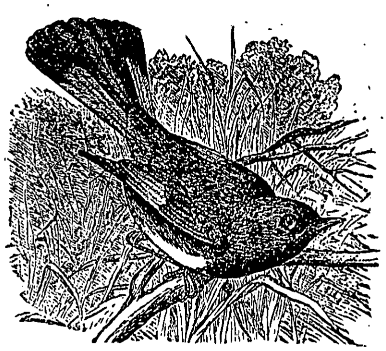
Black-and-White Creeping Warbler (*Miniotilta varia*). After B., B. and R.

Fig. 116.



Maryland Yellow-throat (*Geothlypis trichas*). After B., B and R.

Fig. 117.



Redstart (*Setophaga ruticilla*). After B., B. and R.

Tabular Summary of Economic Relations showing the number of specimens containing animal and vegetable food, and the number of insects, spiders, worms and snails taken from the stomachs, classified as to economic relations under the heads Beneficial, Detrimental and Unknown Relations.

Number and Name of Specimens Examined.				Classification of Food.	Ratios Represented by Lines.
Of seventeen Black and White Creepers examined	17	Contained		Animal food	
				Vegetal food	
				Beneficial	
	6		34	Detrimental	
	16		79	Unknown	
Of thirty-three Tennessee Warblers examined	33	Contained		Animal food	
				Vegetal food	
				Beneficial	
	12		90	Detrimental	
	31		112	Unknown	
Of twelve Black-throated Green Warblers examined	12	Contained		Animal food	
				Vegetal food	
				Beneficial	
	5		9	Detrimental	
	11		46	Unknown	
Of six Black-throated Blue Warblers examined	6	Contained		Animal food	
				Vegetal food	
				Beneficial	
	1		2	Detrimental	
	6		22	Unknown	
Of twenty-one Yellow-rumped Warblers examined	21	Contained		Animal food	
	1			Vegetal food	
	2		5	Beneficial	
	5		25	Detrimental	
	19		75	Unknown	
Of nine Hemlock Warblers examined	9	Contained		Animal food	
	1			Vegetal food	
	1		1	Beneficial	
	6		29	Detrimental	
	8		26	Unknown	

Tabular Summary of Economic Relations of American Warblers—continued.

Number and Name of Specimens Examined.				Classification of Food.	Ratios Represented by Lines.
Of nineteen Bay-breasted Warblers examined	19	Contained		Animal food......	
				Vegetal food	
	2		3	Beneficial	
	6		15	Detrimental	
	17		71	Unknown.........	
Of eleven Chestnut-sided Warblers examined	11	Contained		Animal food......	
				Vegetal food	
				Beneficial	
	4		21	Detrimental	
	9		29	Unknown.........	
Of seventeen Black and Yellow Warblers examined	17	Contained		Animal food	
				Vegetal food	
	1		1	Beneficial	
	8		23	Detrimental......	
	16		48	Unknown.........	
Of eight Palm Warblers examined	8	Contained		Animal food	
				Vegetal food	
	1		1	Beneficial	
	2		10	Detrimental	
	6		41	Unknown.........	
Of ten Oven-birds examined	8	Contained		Animal food	
	8			Vegetal food	
				Beneficial	
	1		8	Detrimental	
	8		23	Unknown.........	
Of seven Water Wagtails examined	7	Contained		Animal food	
	1			Vegetal food	
	1		1	Beneficial	
	2		5	Detrimental	
	7		46	Unknown.........	
Of twenty-one Maryland Yellow-throats examined	21	Contained		Animal food	
				Vegetal food	
	4		12	Beneficial	
	7		44	Detrimental	
	18		78	Unknown.........	

Tabular Summary of Economic Relations of American Warblers — continued.

Number and Name of Specimens Examined.				Classification of Food.	Ratios Represented by Lines.
Of twenty-nine Redstarts examined.....	29	Contained		Animal food	
				Vegetal food	
	2		4	Beneficial	
	3		5	Detrimental	
	29		173	Unknown.........	

Table showing kinds and numbers of animals, mostly insects, eaten by American Warblers.

Number and Name of Specimens Examined.				Classification of Food.	Ratios Represented by Lines.
Of seventeen Black-and-white Creepers examined	3	Contained	5	Ants.............	
	5		25	Lepidoptera......	
	3		5	Diptera...........	
	6		16	Beetles	
	2		7	Heteroptera	
	1		1	Caddis-fly	
	1		1	Snail..............	
	17		91	Adult forms......	
	3		22	Larvæ............	
	2		101	Insect eggs	
Of thirty-three Tennessee Warblers examined	2	Contained	2	Hymenoptera	
	7		13	Caterpillars	
	8		15	Diptera...........	
	6		13	Beetles	
	3		42	Plant-lice.........	
	3		35	Heteroptera	
	33		189	Adult forms	
	11		19	Larvæ............	
	1		11	Insect eggs	
Of twelve Black-throated Green Warblers..	4	Contained	8	Lepidoptera......	
	1		2	Diptera...........	
	3		11	Beetles	
	1		1	Heteroptera	
	10		42	Adult forms	
	4		13	Larvæ............	

Table showing kinds and number of animals, mostly insects, eaten by American Warblers — continued.

Number and Name of Specimens Examined.			Classification of Food.		Ratios Represented by Lines.
Of six Black-throated Blue Warblers examined	1	Contained	2	Ants	
	1		2	Caterpillars	
	1		5	Beetles	
	6		22	Adult forms	
	1		2	Larvæ	
Of twenty-one Yellow-rumped Warblers examined	4	Contained	22	Lepidoptera	
	5		14	Diptera	
	15		48	Beetles	
	1		4	Hymenoptera	
	1		1	Caddis-fly	
	1		1	Spider	
	19		84	Adult forms	
	8		21	Larvæ	
	1		15	Tipulid eggs	
Of nine Hemlock Warblers examined	2	Contained	8	Hymenoptera	
	5		19	Caterpillars	
	3		7	Diptera	
	4		9	Beetles	
	2		2	Heteroptera	
	8		37	Adult forms	
	5		19	Larvæ	
Of nineteen Bay-breasted Warblers examined	3	Contained	7	Ants	
	6		7	Lepidoptera	
	3		6	Diptera	
	7		15	Beetles	
	1		6	Leaf-hoppers	
	1		1	Dragon-fly	
	18		80	Adult forms	
	5		6	Larvæ	
	1		1	Pupa	
Of seventeen Black-and-yellow Warblers examined	3	Contained	4	Hymenoptera	
	6		18	Lepidoptera	
	6		15	Diptera	
	6		12	Beetles	
	15		50	Adult forms	
	7		20	Larvæ	

Table showing kinds and number of animals, mostly insects, eaten by American Warblers — continued.

Number and Name of Specimens Examined.			Classification of Food.		Ratios Represented by Lines.
Of eleven Chestnut-sided Warblers examined	1	Contained	3	Ants	
	2		4	Caterpillars	
	1		1	Tipulid	
	5		12	Beetles	
	1		15	Plant-lice	
	1		1	Grasshopper	
	10		44	Adult forms	
	5		7	Larvæ	
Of eight Palm Warblers examined	1	Contained	1	Hymenoptera	
	1		5	Moths	
	1		3	Diptera	
	2		13	Beetles	
	1		5	Plant-lice	
	8		49	Adult forms	
	1		3	Larvæ	
Of ten Oven-birds examined	1	Contained	3	Caterpillars	
	1		3	Beetles	
	7		23	Adult forms	
	1		3	Larvæ	
Of seven Water Wagtails examined	2	Contained	6	Diptera	
	3		6	Beetles	
	2		3	Orthoptera	
	1		1	Dragon-fly	
	1		1	Hair-worm	
	4		14	Snails	
	6		45	Adult forms	
	2		4	Larvæ	
	1		4	Orthoptera eggs	
Of twenty-nine Redstarts examined	2	Contained	4	Hymenoptera	
	4		5	Lepidoptera	
	25		90	Diptera	
	1		1	Heteroptera	
	9		19	Beetles	
	29		190	Adult forms	
	1		2	Larvæ	

Table showing kinds and number of animals, mostly insects, eaten by American Warblers — continued.

Number and Name of Specimens Examined.			Classification of Food.		Ratios Represented by Lines.
Of twenty-one Maryland Yellow-throats examined...........	2	Contained	3	Hymenoptera....	
	8		35	Lepidoptera......	
	4		7	Diptera..........	
	6		16	Beetles...........	
	3		7	Hemiptera.......	
	1		2	Grasshoppers....	
	3		6	Dragon-flies......	
	2		3	Spiders...........	
	21		103	Adult forms.....	
	7		33	Larvæ...........	
	1		2	Grasshopper eggs	

26. Miniotilta varia (Linn.), Vieill. **BLACK-AND-WHITE CREEPING WARBLER.** Group I. Class a.

If this active little species was ever more closely united, in habits and structure, to the "*wood warblers par excellence*," it has, probably, in some distant time, found with them so vigorous a competition as to oblige it to seek a living with a much smaller class of birds. Whatever may have been its habits in previous ages, it is to our advantage that it has assumed the creeper-like life it leads. It is another of those birds which has learned that a large number of nocturnal insects court security by day in the crannied bark of trees, or resort there to undergo their transformations, and, like the Nuthatches and true Creepers, upon such forms it feeds. Sometimes it pursues upon the wing moths which it has startled from their hiding places, and occasionally it searches for insects among the foliage of trees.

The Black-and-white Creeper is a rather common summer resident, and it usually affects, during the breeding season, unpastured groves and woods, where it builds its nest upon the ground, depositing therein from three to seven eggs; from these places, after the middle of July, it disperses over other woods and groves and often appears in orchards and about dwellings. It has been known to build its nest in the immediate vicinity of houses, and the fact bespeaks for it a growing familiarity and a greater usefulness. It is doubtful, however, owing to its breeding habits, whether it can ever become abundant about dwellings during the breeding season, at least where dogs and cats are allowed to live. These birds are often doomed to become the foster parents of the Cowbird, and no doubt their general abundance is greatly reduced on this account. Owing to the small size of these birds, they find it profitable to feed extensively upon very small insects. For this reason they are able to do a work for which the Nuthatches and Woodpeckers are not so well fitted. It is, therefore, especially desirable that they should attain a greater abundance with us.

Food: Of seventeen specimens examined, three had eaten five ants; two, twenty-one caterpillars, twenty of which were small measuring-worms; three, four moths; three, five diptera; six, sixteen beetles, one of which was a curculio; two, seven heteroptera; one, a caddis-fly; and one, a small snail *(Physa)*. Two had eaten one hundred and one insect eggs, but these, I believe, were contained in insects which the birds had eaten.

Ants and other insects (Wilson). Insects and their larvæ (Brewer). Insects which hide under the bark of trees and in its crevices (De Kay). Beetles and moths (Forbes).

27. Parula Americana (Linn.), Bp. **BLUE YELLOW-BACKED WARBLER.** Group I. Class b.

This elegant little Warbler appears to be nowhere abundant, and, throughout its range, seems to be largely confined to particular localities. Mr. Nelson, however, speaks of it as an abundant migrant, and as breeding rarely in Northeastern Illinois. I obtained a single specimen September 15, 1876. It was flitting among the outermost branches of the trees, in a piece of high, open woods, when taken. It is said to frequent the tops of the tallest trees, and to move with great agility among the terminal foliage in quest of winged insects and caterpillars. Orchards and all sorts of woodlands are said to be visited by it.

Food: Six small insects were taken from one stomach.

Small winged insects and caterpillars (Wilson). Winged insects and caterpillars (Brewer). Small caterpillars *(Geometridæ)*, small lace-winged flies and small spiders (Samuels).

28. Helmintherus vermivorus (Gm.), Bp. **WORM-EATING WARBLER.** Group II. Class a.

This southern species appears to be a very rare visitant. Dr. Hoy has said that a few nest near Racine, and Mr. Nelson states that a single specimen was observed at Waukegan, May 21, 1876.

29. Helminthophaga chrysoptera (Linn.), Bd. **BLUE GOLDEN-WINGED WARBLER.** Group II. Class a.

This species appears to be nowhere abundant. Mr. Nelson speaks of it as "comparatively rare" in Northeastern Illinois, and two nests are reported to have been taken near Racine by Dr. Hoy. Its nest is placed upon the ground, and, at times, becomes the receptacle for the eggs of the Cowbird.

30. Helminthophaga ruficapilla (Wils.), Bd. **NASHVILLE WARBLER** Group I. Class a.

Both Dr. Hoy and Mr. Nelson speak of this Warbler as common during the migrations, along the lake shore, in the spring and fall. This has not been my experience for Central Wisconsin. The only specimens which I have seen were taken near Waupaca. They represented both sexes and were taken in different localities. The first, a male, was taken July 21st, while perched upon the limb of a dead poplar which was standing in an old "clearing" overgrown with small poplars, between large piles of brush. The second was obtained in a grove of small tamaracks, while it was nimbly searching for food among the delicate sprays. Mr. Allen states that at Springfield, Mass., during two or three weeks of the spring migration, these birds are common in the orchards and gardens, actively gleaning insects among the unfolding leaves and blossoms of fruit trees. It nests upon the ground.

Food: The two specimens examined had in their stomachs four small green caterpillars, and a few very fine fragments of insects.

31. HELMINTHOPHAGA CELATA (SAY), BD. ORANGE-CROWNED WARBLER.
GROUP II. CLASS a.

This species, like the last, I believe to be of rare occurrence in Central Wisconsin. Mr. Nelson, however, says that it is common, during its migrations, along the lake shore. Possibly this species, in its autumnal dress, which so closely imitates that of the next, has been mistaken for that species.

Food: Insects (Cooper). Insects taken chiefly among the branches of trees, and shrubbery, but also upon the wing (Audubon).

32. HELMINTHOPHAGA PEREGRINA (WILS.), CAB. TENNESSEE WARBLER.
GROUP I. CLASS b.

This Warbler is extremely abundant during some of its fall migrations. During September of 1876 the borders of groves literally thronged with these little nymphs of the woodland, and hundreds of them might have been easily obtained. During September of 1877 they were much less numerous, but common. The first arrivals were noted August 15, but the body of them came along after the first of September. Its favorite haunts, in the fall, are the borders of groves, but it is a frequent visitor to orchards and vineyards. It is also to be found in willow thickets along the margins of streams, among the foliage of high open woods, and in tamarack swamps. I have twice taken it in cornfields bordered by groves, and in the stomach of each of these was found a greenish plant louse, probably *Aphis maidis*, Fitch.

It is very dexterous in its movements, and obtains the greater part of its food upon and among the terminal foliage of trees. Titmouse-like, it often swings pendant from a leaf while it secures an insect which it has discovered. Small insects of various kinds, not especially attractive to larger birds, are destroyed by this species in large numbers; and its slender, acute bill serves it much better in picking up these forms than a heavier, more clumsy one could. There is another use, however, to which this Warbler puts its slender, acute bill, and for which it is well adapted. It is that of probing ripe grapes, apparently for the purpose of obtaining the sweet juice. September 8, 1876, I observed one of these birds picking at a cluster of ripe Delaware grapes, and upon examination it was found that two of the berries had been recently pierced with some sharp instrument, and that the juice was oozing from the wounds. On inquiring of Mr. Bates, a grape-grower at Whitewater, whether there were any birds which troubled seriously his grapes, he informed me that there was a little green "Grape-sucker" which troubled him very much some seasons, and that it was now at work upon his Delaware and Catawba grapes. I examined his vineyard and found that many of his grapes were probed in the manner described above, as high as eight berries on some bunches being thus injured. Only the ripe grapes appeared to be molested, and the sweet varieties, he says, are preferred to the sour.

As soon as the berries are wounded they are attacked by ants, bees and flies, and soon destroyed. I requested Mr. Bates to secure one of the "Grape-suckers" for me, and the next morning he kindly presented me with a bird of this species. Mr. Floyd, of Berlin, informed me in September, 1873, that there was a little green bird with a very sharp bill sucking his grapes, but he was unable to obtain a specimen. Mr. Lowe, of Palmyra, enters the same complaint against a similar bird. From this evidence I think that there can be no doubt that this species is injurious to grapes in the manner described. It does by no means follow, however, that the bird should be exterminated. I am confident that the service which this species renders in Wisconsin alone, during its hurried transits in the fall and spring, more than compensates for what injury it may do to grapes. It is unfortunate that the grape-grower should be obliged to sustain the whole injury of this species while the state at large shares its benefits, but such conditions are common, and, so far as I can see, to be endured. Should it be proved that the injury which the state sustains from this Warbler is greater than the service it receives, it would not then follow, as was stated in the "Introduction," that it should be exterminated. We are not the only people whose interests are affected by this bird. What the extent of its services during its five months' stay in the south is, we do not know. Until we do, we should be cautious how we destroy it for any trivial injury which it may do.

Food: Of thirty-three specimens examined, two had eaten two very small hymenoptera (probably parasitic); seven, thirteen caterpillars; three, fifteen diptera; six, thirteen beetles; three, forty-two plant-lice, among which were two specimens of the corn plant-louse *Aphis maidis (?)*; three, thirty-five small heteroptera, .09 of an inch long; and one, eleven insect eggs.

33. DENDRŒCA ÆSTIVA (GM.), BD. BLUE-EYED YELLOW WARBLER; GOLDEN WARBLER; SUMMER YELLOWBIRD. GROUP I. CLASS b.

This elegant little species and common summer resident frequents most commonly the willow clumps of alluvial meadows, but is also to be seen in groves, along wooded water-courses, and in villages, orchards and gardens. In the Eastern and Middle States it is much more familiar and abundant than with us. At Ithaca, N. Y., it nests very commonly in the city, building in the shade and fruit trees, sometimes so close to the windows of the dwellings that its nest can almost be reached from them. It only requires suitable breeding places to become, in time, extremely serviceable as a destroyer of garden and orchard insects. It loves to search for insects in rosaries and among berry bushes.

Food: Of five specimens examined, two had eaten four small larvæ; two, two beetles.

Small green caterpillars (Wils.). Said to feed on juicy fruits in autumn (Cooper). Canker-worm (Maynard). Hymenoptera, moths and caterpillars, among them canker-worms, beetles, diptera, hemiptera, spiders and myriapods (Forbes).

34. DENDRŒCA VIRENS (GM.), BD. BLACK-THROATED GREEN WARBLER. GROUP I. CLASS a.

Migrant. Common during the middle of May, and again during nearly the whole of September; a few are said to breed in the state. Much of its food is taken upon the wing among the branches of trees. During its migrations it may usually be seen darting among the uppermost branches of high open woods, but tamarack swamps, groves, and orchards are also visited by it.

Food: Of twelve specimens examined, one had eaten a moth; three, seven caterpillars; one, two diptera; one, six larvæ — probably caterpillars; three, eleven beetles; and one, a heteroptera.

The smaller winged insects, caterpillars and other larvæ (Brewer). Larvæ of insects that prey upon opening buds (Wilson). Hymenoptera, caterpillars and curculios (Forbes).

35. DENDRŒCA CŒRULESCENS (LINN.), BD. **BLACK-THROATED BLUE WARBLER.** GROUP I. CLASS a.

Migrant. I have not found it common. Its favorite haunts are among the heavy timber, but it also visits groves, low, damp thickets, and village shade-trees. A considerable portion of its food is gleaned from the bark of the larger branches of trees. It poises itself, upon the wing, humming-bird-like, to remove insects from the under sides of large limbs, and I have seen it light upon the trunks of trees for the same purpose. Dr. Brewer states that it is an expert catcher of small-winged insects. One of these birds came into the school-room at Berlin in May, 1875.

Food: Of six specimens examined, all had eaten insects; one, two ants; five, beetles; and one, two caterpillars.

Larvæ, the eggs of insects and spiders (Brewer).

36. DENDRŒCA CŒRULEA (WILS.), BD. **CŒRULEAN WARBLER.** GROUP II. CLASS a.

Mr. Nelson, in his "Birds of Northeastern Illinois," says of this species: "A regular but rare migrant. May 12th to 20th, and the first of September. Prefers high woods. Rare summer resident here, but near Detroit, Michigan, I am informed it is one of the common species at this season." Of its occurrence in Wisconsin, Dr. Hoy says: "Not common. A few breed."

37. DENDRŒCA CORONATA (LINN.), GRAY. **YELLOW-RUMPED WARBLER.** GROUP I. CLASS b.

This Warbler, like most of its genus, is only a migrant. A few may breed in Northern Wisconsin, for I obtained a male at Elk Lake in Chippewa county, July 26, 1876.

During the fall, from the middle of September until well along toward November, it is extremely abundant, when it may always be seen in dry open fields, along fences and roadsides, and often in orchards and gardens about dwellings. On cold, windy days it often hops and flits about porches and windows in quest of flies. It also occurs in groves, woods, and tamarack swamps. It is an adept at catching insects on the wing, but it secures more of the steady flying coleopterous forms than those which have a jerky, zigzag flight.

Food: Of twenty-one Yellow-rumped Warblers examined, one had eaten a moth; two, twenty-one caterpillars — mostly measuring-worms; five, fourteen diptera, among which were three tipulids; fifteen, forty-eight beetles; one, four of the Ichneumonidæ; one, a caddis-fly; one, a spider; and one, fifteen tipulid eggs. As these eggs were found in the stomach with the tipulids, they, beyond question, were not eaten separately. From the stomach of one bird was taken a single tamarack seed.

Five specimens examined by Prof. Forbes gave evidence of having eaten hymenoptera, among them ichneumons; caterpillars; beetles, among which were leaf-chafers and long-horns; diptera, hemiptera, spiders and seeds.

Larvæ, and berries of wax myrtle (Wilson). Caterpillars and berries of wax myrtle (De Kay). Spiders, insects and their larvæ (Audubon).

38. DENDRŒCA BLACKBURNIÆ (GM.), BD. **BLACKBURNIAN WARBLER; HEMLOCK WARBLER.** GROUP I. CLASS a.

This beautiful species, while among the uppermost branches of high open woods, reminds one both of the Redstart and the Black-and-white Creeper, whose methods of obtaining food it copies to some extent. It even drops onto the underside of horizontal limbs to secure some insect which may have retreated thither for safety. Besides high open woods, it affects groves and tamarack swamps. In May, 1874, one of these birds came into the school-room at Berlin.

They pass us northward about the middle of May, and return between the 1st and 20th of September. I have taken the males in tamarack swamps as early as August 7th.

Food: Of nine specimens examined, four had eaten nine small beetles; five, nineteen caterpillars; one, ants; and one, small winged insect. In the stomachs of three examined collectively, were found four caterpillars, four ants, one dipterous insect .09 of an inch long, one medium sized heteropterous insect, four large crane-flies, and one ichneumon-fly (?) Another bird had in its stomach one heteropterous insect *(Tingis)*, nine small caterpillars, two leaf-beetles, and two large crane-flies. One specimen had eaten beetles and small diptera (Forbes). Small insects and berries (De Kay).

39. DENDRŒCA STRIATA (FORST.), BD. **BLACK-POLL WARBLER.** GROUP I. CLASS a.

The extremely close resemblance between this species and the next in their autumnal attires, renders it very difficult to state, with certainty, which is the more abundant during the fall migration. It is my opinion that the Bay-breasted Warbler far outnumbers this one. It is a migrant, and most of them pass south during the latter half of September. Woods, swampy groves and orchards are its usual haunts in the fall.

Food: Of four specimens examined one had eaten a caterpillar, and one three beetles. Other insects, estimated at thirteen, were observed.

Canker-worm (Brewer). Insects caught upon the wing (Coues). Winged insects (Wilson). Canker-worm (Maynard).

40. DENDRŒCA CASTANEA (WILS.), BD. **BAY-BREASTED WARBLER; AUTUMNAL WARBLER.** GROUP I. CLASS b.

This abundant migrant passes north between the 10th and 25th of May, and returns again, greatly reinforced, between the 1st and 20th of September. At these times it is most abundant in groves of small oaks and in high, open woods adjacent to fields, but orchards, the borders of damp thickets, and clumps of willows in low meadows are also visited by it. It is an active and skillful insect-hunter, and obtains its food along the branches of trees, among the foliage and upon the wing. It is not, however, as habitually a fly-catcher as many others of its genus.

Food: Of nineteen specimens examined, three had eaten seven ants; five, six caterpillars — one of them hairy and 1.5 inches long; one, a moth; three, six diptera; seven, fifteen beetles, among which were two lady-birds *(Chilocorus bivulnerulus)*, and two squash beetles *(Diabrotica vittata)*; one, six leaf-hoppers *(Cicadellina)*; and one, a small dragon-fly. The whole number of insects contained in the nineteen stomachs was eighty-seven, of which eighty were adult forms.

In the stomachs of two birds were found one caterpillar (geometer), five flies, one ichneumon-fly, one winged ant, one small beetle and one small chrysalid.

Larvæ of insects (Wilson). Canker-worm and other insects (De Kay). Small insects, many of which are taken upon the wing. It also searches for insects among the blossoms of the cotton plant (Audubon).

41. Dendrœca pennsylvanica (Linn.), Bd. **CHESTNUT-SIDED WARBLER.** Group I. Class a.

It has been my experience to find this Warbler barely common. It is a summer resident from Berlin northward in Central Wisconsin. Dr. Hoy speaks of it as breeding in abundance at Racine, but during three summers' collecting in Jefferson county it was not my fortune to meet with it except during the migrations, and even then, it has been among the rarest of this genus with which I have met. During the breeding season, it has been Mr. Allen's experience to find this bird usually in low woods and swampy thickets, nesting in bushes. Mr. Ridgway found it breeding in oak openings and among the prairie thickets of Southern Illinois. Dr. Hoy states that it prefers localities with a dense underbrush, especially hazel, thinly covered with trees. While at Waupaca, between July 20th and 24th, I met two pairs of these birds busily feeding their broods high among the tops of deep, heavy maple woods, and another similarly engaged on the borders of a tamarack swamp. At Berlin during the month of June I observed it in similar situations. It usually lays four eggs in a nest placed in the upright forks of a low bush. The Cowbird sometimes deposits its eggs in the nests of this species.

Food: Of eleven specimens examined, one had eaten three ants; two, four caterpillars; one, a tipulid; five, twelve beetles; one, fifteen plant-lice; and one, a small grasshopper.

Among the caterpillars were two geometers, marked above, on a yellow ground, with numerous fine wavy black lines. These were very abundant at Berlin in June of 1874, feeding upon the red, white and burr oaks, the hazel, hickory, plum, cherry, apple, pear and currant.

Insects (Wils.). Flies and other insects (De Kay). Canker-worms (Maynard).

42. Dendrœca maculosa (Gm.), Bd. **BLACK-AND-YELLOW WARBLER.** Group I. Class a.

This elegant little Warbler is nearly as abundant as the Yellow-rump, and, like it, a migrant. Its spring migration occurs between the 5th and 28th of May. Between the 2d and 27th of September it returns again to the south. During these movements it frequents groves and the borders of woodlands, where it gleans among the branches and foliage after the manner of the Creepers and Flycatchers. It is also to be seen in osier and alder thickets, in tamarack swamps and in the clumps of willows that grow on wet marshes.

Food: Of seventeen specimens examined, three had eaten four hymenoptera, among which were two ants; one, one moth; six, seventeen caterpillars; six, fifteen diptera; six, twelve beetles; and one, two larvæ. Two tipulids were represented among the diptera.

43. Dendrœca tigrina (Gm.), Bd. **CAPE MAY WARBLER.** Group I. Class a.

This Warbler, once so rare as to have escaped entirely the notice of both Audubon and Nuttall, is apparently becoming not uncommon. Mr. Nelson says of it: "Very common migrant. May 7th to 25th, and September 5th to 20th. In spring, found almost exclusively in the tops of trees; in autumn, found in large numbers along roadsides, borders of woods and fields in company with *D. palmarum*, from which it is with difficulty distinguished at gun-shot, so closely alike are their habits and movements at this season."

The four specimens which I have obtained were taken between September 6th and September 22d. Of these, two were obtained in high open woods, one in a tamarack swamp, and one in a front yard.

Food: Only beetles were identified among the contents of the four stomachs examined, except a single ant. Ten beetles were taken from the stomach of one bird.

44. DENDRŒCA DISCOLOR (VIEILL.), BD. **PRAIRIE WARBLER.** GROUP II. CLASS a.

This Warbler enjoys, as a rule, a more southern latitude than our own, and although Mr. Allen finds it not uncommon in Massachusetts, Mr. Ridgway cites it as rare in Southern Illinois. But one instance of its occurrence in Wisconsin is recorded. As a fly-catcher, Dr. Coues regards it the equal of most of its tribe.

Food: Flies and larvæ (Nuttall). Small caterpillars and winged insects (Wilson). Small insects and flies often seen in cotton fields (Audubon). Insects caught in the air (Coues).

45. DENDRŒCA DOMINICA ALBILORA, BD. **YELLOW-THROATED GREY WARBLER.** GROUP II. CLASS a.

This is another of those southern species which probably occurs rarely in the state. As with the last species, Dr. Hoy has noted one instance of its occurrence near Racine. Of its manners, Dr. Brewer says: "It is almost as much of a creeper as *Miniotilta varia*, being frequently seen creeping not only along the branches of trees, but out over the eaves and cornices of buildings, with all the ease and facility of a Nuthatch."

46. DENDRŒCA PALMARUM (GM.), BD. **PALM WARBLER.** GROUP I. CLASS a.

The Palm Warbler reaches us, from the British Possessions, early in September, and not until after October has nearly gone have the last of the train passed us for Southern homes. It associates on friendly terms with the Yellow-rumps, whose autumnal dress its own so closely resembles, and with them it drives a vigorous competition along roadsides and fence-rows, and among the rank weeds and low bushes of neglected fields. While it is peculiarly terrestrial in its habits, it is quite an adept at catching insects on the wing. It pursues them from the ground or among the weeds into the air, whither they have taken flight for safety. It even sits upon the lower limbs of trees in open fields, and beats out for passing insects, returning again to the tree with its victim; or, marking from its perch a small moth or beetle in the grass below, it will drop quickly upon its prey, as the Pewee often does. "The odd sheep of the flock," it alone of all this genus, so far as I know, builds its nest upon the ground.

Food: Of eight specimens examined, one had eaten a small hymenoptera; one, five small moths; one, three diptera; two, thirteen beetles; and one, five plant-lice.

47. DENDRŒCA PINUS (BARTR.), BD. **PINE-CREEPING WARBLER.** GROUP II. CLASS a.

This species is said to breed among the pines in the northern portion of our state, and Mr. Nelson speaks of it as a common migrant, passing north between April 27th and May 20th, and returning again between September 15th and October 5th. It has not been my fortune to meet with the species. As its name implies, its favorite haunts are among the coniferous forests, where it frequents the tops of the taller trees. During the spring and fall, in Massachusetts, it frequents situations similar to those chosen by the Palm Warbler, the two species at these times often associating together. While in the forests, its habits are said to closely resemble those of the Creepers, but it is also said to capture insects on the wing.

Food: Seeds of pitch pine and various bugs (Wilson). Insects taken principally among the branches of trees, but occasionally upon the ground; young crickets, and a small red beetle found enclosed in the leaves or stipules of pines (Audubon).

I obtained a single specimen of this species in May of 1880, at River Falls, since the above was written.

48. Siurus auricapillus (Linn.), Sw. GOLDEN-CROWNED THRUSH. Group I. Class b.

This trim bird-of-the-woodlands breeds with us commonly. Dry groves and woods are its usual haunts, but it also frequents osier and alder thickets. Most of its time is spent upon the ground, running and scratching among the fallen leaves for food. Here, too, its quaint nest is built, and diligently sought for by the Cowbird as a receptacle for her eggs. Two broods are said to be reared each season.

Food: A considerable portion of the food of this species consists of seeds gathered in the woods. Eight out of ten specimens examined had eaten seeds; one, three caterpillars; and one, three beetles. In the stomachs of five, there were fine bits of insects, none of which were identified.

Ants, small beetles, and caterpillars (De Kay). Small insects, smooth caterpillars, spiders, and berries (Audubon). Seeds, mud-insects, caterpillars, and small turbinated snails (Gosse).

49. Siurus nævius (Bd.), Coues. WATER THRUSH; WATER WAGTAIL. Group I. Class b.

This is not an abundant bird in Wisconsin, and I have never met with it earlier than August 10th, although a few are said to breed in the dark, gloomy swamps. It is terrestrial in its habits, but more timid and suspicious than its cousin. Unfrequented woodlands where pools abound, or through which some stream runs, are its usual resorts. Sometimes it leaves the wood a mile or more to visit streams winding through marshy tracts. In these places it often wades the shallows to obtain aquatic forms of life which may be within its reach.

Food: The contents of four stomachs, examined collectively, included three dipterous larvæ, two crickets, one grasshopper, three beetles — two of them curculios,— six dipterous insects, one dragon-fly, one hair-worm, six small mollusks, four orthopterous eggs, and two capsules and pedicels of some moss.

Aquatic insects and mollusks (Gosse). Principally aquatic insects (Wilson).

50. Oporornis agilis (Wils.), Bd. CONNECTICUT WARBLER. Group III. Class b.

This rare Warbler is said to be quite abundant in Illinois and Wisconsin in the spring, but very rare in the fall. Mr. Nelson, however, speaks of it as being about equally abundant at both seasons. During the migrations it appears to prefer swampy places in the vicinity of ponds. Dr. Coues found it frequenting old buckwheat and corn fields searching for food among the rank weeds. Wilson only found it in low thickets. Audubon saw it chasing spiders that run nimbly over the water. Mr. Henshaw found it almost always seeking its food upon the ground, but on two occasions he saw it feeding in the tops of willows, among the fresh pond marshes about Cambridge, Mass. Mr. Jencks has obtained specimens in May which were singing on the lower branches of a pine standing close by a house.

Food: Spiders and small caterpillars (Samuels). Spiders (Audubon).

51. Oporornis formosa (Wils.), Bd. KENTUCKY WARBLER. Group III. Class b.

A single specimen of this species is reported by Dr. Hoy to have been taken near Racine; and Mr. Nelson speaks of it as a very rare summer visitant from Southern Illinois.

Food: Spiders, insects and their larvæ (De Kay). It destroys great numbers of spiders (Audubon).

52. Geothlypis trichas (Linn.), Cab. MARYLAND YELLOW-THROAT; BLACK-MASKED GROUND WARBLER. Group II. Class a.

This is a common summer resident in its favorite resorts, and it arrives early in May and has departed again by September 23d. Hazel patches, willow clumps, berry brush and rank weed tangles, and the borders of woods heavily fringed with small bushes, are the surroundings that suit it best, and these are usually chosen in damp situations. During the migrations it also visits open fields, orchards and gardens. It is a diligent insect-hunter, but we must know more of its food, and of the habits of the insects upon which it feeds, before we can know what its real influence is. The dragon-flies, spiders, and hymenopterous insects included in the list below suggest that its injurious effects are not slight; but we know far too little in regard to the actual service which these insects render to enable us to calculate, even approximately, the magnitude of the injury.

Food: Of eight specimens examined, four had eaten, among other insects, eight caterpillars; and three, beetles. Among the contents of the stomachs of eleven birds, examined collectively, were found twenty-two case-bearing caterpillars (*Coleophora?*); five other larvæ — two of them caterpillars; six small dragon-flies; three moths; three dipterous insects; three very small hymenopterous insects; three beetles — among them a squash-beetle; three spiders; two small grasshoppers; one leaf-hopper; two hemipterous insects; and two insect eggs.

53. Geothlypis Philadelphia (Wils.), Bd. MOURNING WARBLER. Group II. Class a.

This species is introduced in this connection on the evidence of its general distribution, and on that of Dr. Hoy's Report. It appears to be an uncommon bird everywhere east of the Mississippi in our latitude. Mr. Trippe, in giving his observations in Minnesota, says of it: "The Mourning Warbler haunts the edges of tamarack swamps and the damp thickets that adjoin them. They are similar in their habits to the Maryland Yellow-throat, but are not so exclusively devoted to thickets and underbrush, frequently ascending the tops of tamaracks, for which they show a great predilection." It obtains the greater part of its food in a manner similar to that of the last species, but is perhaps a more expert fly-catcher.

54. Icteria virens (Linn.), Bd. **YELLOW-BREASTED CHAT.** Group I. Class b.

This is another of the birds which is seen but rarely in Wisconsin, and its regular occurrence north of Pennsylvania is disputed. It is described as somewhat terrestrial in its life, frequenting tangled thickets of vines, briers and brambles, and keeping itself very carefully concealed.

Food: Large black beetles and other insects (Wilson). Beetles, and berries of various kinds (De Kay). Spiders, and insects found among the thick shrubbery of brier patches and on the ground among the leaves (Samuels). Chiefly beetles and other insects, berries and other small fruits. It is said to be especially fond of wild strawberries (Brewer).

55. Myiodioctes mitratus (Gm.), Aud. **HOODED FLY-CATCHING WARBLER.** Group II. Class a.

As with the last, this is a southern species, probably to be found only along the lake shore, and there but rarely.

Food: Insects taken on the wing (Brewer). Winged insects (Wilson). Insects which it takes on the wing (De Kay).

56. Myiodioctes pusillus (Wils.), Bp. **BLACK-CAPPED FLY-CATCHING WARBLER.** Group II. Class a.

his species is credited to North America at large, and regarded as common; yet it has not been my good fortune to meet with it. Nelson states that it is found along the borders of woods and about willow patches, and that it is a common migrant in Northeastern Illinois, May 7th to 25th, and the first of September. Since writing the above, one of these birds was picked up dead at River Falls after the cold wave of May, 1882, by which it had been killed.

57. Myiodioctes Canadensis (Linn.), Aud. **CANADA FLY-CATCHER.** Group I. Class a.

This bird is chiefly a migrant in the United States. It is probable, however, that it breeds regularly in the northern portion of the state, as it does in Maine, for I obtained a young specimen, fully fledged, near Worcester, July 19, 1876. It was on the border of a cedar swamp flitting along among the lower branches of the hemlocks and pines which abound in that region. In the southern portion of the state, during the migrations, it frequents the densely wooded banks of streams. It is not common, at least in Central Wisconsin.

Food: Of three specimens examined, two had eaten flies; one, a hymenopterous insect; one, beetles; and one, larvæ.

Insects (Wilson). Insects taken on the wing (Samuels).

58. Setophaga ruticilla (Linn.), Sw. **AMERICAN REDSTART.** Group I. Class b.

A few Redstarts breed in the southern part of the state, but the great majority pass northward, at least beyond Waupaca, to nest. During the last days of July or early in August, they become suddenly abundant and remain so until the middle of September, after which only loiterers are to be found. Its favorite haunts are the interior woodlands, both damp and dry, the wooded banks of streams, and low, damp thickets. Groves, fence-rows and orchards are also visited by it frequently.

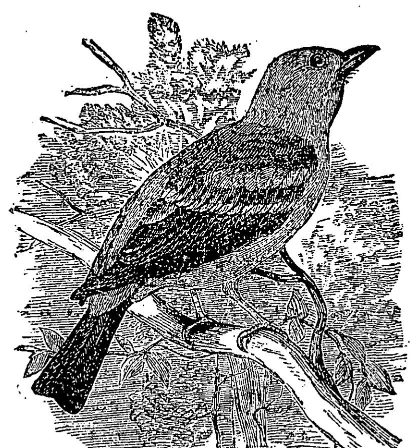
In its method of obtaining food, the Redstart is a fly-catcher of the most expert and vigorous sort, but its small size, its great dexterity, and its peculiar hunting grounds enable it to do a work quite distinct from that of the true Fly-catchers, even of the woodland species. Instead of stationing itself on the terminal branches where it can survey the openings between the tree-tops or command the fields above or below them, its peculiar field is within each particular tree-top, and here it plunges headlong through the branches, turning somersaults and performing such aerial movements in pursuit of its prey as only a Redstart can. It does beat out into the open air and plunge in hawk-like swoops to the ground, but these are its sports — its trespassings upon the rights of others. Its broad-based bill, and strong depending rictals, giving to the mouth, when open, the shape of a wide funnel, its keen vision, and its whole aerial outfit are adjusted to the gall-flies, leaf-miners, and other diminutive insects among which it lives, and upon which, I have no doubt, it feeds. Could it be induced to live in orchards, vineyards, gardens and parks, it would do there a work which the Pewee, the Least Fly-catcher and the Kingbird cannot. Mr. Samuels says that he has known a pair to build, and rear a brood, in a garden within five rods of a house.

Food: From the contents of eleven stomachs, examined collectively, were taken fourteen small beetles — some of them .09 of an inch long; four very small moths, four small hymenopterous insects — one, an ichneumon, and one, one of the *Proctrotrypidæ?* .1 of an inch long; one heteropterous insect, .08 of an inch long, and a large number of dipterous insects, the majority of them less than one-tenth of an inch long. Three others had in their stomachs a single small larva each.

Winged insects (Wilson). Various insects and their larvæ (De Kay). Winged insects and larvæ (Audubon). Three specimens examined by Professor Forbes gave evidence of having eaten an ichneumon-fly, moths and caterpillars, beetles and leaf-hoppers.

FAMILY TANAGRIDÆ: TANAGERS.

FIG. 118.



LOUISIANA TANAGER (*Pyranga ludoviciana*). After Baird, Brewer and Ridgway.

Tabular Summary of Economic Relations showing the number of specimens containing animal and vegetable food, and the number of insects and spiders taken from the stomachs, classified as to economic relations under the heads Beneficial, Detrimental and Unknown Relations.

Number and Name of Specimens Examined.			Classification of Food.		Ratios Represented by Lines.
Of twenty-nine Scarlet Tanagers examined.	29	Contained		Animal food..	
	4			Vegetal food .	
	7		15	Beneficial.....	
	10		38	Detrimental...	
	25		94	Unknown.....	

Table showing the kinds and number of insects and spiders eaten by the Scarlet Tanager.

Number and Name of Specimens Examined.			Classification of Food.		Ratios Represented by Lines.
Of twenty-nine Scarlet Tanagers examined.	4	Contained	4	Hymenoptera	
	8		26	Caterpillars ..	
	8		6	Diptera.......	
	17		47	Beetles	
	8		6	Hemiptera ...	
	4		7	Grasshoppers.	
	1		1	Dragon-fly....	
	8		11	Spiders	
	27		120	Adult forms..	
	8		26	Larvæ........	
	1		1	Pupa	

59. Pyranga rubra (Linn.), Vieill. SCARLET TANAGER. Group I. Class b.

This brilliant bird is very common with us, and breeds abundantly in groves and the borders of woodlands, and, occasionally, in orchards. These situations are also its usual haunts during the summer. In its choice of food and in its manner of obtaining it, the Scarlet Tanager is quite comprehensive. It is quite an expert fly-catcher, but, apparently, seizes only the larger winged insects. I have seen it beat out into a field, from the border of a piece of woods, and capture a butterfly *(Colias philodice)*, which was flying ten rods distant. If proper breeding grounds are provided for it, I see no reason why it should not maintain a steady and considerable abundance, and prove itself a very useful bird. The few berries which it occasionally eats are valueless compared with the service which it is capable of rendering.

Food: Of twenty-nine specimens examined, one had eaten ants; three, three ichneumon-flies, two of them *Thalessa lunator?*, the other a small species having an extent of wing of one-tenth of an inch; eight, twenty-six caterpillars; three, six diptera, three of them tipulids; seventeen, forty-seven beetles; three, six hemipterous insects; four, seven grasshoppers; one, a small dragon-fly; one, a very large spider; and two, ten harvest-men. Curculios, elaters and leaf-chafers, some of them three-fourths of an inch long, were represented among the beetles. From the stomachs of three young birds less than a week old were taken four caterpillars, one fly, one small grasshopper, one hemipterous insect, together with undetermined fragments.

Wasps, hornets, humble bees and other large winged insects; also, cherries, huckleberries and other fruits (Wils.). Insects found among tall cottonwood trees, and frequently a kind of bee found on laurea bushes (Cooper). Insects and their larvæ, preferring beetles, wasps, etc.; also, berries and grapes (De Kay). Insects (Samuels). Cherries, dogwood berries and cedar berries. Spends much of its time in pursuit of insects (Audubon).

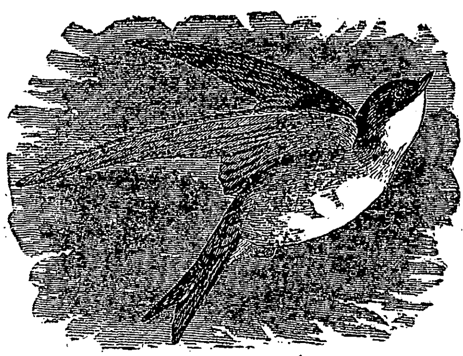
60. Pyranga ludoviciana (Wils.), Bp. LOUISIANA TANAGER. Group II. Class a.

Mr. Thure Kumlien informs me that he obtained a pair of these birds breeding near Busseyville, in May, 1877. The bird appears, however, to be out of place.

Food: Insects and berries (Cooper). The stomach of a specimen examined by Dr. Suckley contained insects, principally coleoptera, among them many fragments of a large *Buprestis*, found generally on the Douglas fir-trees (Coues).

Family HIRUNDINIDÆ: Swallows.

Fig. 119.



White-bellied Swallow (*Iridoprocne bicolor*). After Baird, Brewer and Ridgway.

Tabular Summary of Economic Relations showing the number of specimens containing animal and vegetable food, and the number of insects, spiders and mollusks taken from the stomachs, classified as to economic relations under the heads Beneficial, Detrimental and Unknown Relations.

Number and Name of Specimens Examined.				Classification of Food.	Ratios Represented by Lines.
Of eleven Barn Swallows examined	11	Contained		Animal food	
				Vegetal food	
	1		1	Beneficial	
	4		35	Detrimental	
	5		28	Unknown	
Of fourteen White-bellied Swallows examined	14	Contained		Animal food	
				Vegetal food	
	6		36	Beneficial	
	9		68	Detrimental	
	7		62	Unknown	
One Eave Swallow examined	1	Contained		Animal food	
				Vegetal food	
	1		2	Beneficial	
	1		19	Detrimental	
	1		6	Unknown	
Of five Purple Martins examined	5	Contained		Animal food	
				Vegetal food	
	5		28	Beneficial	
	2		2	Detrimental	
	3		12	Unknown	

Table showing the number and kinds of insects, spiders and mollusks eaten by the Swallows.

Number and Name of Specimens Examined.				Classification of Food.	Ratios Represented by Lines.
Of fourteen White-bellied Swallows examined	5	Contained	5	Hymenoptera	
	8		10	Diptera	
	13		63	Beetles	
	3		23	Hemiptera	
	2		2	Grasshoppers	
	6		33	Dragon-flies	
	1		1	Spider	
	14		142	Adult forms	

Table showing the number and kinds of insects, spiders and mollusks eaten by the Swallows — continued.

NUMBER AND NAME OF SPECIMENS EXAMINED.			CLASSIFICATION OF FOOD.		RATIOS REPRESENTED BY LINES.
Of eleven Barn Swallows examined......	7	Contained	14	Moths	
	7		40	Diptera.	
	2		6	Beetles	
	1		1	Dragon-fly	
	11		68	Adult forms......	
One Eave Swallow examined..............	1	Contained	2	Ichneumon	
	1		7	Diptera...........	
	1		6	Beetles	
	1		12	Leaf-hoppers.....	
	1		27	Adult forms.....	
Of five Purple Martins examined	3	Contained	14	Bees.............	
	2		8	Tiger-beetles	
	2		2	Butterflies	
	3		9	Breeze-flies	
	3		6	Dragon-flies	
	1		3	Mollusks	
	5		42	Adult forms......	

61. Hirundo erythrogastra horreorum (Bartr.), Coues. BARN SWALLOW. Group I. Class b.

The Barn Swallow, familiar as it is in most thickly settled districts, for which it has abandoned its native haunts to obtain dryer and securer breeding places, nowhere receives that attention and encouragement which it merits. The trim, tasty barns, so fast supplanting the old oaken excuses, intentionally exclude the Swallow in almost every case; even the projecting rafters under the generous eaves are so smoothly cased as to preclude a foothold for the birds. There is nothing out of the way in a tight, tasty barn, but it should make special provision for both the Barn and Eave Swallows. The trifling litter which they may produce in the barn is nothing when compared with the service they render, nor the half of what is often freely permitted from poultry. He who excludes them because of their twitter must be irritable indeed. Generous swallow-holes should be made in the gables. If brackets, designed with a view to their adaptability to birds, were put up under the broad eaves, they would serve the double purpose of ornamentation and utility. Robins, Pewees and Chipping Sparrows are all learning the inaccessibleness of such places to cats and other enemies, for I have found their nests in such situations, and Eave Swallows could certainly secure their nests much more readily if such provisions were made.

One great advantage of the Barn Swallow, and of all of them in fact, as a bird to be encouraged in agricultural districts, is its independence of woodlands and groves, which must necessarily grow smaller and fewer as land increases in value. Again, their strong power of flight enables them to remain persistently upon the wing for hours at a time, and thus to do in the open fields, away from fences and trees, what other fly-catching birds are not able to accomplish. I have seen a squad of these birds follow a horse-rake back and forth across a stubble, apparently catching insects which were frightened into the air by the rake. They often hover about a flock of sheep, either to capture the flies which trouble them, or the insects which they startle while feeding. As the Swallow feeds to a considerable extent upon small dipterous insects and upon moths, we may expect to learn by careful study, that the Hessian fly and the clover-moth, which flies to some extent during cloudy weather, are destroyed by it in considerable numbers, as well as allied forms which affect similar situations.

Food: Of eleven Barn Swallows examined, seven had eaten fourteen small moths; seven, forty diptera, among which were thirty-three tipulids *(Pachyrrina ferrugina ?)*; two, six beetles; and one, a small dragon-fly.

Insects (Cooper). Destroys numerous noxious winged insects (De Kay). Of two specimens examined by Prof. Forbes, each had eaten hymenoptera; one, leaf-chafers; one, diptera; one, hemiptera; and one, dragon-flies.

62. Iridoprocne bicolor (Vieill.), Coues. WHITE-BELLIED SWALLOW.
Group II. Class a.

This Swallow is perhaps more abundant than the last species, and during the fall it often collects in very large flocks. By the middle of September, nearly all have left for the South. Early in the summer they are most abundant along the borders of streams and reedy lakes, especially where dead trees abound, in the hollow limbs and trunks of which they breed. In July and August they spread out over fields, pastures and meadows, oftenest in damp situations not far removed from water. During September they affect all open situations. In Eastern Massachusetts this species is said to have undergone a complete change in breeding habits. There it now breeds almost exclusively in martin-houses, and any sheltered and accessible box appears to answer their purpose. In Massachusetts, too, they are most abundant in cities, while in sparsely settled districts they shun dwellings almost entirely.

It is said that during the breeding season this Swallow is somewhat quarrelsome, and even aggressive. Audubon knew of a pair driving the Barn Swallow from its nest and taking possession of it, but this act Dr. Brewer regards as exceptional. The change of habits which this species is undergoing in the East, suggests an apparently ready means of giving it a general distribution and considerable abundance with us, should this be desirable. I have no doubt that, if houses were put up along the fences about the fields, in a few years these birds would take possession of them and become much more abundant than they are at present. Further study of their food appears to be necessary, however, before such steps should be advised. The small species of dragon-flies to which these birds are apparently so destructive are very abundant in grain fields and meadows, especially those that are low and not far from standing or running water. It is known that these insects are predaceous, and a careful study of their food may show that they are very serviceable in holding in check such small insects as the wheat-midge and Hessian fly. This swallow, however, it will be seen, stoops to capture plant-lice and dipterous insects just as small as the wheat-midge. Another very valuable trait in this species is its apparent destructiveness to weevils — insects so many of which are injurious.

Food: From two stomachs were taken sixteen small dragon-flies, seven weevils, all *Brevirostres*, three rove-beetles, one other beetle, two hymenopterous insects, one belonging to the *Evaniidæ*, the other having an extent of .22 of an inch, three winged aphidæ, and one dipterous insect equal in size to the wheat-midge. In the stomachs of two others were found five weevils, five lamellicorn beetles, four small dragon-flies, one heteropterous insect belonging to the tribe *Obscuta*, and two winged ants. Two other specimens had eaten nineteen winged aphidæ, five small dragon-flies, nine small beetles, among them a click-beetle (*Elater hieroglyphicus*), a weevil and a lamellicorn beetle, and two ichneumon-flies. Of ten other specimens examined, six had eaten beetles; two, small grasshoppers; and one, only dipterous insects, among them crane-flies.

In the fall, principally myrtle-berries (Wilson). Insects and myrtle-berries (De Kay).

63. Petrochelidon lunifrons (Say), Cab. **CLIFF SWALLOW; EAVE SWALLOW.** Group I. Class b.

The Eave Swallow is not uniformly distributed throughout the state, but in certain localities it is abundant. In Jefferson or Walworth county I have never met with them, but in Green Lake and Waupaca they are common. As many as twenty-five nests, nearly all occupied, have been counted under the eaves of a single barn. They affect, chiefly, dry upland fields, where they skim about over wheat fields and meadows. They may frequently be seen sweeping close to the ground over a freshly cut piece of clover before the grass has been taken up, often dipping into the grass for insects.

Food: From the stomach of a specimen shot while skimming over a field of wheat were taken twelve leaf-hoppers, a green and brown species, seven dipterous insects, one of them a large crane-fly, six small beetles, and two medium-sized ichneumon-flies.

Dr. Cooper states that he has seen this species catching small grasshoppers when they were swarming on a dry hillside. Of five specimens examined by Prof. Forbes, four had eaten hymenoptera, ants, wasps, ichneumons; five, beetles, ground-beetles, Nititulidæ, fungus-beetles, rove-beetles, leaf-chafers, curculios and long-horns; one, diptera; and two, hemiptera.

64. Cotyle riparia (Linn.), Boie. **BANK SWALLOW.** Group II. Class a.

The Bank Swallow still clings to its ancient breeding habits, and places its nest in burrows made in sandy banks and cliffs, usually adjacent to streams or lakes, but sometimes where a stone quarry has been opened. Its distribution is, therefore, local during the breeding season, and determined by suitable breeding places. It is social in its habits, and a hundred families often breed together in a single bank. Wilson states that the Crow sometimes watches at the entrance to their nests for the young birds when they emerge.

Food: Small hymenopterous insects, which they take on the wing (De Kay).

65. Stelgidopteryx serripennis (Aud.), Bd. **ROUGH-WINGED SWALLOW.** Group II. Class a.

A single specimen of this species was taken while skimming about over Fox river at Berlin, May 2, 1874. It was in company with a dozen more Swallows, probably of the same species. It is apparently uncommon here, and Mr. Nelson cites it as a rare summer resident in Northeastern Illinois. It is quite similar in habits to the last species, in company with which it sometimes nests. It is said to enter towns occasionally, and to build its nest under the eaves and in holes in old walls.

Food: The single specimen examined had eaten only small beetles.

66. PROGNE SUBIS (LINN.), BD. PURPLE MARTIN. GROUP II. CLASS a.

This species, so common, familiar, and confiding, is quite as general a favorite as any bird we have; how justly, however, recorded facts, so far as I know them, do not warrant an assertion. Apiarists enter severe complaints against it, and with some justice, as my own notes indicate. But its injuries are not confined to the destruction of bees. Dragon-flies, tiger-beetles, and predaceous wasps and flies are destroyed by it, apparently in large numbers. These insects are, presumably, as beneficial, so far as the character of their food is concerned, as any purely insectivorous bird can be.

Let us suppose that, during the first one hundred days of the Martin's stay with us, it destroys on an average, besides noxious insects, three insects per day, each as beneficial as a tiger-beetle. The entire destruction, during the time, would be three hundred individuals. Allowing each insect to lead an average active life of thirty days, and to destroy insects at the rate of three per day, 27,000 insects would represent the aggregate destructiveness of the three hundred individuals. It would, therefore, be necessary for the Martin to consume noxious insects at the rate of two hundred and seven per day for one hundred and thirty days, to recompense the services of these insects.

It is Dr. Brewer's opinion that the Martin is, on the whole, very beneficial, and were it only destructive to bees, there could be no doubt that his views are correct. As it is, the few definite facts which we have must be held until many more can be placed with them before final conclusions can be reached. It should be said that the destructiveness of this species to bees is not confined to those birds which chance to breed near the hives. The four young birds from which the following notes were obtained were bred in a martin-house which stood fully two miles from any hive, and there was no extensive apiary in the neighborhood.

Food: In the stomachs of four young birds about eight days old were found respectively, (a) two butterflies (*Colias philodice*, and a skipper), six honey-bees and many bits of shells of small mollusks; (b) two large dragon-flies, a large bee-fly, two honey-bees and bits of shells of small mollusks; (c) one large dragon-fly, three honey-bees, and fragments of the shells of small mollusks; (d) two medium-sized dragon-flies, one honey-bee, and small pieces of shells. Another young bird, which had recently left the nest and was being fed by its parents, had in its stomach the remains of seven tiger-beetles (*Cicindela vulgaris*), with a few minute fragments of insects. As an offset to the above, Packard states: "When a storm prostrated a martin-box, one of its compartments was found literally packed with the dried remains of the little yellow and black squash beetle."

Large beetles — among them the Goldsmith beetle,— wasps and bees (Wilson). Various winged insects, as wasps, bees, and large beetles (De Kay). Large numbers of bees (I. L. Hersey, Am. Nat., Vol. VII, p. 434). The larger kinds of insects, especially beetles (Brewer).

FAMILY AMPELIDÆ: WAXWINGS.

FIG 120.

CEDAR WAXWING (*Ampelis cedrôrum*). From Tenney's Zoology.

67. AMPELIS GARRULUS, LINN. **BOHEMIAN WAXWING.** GROUP II. CLASS a.

An irregular winter resident, often appearing in large flocks.

Food: Berries of the mountain ash, the hawthorn and the ivy; it also feeds on insects, catching them on the wing as dexterously as a Flycatcher (Brewer). Juniper berries (Samuels). Chiefly insects and berries (Cooper). Juniper berries (E. W. Nelson).

68. AMPELIS CEDRORUM (VIEILL.), BD. **CEDAR WAXWING; CHERRY BIRD.** GROUP I. CLASS b.

The Cedar Bird, like the last species, leads a wandering life, but unlike that bird, it is a common summer resident. It is also one of the earliest birds that reaches us in the spring, sometimes arriving in February. As yet, with us, it is confined principally to wooded districts until after the breeding season, but it does occasionally nest in orchards and villages. Late in July or early in August they unite in small squads, composed of two or three families, and rove here and there about the country. It is an exceedingly hardy and voracious bird, and for this reason has become adapted to a wide range of food. During the spring and early summer they are said to feed almost exclusively upon insects, and my own notes prove that during the last of July and August they feed to a considerable extent upon them. They are dexterous fly-catchers, and when in the woods they labor in a field almost peculiar to themselves. There they often station themselves on the topmost branches of some dead tree-top which commands a view above the forest, and there watch hours together for insects, every few minutes beating off and up into the air to secure the winged forms that are passing above them. On the borders of woods they often beat out into the fields, six or more rods, for passing insects. Besides being fly-catchers, they search much among the foliage of trees for larvæ of various kinds.

Notwithstanding the many times this handsome bird has been sentenced to extirpation because it is especially fond of cherries, the justice or injustice of such decisions yet remain to be established. And this leads me to suggest that it may yet be found advisable for farmers to plant cherry trees for the express purpose of attracting birds about their premises. Many of our Western farmers are not only scrupulously careful to cut down every tree that may be growing in their fields, but they are often equally careful to grub out those that remain along the fences. In view of the great service which insectivorous birds render to agriculture, and the conditions which must be observed in order to retain them in abundance in agricultural districts, the destruction of trees to which I have referred must be looked upon as false economy. There are very few of our birds which can or will withstand the piercing rays of the mid-summer noon-day sun, unprotected by shade of some sort; and a still smaller number of the insectivorous species which are so common and useful now can possibly remain after the groves and woods are gone, unless some special provisions are made for them.

The planting of shade-trees along the streets, which so many are now doing, is a step in the right direction; and the setting of trees along "line-fences," which a few on the prairies are attempting, is still more to the point. I believe that nearly every *stationary* fence on the farm should have its row of *deep-rooting* shade-trees; and especially should this be the case on the prairies, where there are so few attractions for birds. It need only be added, in urging this point, that scientific men have earnestly advised long ago this planting of trees for other purposes. In clearing farms in the future, much labor and expense may be saved by reserving such trees as are already growing where they are needed. I have said that it may yet be found advisable to plant cherry trees for the purpose of attracting birds. The place for them would be along the fences, where they could serve not only as shade and to draw the birds into the fields, but at the same time enable certain species to maintain a greater abundance. A more careful survey of the questions involved, however, is needed before such steps can be advised unhesitatingly.

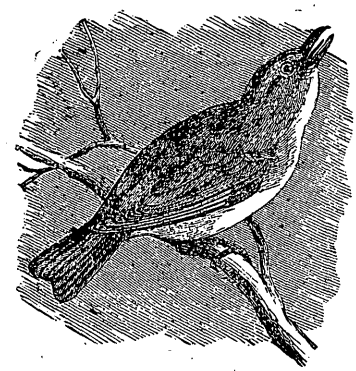
Food: Of fifteen specimens examined, all but two had eaten cherries; two, raspberries; and two, red elder-berries. One had eaten five ichneumons (?); two, three beetles; one, three crickets; one, four tipulids; one, fifty tipulid eggs; one, two lace-wings; and one, a caddis-fly.

Whortleberries, berries of sour gum, red cedar-berries, cherries, and a few beetles and other insects (Wilson). Myrtle-berries (Cooper). Cherries, small beetles, canker-worms, and other caterpillars (De Kay). Cherries and caterpillars (Samuels). Caterpillars, beetles, canker-worms and various insects. It more than pays for the cherries it eats (Nuttall). They are, by preference, eaters of berries and other vegetable food, except in the spring and early summer, when they eat insects almost exclusively, feeding upon the larvæ of the span-worms and canker-worm and small caterpillars, by supplying these to their young (Brewer). Wilson, speaking of its food in the South, says: "Berries of red cedar, myrtle, holly, Cassine shrub, many species of smilax, together with gumberries, and a profusion of others with which the luxuriant swampy thickets of those regions abound, furnish them with a perpetual feast." He also states that they feed upon winged insects, of which they are very fond and remarkably expert at catching.

How destructive these birds are to caterpillars, at times, is shown conclusively by Prof. Forbes in one of his excellent reports on the food of birds. He says, in discussing the food of some birds which were collected in an orchard, severely attacked by canker-worms, in May, 1881: "Next comes the gem of our ornithological beauties, the Cedar-bird, sometimes called the Cherry-bird, and greatly persecuted for its love of cherries. A flock of about thirty had apparently taken up their residence in this orchard. The food record of the seven which were killed is very brief — canker-worms one hundred per cent. expressed it all. The number of canker-worms in each stomach, determined by actual count, ranged from seventy to one hundred and one, and was usually nearly one hundred. Assuming that these constituted a whole day's food, the thirty birds were destroying three thousand worms a day, or ninety thousand for the month during which the caterpillar is exposed."

FAMILY VIREONIDÆ: GREENLETS.

FIG. 121.



RED-EYED GREENLET (*Vireo olivaceus*). After Baird, Brewer and Ridgway.

Tabular Summary of Economic Relations showing the number of specimens containing animal and vegetable food, and the number of insects and spiders contained in the stomachs, classified as to economic relations under the heads Beneficial, Detrimental and Unknown Relations.

Number and Name of Specimens Examined.				Classification of Food.	Ratios Represented by Lines.
Of forty-nine Red-eyed Vireos [1] examined ..	47	Contained		Animal food......	
	14			Vegetal food	
	6		8	Beneficial	
	37		145	Detrimental......	
	32		116	Unknown.........	
Of sixteen Warbling Vireos examined....	16	Contained		Animal food......	
				Vegetal food	
	1		1	Beneficial	
	10		41	Detrimental......	
	5		11	Unknown.........	
Of twenty-one Yellow-throated Vireos examined..............	21	Contained		Animal food......	
				Vegetal food	
				Beneficial	
	13		25	Detrimental......	
	13		55	Unknown.........	

[1] Scale reduced one-half for the Red-eyed Vireo.

Table showing the kind and number of insects and spiders eaten by the Vireos.

Number and Name of Specimens Examined.			Classification of Food.		Ratios Represented by Lines.
Of forty-nine Red-eyed Vireos [1] examined...	5	Contained	21	Hymenoptera ...	
	32		59	Lepidoptera......	
	4		9	Diptera...........	
	15		32	Beetles	
	5		71	Hemiptera	
	5		6	Grasshoppers	
	4		5	Neuroptera	
	2		2	Spiders...........	
	39		212	Adult forms......	
	1		1	Pupa	
	33		56	Larvæ............	
	3		30	Insect eggs.......	
Of sixteeen Warbling Vireos examined	8	Contained	34	Caterpillars.......	
	2		5	Beetles	
	3		3	Hemiptera	
	2		5	Diptera	
	1		1	Grasshopper	
	6		29	Adult forms......	
	8		34	Larvæ	
	2		28	Insect eggs.......	
Of twenty-one Yellow-throated Vireos examined	7	Contained	19	Lepidoptera	
	2		12	Diptera...........	
	8		18	Beetles	
	2		2	Heteroptera......	
	3		3	Grasshoppers.....	
	16		58	Adult forms	
	5		22	Larvæ	
	2		30	Insect eggs.	

69. Vireo olivaceus (Linn.), Vieill. RED-EYED VIREO; RED-EYED GREENLET. Group I. Class b.

No Vireo in Wisconsin is as numerous, and no summer resident of the woodlands as abundant as this species. The depths of deciduous forests, the outskirts of swamps, low damp woods, and thick groves of young trees are its usual haunts; occasionally it enters orchards, gardens and the shady portions of villages, but these it generally leaves to its cousin the Warbling Vireo. The greater portion of its food is taken from the foliage of trees and shrubs while at rest,

[1] Scale reduced one-half for the Red-eyed Vireo.

but it often pursues and captures on the wing the moths and other insects which it startles from their hiding places beneath the leaves. A departure from its usual habits leads it occasionally from the woods and groves into adjoining wheat-fields, where it feeds upon chinch-bugs. This departure is a very desirable one, but it is doubtful whether, even with a generous planting of shade-trees, this species can become sufficiently abundant to render any appreciable service in this direction, but its ability to render service in other directions is very great. It is almost exclusively insectivorous and particularly fond of caterpillars, both naked and hairy, and other larvæ. These birds are often the foster parents of the Cowbird.

Food: From the stomachs of eighteen of this species were taken fifteen caterpillars, five other larvæ; eight beetles — among them five weevils, one long-horn and one darkling beetle; seventy heteropterous insects — among them sixty-seven chinch-bugs; sixteen winged ants, one ichneumon (?), five dragon-flies, two dipterous insects — one of them *Tabanus atratus;* three small moths, two grasshoppers, one aphis, one chrysalid, two spiders, and seven dogwood berries. Of thirty-six other specimens examined, fifteen had eaten caterpillars; two, other larvæ; nine, beetles — among them two *Coccinella mali;* three, grasshoppers; two, ants; two, moths; four, insects, none of which were identified; and seven, fruits or seeds, among which were raspberries, dogwood berries, berries of prickly ash and sheep-berries.

Insects and berries (De Kay). Caterpillars, noxious larvæ and winged insects (Samuels). Canker-worm (Maynard). Caterpillars (Forbes).

70. VIREO PHILADELPHICUS, CASS. BROTHERLY-LOVE VIREO. GROUP II. CLASS a.

Mr. Kumlien is said to have been familiar with this little-known species since 1849, and to have taken specimens of it every year since that period. Mr. Nelson also speaks of it as a common migrant in Northeastern Illinois between May 15th and 25th and September 5th and 25th. It has not been my good fortune to obtain it, and I am confident that I have not mistaken it for the next species. It is not known to stay with us during the summer, and its nest and eggs are unknown.

71. VIREO GILVUS (VIEILL.), BP. WARBLING VIREO; WARBLING GREENLET. GROUP I. CLASS b.

This species is a common summer resident, arriving about the 10th of May and retiring again by the 20th of September. So far as its favorite haunts are concerned, it is the exact counterpart of the Red-eyed Vireo, the shaded streets of cities, nurseries, orchards and the vicinity of dwellings being its favorite resorts. It also frequents the willow clumps of marshes and groves, but is rarely seen in the depths of the forests. It is, therefore, peculiarly adapted to thickly settled districts, and when properly protected and encouraged it may be expected to become abundant. The character of its food and its method of obtaining it are similar to those of the Red-eyed Vireo. No abundance which it is likely to assume can cause it to become injurious, and a pair of these birds breeding in an orchard are to be guarded with the same care as the choicest tree.

Food: Of sixteen specimens examined, eight had eaten thirty-four caterpillars; two, five beetles, among which were a lady-bird *(Coccinella 9-notata)*, and a *(Diabrotica duodecim-punctata);* three, three heteropterous insects; two, two crane-flies; one, grasshoppers; two, twenty-eight insect eggs; and one, dogwood berries.

Caterpillars and winged insects (Wilson). Caterpillars and various seeds and berries (De Kay). Small black caterpillars which infest the poplars of streets (Audubon). Caterpillars and diptera; larvæ of carabidæ, the vine-chafer and long-horned beetles (Forbes).

72. VIREO FLAVIFRONS, VIEILL. **YELLOW-THROATED VIREO; YELLOW-THROATED GREENLET.** GROUP I. CLASS a.

This Vireo is also a summer resident, and quite as numerous as the last species. Its haunts, with us, are somewhat intermediate between *olivaceus* and *gilvus*, but approaching closer to the former. In the Eastern States, however, its haunts are more nearly those of the Warbling Vireo. In regard to this point Dr. Brewer says: "I have found none of this genus, not even the *gilvus*, so common in the vicinity of dwellings, or more familiar and fearless in its intercourse with man. All its nests that I have ever met with have been built in orchards and gardens, and in close proximity to dwellings." It has been said to seek its food chiefly among the upper branches of trees. My experience has been to find it more commonly feeding low down, and especially among the under-brush. It even searches about old brush-piles for beetles. It is a stronger, coarser natured bird than any of the preceding, and appears to feed less upon caterpillars; but it promises to become quite as useful as *gilvus*.

Food: Of twenty-one specimens examined, seven had eaten caterpillars — among them geometers; seven, beetles — among them weevils and a Buprestis; three, grasshoppers; two, moths; two, heteropterous insects — among them leaf-hoppers; three, dipterous insects.

Principally winged insects (Wilson). Caterpillars, small moths, wild bees and wasps (Audubon). Chiefly insects; later in the season various small berries (Brewer). Moths, caterpillars, diptera (Forbes).

73. VIREO SOLITARIUS, VIEILL. **SOLITARY VIREO; SOLITARY GREENLET.** GROUP I. CLASS a.

This bird is an uncommon bird wherever I have collected, and I have obtained it only in May and September. Low, damp woods, and the thickets bordering streams are some of its haunts. Mr. Nelson speaks of it as abundant during the migrations, and found everywhere in woods and thickets in Northeastern Illinois. Dr. Brewer records an instance of a pair once nesting near his dwelling. This nest became the receptacle for two Cowbirds' eggs, which were removed. Subsequently, the nest was pillaged by the Black-billed Cuckoo.

Food: One specimen of three examined had eaten two caterpillars, one beetle and a hymenopterous insect.

Insects and berries (De Kay).

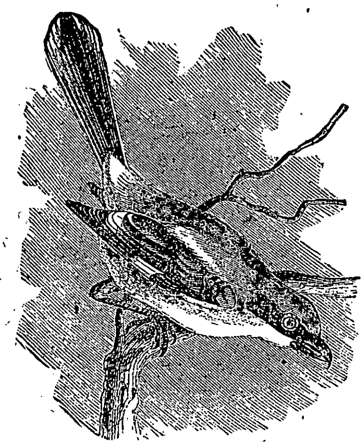
74. VIREO NOVEBORACENSIS (GM.), BP. **WHITE-EYED VIREO; WHITE-EYED GREENLET.** GROUP I. CLASS a.

Dr. Brewer states that this Vireo is one of the most common and one of the most widely diffused of its genus in all parts of the United States east of the Rocky Mountains, and that it breeds abundantly in the Northwestern States, Illinois, Iowa, and Wisconsin. The bird, however, must be rare in the places I have visited, for I have never met with it. Its usual haunts are said to be the wild, swampy, open grounds near the edges of woods, and where there are thickets of smilax, briers and wild vines.

Food: Insects and berries (De Kay). Canker-worm (Brewer).

FAMILY LANIIDÆ: SHRIKES.

FIG. 122.



WHITE-RUMPED SHRIKE (*Lanius ludovicianus excubiteroides*). After Baird, Brewer and Ridgway.

Tabular Summary of Economic Relations showing the name and number of specimens eating animal and vegetable food, and the number of insects, birds, mice and snails contained in the stomachs or killed by them, classified as to economic relations under the heads Beneficial, Detrimental and Unknown Relations.

NUMBER AND NAME OF SPECIMENS EXAMINED.				CLASSIFICATION OF FOOD.	RATIOS REPRESENTED BY LINES.
Of fifteen White-rumped Shrikes examined	15	Contained		Animal food..	
				Vegetal food .	
	7		8	Beneficial	
	13		42	Detrimental..	
	10		24	Unknown.....	

Table showing the kinds and number of animals killed or eaten by the White-rumped Shrike.

Number and Name of Specimens Examined.			Classification of Food.		Ratios Represented by Lines.
Of fifteen White-rumped Shrikes examined or observed	4	Had killed or contained	12	Lepidoptera ..	
	2		11	Diptera.......	
	9		18	Beetles	
	5		22	Grasshoppers.	
	2		2	Crickets	
	3		6	May-flies	
	2		4	Snails	
	2		3	Birds	
	2		2	Mice..........	
	15		75	Adult forms .	
	4		6	Larvæ........	

75. Lanius borealis, Vieill. BUTCHER BIRD; NORTHERN SHRIKE.
Group III. Class b.

This bird is a regular winter visitor to Wisconsin, but not in large numbers. Early in October it reaches the pine barrens in the northern part of the state, and shortly after makes its appearance further south. During the winter they often visit corn-fields for mice, where they will hover over a wagon to seize the first mouse that runs out upon the snow from the shocks that are being removed. They are quarrelsome among themselves, decidedly rapacious, and the dreaded foes of smaller birds. Sagacious and wily, they imitate the notes of other birds to decoy them within reach, or remain concealed until their victims approach, when they pounce upon them unawares. Their audacity is so great that they have been known to enter dwellings to rob the canary cage of its inmates. They dart hawk-like upon their prey, with almost certain aim, and pursue it with rapidity and pertinacity through the thickets in which it seeks shelter. Mr. Tripp has witnessed this bird kill and bear off in its bill a Snowbird. Dr. Brewer speaks of a pair that visited the Boston Common, killing one or more English Sparrows on several successive days. Mr. Samuels has seen it fly into a flock of Tree Sparrows and kill three before they had dispersed. And August Fowler says they are the deadliest enemy of the Chickadee.

These observations, it should be observed, were made during the winter season, when a scanty supply of food doubtless makes the bird much more desperate than it is in its summer home, surrounded by an abundance of insects upon which it also feeds. There can be but little doubt, however, that even there the birds which it destroys would be more effective in destroying insects, if permitted to live, than it can be.

Food: Mice and beetles. Principally grasshoppers, some other insects and spiders, occasionally birds (Wilson). Mice, small birds and insects (Cooper). Small birds, mice, insects and their larvæ (Samuels). Snowbird (Mr. Trippe). English Sparrow (Brewer). Black-capped Chickadee (August Fowler). Field-mice and small birds (Dr. Hoy).

76. Lanius ludovicianus excubiteroides (Sw.), Coues. WHITE-RUMPED SHRIKE. Group III. Class b.

This bird is a common summer resident, but happily not very abundant. It is peculiarly a bird of open countries and frequents fields, pastures and meadows of both high and low lands. It possesses many of the traits of the last species, but is a smaller and weaker bird. Dr. Cooper has seen it kill a Sparrow, but he thinks that the occurrence is exceptional; and Mr. Ridgway found a Chimney Swallow which it had impaled on a thorn. He also saw one of these birds dash upon a canary bird cage, and when the frightened inmate thrust its head between tho wires, the Shrike seized and tore it off with its powerful beak. I have seen four Robins together attempting to drive one of these birds from the vicinity of a nest of half-grown young; and the Shrike only shifted its position upon the limbs of the tree to face its enemies, until my gun brought it to the ground. A nest which was built in an apple tree, but recently abandoned, I found literally lined with the wing-covers and legs of three species of tiger-beetles.

Since writing the above there has come to my knowledge positive evidence of this species having killed three other birds. One of them was a canary bird which belonged to Mr. Thomas Martin, of River Falls. The bird was hung in its cage outside the door, where it was discovered by this Shrike and its head torn from its body. This spring, 1882, a pair of these Shrikes built their nest in an evergreen standing in the cemetery at River Falls. Mr. Harry Smith, while passing one morning, observed a Shrike flying toward the graveyard with a small bird in its mouth. He followed the Shrike and observed him fix his bird in the crotch of a limb and proceed to pick off the feathers. Very soon the Shrike tore off the head of its prey and ate it, after which another piece was removed, and this was carried to the nest and disposed of there. The remainder of the bird Mr. Smith carried away. Two days after this event I visited the scene described, in company with Mr. Smith, and we found in the tree where the bird had been torn in pieces, two short, sharp, stiff, dead limbs standing in two forks of other limbs which were on opposite sides of the same small burr oak. Each of these sharp stubs had been used as a spit, for both were coated with a thick layer of blood, to which were adhering small olive-green feathers, probably those of some Warbler. From this evidence and that of Mr. Smith, it is certain that this pair had killed at least two birds, and, judging from the thickness of the layer of blood, I suspect that more than two had been spitted upon them. On another tree in the vicinity of this Shrike's nest, we found another short, dead limb similarly situated which had been used in the same manner. It was thickly coated with blood, and to it were adhering the hairs of some mouse. We whittled these limbs and returned some days afterward to examine them, but they had not been soiled. Two birds and one mouse at least must have been destroyed by this pair of Shrikes while breeding in the place named. The nest had four young birds in it one week old at the time of our visit.

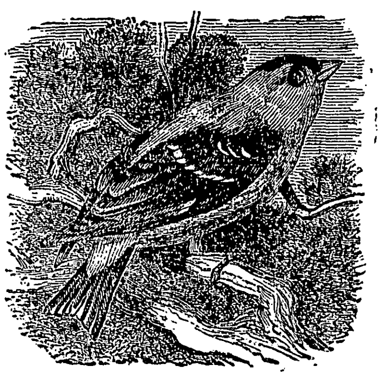
From what is here recorded it is evident that, wherever else this Shrike may be allowed to breed, it should not be tolerated about dwellings and orchards where small birds are so serviceable.

Food: Of fifteen specimens examined or observed, one had eaten seven moths; three, five caterpillars; two, eleven diptera, among them five crane-flies; nine, eighteen beetles, among them three ground-beetles, three carrion-beetles and two leaf-chafers; five, twenty-two grasshoppers; two, two crickets; three, six May-flies; two, four snails. Two had killed three birds — one, a Canary-bird, and one, two Warblers; two, two mice. One of the birds was shot while in the act of killing a meadow mouse *(Arvicola riparia)*.

It depends on grasshoppers and other insects (Cooper). Snakes, lizards and tree-toads (S. O. Gedney, Am. Nat., Vol. III, p. 160). Mice, young birds, and large insects (P. R. Hoy). Mr. Ridgway has found shrews, mice, grasshoppers, spiders, and, as stated above, a Chimney Swallow, spitted to the sharp thorns of the honey-locust.

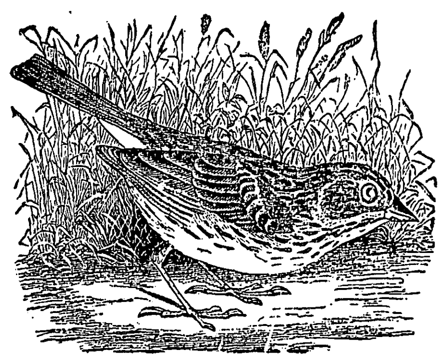
Family FRINGILLIDÆ: Finches, etc.

Fig. 123.



Thistle-bird (*Astragalinus tristis*). After B., B. & R.

Fig. 124.

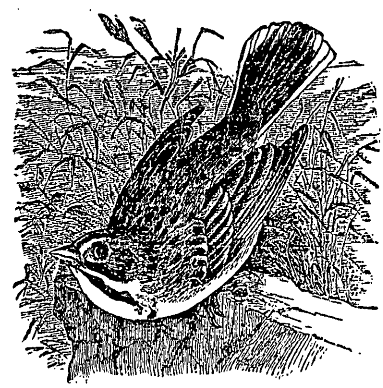


Bay-winged Bunting (*Poœsetes gramineus*). After B., B. & R.

Fig. 125.

Song Sparrow (*Melospiza fasciata*). After B., B. & R.

Fig. 126.



Lark Finch (*Chondestes graminicus*). After B., B. & R.

Tabular Summary of Economic Relations showing the name and number of specimens eating animal and vegetable food, and the number of insects, spiders, millipedes and snails taken from the stomachs, classified as to Economic Relations under the heads Beneficial, Detrimental and Unknown Relations.

Number and Name of Specimens Examined.			Classification of Food.		Ratios Represented by Lines.
Of nine Purple Finches examined	1	Contained		Animal food	
	8			Vegetal food	
	1		50	Detrimental	
Of two Red Crossbills examined		Contain'd		Animal food	
	2			Vegetal food	
Of thirty-four Thistle Birds examined	1	Contained		Animal food	
	33			Vegetal food	
	1		20	Detrimental	
Of six Lapland Longspurs examined		Contain'd		Animal food	
	6			Vegetal food	
Of ten Savanna Sparrows examined	2	Contained		Animal food	
	10			Vegetal food	
	1		2	Detrimental	
Of thirty-six Bay-winged Buntings examined	25	Contained		Animal food	
	34			Vegetal food	
	1		1	Beneficial	
	8		12	Detrimental	
	22		69	Unknown	
Of three Lincoln's Finches examined	3	Contained		Animal food	
	2			Vegetal food	
	3		10	Unknown	
Of twenty-five Swamp Sparrows examined	20	Contained		Animal food	
	13			Vegetal food	
	3		3	Beneficial	
	8		18	Detrimental	
	15		67	Unknown	
Of fifty-two Song Sparrows examined	30	Contained		Animal food	
	34			Vegetal food	
	5		10	Beneficial	
	9		22	Detrimental	
	27		71	Unknown	

Tabular Summary of Economic Relations of Finches—continued.

Number and Name of Specimens Examined.				Classification of Food.	Ratios Represented by Lines.
Of eight Winter Snowbirds examined	2	Contained		Animal food	
	8			Vegetal food	
	2		4	Unknown.........	
Of fifteen Tree Sparrows examined......	2	Contained		Animal food......	
	15			Vegetal food	
	1		1	Beneficial	
	1		1	Unknown.........	
Of fifty-two Chipping Sparrows examined.	29	Contained		Animal food......	
	27			Vegetal food	
	1		1	Beneficial	
	16		29	Detrimental	
	14		41	Unknown.........	
Of seven Field Sparrows examined......	5	Contained		Animal food......	
	6			Vegetal food	
	1		1	Beneficial	
	3		4	Detrimental	
	3		8	Unknown.........	
Of thirteen Clay-colored Sparrows examined................	10	Contained		Animal food......	
	7			Vegetal food	
				Beneficial	
	4		13	Detrimental	
	7		22	Unknown.........	
Of sixteen White-throated Sparrows examined	6	Contained		Animal food	
	14			Vegetal food	
				Beneficial	
	3		5	Detrimental.	
	5		15	Unknown.........	
Of four Lark Finches examined		Contain'd		Animal food......	
	4			Vegetal food	
Of three Fox Sparrows examined	1	Contained		Animal food......	
	3			Vegetal food	
	1		50	Detrimental	

Tabular Summary of Economic Relations of Finches — continued.

Number and Name of Specimens Examined.			Classification of Food.		Ratios Represented by Lines.
Of eight Rose-breasted Grosbeaks examined	3	Contained		Animal food......	
	8			Vegetal food....	
	3		8	Unknown.........	
Of nineteen Indigo-birds examined......	5	Contained		Animal food.....	
	18			Vegetal food....	
	2		4	Detrimental.....	
	3		8	Unknown.........	
Of seventeen Marsh Robins examined....	11	Contained		Animal food......	
	14			Vegetal food.....	
	1		1	Beneficial........	
	5		12	Detrimental.....	
	8		19	Unknown.........	

Table showing the kinds and number of insects, spiders, myriapods and snails eaten by the Finches.

Number and Name of Specimens Examined.			Classification of Food.		Ratios Represented by Lines.
Of nine Purple Finches examined..........	1	Contained	1	Caterpillar.......	
	1		50	Plant-lice.........	
	1		50	Adult forms......	
	1		1	Larve	
Of thirty-four Thistle-birds examined.....	1	Contain'd	20	Plant-lice.........	
	1		20	Adult forms......	
Of ten Savanna Sparrows examined......	1	Contained	2	Lepidoptera......	
	1		1	Adult form.......	
	1		1	Larve	
Of thirty-six Bay-winged Buntings examined..............	3	Contained	8	Moths............	
	1		3	Diptera...........	
	1		3	Ants..............	
	14		27	Beetles...........	
	4		4	Grasshoppers....	
	1		3	Snails............	
	17		72	Adult forms......	
	4		10	Larvæ...........	
	1		8	Grasshopper eggs.	

Table showing the kinds and number of insects, spiders, myriapods and snails eaten by the Finches — continued.

Number and Name of Specimens Examined.				Classification of Food.	Ratios Represented by Lines.
Of twenty-five Swamp Sparrows examined.	2	Contained	2	Hymenoptera....	
	6		14	Lepidoptera......	
	3		3	Diptera...........	
	6		13	Beetles...........	
	2		2	Hemiptera.......	
	2		2	Grasshoppers....	
	1		6	Snails............	
	17		75	Adult forms......	
	5		13	Larvæ............	
Of fifty-two Song Sparrows examined......	6	Contained	11	Lepidoptera......	
	2		4	Diptera...........	
	9		25	Beetles...........	
	3		6	Hemiptera........	
	4		5	Orthoptera.......	
	2		3	Neuroptera.......	
	1		1	Spider............	
	1		1	Millipede.........	
	29		75	Adult forms......	
	10		17	Larvæ............	
	3		4	Grasshopper eggs.	
Of fifty-two Chipping Sparrows examined.	1	Contained	2	Ants..............	
	1		12	Lepidoptera......	
	1		1	Fly...............	
	4		9	Beetles...........	
	3		9	Hemiptera.......	
	6		8	Grasshoppers....	
	1		1	Spider............	
	11		59	Adult forms......	
	8		12	Larvæ............	
Of seven Field Sparrows examined......	1	Contained	1	Caterpillar.......	
	1		1	Heteroptera......	
	1		2	Grasshcppers....	
	1		1	Spider............	
	5		12	Adult forms......	
	1		1	Larve............	

Table showing the kinds and number of insects, spiders, myriapods and snails eaten by the Finches — continued.

Number and Name of Specimens Examined.			Classification of Food.		Ratios Represented by Lines.
Of thirteen Clay-colored Sparrows examined	3	Contained	6	Beetles	
	3		12	Hemiptera	
	1		1	Grasshopper	
	10		31	Adult forms	
	1		1	Larvæ	
Of sixteen White-throated Sparrows examined	2	Contained	4	Caterpillars	
	2		4	Beetles	
	1		1	Grasshopper	
	1		1	Caddis-fly	
	6		16	Adult forms	
	2		4	Larvæ	
Of three Fox Sparrows examined	1	Contained	50	Chinch-bugs	
	1		50	Adult forms	
Of eight Red-breasted Grosbeaks examined.	2	Contain'd	7	Beetles	
	3		8	Adult forms	
Of nineteen Indigo-birds examined	1	Contained	2	Caterpillars	
	1		2	Beetles	
	1		1	Grasshopper	
	5		10	Adult forms	
	1		2	Larvæ	
Of seventeen Marsh Robins examined	3	Contained	3	Hymenoptera	
	1		7	Moths	
	3		9	Beetles	
	4		5	Orthoptera	
	10		31	Adult forms	
	1		1	Larvæ	
	1		4	Walking stick eggs	

77. Hesperiphona vespertina (Coop.), Bp. **EVENING GROSBEAK.** Group III. Class c.

This is a winter visitant of somewhat irregular occurrence; at least in the southern portion of the state. During the winter of 1871 it is said to have been quite common.

Food: Seeds of the poplar, pine and spruce, the buds of Negundo, and the leaves of various small plants (Cooper). Keys of the ash-leaved maple (Captain Blakinston). Seeds of pine and the larvæ of a large black ant (Brewer). Seeds of the sugar maple (Dr. Hoy).

78. PINICOLA ENUCLEATOR (LINN.), V. **PINE GROSBEAK.** GROUP II. CLASS c.

The Pine Grosbeak, like the last species, is a winter visitant of irregular occurrence. Mr. Trippe states that it appears in Wisconsin about the middle of November, when it feeds on the buds and seeds of the alder, birch, etc., together with the seeds of weeds that abound on the prairies. During severe winters they are sometimes driven southward in great numbers into cities and about dwellings, in quest of food. During the winter of 1869–70, large numbers visited the coast of Massachusetts, and did considerable damage to the fruit buds of the apple and pear of that region.

Food: Buds of birch and willow (Wilson). Buds, berries and seeds of pines (De Kay). Seeds of white spruce (Richardson). Buds of apple and pear, and berries of red cedar (Brewer). Buds of poplar in the Yukon Territory (Mr. Dall).

79. CARPODACUS PURPUREUS (GM.), GRAY. **PURPLE FINCH.** GROUP I. CLASS c.

This species is common during the migrations, and a few breed in the central part of the state. Mr. Nelson speaks of it as a winter resident in Northeastern Illinois, where it arrives the last of October. With us it makes its appearance early in September. At Ithaca, N. Y., it is a common summer resident, breeding in and about the city; and there, the Cowbird often deposits her eggs in its nest. Dr. Brewer states that one season no less than seven pairs of this Finch took up their abode in his yard. It is, therefore, fast assuming familiarity with man. As with the last two species, it is quite extensively a vegetable-feeder, and the character of its food is such as to bespeak for it some dangerous tendencies. It is often an unwelcome visitor to fruit-growers in Massachusetts, owing to its fondness for the blossoms of the apple, cherry, plum and peach. Mr. Samuels says that it is one of the few injurious birds of New England.

In a single instance, I saw one of these birds, early in the spring, feeding upon the fruit buds of an apple tree. It passed in succession from one bud to another, first picking the bud and shucking off the coarser scales, eating only the tender portion. There is another habit which this bird possesses, which I hope will be found to more than compensate for what injury it may do. It is that of destroying aphidæ. June 24, 1878, Mr. Trelease and myself observed one of these birds at work upon one of the small elm shade-trees on the campus of Cornell University, which was infested with a species of plant-louse that lives in colonies of a hundred or more on the underside of the leaves, causing them to curl backward so as to completely encase the plant-lice. The bird would turn its head sideways to the leaf and thrust its bill under its crumpled edge to extract the lice. We watched it pass to several leaves and rid them of their vermin in this manner; and the whole procedure was so direct and unhesitating as to leave no doubt in my mind that the practice was not a new one. It would even hang back downward in order to better get at the infested leaves.

Food: Seeds of the ironwood, and of various weeds and plants, buds of the apple, plant-lice, and caterpillars.

Seeds of poplar and button-wood and of many rank weeds, the blossoms of the elm and the stamens of the cherry and apple blossoms (Wilson). Buds and berries of evergreens in winter, in summer, insects (De Kay). Buds of trees, insects, and the tender parts of spruce cones (Audubon). Seeds, berries and buds (Cooper).

80. LOXIA CURVIROSTRA AMERICANA (WILS.), COUES. **AMERICAN RED CROSSBILL.** GROUP II. CLASS a.

During October and November of 1877 this species was very abundant all along the Flambeau river. They associated in flocks of considerable size and frequented the tops of the tallest trees. Occasionally small troops came down among the willows and alders along the banks of the streams. About the logging camps they are very familiar, often venturing in-doors when left open. In midsummer of 1868 the Crossbills appeared in great numbers in Western Maine, and there proved very destructive to the oats, disappearing again as soon as the harvest was over.

Food: Seeds of the white pine and of various plants.

Seeds of coniferous trees, other small seeds, and sometimes buds of trees (Cooper). Seeds of pines and firs (Audubon). Seeds of pines, birches, etc. (T. M. Trippe). Seeds of coniferæ and other seeds (Brewer). Seeds of sunflower (Hoy).

81. LOXIA LEUCOPTERA, GM. **WHITE-WINGED CROSSBILL.** GROUP II. CLASS a.

This species, like the last, is probably a regular winter resident in Northern Wisconsin, but appears to be much less abundant. It scuds about in small troops, accompanied by a few of the Red Crossbills, and is also familiar about logging camps, where it comes for crumbs.

Food: Seeds and crumbs gleaned about dwellings.

Seeds of white spruce (Richardson). Canker-worm (Maynard).

82. ÆGIOTHUS LINARIA (LINN.), CAB. **RED-POLL LINNET.** GROUP I. CLASS b.

This familiar boreal species is an abundant winter resident, and while here it moves about the fields and pastures in flocks, gathering such seeds as it may find above the snow. Mr. Trippe states that, in Minnesota, the Lesser Red-poll appears in vast numbers, about the middle of October, and remains during the entire winter.

Food: Seeds of the common alder (Wilson). Seeds of various trees, as pine, birch, linden and alder (Cooper). Seeds of grasses, and of pine, also berries and buds (De Kay). Weed and grass seeds, and seeds of white birch (Samuels). Seeds of birch and pine, sometimes fruit-buds (Nuttall). Seeds of birch and alder. It also eats the buds of trees, and (when in flocks) proves in this way seriously injurious to young plantations (Selby, Brit. Birds). A maimed specimen which Dr. Kirtland kept in his greenhouse fed upon the aphidæ that infested his pelargoniums.

83. ÆGIOTHUS EXILIPES, COUES. **AMERICAN MEALY RED-POLL.** GROUP II. CLASS a.

This species enjoys a more northern habitat than the last, and is resident in Greenland. It is said to enter the United States in winter, passing as far south as Mount Carroll, Illinois.

84. CHRYSOMITRIS PINUS (BARTR.), BP. **PINE LINNET.** GROUP I. CLASS a.

This species is quite erratic in its movements, causing the time of its occurrence and its abundance to vary greatly. Ordinarily it is only a winter resident. A few may breed in the state. Mr. Trippe observed it in great numbers in the fall in Minnesota, and Mr. Jordan is said to have taken it in midsummer near Indianapolis. Evergreen forests are its favorite haunts, but those of deciduous trees, willow and alder thickets, fields and gardens are also visited by it. It is said to frequent apple orchards, at times, where it feeds upon plant-lice.

Food: Small weed and grass seeds.

Black alder and pine seeds (Wilson). Spruce, juniper, alder and willow seeds (Cooper). Pine and larch seeds (De Kay). Pine seeds (Samuels). Berries of sweet gum (Audubon). Seeds of grasses and weeds (Brewer).

85. ASTRAGALINUS TRISTIS (LINN.), CAB. **AMERICAN GOLDFINCH; THISTLE-BIRD.** GROUP I. CLASS b.

This elegant little Finch is one of our most abundant birds, and, to a considerable extent, resident throughout the year. In its less showy winter dress, however, it is not so well known. Its almost universal distribution through the open fields, pastures and meadows, together with its tendency to unite only in small flocks, completely counteract the concentrating tendency of its gregarious nature, so that, practically, its effects are those of a bird which is not gregarious. Few birds are more completely graminivorous than it; but it feeds so extensively upon the seeds of noxious weeds that the little grain and garden seeds which it eats are but a just compensation for the service it renders. No class of seeds suit it so well as those of the Composite Family, which are readily hulled, and the service which the Thistle-bird renders in destroying the seeds of the almost uncontrollable Canada thistle, throughout the Eastern and Middle States, must be very great. With us it renders an equal service by destroying the seeds of the pasture thistle, and those of other troublesome weeds. Dr. J. M. Wheaton states that it feeds upon the Hessian-fly. I have seen it feeding upon the plant-louse mentioned in connection with the Purple Finch.

Food: Thistle, dandelion, burdock, bitter-weed and lettuce seeds, seeds of foxtail grass *(Setaria viridis)*, and corn cockle, wheat, rye, and clover seed. Seeds of composite flowers in summer, and of cotton-wood and cockle-bur in winter (Cooper). Thistle, hemp, lettuce and salad seed (Wils.). Sunflower, lettuce and thistle seeds (De Kay). Seeds of various weeds and grasses (Samuels).

86. PLECTROPHANES NIVALIS (LINN.), MEYER. **SNOW BUNTING; SNOW-FLAKE.** GROUP I. CLASS a.

This boreal, eminently terrestrial and gregarious species is an abundant winter resident. It makes its appearance late in October and retires early in April. They frequent cultivated fields in large flocks, and feed largely upon the seeds of troublesome weeds. Their terrestrial habits preclude their becoming injurious to the buds of trees.

Food: Seeds of black bind-weed, and foxtail grass *(Setaria viridis)*.

Grass seeds, insects and small mollusks (De Kay). Seeds of various wild plants and small mollusks (Samuels). Larvæ obtained on the houses of Greenlanders (Brewer).

87. Centrophanes lapponicus (Linn.), Kaup. **LAPLAND LONGSPUR.** Group I. Class a.

This species, like the last, is a winter resident, terrestrial, and often occurs in immense flocks in stubble and corn-fields in quest of weed seeds.

Food: Each of six specimens examined had in their stomachs more than one hundred seeds of the pigeon-grass and black bind-weed.

Seeds of grasses and berries (De Kay). Seeds of Alpine arbutus (Richardson).

88. Centrophanes pictus (Sw.), Cab. **PAINTED LARK BUNTING.** Group I. Class a.

A winter resident. Not common. Terrestrial and gregarious. Frequents cultivated fields in quest of seeds.

89. Passerculus sandvicensis savana (Wils.), Ridg. **COMMON SAVANNA SPARROW.** Group I. Class a.

A common migrant from the last of April to the middle of May, and again throughout September and the early part of October. They are especially fond of the marshy banks of streams and low pastures and meadows, but stubble and corn-fields are also visited by them, and occasionally they may be met with in hazel and willow patches. Nearly their whole time is spent upon the ground.

Food: Each of ten specimens examined had eaten small seeds; one had eaten one caterpillar, and one a moth.

Beetles and seeds of grass (De Kay). Beetles and seeds (Samuels).

90. Pocœsetes gramineus (Gm.), Bd. **BAY-WINGED BUNTING; GRASS FINCH.** Group I. Class b.

A very abundant summer resident. Arrives early in April and remains until October. It spends most of its time upon the ground and feeds to some extent upon insects throughout the season. I estimate that fully one-third of its food consists of insects, and the remainder largely of seeds of noxious plants. The specimen mentioned below, which had eaten two kernels of wheat, and the one which had eaten a single kernel of rye, appear to have made an exceptional choice of food. Especial value attaches to the services of this species on account of its favorite haunts, which are cultivated fields, particularly the corn and grain fields. In these places it breeds, and rears from two to three broods each season, placing the nest upon the ground, often in a hill of corn.

Food: Of thirty-seven specimens examined, thirty-one had eaten various small weed seeds; five, four grasshoppers; one, eight grasshoppers' eggs; four, ten larvæ; fourteen, twenty-seven small beetles; three, eight moths; one, three flies; one, three land snails *(Helix)*; one, two kernels of wheat; and one, a kernel of rye.

Insects and grass seeds (De Kay). Principally seeds of grasses and other plants and a few insects (Audubon).

91. Coturniculus passerinus (Wils.), Bp. **YELLOW-WINGED SPARROW.** Group I. Class a.

In speaking of this species Dr. Brewer says: "The common Yellow-winged Sparrow appears to be a bird of irregular and unequal distribution, found in certain localities in great abundance and not seen in intervening districts." It has not been my fortune to meet with it in Wisconsin, but Dr. Hoy states that it is not uncommon in the reedy sloughs on the prairies. Such haunts are different from those usually attributed to it by other writers.

It appears to be a somewhat southern species. Mr. Nelson in referring to it says: "One of our most abundant summer residents. Found everywhere in fields and on prairies, from the middle of May until the first of September." Its habits and economic relations appear to be very similar to those of the last species.

Food: Grass seeds and the larvæ of insects (Wilson). Insects and their larvæ, seeds of grasses and other plants (De Kay). Larvæ, insects, seeds, grasses and small weeds (Brewer).

92. Ammodramus caudacutus Nelsoni (Allen). **NELSON'S SHARP-TAILED FINCH.** Group II. Class a.

A single specimen of this recently discovered variety was obtained in the marsh on the border of Cold Spring Pond, September 7, 1877, and identified by Mr. Ridgway, through the kindness of Prof. Baird. Mr. E. W. Nelson thinks that it breeds in Northeastern Illinois, but that many pass to the north for the same purpose. Its usual haunts appear to be low, wet, reedy marshes.

93. Melospiza Lincolni (Aud.), Bd. **LINCOLN'S FINCH.** Group I. Class a.

This species is properly regarded as a migrant in Wisconsin, although a few are known to breed in the state. I have found it an uncommon bird, but Mr. Nelson speaks of it as common in Northeastern Illinois during the migrations. Two specimens were taken, September 26th, in company with *fasciata*, darting in and out of a hedge of rank weeds that grew along a corn-field.

Food: Seeds. One had eaten five case-bearing caterpillars *(Coleophora)*; one had eaten three other insects. Insects and berries (Audubon). Seeds (Mr. Dresser).

94. Melospiza palustris (Bartr.), Bd. **SWAMP SPARROW.** Group I. Class b.

This Sparrow is a summer resident and very abundant in its favorite resorts, which are the sedgy and reedy swales bordering streams, ponds and lakes. From these places it rambles off into the damp meadows to feed, but never far until it leaves for the south. A few frequent the open glades of tamarack swamps. It is insectivorous throughout the season, and but little more than one-half of its food consists of seeds. The bird is especially to be encouraged because it frequents, in part, those haunts where the troublesome army-worm breeds; and the three broods which it sometimes rears in a season necessarily make its destruction of insects very great. Audubon states that it forms the principal food of the Sparrow and Pigeon Hawks and of the Marsh Harrier, in certain localities, during some portions of the year.

Food: Of twenty Swamp Sparrows examined, two had eaten two parasitic hymenoptera — one a small ichneumon-fly and the other a chalcidian?; one, one moth; six, thirteen beetles; two, two hemiptera, one of them of the cicadellina, the other a plant-louse; two, two grasshoppers; and one, six snails. Five of the caterpillars eaten by two of the birds were case-bearers *(Coleophora)*, and one of them a hairy arctian. Thirteen of twenty-five had eaten small seeds of grasses, sedges and other plants.

Grass seeds and aquatic insects (De Kay). Principally grass seeds, wild oats, and insects (Wilson). Old birds in the spring, and the young, largely insects, principally coleopterous forms. After the breeding season, when the young are able to take care of themselves, almost entirely seeds of coarse grasses and sedges (Brewer).

95. MELOSPIZA FASCIATA (GM.), SCOTT. **SONG SPARROW.** GROUP I. CLASS b.

No Finch in Wisconsin is as abundant, and none of the summer residents arrive as early or tarry as late as this species. The borders of cultivated fields, and the fringing shrubbery of woodlands, groves and banks of streams are its favorite haunts; from these it sallies into the adjoining fields for food. They are particularly fond of the weedy hedges that often grow along neglected fences, and I am not sure but that these tangles so irritating to the thrifty farmer better be encouraged in the back fields rather than rooted out. Like the last species, it is insectivorous from its arrival until it leaves, and two if not three broods are reared each season. I have found the young unable to fly as late as September 6th.

Food: Of fifty-two specimens, twenty-nine had eaten a few or many seeds; one, two kernels of wheat; nine, twenty-five beetles — among them a lady-bird *(Coccinella tibialis)*, several ground-beetles and lamellicorn beetles; four, five grasshoppers; three, four grasshopper's eggs; one, a moth; one, two dragon-flies; one, a cricket; one, a spider; one, a millipede; two, four dipterous insects; one, a heteropterous insect; and one, small fungi, chiefly insects (De Kay). Grass seeds, some berries, grasshoppers and other insects, some of which it takes upon the wing (Audubon). Caterpillars and other larvæ, and small moths. The canker-worm is a favorite article of food (Brewer). Seeds of weeds (Forbes).

96. JUNCO HYMEMALIS (LINN.), SCL. **WINTER SNOWBIRD.** GROUP I. CLASS a.

A very abundant migrant. A few summer in Northern Wisconsin. Weed-grown fields, the hedges along fences, the borders of groves and woods, and willow, osier and alder thickets are its favorite haunts, but it is much about dwellings and often enters villages. During their migrations these birds are almost exclusively graminivorous.

Food: Seeds of foxtail grass, pigweed, and occasionally an insect. Seeds (Wilson). Grass seeds, berries, grains and insects (De Kay). Small berries, seeds of grasses, and other small plants, insects and larvæ (Brewer). Seeds of weeds (Forbes).

97. SPIZELLA MONTICOLA (GM.), BD. **TREE SPARROW.** GROUP I. CLASS b.

But very few, if any, of this late migrant remain during the winter. Late in March and early in April they pass us northward. Woods, groves, the banks of streams, and the tall weed and willow patches of marshes, are its usual haunts. After the 16th of October, 1877, these birds became very abundant all along the Flambeau river, where they frequented the willow and alder thickets in small troops.

Food: Of fifteen examined all had eaten small seeds, one an insect, and one a spider. Beetles, hard seeds and berries (De Kay). Seeds of grasses and weeds (Samuels). Hard seeds, berries, beetles and mollusks (Audubon). Weed seeds (Coues). Beetles (Forbes).

98. SPIZELLA DOMESTICA (BARTR.), COUES. **CHIPPING SPARROW; HAIR-BIRD.** GROUP I. CLASS a.

No one of our native Finches has assumed such familiar relations with man as this species. It is constantly about dwellings in the summer, and it even presumes to place its nest, at times, on the brackets under the eaves of the porches, almost within hand's reach. Its services are especially valuable because it is so much on the ground, where it and the Robin, about dwellings and in orchards and gardens, are almost alone. During rainy days it may often be seen with a cut-worm in its mouth, and fully one-third of its food during the summer consists of insects of various kinds. So far as I know, it is harmless to garden seeds and never molests grains, while it feeds much upon the seeds of weeds. It nests in orchard trees and garden shrubs, among the branches of which it obtains a portion of its food, and is often doomed to become the foster parent of the heartless Cowbird. Marauding cats kill many of these birds, and, doubtless, prevent many more from nesting nearer dwellings. Properly constructed buildings and traps should make cats unnecessary.

Food: Of fifty-two specimens examined, twenty-seven had eaten small seeds; seven, ten caterpillars — among them a young *Sphinx* and three cut-worms; two, two moths; four, nine beetles; two, large winged ants; two, nine small heteropterous insects — among them seven individuals of the same species mentioned under the Tennessee Warbler; three, three dipterous insects; and two, two grasshoppers.

Small insects and seeds (De Kay). Canker-worm (Maynard). Canker-worm and other caterpillars and larvæ (Brewer). Moths, caterpillars, beetles, among them curculios; leaf-hoppers, Reduviidæ, grasshoppers and weed seeds (Forbes). It sometimes becomes a prey to the Sharp-shinned and Marsh Hawks and to the black snake (Samuels).

99. SPIZELLA AGRESTIS (BARTR.), COUES. **FIELD SPARROW.** GROUP I. CLASS a.

Not a very common summer resident. The borders of groves, hazel patches in pastures, the borders of woods and "clearings," and the hedges along field-fences are its usual haunts; from these it makes frequent excursions into the adjoining fields for food. It is sometimes two-brooded, and places its nest upon the ground or in trees or bushes. If it were more abundant it would be quite as serviceable in the fields as the Chippy is about dwellings.

Food: Of seven specimens examined, four had eaten small weed seeds; one, a caterpillar; one, two grasshoppers; one, a very small heteropterous insect; one, a harvest-man; and one, a spider. In the stomachs of two there were bits of insects, none of which were identified.

Caterpillars, beetles, hemiptera and the seeds of weeds. Tenebrionidæ among beetles (Forbes).

100. SPIZELLA PALLIDA (SW.), BP. **CLAY-COLORED SPARROW.** GROUP I. CLASS b.

Thirteen specimens which answered closely to descriptions of this species, and which differed markedly, it appeared to me, from *domestica* and *agrestis*, having been taken in Wisconsin — four in Green Lake, two in Waushara, and seven in Jefferson county,— and I have no doubt that my identification has been correct. They frequent the edges of groves and woods bordering dry fields, pastures with scattering trees, and occasionally they approach dwellings in company with the Chippy.

Food: Of thirteen specimens examined, seven had eaten small seeds; three, six beetles; one, a grasshopper; one, larvæ; two, eleven plant lice and other small hemipterous insects. Three had eaten insects, none of which are identified.

It feeds upon the buds of elms and other trees in the spring, in Iowa (P. M. Trippe).

101. ZONOTRICHIA ALBICOLLIS (GM.), BP. **WHITE-THROATED SPARROW.** GROUP I. CLASS a.

This species is a migrant in the southern portion of the state, but from Wisconsin Valley Junction and Angelica northward it breeds in abundance. In its summer home it is partial to wind-fall tracts. In the fall they frequent the hedges along fences and other places where rank weeds abound. They are feeding their young as late as July 26th, from which it may be inferred that they rear two broods each season. It feeds mostly upon the ground, and, until after July, its food is largely insects.

Food: Of sixteen specimens examined, thirteen had eaten many or a few seeds; one, raspberries; one, a grasshopper; two, four caterpillars; two, four beetles; and one, a caddis-fly.

Seeds of rank weeds (Wilson). Seeds and insects (De Kay). Seeds, berries, and insects (Samuels). Caterpillars and seeds of weeds (Forbes).

It is killed by the Sparrow and Sharp-shinned Hawks, and especially by the Marsh Harrier (Audubon).

102. ZONOTRICHIA LEUCOPHRYS (FORST.), SW. **WHITE-CROWNED SPARROW.** GROUP I. CLASS a.

Only a migrant in Wisconsin, so far as known at present, and it is much less numerous than the last. Its haunts and habits are similar to those of the last. Audubon states that in the fall it occasionally pursues insects on the wing.

Food: A single specimen examined had eaten weed seeds.

Seeds of weeds (Forbes). While in Labrador, beetles, grass seeds, a variety of berries, and small mollusks (Audubon).

NOTE.—A single specimen of var. *intermedia* of this species, and of *Z. coronata* and *Z. querula*, Dr. Hoy reports to have taken at Racine.

103. CHONDESTES GRAMMICUS (SAY), BP. **LARK FINCH.** GROUP I. CLASS a.

I have only met with this species at Berlin. There it arrives early in May, and is quite common. Several pairs bred on the ground in the park and in the school yard. It is a terrestrial species, though not exclusively so, and its favorite haunts are the open prairies. I am inclined to think that it sets off for the south early in July, for I have never seen it later. Since writing the above, I have found a species breeding regularly at River Falls.

Food: Four specimens, taken in May and June, had eaten only small seeds.

Seeds of grasses and other small plants (Brewer).

104. PYRGITA DOMESTICA, CUV. **ENGLISH SPARROW.** GROUP III. CLASS b.

Within the last few years this European bird has been introduced into Milwaukee, and is rapidly becoming abundant in many of the towns and cities in the southern part of the state.

Without reviewing the flood of literature that has appeared during the past ten or fifteen years relating to the usefulness of this species, it will be sufficient to say that I believe it to be a bird for which we have no present need, and that it is positively in the way of a score of more useful species. The bird has very few of those qualifications, indeed, which are combined in good insect destroyers, while it has many traits that are positively vicious. One Chipping Sparrow is worth two score of these imported gamins.

105. PASSERELLA ILIACA (MERR.), SW. **FOX-COLORED SPARROW.**
GROUP I. CLASS a.

This elegant species is not a very common migrant. It passes us in the fall between the last of September and the first of November. During this time it frequents old "clearings," hazel and briar patches, and the rank weeds that grow along neglected fences. It is terrestrial in its habits, and obtains much of its food by scratching upon the ground among fallen leaves. One of these birds which was taken in a hazel thicket adjoining a wheat field in October, had its stomach distended with chinch-bugs. These pests had doubtless crawled in among the fallen leaves to hibernate; and the fact shows that a bird which never visits cultivated fields, and which is only a migrant, may nevertheless be directly beneficial to agricultural interests. It shows, also, that such birds should be protected, if possible, in their building haunts and in their southern homes.

Food: Three out of four specimens examined had in their stomachs nothing but small seeds of various kinds; the other had in its stomach more than fifty chinch-bugs.

Grass seeds and eggs of insects (Wilson). Seeds and insects (De Kay). Seeds and insects (Samuels). Hymenoptera, long-horn beetles, hemiptera and spiders (Forbes).

106. SPIZA AMERICANA (GM.), BP. **BLACK-THROATED BUNTING.**
GROUP I. CLASS a.

It has been my experience to find this an uncommon bird in Wisconsin. It is, at least, rare in places where it might be expected to occur in abundance. It has been taken in the spring at Whitewater and I have seen it in May at Berlin.

It breeds at Racine; and in Northeastern Illinois it is said to be common in some places and abundant in others. It is terrestrial in its habits and frequents orchards and cultivated fields, nesting in both situations. It is apparently a bird which we could wish to have much more abundant.

Food: Caterpillars, beetles, canker-worms and other destructive insects (De Kay).

Prof. Forbes, in his report on "Birds and Canker-worms," says of this species: "This was the most common bird in the orchard, and it was undoubtedly destroying great numbers of the worms. Again and again they were observed busily searching the leaves and apparently taking every worm as they went. . . . Eleven specimens were obtained, eight of which had eaten canker-worms, which made about half of the food of the whole number. Other measuring worms were five per cent., cut-worms seventeen per cent., coleoptera nine per cent. (about one-third of them Carabidæ), and snails seven per cent. A wild bee, an ant or two, a few scavenger beetles, curculios and seeds of pigeon-grass were also found."

107. Zamelodia ludoviciana (Linn.), Coues. **ROSE-BREASTED GROSBEAK.** Group I. Class b.

The Rose-breasted Grosbeak is a summer resident, but nowhere abundant, nor is it uniformly distributed throughout the state in apparently suitable localities. Its favorite resorts are the thickly wooded banks of streams, willow and alder thickets and high open woods. Groves and the shade-trees along roadsides are also visited by it. Prof. F. W. Bundy writes me that they often visit the potato patches in the vicinity of Sauk City in quest of potato beetles; and my friend F. H. Severance informs me that it is of frequent occurrence among the shade-trees on the college campus at Galesburg, Illinois.

Dr. Bachman, quoted by Audubon, makes the following notes concerning the food of one of these birds which he kept in confinement three years: "It fed readily on various kinds of food, but preferred Indian meal and hemp seed. It was also very fond of insects, and ate grasshoppers and crickets with a peculiar relish. It watched the flies with great apparent interest, and often snatched at and secured the wasps that ventured within its cage."

Food: Of eight specimens examined, six had eaten small seeds; two, seven beetles; and one, berries. Two had in their stomachs only finely comminuted vegetable material.

Berries of sour gum (Wilson). Sometimes buds of trees (Cooper). Grain, berries and insects (De Kay). Seeds of birch and alder, berries, buds and insects (Samuels). Tender buds of trees (Audubon). Potato-beetle (F. W. Bundy). Potato-beetle (H. H. Mapes, Am. Naturalist). Canker-worms, army-worms and other caterpillars, wood-boring, leaf-chafing and snout beetles, also hymenoptera and the seeds of weeds (Forbes).

108. Passerina cyanea (Linn.), Gray. **INDIGO BIRD.** Group I. Class a.

This little Finch is an abundant summer resident in some portions of the state, while in other portions, apparently equally well suited to their tastes, only occasional pairs are seen. In Waupaca county, in July, 1876, it was one of the most abundant species, frequenting the borders of the fields in loose flocks. Its usual summer resorts are the borders of cultivated fields adjoining woods and groves. Willow and osier thickets, roadsides and pastures are also visited by them during the migrations.

Food: Of nineteen specimens examined, eighteen had eaten seeds of various weeds; one, two caterpillars: one, a grasshopper; one, two beetles; one, raspberries; and one, elder berries. Two had eaten insects, none of which were identified.

Caterpillars, worms, grasshoppers and seeds (De Kay). Small seeds of various kinds, as well as insects, some of which are taken on the wing (Audubon). Canker-worms and other caterpillars, spring-beetles, vine-chafers and curculios, hemiptera and seeds of weeds (Forbes).

109. Cardinalis Virginianas, Bp. **CARDINAL GROSBEAK.** Group II. Class a.

This gaudily attired songster, so highly prized both in this country and in Europe as a cage bird, is a southern species, and in this latitude it only occurs as a straggler at long and irregular intervals. Dr. Hoy reports that a few stragglers breed near Racine.

Food: Indian corn is its favorite article of food (Brewer). Fruits, berries, Indian corn and seeds (De Kay).

110. PIPILO ERYTHROPHTHALMUS (LINN.), VIEILL. **GROUND ROBIN; CHEWINK.** GROUP I. CLASS b.

This retiring and peculiarly terrestial species, though a common summer resident, is not as abundant as its two broods should tend to make it. Doubtless some fatal enemy holds it in check. Groves, thickets and woods crowded with underbrush, in upland situations, are its favorite haunts. From these resorts it only makes occasional visits into the adjoining fields or gardens, if near at hand. It is a large, strong bird, and capable of doing great mischief to the insects that infest its haunts.

Food: Of seventeen specimens examined, five had eaten small seeds; one, wheat; one, oats; one, raspberries; one, seven moths; three, nine beetles; one, ants; one, a wasp; one, an ichneumon; two, three grasshoppers; two, two cockroaches; one, a walking-stick *(Spectrum femoratum)*, and four of its eggs; and one, a larve.

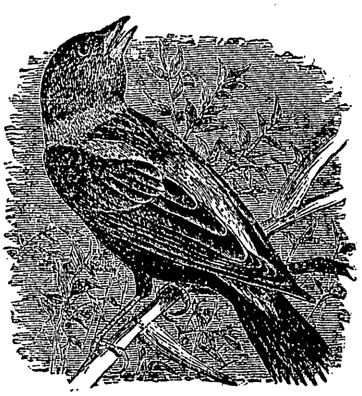
Worms, beetles, and eggs of insects (Wilson). Earth-worms, wire-worms, and the larvæ of insects (De Kay). Worms, insects and seeds (Samuels). Beetles and seeds of weeds (Forbes).

NOTE.— The following is found as a foot-note in Birds of Northeastern Illinois:

"Through Dr. Hoy I learn that two specimens of *P. arcticus* have been taken in Wisconsin, one near Milwaukee, where it is now preserved, and a second opposite Dubuque, Iowa. He has seen both specimens and is positive of their identity."

FAMILY ICTERIDÆ: AMERICAN STARLINGS.

FIG. 127.



BOBOLINK (*Dolichonyx oryzivorus*). After B., B. and R.

FIG. 128.

RED-WINGED BLACKBIRD (*Agelæus phœniceus*). After B., B. and R.

Tabular Summary of Economic Relations showing the name and number of specimens eating animal and vegetable food, and the number of insects, cray-fish and earth-worms contained in the stomachs, classified as to economic relations under the heads Beneficial, Detrimental and Unknown Relations.

Number and Name of Specimens Examined.			Classification of Food.		Ratios Represented by Lines.
Of thirteen Bobolinks examined	10	Contained		Animal food	
	4			Vegetal food	
	2		2	Beneficial	
	6		11	Detrimental	
	6		27	Unknown	
Of six Cowbirds examined	4	Contained		Animal food	
	2			Vegetal food	
				Beneficial	
	3		9	Detrimental	
	4		12	Unknown	
Of eighty-four Red-winged Blackbirds examined	21	Contained		Animal food	
	80			Vegetal food	
				Beneficial	
	5		9	Detrimental	
	16		26	Unknown	
Of twenty-one Meadow Larks examined	21	Contained		Animal food	
	1			Vegetal food	
	7		10	Beneficial	
	15		30	Detrimental	
	12		32	Unknown	
Of eight Baltimore Orioles examined	8	Contained		Animal food	
	1			Vegetal food	
				Beneficial	
	6		50	Detrimental	
	4		9	Unknown	
Of five Rusty Grackles examined	3	Contained		Animal food	
	3			Vegetal food	
				Beneficial	
	1		8	Detrimental	
	3		9	Unknown	
Of nine Purple Grackles examined	5	Contained		Animal food	
	6			Vegetal food	
				Beneficial	
	1		2	Detrimental	
	5		14	Unknown	

Table showing the kinds and number of insects, cray-fish and earth-worms eaten by the American Starlings.

Number and Name of Specimens Examined.			Classification of Food.		Ratios Represented by Lines.
Of thirteen Bobolinks examined	1	Contained	1	Wasp............	
	2		2	Lepidoptera......	
	3		6	Diptera..........	
	3		7	Beetles..........	
	4		8	Orthoptera.......	
	1		1	Dragon-fly........	
	1		1	Earth-worm	
	9		34	Adult forms......	
	4		6	Larvæ...........	
	1		10	Grasshopper eggs.	
Of six Cowbirds examined	3	Contained	4	Lepidoptera	
	1		1	Hornet	
	3		9	Diptera..........	
	2		4	Orthoptera	
	2		4	Beetles	
	5		22	Adult forms	
	1		1	Larve	
	1		30	Moth eggs	
Of eighty-four Red-winged Blackbirds examined	2	Contained	2	Lepidoptera......	
	5		7	Beetles	
	4		7	Grasshoppers	
	8		8	Mollusks	
	11		36	Adult forms	
	1		1	Larve	
Of twenty-one Meadow Larks examined	5	Contained	8	Lepidoptera	
	12		40	Beetles	
	11		19	Grasshoppers.....	
	1		1	Dragon-fly........	
	20		61	Adult forms	
	6		11	Larvæ	
	1		15	Insect eggs.	
Of eight Baltimore Orioles examined	6	Contained	50	Caterpillars.......	
	3		7	Beetles	
	2		2	Snails............	
	4		9	Adult forms......	
	6		50	Larvæ	

Table showing the kinds and number of insects, cray-fish and earth-worms eaten by the American Starlings — continued.

Number and Name of Specimens Examined.			Classification of Food.		Ratios Represented by Lines.
Of five Rusty Grackles examined	1	Contained	8	Moths	
	3		7	Beetles	
	1		2	Snails	
	3		17	Adult forms......	
Of nine Purple Grackles examined .	1	Contained	2	Beetles	
	1		2	Water Scorpions .	
	1		1	Cray-fish	
	4		15	Adult forms......	
	1		2	Larvæ............	
	1		10	Insect eggs.......	

111. Dolichonyx oryzivorus (Linn.), Sw. **BOBOLINK; REED-BIRD; RICE-BIRD.** Group I. Class b.

From the first till the middle of May these northward-moving night-travelers are spirited into our meadows out of the impending darkness, some to select summer homes, but many more to feed and rest and then hurry to the Saskatchewan country, as if anxious to cut short the time when they may return to the sunny south; and true to their instincts, early in August they come trooping back, and, joined by those who have bred by the way, they are all off by the middle of the month.

These birds confine themselves, until after the breeding season, almost exclusively to meadows, frequenting both the wet and the dry. Such haunts as these and their insectivorous habits place them among our most valuable birds. The occasional and brief visits which these birds make to grain-fields, in August, result in so trifling an injury that it should be entirely overlooked in view of the great service they render in the meadows.

It is greatly to the loss of the Northern States that so many of these birds are destroyed in the South, where their destruction to the rice crop is very great. But before we can consistently ask our Southern friends to stay this destruction, we must know more definitely than we do now what injury and what service the Bobolink renders to them, and what its economy is farther south where it spends the winter; we must know, too, what proportion of those which are permitted to come back may be induced to breed with us in preference to passing on to the north of the United States.

Dr. Brewer states that more recently it has been ascertained that these birds feed greedily upon the larvæ of the destructive cotton-worm, and that in so doing render an immense service to the cultivators of Sea Island cotton. What has been said in the Introduction in regard to the army-worm should be called to mind in this connection.

Food: Of thirteen specimens examined, one had eaten caterpillars; three others, larvæ, probably caterpillars; three, seven beetles, among them two lamellicorns and one elater; three, six dipterous insects, among them four Mucidæ; four, seven grasshoppers; one, a cricket; one, ten grasshoppers' eggs; one, a moth; one, a dragon-fly; one, wheat; three, oats; and one, grass seeds. The stomachs of two specimens contained insects, none of which were identified.

Grubs, caterpillars, may-flies and other insects, green corn, wheat, barley and wild oats (Wilson). Crickets, grasshoppers, beetles, spiders and seeds of various kinds (De Kay). Crickets, grasshoppers, beetles, spiders and various grass-seeds (Samuels). Cotton-worm (Brewer). Canker-worm (Maynard). Hymenoptera, caterpillars, leaf-chafers, curculios and seeds of weeds (Forbes).

112. MOLOTHRUS ATER (BODD.), GRAY. **COWBIRD.** GROUP III. CLASS b.

This species reaches us early in the spring, and, like the Bobolink, disappears in August. I have never seen it later than the 9th of this month. "A strange point in the history of this species is its unexplained disappearance, generally in July, from many or most localities in which it breeds. Where it goes and for what purpose are unknown." In the spring they are often about stock-yards in quest of corn and seeds. Later they frequent pastures, keeping close to the cattle and horses, apparently for the purpose of obtaining the insects that are startled by the grazing herd. They are said also to feed upon the parasites that infest cattle.

Whatever speculations may be indulged as to the origin of the strange parasitism of the Cowbird, we must always regret that so pernicious a trait should have been engrafted upon bird-nature. Why the Cowbird should not incubate her own eggs does not appear in her structure; but that she generally deposits them where the foundlings will receive unstinted care is attested by the observations of many. Did not the adventitious fledglings result sooner or later in the destruction of the rightful young, we might deal more leniently with this species. As it is, on grounds of economy, and in view of the scant abundance of insectivorous birds in agricultural districts, the Cowbird merits no protection. Nearly every species which rears the young of this parasite is as useful as itself, but in most instances, if not all, a single Bunting supplants a brood of from three to five individuals. Where a pair of Vireos, for instance, might have reared four or five young birds of their kind, their energies have been devoted to a single Bunting.

The following are some of the birds that are known to act as foster parents to this species: *Turdus mustelinus, T. fuscescens, Minniotilta varia, Polioptil cœrulia, Helminthophaga ruficapilla, Dendrœca æstiva, D. virens, D. Blackburniæ, D. discolor, D. Pennsylvanica, Geothlypis trichas, Siurus aurocapillus, Setophaga ruticilla, Passerina cyanea, Vireo olivaceus, V. solitarius, V. gilvus, V. noveboracensis, V. flavifrons, Sayiornis fuscus, Empidonax minimus, Contopus virens, Sturnella magna, Harporhynchus rufus, Spizella domesticus* and *Pipilo erythrophthalmus.* It has been stated on a previous page that seven out of fourteen Pewees' (*S. fuscus*) nests visited at Ithaca, N. Y., in the spring of 1878, contained either the eggs or the young of the Cowbird. From this fact it appears that instead of twenty-eight or thirty-five Pewees which might have been reared in the seven nests, only seven Cowbirds could have taken their place as insect destroyers. Such is the check which this bird imposes upon the Pewee at Ithaca. If, as is generally believed, each existing Bunting represents a brood of young birds whose birth has been prevented, it is doubtless within the bounds of truth to assert that the number of Cowbirds existing at any time represents a deficiency in the bird population of the country of three times their number; and as the nests in which this parasite usually deposits her eggs are those of the most exclusively insectivorous species we have, it is evident that the Cowbird must prevent the destruction of many more insects than it is possible for it to destroy. This is the more to be lamented since the Bunting has become so thoroughly accustomed to agricultural districts, where there are so many conditions which react against purely insectivorous birds, and where, more than anywhere else, the services of these birds are especially needed.

It should be added in this connection, that, so far as is known at present, the tendency of the Cowbird to prevent an undesirable abundance of birds is in a direction where there is the least danger. It appears wholly improbable that purely insectivorous birds can, under any circumstances, become over abundant, unless it be some forms which may be proved to feed largely upon beneficial insects. If there can be danger of any insect-eating bird, which is not destructive to other birds, becoming too numerous, it must be mainly among those which, like many of the Finches and Starlings, can subsist upon seeds, grains and fruits when insects are scarce. As the Cowbird does not appear to affect, in any marked degree, these birds, it is likely to prove to be less serviceable, in this direction, than either the Shrikes, Crows, Owls or Hawks. While it cannot be deemed safe, in the light of present knowledge, to extirpate this species, it should be subjected to very careful observation, with a view to ascertaining, if possible, its actual influence over the abundance of other birds, and then, if this method should prove to be inconclusive, it should be nearly exterminated from some wide and suitable north-and-south belt for a series of years, and the results carefully noted by competent observers. In this way it may be hoped that reliable results may be obtained upon which future action may be safely based.

Food: Of seven specimens examined, one had nothing in its stomach; one had eaten a hornet; two, three moths; one, a caterpillar; three, nine dipterous insects; one, three grasshoppers; one, a cricket; two, four beetles — one of them an elater; one, thirty eggs, probably those of a moth which had been eaten; two, seeds; and one, wheat.

One bird taken from the nest of a Pewee had in its stomach a hornet, a cricket, five flies, one caterpillar and two moths. Another taken from a Pewee's nest had been fed one elater, one moth, and two flies. It was this specimen which contained the thirty insect eggs.

Corn, rice and various species of intestinal worms (Wilson). Insects (Cooper). Intestinal worms (Audubon). Flies, grubs, beetles, etc. At times it visits corn-fields (T. M. Trippe, Am. Nat., Vol. III, p. 294). Moths, caterpillars, beetles, hemiptera, spiders and seeds of weeds (Forbes).

113. Agelæus phœniceus (Linn.), Vieill. RED-WINGED BLACKBIRD.
Group I. Class b.

In suitable localities no bird is as abundant as this species, and none as gregarious. All are familiar with Blackbird-concerts in the spring and with the clouds of Redwings which scud across the fields in the fall. Late in May or early in June these birds disband and repair to wet meadows or to the sloughs bordering streams, ponds and lakes, and these places, together with the high lands immediately adjoining them, are their feeding-grounds during June and July. Until after July — nearly four months — these birds feed almost exclusively upon insects and lead lives of nearly unalloyed usefulness. They breed, it should be remembered, in the native haunts of the army-worm, and it is presumable that they exert a great influence in holding them in check. Most of the corn-pulling which is attributable to the Blackbirds is done by the Purple Grackle, at least this has been my observation.

It is only late in August or early in September that these birds do any considerable damage, and then only in localities not far removed from their breeding grounds, for, as is well known, they return to the wet, reedy swamps to roost at night. After the corn has passed through the milk state and become hard and firm on the cob, the Redwings trouble it but little. They do not appear to be able to remove the kernels. They continue to visit the corn and stubble-fields, but it is for the purpose of obtaining the seeds of weeds and insects. Even while corn is in the milk state, the birds which visit the corn-fields appear to feed more upon the seeds of weeds than upon corn. All but five of the eighty-four specimens whose food is given below were taken between August 9th and September 20th, and the majority of these either while they were in the corn-fields or just as they were returning from them. By examining that list it will be seen that more than two-fifths of them had eaten no corn at all, while less than one-tenth had eaten only corn. Were the little injury which this species does evenly distributed over the country, instead of being localized about its breeding haunts and roosting places, I am convinced that it would never be felt.

Food: Of eighty-four specimens examined, thirty-seven had eaten corn and seeds of various weeds; thirty-one had eaten only seeds; seven had eaten only corn; three, rye; two, oats; eight, wheat; two, tender herbage; five, seven beetles; four, seven grasshoppers; one, a moth; and one, a caterpillar. In the stomachs of two birds there were bits of insects none of which were identified. Eight had eaten small mollusks; and one, berries.

The gleanings of old rice, buckwheat and corn fields in the fall and winter, and grub-worms, caterpillars, and other larvæ in the spring (Wilson). Canker-worms (Maynard). Caterpillars, beetles, spiders, wheat and seeds of weeds (Forbes).

114. Zanthocephalus icterocephalus (Bp.), Bd. YELLOW-HEADED BLACKBIRD. Group I. Class b.

This species is not very common except in certain localities. Its haunts are similar to those of the Red-winged Blackbird, with which it often associates in the fall. It breeds, as a rule, farther out in the marshes about lakes and ponds, and until fall confines itself quite closely to those localities. In its economic relations it differs from the last species only in degree — it being a larger and stronger bird and thus better able to do mischief in the fall, while its retiring habits render it less serviceable during the summer.

Food: Of three specimens examined, one had eaten only corn; one, corn and the seeds of black bind-weed; and one, only six beetles.

In Kansas, these birds render great service to farmers by destroying the swarms of young grasshoppers (I. M. McLaughlin, Am. Nat., II, p. 493).

115. Sturnella magna (Linn.), Sw. MEADOW LARK; FIELD LARK. Group I. Class b.

The sweet-voiced Meadow Lark is one of our most useful birds, and yet few are persecuted more than it. Every sportsman — and they are many — must learn to shoot on the wing, and invariably this bird is doomed to be their target. What is even worse, boys from the towns are permitted to stroll through the fields, shooting, in their recklessness, almost any bird they meet. Farmers must stop all of this if they would have birds do effective work in protecting their crops. The Meadow Lark is almost exclusively insectivorous and nearly one-half of its food consists of grasshoppers. It is always in the open meadows and pastures where other birds are few, and its large size would enable it to render an immense service if it were permitted to become more abundant. Its flesh is sweet, but its natural enemies are too numerous, its nesting places too exposed, and its usefulness in destroying insects too great to justify its sacrifice to the taste of the epicure. In the south it is accused of pulling rye and wheat, but the only injury which I know of its doing in Wisconsin is its destruction of some of the ground and tiger-beetles.

Food: Of twenty-one specimens examined, twelve had eaten forty beetles — among them a may-beetle; one, a weevil; eight, ground-beetles; and one, a tiger-beetle; eleven, nineteen grasshoppers; four, seven caterpillars; and three, four other larvæ. Among the caterpillars a hairy form. Two, two small moths; one, a small dragon-fly; and one, a single thistle-seed.

Insects, grub-worms, caterpillars and grass seeds (Wilson). Seeds and various insects (De Kay). Beetles and various other insects, and grass seeds (Nuttall). Caterpillars, beetles — among them ground-beetles, one of the Silphidæ, flower-beetles and plant-beetles; grasshoppers, myriapods and corn (Forbes).

116. Sturnella magna neglecta (Aud.), All. WESTERN MEADOW LARK. Group II. Class a.

This variety is reported by Dr. Hoy as occurring occasionally near Racine, and as it occurs commonly in Iowa it may be expected to occur occasionally in the western part of the state. Since writing the above I have found it on Hudson Prairie, St. Croix county, where it breeds.

117. Icterus spurius (Linn.), Bp. ORCHARD ORIOLE; CHESTNUT HANGNEST. Group I. Class a.

Mr. Nelson gives this species as a rather common summer resident in Northeastern Illinois, and it has been so reported by Dr. Hoy from Racine. It is certainly a rare bird in Central Wisconsin. As its name implies, it is partial to orchards, is almost wholly insectivorous, and has not been known to molest any of the products of husbandry. Its southern habitat, however, excludes it from the state at large.

118. Icterus galbula (Linn.), Coues. BALTIMORE ORIOLE; GOLDEN ROBIN; HANGNEST. Group I. Class b.

This energetic and brilliantly attired vocalist and its ingenious hanging nest are familiar objects to all. Shady villages, orchards, and the vicinity of dwellings where trees abound are its favorite haunts, but groves and the borders of woodlands also offer it special attractions. In New England it is accused of feeding upon the esculent pods of pea-vines; and horticulturists complain that it feasts upon their berries, grapes and cherries — destroying at times more than it eats, by biting into the fruit. For these misdemeanors it has been consigned to extirpation; and yet, it would be equally consistent and generous to discharge a faithful servant for eating a few of the fruits he tends.

The Golden Oriole appears to be very fond of caterpillars of various kinds, and what is still more in its favor, it feeds extensively upon some forms which are either not relished by other birds or are protected in some way from them. Prof. J. H. Comstock informs me that he has seen it thrust its head through the web of the tent-caterpillar and remove the inmates. An instance which came under my own observation shows how destructive they are to those leaf-rollers which tie themselves up so securely in the leaves of various trees and shrubs. While walking through a dense grove of young oaks, my attention was attracted by a loud noise of tearing leaves. On approaching the spot a family of Orioles flew to a large tree near by, and the noise ceased. In the stomach of one of these birds were found twenty of the leaf-rolling larvæ, which were very common at the time on the red oak. The strong beak of this bird fits it well for tearing open the firm cases which enclose these pests. It may be seen searching in the corners of the guards about shade-trees for chrysalids, and it often resorts to clover and grass-fields for insects.

Food: Of eight specimens examined, six had eaten three, twenty-five, fifteen, four, two, and one caterpillars respectively. Three had eaten seven beetles; and two, two snails. Twenty-five of the caterpillars were leaf-rollers, and seven of them the larvæ of a species of *Vanessa.*

Caterpillars, bugs and beetles, particularly one of a brilliant metallic green color (Wilson). Of three specimens examined by Prof. Forbes three had eaten caterpillars; one, beetles; and two, blackberries. Flies, beetles and caterpillars (De Kay). Smooth and hairy caterpillars, and other injurious insects, particularly the tent-caterpillar (Samuels). Caterpillars and green beetles (Audubon). Canker-worms (Maynard). Canker-worm, tent-caterpillar and green peas (Brewer). Tent-caterpillar (Prof. J. H. Comstock). According to Harris it is said to eat the pea-weevil and to knock open the pod to get the grub in the green pea. Tent-caterpillar (Le Baron).

119. SCOLECOPHAGUS FERRUGINEUS (COM.), SW. **RUSTY GRACKLE.** GROUP I. CLASS a.

This species is mainly a migrant in Wisconsin. It occurs as late as May 16th at Berlin, and I have never obtained it in the fall earlier than the first of October; it is said, however, to pass through Illinois from September to the middle of November. It leaves too early in the spring and returns too late in the fall to do any injury to corn.

Food: Of five specimens examined, three had eaten seven beetles — among them three aquatic species; one, moths; one, two small mollusks; and two, small seeds.

Corn, principally, in October (Wilson). Grubs, beetles, moths and grains of various kinds (De Kay). Grasshoppers, caterpillars and other injurious insects, worms, crustaceans, various weed seeds, and grains left in the fields (Samuels).

120. SCOLECOPHAGUS CYANOCEPHALUS (WAGL.), CAB. **BLUE-HEADED BLACKBIRD; BREWER'S GRACKLE.** GROUP I. CLASS a.

This species is met with very rarely in the eastern portion of the state, but as it occurs regularly in Minnesota it may be found along the Mississippi.

Food: A single mature male obtained in July on the large marsh just east of Princeton had its stomach greatly distended with grasshoppers.

121. QUISCALUS PURPUREUS (BARTR.), LICHT. **PURPLE GRACKLE.** GROUP II. CLASS c.

I am not at all certain that the only Purple Grackle of Wisconsin is *œneus*, as appears to be the opinion of some recent writers. The birds which we have arrive early in April, are common during the summer, and by the middle of

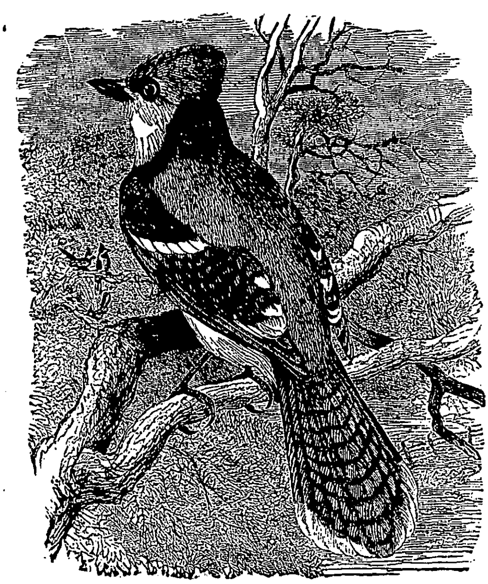
October all have gone south. They frequent the high lands as well as the low during the breeding season, and often nest in trees about dwellings and in villages. They are more familiar and less gregarious than the Red-winged Blackbird, and more destructive to corn in the fall, in proportion to their numbers. So far as I have observed, most of the corn-pulling in the spring is done by this species. It often follows the plow in quest of grubs and cut-worms, and in the fall small troops are often seen strolling about village lawns. In "Birds of the Northwest" occurs the following from Thomas T. Gentry, who, in speaking of this species, says: "It is obviously of great service in the destruction of insects. But it has one very bad trait, perhaps not generally known. Like the Crow, a not distant relative, it is fond of birds' eggs and tender nestlings, and it destroys a great many, particularly Robins." It is this trait which makes the economic position of the Purple Grackle doubtful.

Food: Of nine specimens examined, six had eaten corn; two, beetles; one, two water scorpions *(Nepidæ)*; one, a small cray-fish; and one, a few seeds. I have often seen these birds follow the plow and pick up and eat grub-worms and cut-worms.

Worms, grubs and caterpillars in the spring, and corn in the fall (Wilson). Grubs, beetles, caterpillars, moths and grain of various kinds (De Kay). Caterpillars, moths, beetles, beech nuts, acorns, and seeds of weeds and various wild plants (Samuels),

FAMILY CORVIDÆ: CROWS, JAYS, ETC.

FIG. 129.



BLUE JAY (*Cyanocetta cristata*). After Bd., Br. and Ridg.

Tabular Summary of Economic Relations showing the number of specimens containing animal and vegetable food, and the number of insects and spiders taken from the stomachs, classified as to economic relations under the heads Beneficial, Detrimental and Unknown Relations.

Number and Name of Specimens Examined.			Classification of Food.		Ratios Represented by Lines.
Of thirty-one Blue Jays examined........	25	Contained		Animal food	
	26			Vegetal food	
	2		5	Beneficial	
	7		10	Detrimental	
	20		39	Unknown.........	

Tabular summary of the number and kinds of insects and birds eaten or killed by the Blue Jay.

Number and Name of Specimens Examined.			Classification of Food.		Ratios Represented by Lines.
Of thirty-one Blue Jays examined	1	Contained or killed	1	Ant...............	
	2		2	Caterpillars	
	15		30	Beetles	
	3		4	Grasshoppers	
	1		3	Young Robins....	
	21		47	Adult forms......	
	5		7	Young forms.....	

122. Corvus corax, Linn. RAVEN. Group III. Class b.

This species rarely visits the southern portion of the state, and only in the winter. During October and November, 1877, it was very common throughout the whole length of the Flambeau river. Several were observed daily, and it always occurred singly or in pairs. Notwithstanding the carrion-eating propensity of this species, its insectivorous habits, and the fact that it does not now frequent the settled portions of the state, its reputed robbery of birds' nests must class it among the birds whose injuries exceed their services. Its large size, its fondness for flesh, and its ability to move where it will, all indicate that but few birds which breed in its haunts may not suffer from its attacks.

Food: Dead fish, and animal matter of all kinds, birds' eggs, young ducks, chickens, lambs, reptiles, grubs, worms and mollusks (Wilson). Dead animals, birds' eggs, young chickens, lambs and fawns, when they are found unprotected, lizards, snakes, and occasionally potatoes and grain (Cooper). Field mice, grubs, worms and grains (De Kay). Small animals of every kind, dead fish, carrion, insects, worms, eggs, nuts, berries, and other kinds of fruits (Audubon).

123. Corvus frugivorus, Bartr. COMMON CROW. Group III. Class b.

The Crow is common throughout the southern portion of the state, and, to a considerable extent, resident during the winter. It is not, however, numerous, and I have not seen it north of Stevens Point, in the eastern part of the state.

In the western part it occurs as far north as New Richmond. As in the Eastern States, it frequents agricultural districts, and is most abundant in the wooded sections. It is much upon the ground in open fields, but there is no piece of woodland through which it does not stroll.

The wary, suspicious nature, so characteristic of the Crow in the Eastern States, appears to be wholly acquired, and is not possessed by the Crow of the Western Plains, nor of that of unsettled districts where it is not molested. However desirable an unsuspicious and familiar nature may be in a bird like the Robin, when possessed by one likely to become rapidly abundant, when left to itself, and whose propensities are those of the Crow, it detracts from rather than adds to its usefulness. With all deference to the opinions of ornithologists, who should speak with authority on this subject, I must believe that they err when they advise the withdrawal of restraint from this species. Every element of its nature fits it for an almost unlimited abundance when fostered by the conditions of agriculture; no bird can take its food from it, and there is nothing edible which it may not eat. Its familiarity with man in regions where its rights have never been questioned, and the readiness with which young birds accept domestication, leave no doubt that it would take unbearable liberties about dwellings. Nesting, as it does, in high, inaccessible tree-tops, it has no natural enemies, in thickly settled districts, which could hold it within safe bounds. Its ability to overpower any of our small birds, its ravenous appetite for flesh, especially when young, and its fondness for the eggs and young of birds, would, under conditions of no restraint, make it more destructive to bird-life than all the Hawks and Owls combined. There are only a few large injurious insects, like the may-beetles, which it can destroy better than other birds, while its large. clumsy body utterly disqualifies it for the vast work which is done by the birds whose life it would not permit. Viewed in this light, the Crow can but be regarded as one which must be held in the scantiest abundance.

Food: Of two specimens examined, each had eaten corn, and one a small chrysalid. In the stomach of one were found two very small pieces of bones.

Myriads of mice, moles, beetles, grubs, caterpillars and worms, young birds and their eggs. It robs hens' nests and kills young chickens. In the spring it pulls young corn; sometimes whole corn-fields are laid waste by the feeding of a single flock lighting upon it at once (Wilson). Fish, immense numbers of grubs and grasshoppers, clams and oysters (Cooper). Follows the plowman for worms and larvæ of insects; pulls corn; eats corn in the milk state, and kills young chickens, turkeys and goslings, and destroys every egg in its reach (De Kay). Fruits, seeds, vegetables, snakes, frogs, lizards, and other small reptiles; worms, grubs, insects, and eggs of birds (Aud.). Insects and various vermin, young Robins and birds' eggs (Samuels).

124. Pica rustica Hudsonica (Lab.), Ridg. AMERICAN MAGPIE.
Group III. Class b.

This bird is said to visit Michigan, Wisconsin (Hoy) and Northern Illinois in the winter. These visits are only occasional, however, and by but a few birds.

Food: Seeds, carrion, insects, etc., and the eggs and young of other birds, of which it destroys a great many (T. M. Trippe). Destroys plantations of young oaks by pulling up the acorns. Destroys great numbers of small birds and birds' eggs. Alights on the backs of cattle to rid them of the larvæ that fester in the skin. Eats carrion, worms, insects of every description, and grains (Wilson). Largely carrion, eggs, young birds and fruits (Cooper). Worms, grubs, young birds, birds' eggs and carrion (De Kay).

125. CYANOCITTA CRISTATA (LINN.), STRICKL. **BLUE JAY.** GROUP III. CLASS b.

The Blue Jay is distributed throughout the state, but, like the Robin, is far more abundant in settled than in unsettled portions. It is a summer and winter resident, but less abundant in the latter than in the former season. Groves, fields, villages, and the vicinity of dwellings are more frequented than woodlands; and although it is an arborial species, it is much upon the ground in quest of food. Occasionally it extracts insects from the crevices of the bark on the trunks of trees. When unmolested it becomes more and more familiar, and keeps closer to dwellings; and during the winter, particularly, they crowd into villages to feed upon the crumbs from the kitchens. It is so like the Common Crow in very many of its traits, that much which has been said of that bird applies equally well to this. Its smaller size, however, renders it less dangerous to other birds as a class, and better fitted to do service in destroying insects. Did not the destruction of the eggs and young of other birds appear to be a general trait rather than an individual peculiarity of the Blue Jay, it would be necessary to throw but little restraint over it. As it is, it must be held within narrow limits. The Jay is not an especially valuable bird to agricultural interests when compared with other species. From the first of August until the first of April, two-thirds of the year, not more than one-tenth of its food consists of insects, and during the rest of the year, less than two-thirds of it consists of this material. During August, September and October, about one-tenth of its food consists of grain and other useful products, and it is not especially destructive to the seeds of weeds; while during May and June it is known to feed to a considerable extent upon the eggs and young of other birds.

Dr. Brewer, however, in speaking of this species in "Birds of North America," says: "The Jay is charged with a propensity for destroying the eggs and young of the smaller birds, and has even been accused of killing full-grown birds. I am not able to verify these charges, but they seem too generally conceded to be disputed. These are the only serious grounds of complaint that can be brought against it, and are more than outweighed ten-fold by the immense service it renders to man in the destruction of his enemies. Its depredations on the garden or farm are too trivial to be mentioned." He also says: "Dr. Kirtland has also informed me of the almost invaluable services rendered to farmers in his neighborhood, by Blue Jays, in the destruction of caterpillars. When he first settled on his farm, he found every apple and wild cherry-tree in the vicinity disfigured and denuded of its leaves by the larvæ of the *Clisiocampa Americana*, or tent-caterpillar. The evil was so extensive that even the best farmers despaired of counteracting it. Not long after the Jays colonized upon his place he found they were feeding their young quite extensively with these larvæ, and so thoroughly that two or three years afterwards not a worm was to be seen in the neighborhood; and more recently he has searched for it in vain, in order to rear cabinet specimens of the moth."

I insert this quotation because it illustrates so well the great danger of overestimating the real service which any particular bird may render at a given time. In the first place, it is by no means certain, from what Dr. Kirtland says, that the disappearance of the tent-caterpillar from his neighborhood, at the time he mentions, was in any marked degree due to its destruction by the Blue Jay. It is a well known fact that the tent-caterpillar, and very many other noxious insects, may be very abundant in a given locality for a few years and then suddenly disappear almost entirely, when birds could have had no very great influence in the extermination. In all of these sudden disappearances parasitic foes and climatic influences appear to be the prime agents of destruction. If these pests were as abundant in Dr. Kirtland's neighborhood as his statement indicates, it must have been a large colony of Jays indeed that could have counteracted them, alone, in so short a time. It is the bird's mission to aid in preventing these gigantic culminations of insect life, or to lengthen the periods between their occurrence, and not so much to beat back a wave that has broken over them in spite of all their efforts to prevent it. In the second place, the destruction of the tent-caterpillar in orchards, by birds, is not of so great moment as some have thought. There is perhaps no insect troublesome to orchards more directly and easily controlled than this species. Its tent makes it perfectly conspicuous before it has done any mischief; and since the whole colony congregate under the web when they are not feeding, every caterpillar can be easily and quickly destroyed. Small insectivorous birds should rarely be supplanted by large omnivorous species; and the bird that destroys the Warbling Vireo or the Robin should render an exceedingly valuable service to warrant its encouragemant in orchards and gardens; for this reason I regard a Blue Jay as much out of place in an orchard, during the breeding season, as a Canada thistle in a grain-field.

Food: Of thirty-one specimens examined, nineteen had eaten acorns; fifteen, thirty beetles, among them several species of *Harpalidæ* and a *Cetonia;* two, two caterpillars; two, two grubs; one, some other larvæ; two, grasshoppers; five, corn; one, wheat; and one, berries. No stomach was found to contain only insects; and of those which contained beetles, their remains never composed more than one-fifth of the entire contents, and usually less than one-tenth. One bird was observed to kill three out of a brood of four young Robins and to eat one of them.

Young birds, carrion and acorns (Wilson). Chestnuts, acorns, cherries, large insects, carrion, and the eggs and young of birds (De Kay). The larvæ of *Dryocampa senitoria* (A. J. Cook). In the winter, berries of barberry or black-thorn, with a few eggs or cocoons of insects. In the spring, buds of shrubs, caterpillars and other insects; late in the spring and through the greater part of summer, the eggs and young of smaller birds; later in the summer and early autumn, berries, small fruits, grains, and a few insects; later in the autumn, chestnuts and beech-nuts (Samuels). Beech-nuts, chestnuts, acorns, corn, pears and apples (Audubon). Grubs of the may-beetle (Harris). Tent-caterpillar (Dr. Kirtland). Eggs, young birds, insects, caterpillars, acorns, chestnuts, corn and small fruits (J. M. Wheaton). Caterpillars, corn (Forbes).

126. Perisoreus Canadensis (Linn.), Bp. CANADA JAY; MOOSE BIRD. Group III. Class b.

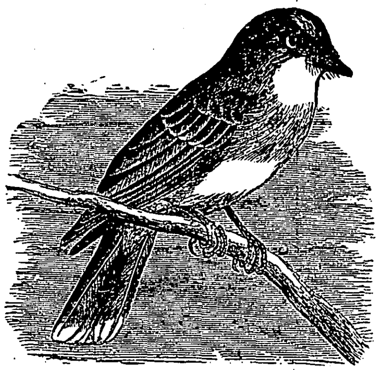
The Canada Jay is a common winter resident in the pineries, where it makes itself familiar about every logging-camp. A few may breed in those regions, but I could not learn that it was ever seen there during the summer.

Food: In the stomachs of two specimens, taken in October, were grasshoppers, cockroaches, larvæ and small seeds.

Seeds, insects and berries (Cooper). Berries, caterpillars, eggs of birds and carrion (De Kay). Eggs of ants, insects, leaves of fir trees. Robs Crows' nests (Audubon). I knew of a single pair of these birds destroying the young in four nests of the Common Snowbird *(J. hyemalis)* in a single day (Samuels).

FAMILY **TYRANNIDÆ**: AMERICAN FLYCATCHERS.

FIG. 130.



KINGBIRD (*Tyrannus Carolinensis*). After B., B. and R.

Tabular Summary of Economic Relations showing the name and number of specimens eating animal and vegetable food, and the number of insects and spiders taken from the stomachs, classified as to economic relations under the heads Beneficial, Detrimental and Unknown Relations.

NUMBER AND NAME OF SPECIMENS EXAMINED.			CLASSIFICATION OF FOOD.		RATIOS REPRESENTED BY LINES.
Of twelve Kingbirds examined	12	Contained		Animal food......	
	3			Vegetal food	
	5		5	Beneficial	
	4		14	Detrimental......	
	6		28	Unknown.........	
Of thirty-seven Pewees examined	37	Contained		Animal food......	
	1			Vegetal food.....	
	12		25	Beneficial	
	17		70	Detrimental	
	20		89	Unknown.........	
Of forty-one Wood Pewees examined	41	Contained		Animal food......	
				Vegetal food	
	8		11	Beneficial	
	14		25	Detrimental......	
	40		233	Unknown.........	
Of five Traill's Flycatchers examined..	5	Contained		Animal food	
	1			Vegetal food	
	2		4	Beneficial	
	1		7	Detrimental.......	
	4		15	Unknown	

Tabular Summary of Economic Relations of Flycatchers — continued.

Number and Name of Specimens Examined.			Classification of Food.		Ratios Represented by Lines.
Of twenty-three Least Flycatchers examined	23	Contained		Animal food......	
				Vegetal food	
	5		8	Beneficial	
	5		10	Detrimental	
	22		131	Unknown.........	

Table showing the kinds and number of insects and spiders eaten by the Flycatchers.

Number and Name of Specimens Examined.			Classification of Food.		Ratios Represented by Lines.
Of twelve Kingbirds examined	1	Contained	1	Bee...............	
	2		2	Lepidoptera......	
	2		7	Diptera..........	
	4		17	Beetles	
	4		4	Dragon-flies	
	1		3	Mollusks..........	
	11		47	Adult forms......	
	1		30	Moth eggs........	
Of thirty-seven Pewees examined	9	Contained	27	Hymenoptera ...	
	12		35	Lepidoptera	
	7		27	Diptera...........	
	14		49	Beetles...........	
	4		4	Hemiptera	
	12		17	Orthoptera	
	4		5	Neuroptera	
	1		1	Spider	
	37		165	Adult forms[1].....	
	8		19	Larvæ............	
	3		258	Insect eggs	
Of five Traill's Flycatchers examined..	1	Contained	1	Ichneumon.......	
	1		1	Fly	
	2		8	Beetles	
	2		3	Dragon-flies	
	4		26	Adult forms......	

[1] Scale only one-fourth.

Table showing the kinds and number of insects and spiders eaten by the Flycatchers — continued.

Number and Name of Specimens Examined.			Classification of Food.		Ratios Represented by Lines.
Of forty-one Wood Pewees examined......	11	Contained	29	Hymenoptera	
	6		7	Lepidoptera	
	14		41	Diptera...........	
	18		66	Beetles	
	2		2	Hemiptera.........	
	1		1	Grasshopper	
	9		13	Dragon-flies	
	41		268	Adult forms [1].....	
	1		1	Larve.............	
	1		40	Tipulid eggs......	
Of twenty-three Least Flycatchers examined.................	4	Contained	39	Hymenoptera ...	
	4		4	Lepidoptera......	
	4		18	Diptera...........	
	10		30	Beetles	
	1		3	Heteroptera	
	2		4	Dragon-flies......	
	1		1	Spider............	
	23		148	Adult forms [2].....	
	2		3	Larvæ............	

127. Tyrannus Carolinensis (Linn.), Bd. KINGBIRD; BEE MARTIN.

Group I. Class b.

The Kingbird arrives early in May, and many of them appear to withdraw before the close of August. It is very common and frequents fields, pastures, meadows and the vicinity of dwellings. Nearly all of its food is taken upon the wing, but it occasionally comes to the ground in the manner of the Bluebird for insects. In "Birds of Northeastern Illinois," it is stated that Mr. Rice saw one of these birds plunge repeatedly into a stream in the manner of a Kingfisher. An examination of the stomach of this specimen showed that it had been eating aquatic insects. I have taken from the stomachs of young birds of this species bits of shells of small mollusks *(Sphœrium)*; how they are obtained is unknown to me.

It often nests in orchards, sometimes close to the house, and the solitary trees standing in fields and pastures are very desirable breeding places for it; from these places it has a good chance to watch for passing insects. It would tend to make these and other birds more abundant if more trees were left standing in the cultivated fields, or were planted there.

Dr. Brewer is of the opinion that writers have somewhat exaggerated the

[1] Scale only one-half. [2] Scale only one-fourth.

quarrelsome disposition of this species. According to his observations, Hawks, Owls, Crows, Grackles, Jays and Cuckoos are about the only birds which it regularly attacks. For these it is always on the alert, and with good reason, no doubt. He also states that a pair of these birds once had their nest in an apple tree in which the Baltimore Oriole and the Robin had their nests at the same time, and that the three families appeared to entertain the most amicable relations. My own observations are in harmony with these statements. A pair of Warbling Vireos once had their nest in an oak tree in a pasture which also bore a nest of the Kingbird. The two nests were only four feet apart, and both contained half grown young when the discovery was made.

The only apparently serious objection to this species with which I am acquainted is its destruction of dragon-flies, and of these insects it appears to be very fond. How serious this objection may be, future investigation must decide.

Food: Of twelve specimens examined, four had eaten seventeen beetles; four, four dragon-flies; one, a bee; one, six crane-flies; one, a large moth; one, a butterfly *(Pieris protodice);* and three, a few raspberries.

Bees, the large black gad-fly and other insects (Wilson). Insects, among them bees, and some berries (Cooper). Mostly winged insects, occasionally grasshoppers and bees (Samuels). Dragon-flies are a favorite food; it also eats bees and may-beetles (J. L. Hersey, Am. Nat., III, 437). Of seven stomachs examined, two contained hymenoptera; one, a wasp; five, lepidoptera; two, caterpillars; four, beetles; one, ground-beetles; three, orthoptera; one, crickets; one, locusts; two, grasshoppers; one, a spider; one, a harvest-man; one, wheat; and one, fruit (Forbes). Of the food of two specimens shot in an apple orchard, canker-worms, which infested it, made forty-three per cent., vine-chafers *(Anomala binotata)* seventeen per cent., spring-beetles *(Melanotus)* ten per cent., scavengers twenty per cent., Lampyridæ three per cent., and various hymenoptera seven per cent. (Forbes).

128. Myiarchus crinitus (Linn.), Cab. GREAT CRESTED FLYCATCHER. Group I. Class b.

This species is certainly rare in Central Wisconsin, but is given as a rather common summer resident in Northeastern Illinois, and Dr. Hoy gives it as breeding at Racine. It is said to inhabit damp swampy woods, and to be quarrelsome toward birds smaller than itself.

Food: Bees, and other winged insects until fall, when it eats berries (Wilson). Insects, grapes and berries (De Kay). Winged insects, berries, caterpillars, crickets and grasshoppers (Samuels). Insects as long as they can be obtained, then grapes and several species of berries.

129. Sayiornis Sayi (Bp.), Bd. SAY'S FLYCATCHER. Group II. Class a.

Probably accidental in Wisconsin. Dr. Brewer states that one specimen was obtained by Dr. Hoy near Racine, and sent to Mr. Cassin for identification.

130. Sayiornis fusca (Gm.), Bd. PEWEE; PHŒBE-BIRD. Group I. Class b.

This familiar and confiding species arrives early in April and remains until the beginning of October. During this long stay it leads a busy, useful life, though not one wholly unalloyed with mischief. It is an expert fly-catcher, but, like the Bluebird, marks much of its prey upon the ground, and falls directly upon it. By this habit it is fitted for a wider usefulness and a greater abundance. Its places of nesting — under old sheds, beneath porches and bridges, under the eaves of houses, under slightly projecting ledges, and under overhanging, rocky cliffs — are familiar to many.

How it is imposed upon by the Cowbird has already been told.

Food: Of thirty-seven specimens examined, nine had eaten twenty-seven hymenoptera; four, seven ants; one, a wasp; four, fifteen ichneumon-flies; four, four chrysididæ; twelve, thirty-five lepidoptera; seven, eighteen caterpillars; seven, sixteen moths; one, a butterfly *(Colias philodice)*; fourteen, forty-nine beetles; one, a ground beetle; one, a tiger-beetle; one, a lady-bird *(Coccinella 9-notata)*; two, nine leaf-chafers; one, a leaf-beetle *(Chrysomela ?)*; one, two squash-beetles *(Diabrotica vittata)*; one, two *Diabrotica duodecim-punctata*; one, a curculio; seven, twenty-seven diptera; three, three crane-flies; four, twenty Mucidæ; twelve, seventeen orthoptera, crickets and grasshoppers; one, a spider; three, two hundred and fifty-eight insect eggs; three, four small dragon-flies; one, a caddis-fly; one, a leaf-hopper *(Enchenopa)*; one, a heteropterous insect (one of the *Corisiœ)*; and one, dogwood berries. From the stomach of one Pewee were taken ten ichneumon-flies — among them a *Lampronota varia* and four other species — one large moth, having a body 1.25 of an inch long, four smaller moths, and one caddis-fly. An ichneumon-fly, which another specimen had eaten, belonged to the genus *Comptus (?)*. In the stomachs of six young birds were found fifteen flies *(Mucidœ)*, two hymenopterous insects, two grasshoppers, three crickets, one caterpillar and three moths.

Smilax berries and "bees" (Wilson). Insects in the spring and summer; in the winter, berries of various kinds (Samuels). Of five specimens examined. two had eated hymenoptera; one, lepidoptera; four, beetles; two, diptera; and one, hemiptera (Forbes).

131. Contopus borealis (Sw.), Bd. OLIVE-SIDED FLYCATCHER. Group II. Class a.

Reported to have been quite common at one time near Racine, but later to be quite rare (Hoy). Not an uncommon migrant in Northeastern Illinois. It is a woodland species, and Nuttall found it quarrelsome. I think I observed this species at River Falls, June 2, 1882.

Food: Wasps, bees, and similar insects (Brewer). One specimen examined had eaten wasps (Forbes).

132. Contopus virens (Linn.), Cab. WOOD PEWEE. Group I. Class b.

No Flycatcher is so abundant in Central Wisconsin as this species; even in the deep woods of Clark and Chippewa counties its prolonged whistle proclaims its abundance there. With us it is as yet a retiring species, keeping closely within the woods and groves, or, at most, venturing upon their borders. At Ithaca, N. Y., however, it is becoming much more familiar. There it breeds in orchards, about dwellings and in the city. According to Nuttall, it displays at times a tyrannical disposition. So far as I have observed, it is perfectly peaceable and allows other birds to pass it unmolested. Nearly all of its food is taken upon the wing, and when in the woods it usually selects some small opening between the tree-tops for its hunting-grounds.

Food: Of forty-one specimens examined, eighteen had eaten sixty-six small beetles, among them seven metallic-green beetles and several lamellicorns; fourteen, forty-one dipterous insects, among them twelve large crane-flies; two, a butterfly each, one of which was an *Argynnis;* nine, thirteen small dragon-flies; eleven, twenty-nine hymenopterous insects, among them twelve ants, an ichneumon-fly (?) and one of the *Augochlora (?);* one, a heteropterous insect *(Corisicæ);* one, a moth; one, a grasshopper; and one, a larve of a saw-fly (?).

I have seen one Wood Pewee capture and feed to its young, which had recently left the nest, forty-one insects in the course of forty-five minutes. Several of these insects were moths.

Winged insects (Wilson). Insects caught on the wing (De Kay). Of three specimens examined, one had eaten hymenoptera; one, caterpillars; two, beetles; one diptera; and one, dragon-flies (Forbes).

133. EMPIDONAX ACADICUS (GM.), BD. **ACADIAN FLYCATCHER.** GROUP II. CLASS a.

It appears doubtful whether this species has ever been taken in Wisconsin. The fact that Wilson, Audubon and Nuttall appear to have mistaken other birds for this, may perhaps be a sufficient explanation of its reported occurrence.

134. EMPIDONAX TRAILLI (AUD.), BD. **TRAILL'S FLYCATCHER.** GROUP II. CLASS b.

A summer resident, but uncommon. It occurs in woodlands and retired groves. At Waupaca one was obtained in a small tamarack swamp early in July, where, from its great excitement on my approach, I suspect that it had a nest in the vicinity at the time.

Food: One bird examined had in its stomach two small dragon-flies, one ichneumon-fly and two small beetles. Two others had eaten small beetles and dipterous insects, and one, small berries.

135. EMPIDONAX MINIMUS, BD. **LEAST FLYCATCHER.** GROUP I. CLASS b.

This species is the most abundant and the most familiar of our Empidonaces. It arrives about the middle of May and departs late in September. The borders of woods, groves, and hedges along fences are its usual haunts. In the East it has become much more familiar than with us. There it frequents orchards and gardens, and has been known to nest in a clump of honeysuckles on the corner of a piazza. It appears to live amicably with other birds, and to have strong attachments for nesting-places once chosen. On the whole, it appears to be a more desirable bird to have in orchards and about dwellings than either the Kingbird or the Purple Martin. Twice I have found the young fledglings of this species being fed by their parents late in July, and once early in August, from which we may infer that it rears two broods each season with us.

Food: Of twenty-three specimens examined, ten had eaten thirty beetles — among them two squash-beetles *(Diabrotica vittata)*, a lady-bird and two weevils; four, eighteen dipterous insects; one, two small heteropterous insects, equal in size to chinch-bugs; four, thirty-nine hymenopterous insects — two small ichneumon-flies and thirty-seven winged ants; two, three caterpillars; one, a moth; two, four small dragon-flies; and one, a small spider.

Canker-worm (Maynard). Of ten specimens examined by Forbes, two had eaten hymenoptera; two, lepidoptera; eight, beetles — ground-beetles, gyrinidæ, curculios and hydrophilidæ; one, hemiptera; one, locusts; one, spiders; and two, blackberries.

136. EMPIDONAX FLAVIVENTRIS, BD. **YELLOW-BELLIED FLYCATCHER.**
GROUP II. CLASS a.

A single specimen of this species was obtained at Worcester, July 26, 1876. Dr. Hoy identified it at Racine, during the summer of 1869. Mr. Nelson speaks of it as a common migrant in Northeastern Illinois. None of the fragments of five insects found in its stomach were identified.

FAMILY CAPRIMULGIDÆ: GOATSUCKERS.

FIG. 131.

NIGHT-HAWK (*Chordeiles popetue*). After Bd., Br. and Ridg.

Tabular Summary of Economic Relations showing the number of specimens eating animal and vegetable food, and the number of insects taken from the stomachs, classified as to economic relations under the heads Beneficial, Detrimental and Unknown Relations.

NUMBER AND NAME OF SPECIMENS EXAMINED.			CLASSIFICATION OF FOOD.		RATIOS REPRESENTED BY LINES.
Of two Whippoorwills examined	2	Contained		Animal food	
				Vegetal food	
				Beneficial	
	2		10	Detrimental	
	2		14	Unknown	
Of five Night-hawks examined	5	Contained		Animal food	
				Vegetal food	
	1		1	Beneficial	
	2		8	Detrimental	
	5		83	Unknown	

Table showing the number and kinds of insects eaten by the Goatsuckers.

Number and Name of Specimens Examined.			Classification of Food.		Ratios Represented by Lines.
Of two Whippoorwills examined............	2	Contained	10	Moths.............	
	2		14	Beetles...........	
	2		24	Adult forms......	
	1		162	Insect eggs [1]......	
Of five Night-hawks examined............	1	Contained	3	Moths.............	
	3		19	Beetles...........	
	2		23	Heteroptera......	
	1		5	Grasshoppers.....	
	2		4	Neuroptera.......	
	5		94	Adult forms......	

137. Antrostomus vociferus (Wils.), Bp. **WHIPPOORWILL; NIGHT-JAR.** Group I. Class a.

This very useful nocturnal bird is a common summer resident, but its breeding habits and its fondness for secluded retreats during the day appear to preclude it from maintaining abundant numbers in thickly settled districts.

Food: Its food, as indicated by two specimens, appears to consist largely of moths, some of which have an extent of wing of two inches. It also eats many beetles, among which are click-beetles and small lamellicorns.

Large moths, ants, grasshoppers, and such insects as frequent old logs (Wilson). Exclusively winged insects (De Kay). Almost entirely nocturnal lepidoptera (Samuels). Ants, large moths and beetles (Audubon).

138. Chordeiles popetue (V.), Bd. **NIGHT-HAWK; BULL-BAT.** Group I. Class b.

The Night-hawk, by many supposed to be the Whippoorwill, seems gradually growing less numerous. Where, twenty years ago, it was common to see thousands of these birds towards sunset, pursuing insects low over clover-fields in swift and tangled curves, now it is rare to see more than twenty thus engaged. At Ithaca, N. Y., both it and the Whippoorwill are uncommon birds. Dr. Brewer, however, states that it is becoming more numerous about the larger Eastern cities, and that in Boston it has taken to breeding on the flat Mansard roofs of buildings. It is exceedingly destructive to insects, and is especially active during cloudy weather and in the morning and evening twilights. It is very desirable that it should maintain an ample abundance. This is the more desirable since it frequents, so much, cultivated fields. The sportsmen of some of our cities are in the habit of going outside of the city limits toward sunset, and practicing shooting these birds on the wing, preparatory to duck-shooting in the fall. The services of these birds are too valuable to justify such a practice.

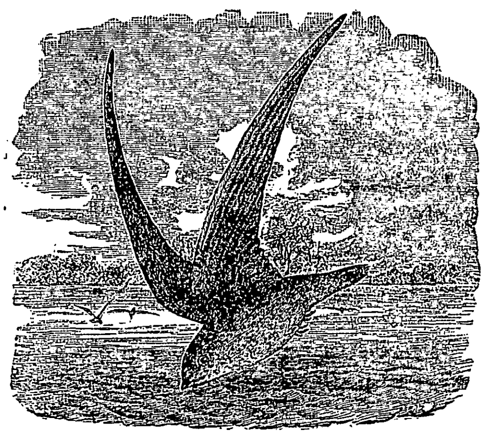
[1] Scale only one-third.

Food: In the stomachs of four specimens were found may-flies, a large dragon-fly, beetles, water-boatmen, scorpion-bugs, berry-bug-like heteroptera and grass-hoppers. The material taken from the stomach of one specimen weighed nine grammes. From the stomach of another were taken five small grasshoppers, eight larvæ of hemipterous insects *(Corisiæ)*, and ten scorpion-bugs, none of them less than three-fourths of an inch long.

Wasps, flies, beetles and other insects. Nearly a snuff-box full were taken from the stomach of one (Wilson). Winged insects (De Kay). Beetles, moths, caterpillars, crickets and grasshoppers (Audubon).

FAMILY CYPSELIDÆ: SWIFTS.

FIG. 132.



CHIMNEY SWIFT (*Chætura pelasgica*). After Baird, Brewer and Ridgway.

139. CHÆTURA PELASGICA (LINN.), STEPH. **CHIMNEY SWIFT.** GROUP II. CLASS a.

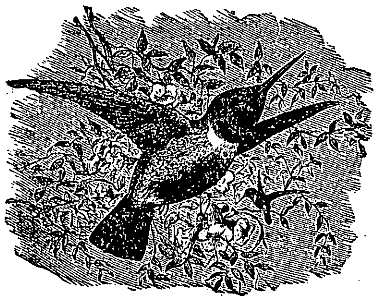
The Chimney Swift, in July, 1876, was much more abundant in the northern unsettled portion of the state than I ever saw it in the southern. There it doubtless follows its primitive habit of breeding in hollow trees. We have no bird so incessantly on the wing or so dexterous and swift in its aerial movements. While it is abroad at all times of the day, it is out earlier in the morning and later in the evening than the Night-hawk; and it is said to feed its young at intervals during the whole night. Such traits as these appear to make this a very valuable bird; and when we know more definitely than we do now in regard to its food, it may be found advisable to erect cheap hollow towers for it to breed in, in order that it may become more abundant away from cities.

Food: Of three specimens examined, two had nothing in their stomachs, and the other stomach contained two flies.

Of three specimens examined by Prof. Forbes, three had eaten hymenoptera; two, ants; one, lepidoptera, adults; one, beetles; one, ground-beetles; one, rove-beetles; one, plant-beetles; two, dipterous insects; two, hemiptera; and one, spiders.

Family TROCHILIDÆ: Humming-birds.

Fig. 133.



Black-chinned Humming-bird (Not found in Wisconsin). After B., B. and R.

140. Trochilus colubris, Linn. RUBY-THROATED HUMMING-BIRD.
Group I. Class b.

This exquisite little species is very common with us, and, according to my observations, quite as much a bird of the woodlands as of open, sunny places, where flowers abound.

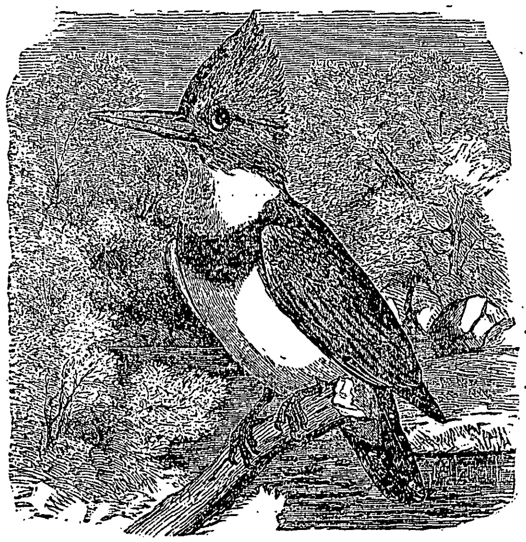
I have met with it commonly in the heart of the heaviest timber of Jefferson county, and among the deep woods in the northern portion of the state. In these places it moves high among the outer branches of the trees, searching for insects upon the leaves, as it does for honey and insects within the corollas of flowers. The wooded banks of streams, willow and alder thickets, hazel patches and the depths of tamarack swamps are also visited by it. They appear to be pugnacious and quarrelsome among themselves, and the little Black-capped Chickadee retreats before these emerald pigmies without the slightest resistance, as if it had long ago acknowledged their superiority.

Food: From the stomachs of five specimens were taken three small spiders, one aphis, and one small chalcidian (?), together with twelve other insects.

Honey of flowers, small beetles and winged insects (Wilson). Principally insects (Samuels). Sweet juice of flowers (De Kay). Small beetles, spiders and winged insects, most of which are captured in the corolla of flowers (J. M. Wheaton).

FAMILY ALCEDINIDÆ: KINGFISHERS.

FIG. 134.



BELTED KINGFISHER (*Ceryle alcyon*). After Bd., Br. and Ridg.

141. CERYLE ALCYON (LINN.), BOIS. BELTED KINGFISHER. GROUP II. CLASS b.

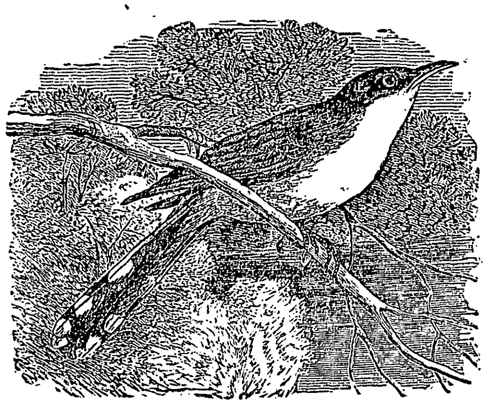
A common summer resident, frequenting all our streams as long as they are free from ice.

Food: Six specimens examined had eaten only fish.

Fish (Wilson, Cooper). Mainly small fish (De Kay). Fish; occasionally a frog or meadow-mouse (Samuels).

FAMILY CUCULIDÆ: CUCKOOS.

FIG. 135.



YELLOW-BILLED CUCKOO (*Coccygus Americanus*). After Bd., Br. and Ridg.

Tabular Summary of Economic Relations showing the number of specimens eating animal and vegetable food, and the number of insects and spiders taken from the stomachs, classified as to economic relations under the heads Beneficial, Detrimental and Unknown Relations.

Number and Name of Specimens Examined.				Classification of Food.	Ratios Represented by Lines.
Of thirteen Black-billed Cuckoos examined..	13	Contained		Animal food......	
				Vegetal food	
	3		3	Beneficial	
	11		93	Detrimental	
	4		31	Unknown.........	
One Yellow-billed Cuckoo examined...	1	Contained		Animal food......	
				Vegetal food	
				Beneficial	
	1		9	Detrimental......	
				Unknown.........	

Table showing the number and kinds of insects and spiders eaten by the Cuckoos.

Number and Name of Specimens Examined.				Classification of Food.	Ratios Represented by Lines.
Of thirteen Black-billed Cuckoos examined..	2	Contained	13	Hymenoptera	
	9		68	Caterpillars	
	2		10	Beetles	
	6		26	Orthoptera	
	2		2	Harvest-men	
	10		53	Adult forms	
	10		70	Larvæ...........	
One Yellow-billed Cuckoo examined...	1	Contained	9	Caterpillars	
				Adult forms	
	1		9	Larvæ...........	

142. Coccygus erythrophthalmus (Wils.), Bd. BLACK-BILLED CUCKOO.

Group II. Class b.

The Cuckoo is a common summer resident, arriving early in May and withdrawing again toward the last of September. Its usual haunts are the interior of woods, groves and the wooded banks of streams. Frequently it visits the grassy swales in marshes where small clumps of willows abound, and during the spring it may be seen in orchards and villages. I know of no insectivorous bird so excessively voracious as it, unless it be the next species. The amount of material which may be found in its stomach at one time seems out of all proportion to its size and activity. I have taken thirty caterpillars *(Dryocampa senatoria)*, three-fourths of an inch long, from the stomach of one of these birds, and six large grasshoppers from that of another. That which gives this species a special value as an insect-destroyer is its fondness for those hairy, spiney and otherwise protected caterpillars not so generally preyed upon by other birds; and it is this trait, together with the fact that it appears to refuse all vegetable food, that goes far toward compensating for what injury it may do in plundering the nests of other birds. It is, therefore, much worthier of encouragement and protection than either the Blue Jay or the Crow.

Food: Of thirteen specimens examined, nine had eaten caterpillars — among them were eight of the fall web-worms *(Hyphantria textor)*, thirty-three of the oak-caterpillars *(Dryocampa senatoria)*, one of the Io caterpillars *(Saturnia Io)*, six of the antiopa caterpillars *(Vanessa antiopa)*, and one of the caterpillars of the archippus butterfly *(Danais archippus)*. One contained five larvæ of the large saw-fly *(Cymbex Americana)*; six, twenty-five grasshoppers; one, a cricket; two, ten beetles; and two, two harvest-men. These observations, it will be seen, differ quite markedly from those given below.

Small mollusks, etc. (Wilson). Minute mollusks and animals, fruits, berries, etc. (De Kay). Insects and their larvæ, small fruits, and the eggs and young of small birds (Samuels). Principally fresh-water mollusks, fish and aquatic larvæ (Audubon). Tent-caterpillar (A. J. Cook, Am. Nat., VIII, 368). Eggs of the Solitary Vireo (Brewer). One specimen had eaten beetles (Forbes).

143. Coccygus Americanus (Linn.), Bp. YELLOW-BILLED CUCKOO.
Group II. Class b.

This species is a summer resident, but not common. I have seen but one specimen. Its habits are similar to those of the last species, and, economically, probably it ranks with it. In speaking of its relations to other birds, Dr. Coues says: "Although not parasites, like the European species, devoid of parental instinct, they have their bad traits, being even worse enemies of various small, gentle birds; for they are abandoned thieves, as wicked as Jays in this respect, continually robbing birds of their eggs, and even, it is said, devouring the helpless nestlings.

Food: The specimen which I examined had its stomach crammed almost to overflowing with a large, black, slightly hairy caterpillar, with a faint dorsal stripe of white, which is often so abundant on black walnut trees as to completely defoliate them.

Caterpillars, particularly those which infest apple trees, and the eggs of other birds (Wilson). Insects, and, at times, small birds and their eggs (Cooper). Hairy caterpillars, large beetles, berries, grapes, and occasionally the eggs of small birds (De Kay). Caterpillars, and other larvæ destructive to fruit and shade trees (Samuels). Caterpillars, butterflies, beetles, wood mollusks, mulberries, grapes, and the eggs of small birds (Audubon). Various large winged insects, various grubs, wood-inhabiting mollusks, different kinds of berries and other soft fruits, and the eggs of small birds (Coues). Of four specimens examined, three had eaten caterpillars; one, beetles; two, harvest-men and vegetable substance (Forbes).

FAMILY **PICIDÆ**: WOODPECKERS.

FIG. 126.

YELLOW-BELLIED WOODPECKER (*Sphyropicus varius*). After B., B. and B.

Tabular Summary of Economic Relations showing the number of specimens eating animal and vegetable food, and the number of insects, spiders and snails taken from the stomachs, classified as to Economic Relations under the heads Beneficial, Detrimental and Unknown Relations.

Number and Name of Specimens Examined.				Classification of Food.	Ratios Represented by Lines.
One Pileated Woodpecker examined...	1	Contained		Animal food......	
	1			Vegetal food	
				Beneficial	
	9			Detrimental......	
	1		18	Unknown.........	
Of twenty-one Hairy Woodpeckers examined	21	Contained		Animal food......	
	3			Vegetal food	
				Beneficial	
	16		82	Detrimental......	
	12		121	Unknown.........	
Of seventeen Downy Woodpeckers examined	16	Contained		Animal food	
	6			Vegetal food	
	1		1	Beneficial	
	7		133	Detrimental.	
	13		48	Unknown.........	

Tabular Summary of Economic Relations of Woodpeckers — continued.

Number and Name of Specimens Examined.			Classification of Food.		Ratios Represented by Lines.
Of thirty Yellow-bellied Woodpeckers examined	27	Contained		Animal food	
	9			Vegetal food	
	1		1	Beneficial	
	4		4	Detrimental	
	26		265	Unknown.........	
Of eighteen Red-headed Woodpeckers examined.......... ...	16	Contained		Animal food	
	14			Vegetal food.....	
	2		2	Beneficial	
	6		8	Detrimental	
	15		66	Unknown.........	
Of twenty-two Golden-winged Woodpeckers examined	20	Contained		Animal food	
	7			Vegetal food	
	2		18	Beneficial	
	8		127	Detrimental.. ...	
	19		1383	Unknown.........	

Table showing the kinds and number of insects, spiders and snails eaten by the Woodpeckers.

Number and Name of Specimens Examined.			Classification of Food.		Ratios Represented by Lines.
One Pileated Woodpecker examined....	1	Contained	18	Ants..............	
	1		18	Adult forms......	
				Larvæ.............	
Of seventeen Downy Woodpeckers examined	2	Contained	7	Ants..............	
	2		3	Caterpillars	
	1		1	Fly	
	9		25	Coleoptera	
	1		110	Hemiptera	
	1		1	Spider	
	10		141	Adult forms	
	14		40	Larvæ......... ..	
	1		1	Pupa	

Table showing the kinds and number of insects, spiders and snails eaten by the Woodpeckers — continued.

Number and Name of Specimens Examined.			Classification of Food.		Ratios Represented by Lines.
Of twenty-one Hairy Woodpeckers examined	10	Contained	105	Ants	
	4		15	Lepidoptera	
	14		61	Coleoptera	
	1		1	Snail	
	12		121	Adult forms	
	16		82	Larvæ	
	2		9	Ootheca (Blatta)	
Of four Black-backed Three-toed Woodpeckers examined	4	Contained	38	Wood-borers	
				Adult forms	
	4		38	Larvæ	
Of thirty Yellow-bellied Woodpeckers examined	26	Contained	242	Ants	
	1		1	Caterpillar	
	1		1	Tipulid	
	5		22	Beetles	
	2		2	Grasshoppers	
	1		1	Spider	
	27		269	Adult forms	
	1		1	Larve	
Of eighteen Red-headed Woodpeckers examined	5	Contained	18	Ants	
	1		1	Caterpillar	
	12		42	Beetles	
	1		1	Heteroptera	
	3		4	Orthoptera	
	15		95	Adult forms	
	1		1	Larve	
Of twenty-two Golden-winged Woodpeckers examined	17	Contained	1059	Ants [1]	
	4		4	Caterpillars	
	4		27	Beetles	
	2		110	Chinch-bugs	
	19		1240	Adult forms [1]	
	5		273	Ant pupæ [1]	
	2		11	Moth pupæ	
	4		4	Larvæ	

[1] Scale only one-half.

144. HYLOTOMUS PILEATUS (LINN.), BD. **PILEATED WOODPECKER.** GROUP I. CLASS b.

This gigantic Woodpecker is a common resident in the pineries, where it frequents especially the windfall tracts abounding in old dead trees. In the character of its food it appears to be most closely allied to the Yellow-bellied Woodpecker, seldom drilling into hard wood for wood-borers. Some of its chiselings, however, into soft decaying timber for ants, and doubtless grubs, are often on a gigantic scale, furrows six inches wide and deep and twelve feet in length being commonly made by it in standing stubs.

Food: A specimen taken on the Flambeau river had its stomach distended with large black ants, small beetles, and some vegetable material.

Insects and larvæ which it takes from decaying pines and other trees. Said also to eat corn, but this is doubtful (Wilson). Insects which it takes from beneath the bark of trees; also corn, chestnuts, acorns, and fruits (De Kay). Borers, black ants, beech-nuts and Indian corn (Samuels).

145. PICUS VILLOSUS, LINN. **HAIRY WOODPECKER.** GROUP I. CLASS b.

This species is a common resident, breeding, as yet, mostly in woodlands and forests. Early in the spring and after the breeding season, it pays frequent visits to orchards, nurseries and villages, where, in the southern portion of the state, it performs a work in which but one other bird, the Downy Woodpecker, takes part, at least to any notable extent. This work is that of destroying wood-boring larvæ, and these pests furnish it nearly one-half of its food both winter and summer. Another trait which gives special importance to its services is that of hammering on the loose and shaggy bark of trees for the purpose of startling the moths and other insects that have hidden beneath it; when they take wing, it pursues to their next place of lighting and captures them. I have seen this bird repeatedly capture moths in this way. Practically, therefore, it, and doubtless all of the Woodpeckers, to some extent, perform in part the work of a nocturnal fly-catcher.

It has been known to nest in orchards and in fence posts, but it seems destined to become less and less numerous as its natural breeding places are destroyed. It enjoys, however, so wide a range in the variety of its food, that, could its breeding habits be changed, it would probably be able to maintain an ample abundance when properly protected.

Food: Of twenty-one specimens examined, eleven had eaten fifty-two wood-boring larvæ; five, thirteen geometrid caterpillars; ten, one hundred and five ants; six, ten beetles; two, two cockroaches; two, nine oötheca of cockroaches; two, two moths; one, a small snail; one, green corn; one, a wild cherry; and one, red elder berries. In the stomach of one of these was a little woody fiber, but this was probably swallowed unintentionally. One of the above birds had in its stomach eleven wood-boring larvæ (Lamides?) and twelve geometers; another, thirteen larvæ of long-horn beetles and four cockroach oötheca; another, nine wood-boring larvæ; and two others together had three wood-boring larvæ, and nine larvæ not coleopterous.

The apple-borer and other larvæ, insects and their eggs (Wilson). Insects and their larvæ, which infest trees (De Kay). Eggs and larvæ of injurious insects which burrow in the wood of orchard and forest trees; it also eats small fruits and berries, and some assert that it eats the buds and blossoms of trees (Samuels). One specimen had in its stomach hymenoptera (Forbes). Cecropia cocoons punctured by them (Am. Nat., Vol. XV, p. 241, F. M. Webster).

146. Picus pubescens, Linn. **DOWNY WOODPECKER.** Group I. Class b.

This species, like the last, is a common resident, but not as abundant as that bird, and its habits resemble those of its large cousin as closely as does its dress; it is, however, a more frequent visitor to orchards. The statements in regard to its probing the bark of young smooth trees to suck the sap appear to be unfounded.

Food: Of seventeen specimens examined, seven had eaten twenty wood-boring grubs; nine, twenty other larvæ, among them three caterpillars; two, seven ants; three, four beetles; one, a chrysalid; one, a fly; one, one hundred and ten small heteropterous insects, about the size of chinch-bugs; one, a spider; one, acorns; and one, small seeds. In the stomachs of four was found a little vegetable fiber, but this was probably taken incidentally, as in each case the bird had eaten wood-boring larvæ. From the stomach of each of two of these birds were taken eight large wood-boring grubs.

Of all our Woodpeckers, none relieve our orchards of so many vermin (Wilson). Insects and their larvæ, grapes and poke-berries (De Kay). In summer, insects and their larvæ; in autumn, fruits of various kinds, among them grapes and poke-berries (Audubon). They are very industrious, and particularly fond of boring the bark of apple trees for insects (Brewer). Wood, hymenoptera, lepidoptera, hemiptera and spiders. Three specimens (Forbes).

147. Picoides arcticus (Sw.), Gray. **BLACK-BACKED THREE-TOED WOODPECKER.** Group I. Class a.

This Woodpecker is common in the northern portion of the state during the fall and winter, and probably resident to some extent during the summer, and I have taken it at Worcester in July. It rarely moves south in the winter beyond the heavy timber line. In the pineries its services must be very great, as it appears to feed almost exclusively upon wood-boring larvæ.

Food: Four specimens examined had eaten respectively, thirteen, twelve, seven, and six larvæ of long-horn beetles. Nothing else was found in the stomachs of these birds.

Wood-boring insects (De Kay). Besides insects they eat berries and small fruits (Audubon).

148. Picoides Americanus, Brehm. **BANDED THREE-TOED WOODPECKER.** Group II. Class a.

This species is introduced in the present connection on the authority of Dr. Brewer, who says, in Birds of North America: "They occur also in Southern Wisconsin, in winter, where Mr. Kumlien has several times in successive winters obtained single individuals."

149. Sphyropicus varius (Linn.), Bd. **YELLOW-BELLIED WOODPECKER.** Group II. Class a.

This species is an abundant summer resident in most suitable localities, but during the breeding season it is confined quite exclusively to forests and the deeper woodlands. At other times, between the last of March and the first of October, it frequents, besides its breeding haunts, more open woods, groves, orchards and villages. Like the preceding species, it is seldom seen upon the ground; but, unlike them, it rarely feeds upon wood-boring larvæ. My own notes appear to indicate, however, that it is quite as insectivorous as they are. "The peculiar formation of its tongue," upon which some lay so much stress in deciding its ability to destroy insects, it should be observed, only disqualifies it for obtaining wood-boring larvæ, and not for other insects.

That the Yellow-bellied Woodpecker does sometimes suck the sap of trees is rendered probable by an instance which came under my observation April 22, 1878. On this date one of these birds was observed at work on a small pignut hickory standing on the campus of Cornell University. Two horizontal series of holes had been recently pierced through the bark, one above the other, but on nearly opposite sides of the tree, and separated by a distance of about four feet. The Woodpecker was seen to pass along each of these series of holes from one end to the other, deliberately, but not forcibly, thrusting its bill into each successive perforation, as if removing something from it. When it had visited every hole it flew to another tree of the same kind standing near by; there it was seen to perform the same operation upon a similar single series of holes. After loitering about the second tree for two or three minutes it returned to the first and repeated the action already described, when, after a short interval, it repeated its visit to the holes on the second tree. On returning from dinner, about twenty minutes afterwards, I found the Woodpecker still at work, and the sap was running down the trunk of the tree from one of the series of holes, wetting it to a distance of a foot below the perforations. On examining these holes they were found to extend through the bark and into the wood to a depth of about an eighth of an inch, and to have a diameter but little greater than that of the bird's bill near its base; toward the bottom they narrowed greatly along their vertical axes and widened considerably along their horizontal axes, so as, at the bottom, to be narrowly oblong — so narrow, indeed, as, in most cases, to be mere incisions through the inner bark. I have examined a large number of the holes made by this species in the bark of the apple and maple, and wherever there has been a series of holes the series has always been horizontal, and the holes have conformed to the description of those above, except that often the wood was merely indented by a close series of punctures. These holes have always been in sound wood, and I have detected no evidence that any insect had been at work beneath the bark at the points where the perforations were made; and the holes have all been so narrow where they have passed through the inner bark, that it does not appear probable that the inner bark could have been the object for which these punctures were made.

This species is, however, very generally accused of feeding extensively upon the inner bark of trees. In regard to this point Dr. Brewer says: "In the spring of the year these birds prey largely upon the inner bark of trees, and where they exist in great numbers they often do a great deal of mischief. In April, 1868, I visited gardens in Racine, in company with Dr. Hoy, where these Woodpeckers had every successive spring committed their ravages, and was eye-witness to their performance. Their punctures were unlike those of the *pubescens*, being much deeper, penetrating the inner bark, and, being repeated in close proximity, the bark becomes entirely stripped off after a while, often resulting in the girdling and complete destruction of the tree. In one garden of some considerable size, all the mountain ash and white pine trees had thus been killed. In prairie countries, where trees are deficient and their cultivation both important and attended with difficulty, these birds prove a great pest, and in a few hours may destroy the labor of many years." Dr. Coues, in his "Key to North American Birds," in speaking of the genus to which this species belongs, says: "Birds of this genus feed much upon fruits, as well as insects, and also, it would seem, upon soft inner bark (cambium); they injure fruit trees by stripping off the bark, sometimes in large areas, instead of simply boring holes."

I have taken the inner bark of trees, or some material which closely resembled it, from the stomachs of six out of thirty specimens which I have examined; three of these specimens were taken in orchards in April, one in August and two in September. The last three were obtained in heavy timber. It should be remarked, however, that in neither of these cases was there more than a trifle of this material; so small, indeed, were the amounts, that they can hardly be regarded as proving much, especially if it is true that these birds are sap-suckers, for it might readily have been taken unintentionally. In cases where the bark is stripped off by these birds in large areas, there would seem but little doubt as to the object of the birds; but in the case of the punctures which these birds usually make, it does not appear that they offer the best way of getting at the inner bark, and the process necessitates the removal of a very large amount of bark in order to furnish even a meager meal for so large a bird. The horizontal series of holes, too, would furnish the readiest means of obtaining sap, while these do not appear to facilitate especially the gathering of the inner bark. No instance in which the bark of trees has been stripped off by these birds has come under my observation, nor do I know of an instance where their puncturings of the bark have been fatal or appreciably injurious to the tree. Their case must stand open at present for a closer investigation.

Food: Of thirty specimens examined, twenty-six had eaten two hundred and forty-two ants; five, twenty-two beetles; one, a crane-fly; two, two grasshoppers; one, a caterpillar; one, wild grapes; one, dogwood berries; one, small seeds; and six had in their stomachs a few bits of fibrous material. Of those birds which had eaten ants, fifteen had nothing else in their stomachs.

Principally insects, among them beetles (Wilson). Insects, worms and berries (De Kay). Wood-worms, beetles, grapes and various berries (Audubon). Several alcoholic specimens sent to the Smithsonian Institution by Dr. Hoy, from Racine, were examined by Prof. S. F. Baird, who found in their stomachs, beetles, larvæ and boring beetles, ants, and fragments of the inner bark of the apple tree (Dr. Bryant, Boston Soc. Nat. Hist., X, 91). Of four specimens, two had eaten beetles; one, hemiptera; and three, wood (Forbes). Sucks sap from the white beach (Am. Nat., Vol. XV, p. 810, H. C. Bumps).

150. Centurus carolinus (Linn.), Bp. RED-BELLIED WOODPECKER. Group I. Class b.

This rather southern species is uncommon in Wisconsin. I have taken but a single specimen, in September, 1876. Wilson states that many of the young which leave the nest before they are able to fly, and climb to the top of the trees, are killed by Hawks.

Food: The single specimen examined had in its stomach small fragments of beetles and pieces of acorns, corn, insects and Indian pepper (Wilson).

151. Melanerpes erythrocephalus (Linn.), Sw. RED-HEADED WOODPECKER. Group II. Class c.

This species is an abundant summer resident in openings, and in thickly settled heavy timbered districts. It is a frequent visitor to orchards and cultivated fields, but is only occasionally seen on the ground. Often it sits upon a fence post and watches for passing insects, which it takes upon the wing in the manner of the Bluebird. So far as I have observed, it is not destructive to wood-boring larvæ, and although it feeds extensively upon insects, other materials furnish it with much of its food. There are some records against it which awaken grave apprehensions as to its usefulness. Audubon accuses it of sucking the eggs of Bluebirds, Martins and Pigeons; and in the American Naturalist (Vol. XI, p. 308) Mr. Charles Aldrich has a note accusing the Red-headed Woodpecker of killing very young Cayuga Ducks. It kills the ducklings by a single blow upon the head and then eats the brains. As this Woodpecker performs no work in the destruction of insects peculiar to itself, and as it is somewhat destructive of grains and fruits, its depredations upon small birds must be very limited indeed to warrant any encouragement being extended to it.

Food: Of eighteen specimens examined, twelve had eaten beetles, among them two long-horns, one click-beetle, one common beetle *(Silpha peltata)*, and one ground-beetle; one, a grasshopper; two, three crickets; one, a caterpillar *(Edema albifrons)*; three, apples; two, wild black cherries; and one, corn.

Cherries, pears, apples, berries of sour gum, corn in the milk, wood-borers, bugs, caterpillars and other insects (Wilson). Apples, pears, cherries, Indian corn in the milk, and insects which infest decaying trees (De Kay). It is more fond of berries than most of its relatives (Samuels). Cherries, apples, pears, peaches, figs, mulberries, and corn; it sucks the eggs of Bluebirds, Martins and Pigeons (Audubon). Sap of the sugar maple (C. A. White, Am. Nat., VII, 496). Young Cayuga Ducks (Charles Aldrich, Am. Nat., XI, 308). Corn from the barnyard, and grasshoppers (Am. Nat., Vol. XIII, p. 522, C. Aldrich). Beetles (Cetoniidæ), seeds of weeds and other vegetable matter (Forbes).

152. Colaptes auratus (Linn.), Sw. GOLDEN-WINGED WOODPECKER. Group II. Class a.

This species is the most abundant and the most terrestrial of our Woodpeckers, and it is a more frequent visitor to prairies than any of its allies. Open fields, pastures and meadows are its favorite resorts, and it is only during the migrations that it is at all common in heavy timber away from cultivated fields. Like the Robin, it obtains its food both upon and beneath the surface of the ground. It is especially fond of ants, and often tears open their hills to obtain them; and it searches much among the fallen leaves and mould in groves for chrysalids and insects in other stages. Like the last species, it does not appear to be destructive to wood-boring larvæ. Ants appear to form the greater part of its food, but it will be seen that it is quite destructive to some of the ground-beetles, usually regarded as beneficial.

The habits of ants, as to their economic relations, have been so little investigated that it is difficult to state whether a bird which feeds largely upon them renders a service or an injury. The injury which ants sometimes do to ripe pulpy fruits, their protection to aphidæ by warding off their enemies, and their obstructions in the way of ant-hills which they often build in damp meadows, are bad traits, but lead to no very marked evil consequences. Some of the leaf-cutting ants are undoubtedly injurious. On the other hand, the fact that ants are often seen dragging about larvæ and various forms of insects which they sometimes carry into their homes, suggests that they may be quite destructive to insects, or scavengers at least. The occurrence of bits of egg-shell in the stomach of one of these birds suggests that it may be guilty of sucking the eggs of other birds.

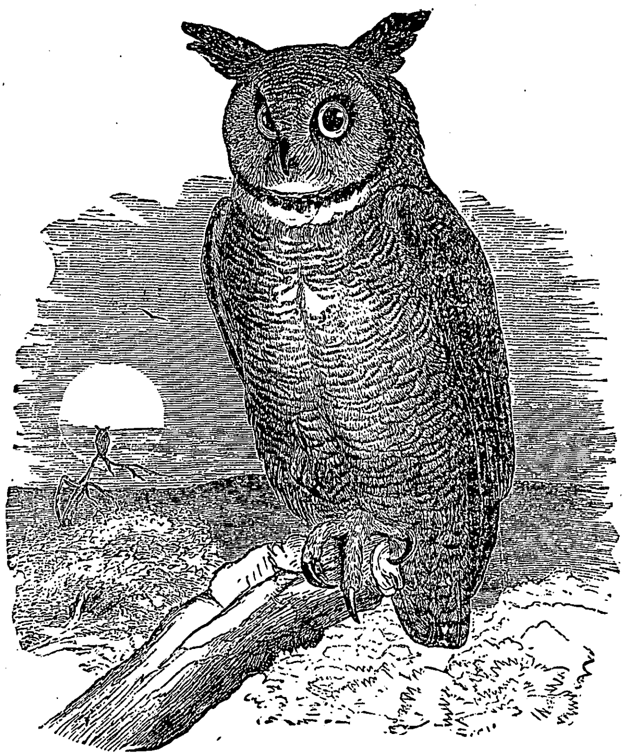
Food: Of twenty-two specimens examined, seventeen had eaten 1,059 ants; five, 278 ant pupæ; four, 27 beetles — among them eighteen ground-beetles

(Harpelini), and a click-beetle; four, four caterpillars; two, chinch-bugs; two, eleven chrysalids of *Dryocampa senatoria* (?); one, a wasp; two, cherries; one, grapes; one, acorns; and one, elder berries. Several pieces of egg-shell were taken from the stomach of one specimen. Among those which had eaten ants, four had eaten respectively 252, 220, 200 and 162 of these insects. The stomachs of those which had eaten chinch-bugs contained thirty-six and seventy-four each. In the stomach of one which had eaten beetles there were eleven ground-beetles (*Anisodactylus*).

Wood-lice, ants and their pupæ and larvæ; cherries and berries of sour gum (Wilson). Ants, caterpillars, beetles, various fruits and corn (Audubon). Insects, berries and grains (Samuels). Of eight specimens examined by Prof. Forbes, all had eaten both wasps and ants.

FAMILY STRIGIDÆ: OWLS.

FIG. 137.



GREAT HORNED OWL (*Bubo Virginianus*). After Bd., Br. and Ridg.

153. ALUCO FLAMMEUS PRATINCOLA (BP.), COUES. **AMERICAN BARN OWL.**
GROUP II. CLASS c.

This species appears to be a rare bird in all the Northern States east of the Rocky Mountains, but farther south it is more abundant. Dr. Hoy records it as occurring near Racine.

Far too little is yet definitely known in regard to the real economic relations of nearly all birds of prey to satisfactorily determine whether they render more of service than of injury. In the "*Report on the practicability of establishing a close time for the protection of Indigenous Animals*," there is no doubt expressed in regard to the great utility of Owls, it being there affirmed that these birds are of the greatest use to the agriculturist in destroying the small mammals which injure his crops. However serviceable Owls may be to the agriculturist in England in destroying noxious mammals, the evidence in regard to the food of the Little Barn Owl, as determined by Dr. Altum, indicates that it is nearly as destructive to useful animals as it is to those which are detrimental. It will be seen that of the remains of 2,562 small animals discovered in the pellets which Dr. Altum examined, there were the remains of 1,204 Bats, Shrews, Moles and birds, all of which are insectivorous, and, therefore, presumably beneficial — and especially so since the mammals are nocturnal. In view of the fact that field-mice do not appear to become more abundant in thickly settled districts, as Hawks and Owls diminish in numbers, it is evident that there are other powerful checks which oppose them, and that an Owl or Hawk which feeds extensively upon bats, shrews, moles or birds must be regarded as injurious so far as its food is concerned, even though it may be more destructive to rats and mice than to these animals. The destruction of one field-mouse cannot compensate for the life of a bat or mole.

Dr. Brewer regards the Barn Owl as one of our most useful birds, and attributes its rarity in the Eastern States, and its thoughtless destruction, to short-sighted and mistaken prejudice. It is certainly to be hoped that the opinion of Dr. Brewer will be speedily confirmed, but facts, so far as we know them, and the great need of a more ample abundance of small birds, do not appear to bear him out.

Food: The stomach of one contained four mice (Wilson). Shrews, moles and field-mice (De Kay). Principally field-mice and rats (Audubon). Rats, mice and other mischievous and injurious vermin (Brewer).

154. BUBO VIRGINIANUS (GM.), BP. GREAT HORNED OWL. GROUP III. CLASS b.

This powerful bird is a resident throughout the year and chiefly a forest bird. It is quite common, and often killed out of mere curiosity. Dr. Brewer states that it is one of the most destructive of the depredators upon the poultry yard, far surpassing in this respect our Hawks. All of its mischief is done at night, when it is almost impossible to detect and punish it.

Food: Chipmunks, striped-snakes and water-snakes.

Young rabbits, squirrels, rats, mice, Partridges, the Golden-winged Woodpecker, common Crow, and various other small birds and poultry (Wilson). The larger birds, poultry, and fish cast upon the shore (De Kay). Rabbits, Grouse and other birds; is very destructive to poultry roosting on trees (Samuels). Chiefly the larger gallinaceous birds, several species of ducks, hares, young opossums, squirrels, and fish cast upon the shore (Audubon). Shrews and *arvicolæ* (Mr. Ross). Rabbits, mice, muskrats and Partridges (Mr. Gunn). Mr. Street, in experimenting upon a young caged bird, found it especially fond of fish and snakes, and was led to conclude that it does not prey upon quadrupeds larger than the hare, that it is rarely able to seize small birds, and that reptiles and fish form no inconsiderable portion of its food (Brewer). Dr. Hoy mentions an instance in which a fine Red-shouldered Hawk was killed and eaten by a caged specimen of this species.

Bubo Virginianus arcticus is a northern form which occurs rarely as a winter visitant. Dr. Hoy knew of one of these birds which carried off from one farm in the space of a month not less than twenty-seven individuals of various kinds of poultry before it was shot.

155. SCOPS ASIO (LINN.), BP. **RED OWL; MOTTLED OWL; SCREECH OWL.** GROUP III. CLASS b.

Common. Resident. It is a frequent visitor to dwellings, but its small size renders it harmless to poultry, except when young. It feeds extensively upon insects, but some of these are diurnal and preyed upon by many other birds. Its familiarity, its haunts and its destruction of small birds are such that should it be found possible for our feathered friends to assume an over-abundance, it may be expected to prove very effectual in holding them within proper bounds.

Food: The stomach of one specimen examined was distended with ten large caterpillars and six grasshoppers, and contained a few small seeds.

Mice, small birds, crickets and beetles (Wilson). Small birds, mice and insects (Cooper). Mice and insects (De Kay). Injurious night-flying moths and beetles, small mammals, and occasionally birds (Samuels). Small birds, field-mice and moles (Audubon). Golden-winged Woodpecker (Mr. A. Fowler). Mice, beetles and vermin; occasionally, when they have young, small birds (Brewer). Nuttall mentions finding in a hollow stump which contained a single brood of this species several Bluebirds and Song Sparrows.

156. ASIO WILSONIANUS (LESS.), COUES. **AMERICAN LONG-EARED OWL.** GROUP. II. CLASS c.

This Owl is quite common, and frequents cultivated fields and the vicinity of dwellings at night. During the day it affects groves and woods, where it nests.

Food: Three out of four specimens examined had their stomachs entirely empty; in the fourth there were a few hairs of some mouse.

Entirely small mammals; it is doubtful if they ever attack poultry (Cooper). Smaller quadrupeds and birds (De Kay). Chiefly quadrupeds, insects, and, to some extent, small birds; Audubon mentions finding the stomach of one stuffed with feathers, hairs and bones (Brewer).

157. ASIO ACCIPITERINUS (PALL.), NEWT. **SHORT-EARED OWL.** GROUP II. CLASS c.

Mr. Nelson speaks of this species as the most abundant Owl in Northeastern Illinois, where it arrives in large numbers the first of November, and disperses through the state. It frequents marshes and prairies in preference to woodlands, and is thus brought especially in contact with field-mice.

Food: It is said to be an excellent mouser (Wilson). Almost exclusively field-mice and hard-winged insects (De Kay). Pellets disgorged by this Owl, and found near its nest, consisted of the bones of small quadrupeds, mixed with hair and the wings of beetles (Audubon).

158. STRIX CINEREA, GM. **GREAT GREY OWL.** GROUP III. CLASS I

While this species is only a winter resident, its destructiveness to small birds unites it closely to agricultural interests even when it is in its summer home.

Food: Mr. Dall found its food to consist principally of small birds. At one time he took from the stomach of one of these birds no less than thirteen crania and other remains of the Pine Linnet *(Ægiothus linarius)*. Mr. Richardson states that it feeds principally upon hares and other small quadrupeds (Brewer). Audubon mentions a caged bird which fed readily upon fish and small birds.

159. Strix nebulosa, Forst. BARRED OWL. Group III. Class b.

This Owl is a resident throughout the year and perhaps is our most abundant species. It is a woodland species, and, though nocturnal, is often abroad by day.

Food: Two out of three specimens examined had their stomachs empty; the third had in its stomach the crania of two mice.

Fowls, Partridges, young rabbits and mice (Wilson). Rats, mice and the smaller birds (De Kay). Small birds, field-mice, reptiles, and frogs (Samuels).

160. Nyctea scandiaca (Linn.), Newt. GREAT WHITE OR SNOWY OWL. Group II. Class c.

This large, imposing species is a winter resident and sometimes quite common. It is said to hunt by day as well as by night, and Mr. Samuels has seen one pursue and capture from a flock a Snow Bunting *(P. nivalis)*. Audubon speaks of its habit of catching fish.

Food: It is said to feed upon hares, mice, grouse, ducks, fish and carrion (Wilson). Rabbits, White Grouse, mice and other small animals (Cooper). Fish and small quadrupeds (De Kay). Fish thrown up by the tide, wounded sea fowl and other birds, and dead animals (Samuels). Fish, hares, squirrels, rats, and muskrats, which it sometimes takes from the traps of hunters, and *Anas boscas* (Audubon).

161. Surnia furnerea (Linn.), Rich. & Sw. AMERICAN HAWK OWL. Group III. Class b.

This is the most diurnal of all our Owls, and, like other birds, retires to roost at night, but it hunts to some extent during the twilight. It is known to capture birds, both large and small, and Mr. Samuels states that a specimen was obtained in Vermont on a woodpile, where it was eating a Woodpecker which it had just captured.

Food: It feeds chiefly upon field-mice *(Arvicola)*; also upon small birds and grasshoppers (Coues). Partridges and other birds (Wilson). Mice and small birds (De Kay). Woodpeckers and other small birds, and mice (Samuels). In summer, principally mice and insects; in winter, Ptarmagan, upon flocks of which it is a constant attendant (Richardson). Principally mice (Mr. Dall).

162. Nyctala Tengmalmi Richardsoni (Bp.), Ridg. RICHARDSON'S OWL. Group III. Class b.

This species is reported by Dr. Hoy to have been taken in Wisconsin. It is, however, described as the most decidedly boreal of any of the American Owls, and Mr. Nelson does not include it in his "Birds of Northeastern Illinois." Sir John Richardson speaks of its very great abundance in the Saskatchewan country. Mr. Ross says that it is a fierce bird and creates great havoc among the Linnets and other small birds.

Food: Its food is principally insects, although mice and the smallest birds are also captured (Coues). Linnets and other small birds (B. R. Ross).

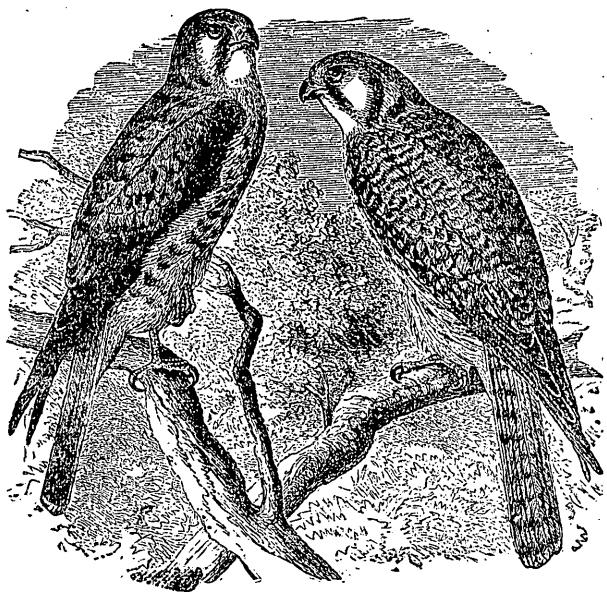
163. NYCTALA ACADICA (GM.), BP. ACADIAN OR SAW-WHET OWL. GROUP II. CLASS c.

This exquisite little species does not appear to be abundant anywhere in the United States. I have obtained but a single specimen, and this was found dead near Whitewater, December 10, 1877. Mr. Nelson speaks of its not uncommon occurrence in Illinois, and over a dozen specimens were taken in the city of Chicago within two years. It is seldom abroad by day and frequently comes about dwellings, but it is too diminutive to be destructive to poultry.

Food: It is a dexterous mouser (Wilson). Small birds and insects (De Kay). Chiefly insects (Coues).

FAMILY FALCONIDÆ: HAWKS.

FIG. 138.



SPARROW HAWK (*Falco sparverius*). After Bd., Br. and Ridg.

164. CIRCUS CYANEUS HUDSONIUS (LINN.), COUES. MARSH HAWK; HARRIER. GROUP II. CLASS c.

The Harrier is by far our most abundant representative of this family, and a summer resident. Most of its time is spent in soaring over treeless tracts in quest of food, but marshes and the vicinity of water are its favorite resorts. It lacks the spirit and dashing movement of Falcons, and for this reason is not as dangerous to mature birds; the young, however, of species which breed in marshes and meadows may suffer greatly from its depredations. Wilson states that it makes sad havoc among the Rice Buntings in the South, and Audubon accuses it of feeding extensively upon the Swamp Sparrow in some localities, while Dr. Coues has found it particularly fond of frogs. It rarely molests poultry, but, when pressed by hunger, has been known to attack Partridges, Plovers, and even Teal.

Food: Of two specimens examined, one had in its stomach four, and the other two meadow-mice *(Arvicola)*. I saw one capture a striped gopher *(Spermophiles tridecem lineatus)*, and another, a Red-winged Blackbird. Insects, especially grasshoppers, frogs, small quadrupeds and reptiles (Coues). Mice and the Rice-bird in the south (Wilson). Small birds, mice, occasionally poultry, snakes and grasshoppers (Cooper). Field-mice (Samuels). Swamp Sparrow, Chipping Sparrow and Virginia Rail (Audubon). Small birds and mice (Mr. Gunn). An indiscriminate feeder upon snakes, fish, and even worms; I took two green snakes from the stomach of one of them (Downes). Mice, lizards, serpents and other reptiles, frogs, and occasionally poultry (De Kay). I have lately seen this bird digging open the ridges formed by *Scalopus aquaticus*, and I once saw the bird overtake and kill the beast, but it did not eat it (Charles C. Abbott, Am. Nat., IV, 377).

165. Elanoides forficatus (Linn.), Coues. **SWALLOW-TAILED KITE.** Group I. Class b.

This species is rare in the eastern part of the state, but is said to occur more frequently along the Mississippi, where it is a summer resident. It is extremely swift and expert in its aerial movements, but I find no records which indicate that it is ever destructive to small birds.

Food: Cicadas, lizards and small green snakes (Wilson). Snakes, lizards and other reptiles (De Kay). Catches insects over the burning fields of the south (Major Le Conte). They feed upon dragon-flies, but their principal food is grasshoppers, grass-caterpillars, pupæ of locusts and the locusts themselves, snakes, lizards and frogs (Audubon). Grasshoppers and the grubs of wasps, to obtain which it carries the nest to a tree and picks out the grubs at its leisure (Dresser). Snakes, particularly a little green one *(Leptophis stivaæ)*, and the different species of *Eutænia;* later in summer largely insects, especially neuroptera (Ridgway). It preys upon swarms of bees (R. Owen, Ibis, 1860, p. 24).

Ictinia Mississippiensis has been noted in the state, but later observations have not detected it.

166. Accipiter fuscus (Gm.), Bp. **SHARP-SHINNED HAWK; PIGEON HAWK.** Group II. Class c.

This spirited little Hawk is common during the fall migrations, and a few are summer residents. Wilson states that it flies with almost unaccountable velocity, and seems to take its prey by surprise or by mere force of flight. "Many have been the times," says Audubon, "when watching this vigilant, active and industrious bird, I have seen it plunge headlong among the brier patches of one of our old fields, in defiance of all thorny obstacles; and, passing through, emerge on the other side, bearing off, with exultation, in its sharp claws, a Finch or Sparrow which it had surprised when at rest." The same writer has witnessed two or three of these Hawks, acting in concert, kill and devour a Golden-winged Woodpecker. It appears to be chiefly a woodland species, but sometimes comes about dwellings for domestic pigeons and young chickens. Nuttall knew of one of these Hawks which carried off thirty or forty chickens from a single yard.

Food: The single specimen which I have examined had nothing in its stomach. The Scarlet Tanager and other small birds, lizards and mice (Wilson). They have been known to take young chickens (Cooper). Birds, reptiles, insects and poultry (De Kay). Principally birds (Samuels). Frequently destructive to doves and young poultry (Nuttall). Small snakes and insects (Brewer). Principally snakes and insects (Coues). Swamp Sparrow and Chipping Sparrow (Audubon).

167. ACCIPITER COOPERI, BP. **COOPER'S HAWK; CHICKEN HAWK.** GROUP III. CLASS b.

This Hawk is much larger, more audacious, feeds less upon insects, and is more destructive to poultry than its congener. Its flight is described as silent, gliding and swift, exceeding that of the Wild Pigeon. It is said to secure its prey by giving open chase, and to dive down upon its quarry with almost incredible velocity. With such powers and tendencies as these, and living constantly among our most useful birds, which it follows south to their winter homes, this Hawk is evidently a most dangerous species.

Food: Often comes to the very door for poultry (Wilson). Chiefly the smaller birds (De Kay). Hares, squirrels, poultry, Grouse, Ducks, small birds, snakes and other reptiles, grasshoppers and crickets (Samuels). The Ruffed Grouse (Brewer). Many Quails and young Grouse, which, together with poultry, constitute their principal fare (Dr. Hoy). It attacks and destroys hares, Grouse, Teal, and even the young of larger ducks, beside capturing the usual variety of smaller birds and quadrupeds, and it occasionally seizes upon insects (Coues).

168. ASTUR ATRICAPILLUS (WILS.), BP. **AMERICAN GOSHAWK.** GROUP III. CLASS b.

This large, powerful species is a somewhat uncommon winter resident. December 5, 1877, one of these birds was taken while it was making an attack upon the inmates of a dove-cot. The day before the same Hawk succeeded in capturing, by direct chase, a dove, which it bore off for its morning repast. Its flight is extremely rapid and protracted; and Audubon has seen it dash into a flock of Purple Grackles and before they could disperse secure four or five victims. So skillful is it said to be in capturing Snipe on the wing, that these birds court security by skulking upon the ground rather than taking flight, when they observe the approach of their enemy.

Food: In February, 1881, I obtained a specimen which had eaten a rabbit. Doves and poultry, Ducks, Pigeons, hares, etc. (De Kay). Canada and Ruffed Grouse, Purple Grackles, Pigeons, Mallards and other wild Ducks, Snipe, squirrels, and hares (Audubon). Grouse (Mr. Street). Ducks, Pigeons and poultry (Mr. Downes). It feeds largely upon White Ptarmagan (Mr. Dall). Poultry (Dr. Hoy).

169. FALCO PEREGRINUS, TUNSTALL. **PEREGRINE FALCON; DUCK HAWK.** GROUP III. CLASS a.

This species rarely occurs except as a migrant, and as such it is not very common. It is a powerful bird, and its gigantic talons are commensurate with its audacity and courage. It can out-fly the Wild Pigeon, and the short turnings of the Swallow do not secure it against fatal attacks from this bird.

Food: Ducks, Geese, Plovers, and other small birds (Wilson). Swallows, Ducks, and other water-fowl (Cooper). It attacks the Sparrow Hawk and anything from the size of a Mallard down to small birds. It captures the Dusky Petrel (Col. Grayson). Wild Pigeon, water-fowl, and small birds (Richardson). The Mallard and other Ducks, Snipe, Blackbirds, wild and domestic Pigeons, and occasionally dead fish (Audubon). Blue-winged Teal (Dr. Hoy).

170. FALCO COLUMBARIUS, LINN. **PIGEON HAWK.** GROUP III. CLASS b.

This spirited, swift-winged little Hawk has been described as one of the most destructive of its tribe. It captures birds upon the wing with little difficulty, and is so audacious as to destroy Ptarmagan birds larger than itself. Its sagacity leads it to take advantage of gregarious species, and it follows all our birds in their migrations north and south. Dr. Hoy states that those which nest near Racine, regularly, morning and evening, visit the lake shore in quest of Bank Swallows which they seize with great dexterity. It appears to breed, as a rule, north of the United States, but Mr. Nelson mentions it as a rare summer resident in Illinois.

Food: Small birds and mice. It often follows flocks of Blackbirds, Pigeons and Robins — many of which become its victims (Wilson). It catches birds as large as itself, follows gregarious species, and preys much upon mice, gophers, and squirrels (Cooper). Destroys Robins, Bluebirds and Sparrows in great numbers, and attacks the Pigeon and Dove (Samuels). Robin, Wild Pigeon, Golden-winged Woodpecker, Yellow-billed Cuckoo, and pursues Snipe and Teal (Audubon). Bank Swallows (Dr. Hoy). Feeds upon small birds, but is not troublesome to farmers (Mr. Downes).

Falco Richardsonii is said to have been taken near Racine.

171. FALCO SPARVERIUS, LINN. **SPARROW HAWK.** GROUP II. CLASS c.

Except the Marsh Harrier, no Hawk is as abundant as this little Falcon. It is more abundant in wooded districts than in prairie sections, and the borders of woodlands and fields with scattering trees are its favorite resorts. It is too small to be destructive to poultry, except when very young, but it is none the less dangerous on this account to our most useful small birds. It captures birds on the wing with little difficulty, is more than a match for the Brown Thrasher, and tears open the bottle-shaped nest of the Cliff Swallow to secure the inmates. When autumn comes and our birds go south, "in their rear rushes the Sparrow Hawk." I have seen this species come close to a house and attempt to capture one of a brood of young Robins which had recently left the nest. At another time a Song Sparrow only escaped its pursuer by diving into a brush pile; and once one of these Hawks flew close over my head, bearing off a small bird in its talons. But its food does not consist of birds alone. Indeed, it consumes so many noxious insects, and is such an excellent mouser, that Dr. Coues says it is to be held a benefactor to the agriculturist, and this view is also entertained by Dr. Cooper. My own notes, viewed with reference to the conditions stated in the Introduction, do not, however, point in this direction. It will be seen that it is very destructive to noxious insects, but it should be observed that these insects are destroyed in great numbers by many less dangerous species. As an insect destroyer it is not, therefore, especially needed. Small birds are not so abundant at present as to demand the assistance of a large number of Birds of Prey to hold them in check; and plows, cultivators, reapers, mowers and horse-rakes work such havoc among field-mice as to preclude their ever becoming excessively abundant in regions where these implements are used. For this reason the service which Rapacious Birds render by destroying mice in agricultural districts is not as great as it appears to be.

Food: Of seven specimens examined, two had eaten two mice; four, twenty-five grasshoppers; three, twenty-five crickets; one, six beetles; one, five moths; and one, two hairy caterpillars *(Arctia)*. One was seen to take a young Robin from the nest and one to capture another bird not identified.

The young are fed upon grasshoppers, mice, Robins, Snowbirds and small birds. The food of the old bird is the same with the addition of lizards and occasionally chickens. When grasshoppers are plenty these form a considerable part of its food (Wilson). Chiefly grasshoppers, mice, gophers, etc. (Cooper). Small birds, but chiefly quadrupeds, reptiles and insects (De Kay), Small birds, young chickens, mice, lizards, snakes and grasshoppers (Samuels). Sparrows, mice, grasshoppers and crickets (Audubon). The Cliff Swallow, Field Sparrow and other birds, mice, lizards, snakes and grasshoppers (Brewer). Sparrows, the Brown Thrush and other birds, lizards *(Sceloporus)*, field-mice and noxious insects (Coues). Small birds, field-mice, shrews and small reptiles (E. Michener).

172. BUTEO BOREALIS (GM.), VIEILL. **RED-TAILED BUZZARD; HEN HAWK.** GROUP II. CLASS c.

In speaking of this Hawk and its close allies Dr. Coues says: "They are unfitted, both by their physical organization and temperament, for the daring feats that the Falcons and Hawks execute, and usually prey upon game disproportionate to their size, which they snatch as they pass along. I have, however, found nearly the whole of a rabbit in its craw." While such sluggish species are far less liable to be destructive to mature birds, they may be expected to be proportionally even more dangerous plunderers of birds' nests than the swifter winged species. Necessarily restricted to slow-moving prey, while their appetite for flesh remains, they are forced to a diligent and scrutinizing search, and are thus likely to be brought in contact with the hidden nests of birds. Of two Hawks which prey upon birds, the addicted nest-robber is the more dangerous.

Food: Hens, frogs and lizards (Wilson). Small quadrupeds and poultry (De Kay). Very destructive to poultry, and feeds upon the Ruffed Grouse and hares (Samuels). Small quadrupeds, small birds, and snakes (Brewer). Marmots (Richardson).

173. BUTEO LINEATUS (GM.), JARD. **RED-SHOULDERED HAWK.** GROUP III. CLASS b.

A common summer resident, keeping closely to the woods except during the migrations.

Food: One specimen examined had eaten only grasshoppers and beetles.

Larks, Sandpipers, Ring-necked Plovers and Ducks (Wilson). Partridges, Pigeons, wounded Ducks, Red-winged Blackbirds, squirrels, cotton-rats, meadow-mice and frogs (Audubon). Small birds and quadrupeds (De Kay). Frogs, cray-fish and insects, rarely troubling large game (Nuttall). It is a dexterous catcher of frogs, with which it sometimes so stuffs itself that it can hardly fly (Brewer). Frogs, cray-fish and insects (Nuttall).

174. BUTEO SWAINSONI, BP. **SWAINSON'S BUZZARD.** GROUP II. CLASS c.

Not common. A summer resident.

Dr. Coues says of this species: "Though really strong and sufficiently fierce birds, they lack the 'snap' of the Falcons and Asturs; and I scarcely think they are smart enough to catch birds very often. I saw one make the attempt on a Lark Bunting. The Hawk poised in the air, at a height of about twenty yards, for fully a minute, fell heavily with an awkward thrust of the talons, and missed. . . . They procure gophers, mice and other small quadrupeds, both by waiting patiently at the mouth of the holes, ready to claw out the unlucky animals the moment they show their noses, and by sailing low over the ground to pick up such as they may find away from home. But I question whether, after all, insects do not furnish their principal subsistence. Those that I shot after midsummer all had their craws stuffed with grasshoppers."

Food: Two whole toads were found in the stomach of one (Richardson). Three toads were found in the stomach of one (Blakiston). Rabbits, squirrels, mice, ducks and white-fish (Dall). Its principal food is grasshoppers, prairie-rats and small birds (Brewer). Gophers, mice, small quadrupeds and grasshoppers (Coues).

Mr. W. Hoffman records an instance where an *Icterus Bullocki* nested within eight feet of the nest of a pair of these Hawks, and states that the birds appeared to live together in harmony.

175. BUTEO PENNSYLVANICUS (WILS.), BP. **BROAD-WINGED BUZZARD.** GROUP II. CLASS c.

Common in the northern portions of the state, where it breeds in the heavy timber.

Food: A specimen taken in Clark county had in its stomach seven large lamellicorn beetles and two grasshoppers, together with a few small fragments of bones.

The White-throated Sparrow and other small birds, squirrels and insects (Wilson). Frogs and species of common field locusts (William Cowper). Small birds and quadrupeds, wood frogs and snakes (Audubon). Chickens, ducklings, animals and insects. It only attacks birds of a weak nature (Brewer).

176. ARCHIBUTEO LAGOPUS SANCTI-JOHANNIS (GM.), RIDG. **AMERICAN ROUGH-LEGGED HAWK.** GROUP III. CLASS b.

This is a northern species, and probably but rarely a summer resident. A few are said to spend mild winters in the state. Mr. Nelson states that it arrives in large numbers in October in Northeastern Illinois and after a few weeks passes further south. Its plumage is owl-like, its flight noiseless, and its search for food often continued long into the evening.

Food: Mice, lame ducks, lizards and frogs (Wilson). It rarely attacks poultry (Cooper). Mice, small birds, frogs, etc. (De Kay). Principally mice, moles and other small quadrupeds and frogs (Andubon). Mice, wounded ducks and small birds (Samuels). Rats (R. H. and F. H. Storer).

177. PANDION HALIAETUS (LINN.), SAV. **FISH HAWK; OSPREY.** GROUP II. CLASS b.

This species is not uncommon along the Mississippi and St. Croix rivers, and I observed several among the numerous lakes of Lincoln county in October of 1877. It is an excellent fisherman and appears to subsist wholly upon the members of the finny tribe. It even allows small birds to nest unmolested among the coarse sticks of its own nest. So far as its food is concerned, it is wholly injurious, but its destruction of fish, by simply feeding upon them, is not of so great moment as to demand an interference with them at present. Should they be found to breed troublesome parasites which are destructive of food-fish, then it may be found necessary to hold their numbers at the minimum.

178. AQUILA CHRYSAETUS (LINN.), CUV. **GOLDEN EAGLE.** GROUP III. CLASS b.

A regular winter visitor, but only in small numbers.

Food: Living quadrupeds, birds, etc., but it rarely touches a dead body (De Kay). Young fawns, raccoons, hares, wild turkeys and other large birds; also carrion (Audubon). Ducks, mice, fawn of the reindeer, Partridges and other animals (McFarland). Carrion (E. W. Nelson).

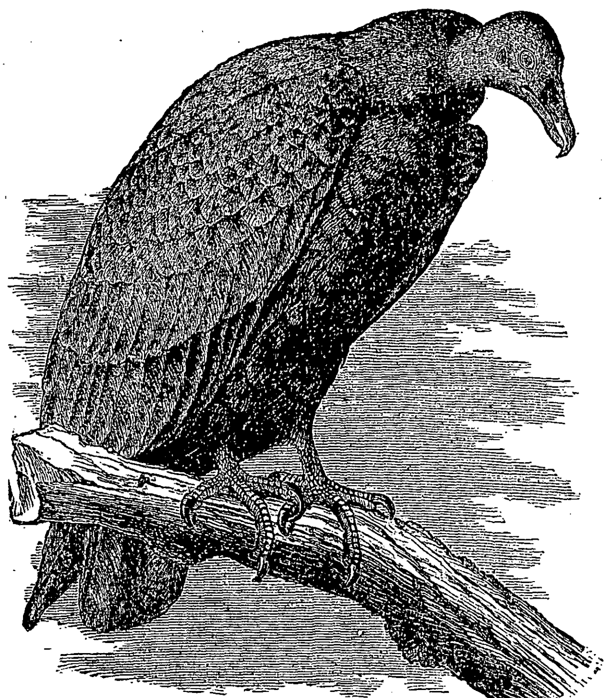
179. HALIAETUS LEUCOCEPHALUS (LINN.), SAV. **WHITE-HEADED EAGLE.** GROUP III. CLASS b.

This species is resident throughout the year and common in the northern portion of the state.

Food: Ducks, Geese, Gulls and other sea-fowl and carrion (Wilson). Weakly lambs, calves, and other animals (Cooper). Fish, wild fowl and small quadrupeds (De Kay). Wild Geese and other wild fowl, small animals, and is very partial to fish, which it takes from the Osprey (Samuels). It fishes when no Fish Hawk is around (S. S. Haldeman, Am. Nat., Vol. I).

FAMILY **CATHARTIDÆ**: AMERICAN VULTURES.

FIG. 139.



TURKEY BUZZARD (*Cathartes aura*). After Bd., Br. and Ridg.

180. CATHARTES AURA (LINN.), ILL. **TURKEY BUZZARD.** GROUP II. CLASS a.

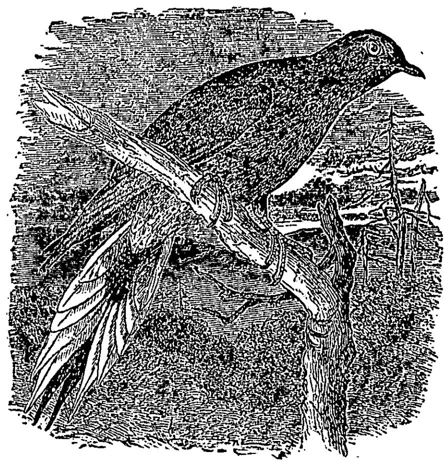
Reported as occurring in the state by Dr. Hoy.

Mr. Trippe states that it is abundant in Minnesota and that it breeds there. From this statement it is probable that it occurs frequently along the Mississippi in Wisconsin, but in the eastern portion of the state it is very rare. Since writing the above I have found it at River Falls. Although generally a scavenger, the Turkey Buzzard, when pressed by hunger, kills young pigs and lambs and other weak and disabled animals. "One excellent service which the Turkey Vultures render," says Dr. Coues, "in warm countries, is the destruction of alligators' eggs." It is also accused of sucking the eggs and devouring the young of many species of Herons. Such tendencies as these render a bird like this of doubtful utility in a climate like ours.

Food: Carrion (Wilson). The carcasses of animals (Cooper). Carrion, disabled animals and eggs of birds, etc. (De Kay). Eggs and young of many species of Herons (Audubon). Skunks in traps (Am. Nat., Vol. XII, p. 821, W. Kite).

FAMILY COLUMBIDÆ: PIGEONS.

FIG. 140.



WILD PIGEON (*Ectopistes migratorius*). After Bd., Br. and Ridg.

181. ECTOPISTES MIGRATORIUS (LINN.), SW. **WILD PIGEON; PASSENGER PIGEON.** GROUP I. CLASS c.

Food: Acorns and other nuts, grain, buckwheat and various small seeds are its usual food. From the stomach of one specimen, however, were taken two large caterpillars — one of which was an *Edema albifrons*,— one harvest-man, nine black crickets and four grasshoppers.

Buckwheat, hemp-seed, Indian corn, hackberries, huckleberries, acorns and chestnuts (Wilson). Beech-nuts, acorns, berries, rice and seeds (De Kay). Acorns, beech-nuts, berries, grains and weed-seeds (Samuels). Acorns (Forbes).

182. ZENAIDURA CAROLINENSIS (LINN.), BP. **CAROLINA DOVE.** GROUP I. CLASS c.

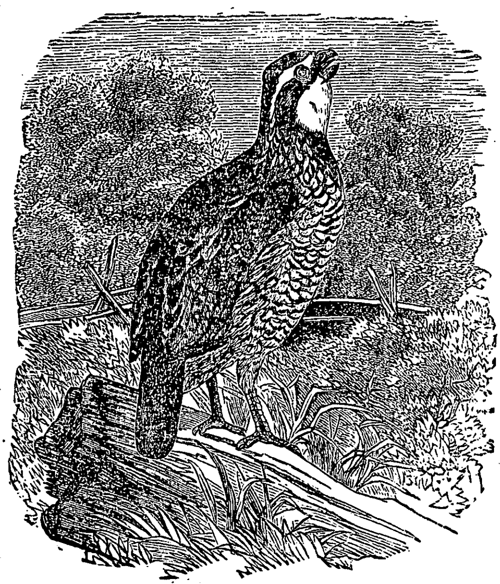
A very common summer resident but never sufficiently gregarious to be injurious to crops to any noteworthy extent.

Food: Seeds of various weeds, buckwheat, rye, wheat and oats. In the stomach of one bird I counted 4,016 seeds of the pigeon-grass and twelve small snails; the latter were probably taken as gravel. Of nine specimens examined, eight had eaten the seeds of weeds; three, wheat; two, rye; and one, oats.

Buckwheat, hemp-seed, corn, berries, acorns, and occasionally peas (Wilson). Grains and berries (Samuels). Seeds, grain, buckwheat, Indian corn (Brewer). Of four specimens examined, four had eaten seeds of weeds; two corn; and one, wheat (Forbes).

FAMILY TETRAONIDÆ: GROUSE, ETC.

FIG. 141.



QUAIL (*Ortyx Virginiana*). After Bd., Br. and Ridg.

183. CANACE CANADENSIS (LINN.), BP. **SPRUCE PARTRIDGE; CANADA GROUSE.** GROUP I. CLASS c.

A very common resident in the coniferous forests of Northern Wisconsin, where it is partial to the swamps.

Food: Buds and cones of spruce and larch (De Kay). Buds, seeds and foliage of evergreens (Samuels). Berries, young twigs and blossoms of several species of plants and berries of the Solomon's Seal (Audubon).

184. PEDIOECETES PHASIANELLUS COLUMBIANUS (ORD.), COUES. **SOUTHERN SHARP-TAILED GROUSE.** GROUP I. CLASS c.

This species is resident from Berlin northward, and was abundant in the vicinity of Lake Flambeau in October, 1877.

Food: Tender leaves, thorn-apples, rose-hips, wheat and grasshoppers.

In winter, buds of elder, poplar, etc. (Cooper). In the fall, chiefly grasshoppers, only varied with a few flowers, weed-tops, succulent leaves, and an occasional beetle or spider; in winter, chiefly berries of the cedar, and buds of the poplar and cottonwood or willow (Coues).

185. CUPIDONIA CUPIDO (LINN.), BD. **PINNATED GROUSE; PRAIRIE HEN.** GROUP I. CLASS b.

A common resident, but rapidly disappearing before the zeal of sportsmen. From early in the spring until after the middle of August this species is confined almost exclusively to meadows, and during this long period it is probable that its food consists very largely of insects, and that the services it renders by holding in check cut-worms and grasshoppers are very great, while its injurious effects are almost inappreciable. There are but few sections in the state where the destruction of the Prairie Hen should not be entirely prohibited, at least for a term of years.

Food: Insects of various kinds, wheat, corn, buckwheat and other grains, weed- and grass-seeds and some vegetable material.

186. BONASA UMBELLA (LINN.), STEPH. **RUFFED GROUSE; PARTRIDGE.** GROUP I. CLASS c.

The Ruffed Grouse, or Partridge, as it is often called, is a common resident during the whole year in all portions of the state suitable to its tastes. Unlike the Prairie Chicken, this species is emphatically a woodland bird, though it is not confined to heavily timbered districts. The numerous dense groves of small trees bordering the prairies and in thickly settled districts are the haunts which please it well. From these resorts it rarely invades cultivated fields. This bird appears to be very fond of the buds of certain trees, upon which it subsists to a considerable extent during the cold months, but it is not likely to become so abundant as to injure shade or forest trees to any appreciable extent.

Food: Of six specimens examined, two had eaten twenty-four caterpillars; one, the grub of a beetle; one, two grasshoppers; one, seven harvest-men; one, fruit; one, foliage; one seeds; one, partridge-berries; and three, buds.

A young chicken, probably not over a week old, had in its stomach thirteen caterpillars, the grub of a beetle and seven harvest-men. An adult bird taken in October had in its stomach and crop three hundred and four white-birch buds.

Various vegetables, whortleberries, partridge-berries, blackberries, seeds of grapes and chestnuts. In winter, buds of alder and laurel, occasionally ants (Wilson). In summer, seeds, berries, grapes and other fruits. In winter, buds of various trees (De Kay). Various seeds, berries, grapes and insects; also leaves of evergreens, buds of trees, pieces of apples left on the trees, mosses and leaves of laurel (Samuels). In the spring, buds of various kinds of trees, especially birches. In Maine, buds of black birch. In summer, largely esculent berries, as raspberries, blueberries and huckleberries. In Maine they have been accused of visiting apple-orchards and fruit-buds (Brewer).

187. Lagopus albus (Gmelin), Aud. **WILLOW GROUSE; WHITE PTARMIGAN.** Group I. Class c.

Dr. Hoy mentions the capture of two of these birds near Racine in 1846. It is doubtful if it ever occurs in Wisconsin except as a very rare straggler from its high-latitude home.

188. Ortyx virginiana (Linn.), Bp. **QUAIL; BOB WHITE.** Group I. Class b.

This species is a common resident throughout the year, though far from being as abundant anywhere in the state as it was twenty years ago.

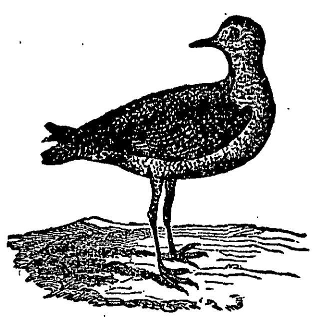
In its haunts, it stands on intermediate ground between the Ruffed Grouse and Prairie Chicken, occupying the borders of groves, hazel patches and open fields. When abundant in the fall, they congregate in flocks of from ten to thirty, often consisting of the two broods reared during the summer, and, if not molested, remain together until spring, moving about from field to field in the vicinity of the breeding grounds. I believe its destruction should be prohibited, for a number of years at least.

Food: Of two specimens examined, one had eaten one potato beetle, one elater, one ground-beetle *(Anisodactylus)*, one grasshopper and five grasshopper eggs, probably from the grasshopper eaten; the other had eaten wild buckwheat, wheat and one beetle.

Grain, seeds, berries and buckwheat, also insects and berries (Wilson). Grains, seeds and berries (De Kay). Potato beetles (Am. Nat., Vol. VII, p. 247, A. S. Packard). One specimen examined by Prof. Forbes had eaten beetles, hemiptera *(Coreidæ)*, grasshoppers, spiders and vegetable materials. Plant-beetles were among the beetles; seeds of various plants and berries. In the fall and late summer, largely grasshoppers. Buckwheat, corn and all kinds of grain (Brewer).

Family CHARADRIIDÆ: Plover.

Fig. 142.



Golden Plover (*Charadrius dominicus*). From Tenney's Zoology.

189. Squatarola helvetica (Linn.), Cuv. **BLACK-BELLIED PLOVER.** Group I. Class c.

This is not a common species with us, and occurs only during the migrations. I have not myself met with it in the state.

Food: Worms, grubs, winged insects and berries (Wilson). Insects and berries (De Kay).

190. CHARADRIUS DOMINICUS (MÜLL). **AMERICAN GOLDEN PLOVER.** GROUP I. CLASS c.

The Golden Plover, like the last, is only a migrant in the state. It is to be seen in the fall during the last of September and the early part of October, frequenting pastures in flocks of twenty or thirty, where it searches diligently for insects.

Food: Of three specimens examined, two had eaten five grasshoppers; two, nine beetles; and two, three caterpillars.

Small shell-fish and animalculæ, in the spring; in the fall, grasshoppers, various insects and berries (Samuels). Grasshoppers (Coues). Insects (Forbes).

191. ÆGIALITES VOCIFERUS (LINN.), CASS. **KILLDEER PLOVER.** GROUP I. CLASS b.

So generally distributed throughout the state and so abundant is the Killdeer Plover, that even the Robin is scarcely better known than it. Unlike most of the waders, it is a summer resident with us, frequenting upland pastures, meadows and open fields, as well as the low flats adjoining bodies of water. I have known it to enter corn-fields infested with wire-worms, and to feed upon these pests.

The food, habits and haunts of the Killdeer are such as to bind it closely in economic relation with that all too small band of birds which, like the Meadow Lark, frequent the open, cultivated fields. On account of this relationship, the Killdeer Plover should be stricken from the list of "game birds," and encouraged to breed in greater abundance in cultivated fields and meadows.

Of thirteen specimens examined, ten had eaten fifty-seven adult insects, and three, ten angle-worms; five had eaten twelve larvæ, and in the stomach of one was found fifty-six grasshopper and cricket eggs.

Four birds had eaten fifteen ants; two, three caterpillars; one, three moths; one, a crane-fly; nine, twenty-eight beetles; one, a grasshopper; four, seven crickets.

One bird had eaten three wire-worms; two, three leaf-beetles; two, four curculios *(Brevirostres)*; one, a copris beetle.

Worms and aquatic insects (Wilson). Earth-worms, grasshoppers, crickets, beetles, small crustacea and snails (Audubon).

Of six birds examined by Prof. Forbes, all had eaten insects; two, caterpillars; three, beetles; one, cray-fish; and two, vegetable miscellany.

Of those eating beetles, one had eaten Histeridæ; two, plant beetles; and two, curculios.

192. ÆGIALITES SEMIPALMATUS (BP.), CAB. **SEMIPALMATED RING PLOVER; RING-NECK.**

193. ÆGIALITES MELODUS (ORD.), CAB. **PIPING RING PLOVER; RING-NECK.** GROUP I. CLASS c

Both the Semipalmated and Piping Ring Plovers are reported as occurring in the state during the migrations, but I have met with neither alive in Wisconsin. nor *Ægialites melodus circumcinctus,* which Mr. Nelson reports as breeding along the lake shore in Northeastern Illinois.

Family HÆMATOPODIDÆ: Oyster-catchers; Turnstones.

194. Strepsilas interpres (Linn.), Ill. **TURNSTONE.** Group I. Class c.

Dr. Hoy and Mr. Nelson speak of this species as a common migrant along the shore of Lake Michigan, but I have met no living specimens.

Family RECURVIROSTRIDÆ: Avocets.

195. Recurvirostra Americana (Gm.), Avocet. Group I. Class c.

A rare migrant.

196. Himantopus Mexicanus (Müll.), Ord. **BLACK-NECKED STILT.** Group I. Class c.

A very rare visitant. Dr. Hoy reports having seen a small flock in 1847.

Family PHALAROPODIDÆ: Phalaropes.

197. Steganopus Wilsoni (Sab.), Coues. **WILSON'S PHALAROPE.** Group I. Class c.

Wilson's Phalarope, though not abundant in the state, breeds in some numbers in various localities. They were abundant in July, 1876, on the marshes bordering Fox river below Princeton, where five young birds fully fledged were obtained.

Of the five specimens examined, three had eaten ten larvæ; three, six beetles; and two, four other insects.

Seeds and insects (Wilson). Small worms and fragments of very delicate shells (Audubon).

198. Lobipes hyperboreus (Linn.), Cuv. **NORTHERN PHALAROPE; RED-NECKED PHALAROPE.** Group I. Class c.

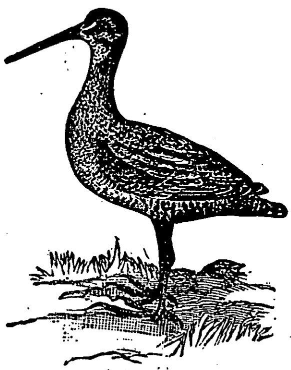
This species must be a rare migrant or of irregular occurrence in the portions of the state where I have collected. I have never met it alive.

199. Phalaropus fulicarius (Linn.), Bp. **RED PHALAROPE.** Group I. Class c.

The Red Phalarope appears to be an exceedingly rare migrant throughout the Mississippi Valley, but Mr. Nelson and Mr. Ridgway each mention it as occurring in Illinois, from which it may be supposed to pass through this state in its journeys.

FAMILY SCOLOPACIDÆ: SNIPES, ETC.

FIG. 143.



WILSON'S SNIPE (*Gallinago Wilsoni*). From Tenney's Zoology.

200. PHILOHELA MINOR (GM.), GR. **AMERICAN WOODCOCK.** GROUP I. CLASS c.

This game bird is not uncommon during the summer in damp woods bordering streams and other suitable localities. I have found it in the corn-field as well.

Food: Of two specimens examined, two had eaten three angle-worms; one, a beetle; and one, some vegetable matter.

Various larvæ and other aquatic worms (Wilson). Chiefly earth-worms and aquatic insects (De Kay). Worms and animalculæ procured from soft earth (Samuels). Earth-worms, grubs, etc. (August Fowler, Am. Nat., Vol. IV, p. 761).

201. GALLINAGO WILSONI (TEMM.), BP. **AMERICAN SNIPE; WILSON'S SNIPE.** GROUP I. CLASS c.

Wilson's Snipe, incorrectly called the English Snipe by many, is very abundant during the migrations, and doubtless breeds with us in considerable numbers, as they were abundant on the banks of the Fox river early in July of 1876. They frequent the wet, treeless banks of streams and low, wet meadows. During the fall they may be seen at times in flocks of from thirty to fifty.

Food: Of eleven specimens examined, ten had eaten thirty-five insects; three, fifteen beetles; one, a dipterous larvæ; and five, vegetable matter.

Larvæ of water insects, leeches, and occasionally grasshoppers and other insects (Samuels).

202. MACRORHAMPHUS GRISEUS (GM.), LEACH. **RED-BREASTED SNIPE; GRAY SNIPE.** GROUP I. CLASS c.

Dr. Hoy has observed this species near Racine. Mr. Nelson speaks of it as a rather common migrant in Northeastern Illinois. I have no personal acquaintance with it in the field.

Food: Snails (Wilson).

203. MICROPALAMA HIMANTOPUS (BP.), BD. **STILT SANDPIPER.** GROUP I. CLASS c.

A rare migrant with which I have not met.

204. Ereunetes pusillus (Linn.), Cass. **SEMIPALMATED SANDPIPER.** Group I. Class c.

Mr. Nelson, in his report, speaks of this species as a very abundant migrant. Dr. Hoy regarded it as rare in 1852. I have not met with it.

205. Actodromas minutilla (V.), Coues. **LEAST SANDPIPER.** Group I. Class c.

I have found this species a common migrant through Central Wisconsin, though Mr. Nelson speaks of it as less abundant than the last. He also speaks of its breeding near the Calumet river.

Food: Of four stomachs examined, three contained ten insects; and one, a few seeds.

Larvæ, shellfish and insects on salt marshes (Wilson). Small shellfish crustaceans, and insects found in pools of water (Samuels).

206. Actodromas Bairdi, Coues. **BAIRD'S SANDPIPER.** Group I. Class c.

This species occurs as an uncommon migrant with other Sandpipers, but I have never taken it.

207. Actodromas maculata (V.), Coues. **PECTORAL SANDPIPER; JACK SNIPE.** Group I. Class c.

This is a common migrant, occurring along the rocky banks of streams and on marshes, sometimes in large flocks.

Food: Of three specimens examined, two had eaten snails *(Physa)*; one, three aquatic larvæ, and one; some vegetable matter.

Various insects found in its haunts, particularly grasshoppers and crickets (Samuels). Beetles, larvæ and common green *Ulva latissima,* as well as small seaweeds (Audubon).

208. Actodromas Bonapartii (Schl.), Coues. **WHITE-RUMPED SANDPIPER.** Group I. Class c.

This is another of the rarer migrant Sandpipers with which I have not met.

Food: Various small aquatic animals, aquatic larvæ and insects.

209. Arquatella maritima (Brünn.), Bd. **PURPLE SANDPIPER.** Group I. Class c.

Dr. Hoy says of this species: "Greatly abundant from 15th of April to 20th of May. Mr. Nelson, however, finds it a very rare visitant in Northeastern Illinois. I have not seen it.

Small shellfish, shrimps and worms (Audubon).

210. Pelida alpina Americana (Cass.), Allen. **AMERICAN DUNLIN.** Group I. Class c.

Mr. Nelson speaks of this species as a very abundant migrant which passes northward along the lake shore in flocks often containing hundreds of individuals. Mr. Thure Kumlien has taken it on Lake Koshkonong, but it has not been my good fortune to meet with it.

Food: Small worms and insects found in muddy flats (Wilson). Small marine animals (Samuels).

211. TRINGA CANUTUS, LINN. RED-BREASTED SANDPIPER; ROBIN SNIPE. GROUP I. CLASS c.

A rare migrant. No specimens obtained.

Food: A bivalve found on the shores (Wilson). Worms and minute shells (De Kay).

212. CALIDRIS ARENARIA, LINN. SANDERLING. GROUP I. CLASS c.

Dr. Hoy and Mr. Nelson speak of this species as abundant along the lake shore during the migrations. It was not obtained by me.

Food: Principally bivalves common on the ocean beach (Wilson). Small shells and crustaceans (Samuels). Small sea-worms, shrimps and shellfish (Audubon).

213. LIMOSA FŒDA (LINN.), ORD. GREAT MARBLED GODWIT. GROUP I. CLASS c.

A rather common migrant, as reported by Mr. Nelson.

Food: Aquatic insects, leeches, small marine mollusks, crabs and worms (De Kay). Small Fiddler crabs (Audubon).

214. LIMOSA HÆMASTICA (LINN.), COUES. HUDSONIAN GODWIT. GROUP I. CLASS c..

This species is included on the authority of Mr. Nelson, who speaks of it as not very rare during the migrations.

215. SYMPHEMIA SEMIPALMATA (GM.), HARTL. SEMIPALMATED TATTLER; WILLET. GROUP I. CLASS c.

Mr. Nelson mentions this species as a rare summer resident in Northeastern Illinois, and Dr. Hoy reports having seen it as late as June 10th.

Food: Small shellfish, marine worms and aquatic insects (Wilson). Aquatic insects, Fiddler and other small crabs (Audubon).

216. TOTANUS MELANOLEUCUS (GM.), V. GREATER TATTLER; STONE SNIPE. GROUP I. CLASS c.

The Greater Tattler probably breeds sparingly in the state as it is said to do in Illinois.

Food: One specimen examined had in its stomach seven water-beetles.

Marsh insects, shrimps, etc. (De Kay).

217. TOTANUS FLAVIPES (GM.), V. LESSER TATTLER; YELLOWSHANKS. GROUP I. CLASS c.

This species is more abundant than the last and a few are summer residents and probably breed.

Food: Of three specimens examined, one had eaten five beetles and three other insects; and one, a rat-tailed maggot *(Eristalis?)*, and a dragon-fly. The stomach of the third was empty.

Small aquatic insects and worms (De Kay). Small fish, worms, shrimps and aquatic insects (Audubon).

218. RHYACOPHILUS SOLITARIUS (WILS.), BP. **SOLITARY TATTLER.** GROUP I. CLASS c.

A common migrant and also a summer resident in small numbers. It frequents small brooks with dry stony banks, as well as the marshy ponds.

Food: Of nine specimens examined, one had eaten a caterpillar; one, the larve of an aquatic beetle; one a grasshopper; one, a diptera; four, nine larvæ; three, eight aquatic beetles; five, ten other insects; and one, three hair-worms (Gordii).

Larvæ of various aquatic insects (Samuels). It is expert in catching insects on the wing, especially the small dragon-flies. I have found in their stomachs aquatic insects, caterpillars and various kinds of black spiders (Audubon).

219. TRINGOÏDES MACULARIUS (LINN.), GR. **SPOTTED TATTLER; SPOTTED SANDPIPER.** GROUP I. CLASS c.

This is a very common summer resident, frequenting the banks of streams and ponds, laying its eggs in dry sandy and sometimes stony places.

Food: Of nine specimens examined, three had eaten fifteen beetles; one, two small dragon-flies; one, a grasshopper; and six, twenty-seven other insects; one had eaten eight hair-worms (Gordii); and one, three mollusks.

Insects and worms (De Kay).

220. BARTRAMIA LONGICAUDA (BECHST.), COUES. **BARTRAMIAN TATTLER; UPLAND PLOVER.** GROUP I. CLASS b.

No member of our wading birds has departed as far from ancestral customs in the search for food as this species. It seems to have abandoned very largely, if not altogether, the muddy shores cherished by its allies, and taken to the dry marshes and broad prairies. It is very abundant on the broad, dry prairies of Minnesota, and is a common summer resident with us. This change of habit introduces it into a band of workers much more closely related to agricultural interests. It is not much hunted for its flesh, and doubtless should not be until it assumes a greater abundance with us than it has at present.

Of three specimens examined, one had eaten six ants, two larvæ and three beetles; one, four snails; and one, three grasshoppers.

Beetles and other winged insects (Wilson). Grasshoppers (De Kay). In the fall, grasshoppers, crickets, grains and seeds (Samuels). Mainly insects, especially grasshoppers, of which they must devour enormous quantities in the aggregate. They also feed on other small animal substances, as well as upon various berries (Coues).

221. TRYNGITES RUFESCENS (V.), CAB. **BUFF-BREASTED SANDPIPER.** GROUP I. CLASS c.

Mr. Nelson speaks of it as a very rare migrant in Northern Illinois. I have never met with it. Dr. Hoy reports it as having been formerly quite common in the fall.

222. NUMENIUS LONGIROSTRIS, WILS. **LONG-BILLED CURLEW.** GROUP I. CLASS c.

The Long-billed Curlew doubtless occurs regularly in the state as a migrant, but it is not common. It may still breed in the state, as it has been known to do so in Illinois as late as 1873.

Food: Mainly crabs; also snails and bramble berries (Wilson). Small shells, insects, worms, crabs and berries (De Kay). Principally small Fiddler crabs; also sea-worms, salt-water shellfish and other animals (Audubon).

223. NUMENIUS HUDSONICUS, LATH. **HUDSONIAN CURLEW.** GROUP I. CLASS c.

A very rare migrant.

Food: Small worms and shells; also bramble berries (Wilson). Aquatic insects, worms, small marine mollusks and seeds of aquatic plants (De Kay). Grasshoppers and berries (Nuttall).

224. NUMENIUS BOREALIS (FORST.), LATH. **ESKIMO CURLEW.** GROUP I. CLASS c.

This species has not been taken by the writer, but Mr. Nelson mentions it as a rather common migrant in Illinois.

Food: In autumn, in Massachusetts; grasshoppers and berries; in Labrador, curlew-berries (Audubon). Curlew-berry (Empetrum nigrum) and small snails. The first is their principal and favorite food (Coues).

FAMILY TANTALIDÆ: IBISES, ETC.

225. TANTALUS LOCULATOR, LINN. **WOOD IBIS.** GROUP II. CLASS b.

In regard to this species Mr. Nelson says: "An exceedingly rare summer visitant from Southern Illinois." "Dr. Hoy has a specimen in his collection obtained at Racine, September 10, 1869, and states that a second specimen was obtained near Milwaukee, and is now in a museum at that place."

Food: Fish, reptiles, young alligators, frogs (Wilson). Entirely fish and aquatic reptiles, of which it destroys more than it can eat. Frogs, young alligators and water snakes (Coues from Audubon). Frogs, young alligators, wood rats, young Rails, Grackles, Fiddler and other crabs, snakes and small turtles (Audubon).

FAMILY GRUIDÆ: CRANES.

226. GRUS AMERICANA (LINN.), TEMM. **WHITE CRANE; WHOOPING CRANE.** GROUP II. CLASS c.

This species was formerly a common migrant along the western margin of the state, but now moves north and south, farther west, largely, if not altogether.

Food: Marine worms, insects, grains, mice, moles and rats (Wilson).

227. GRUS CANADENSIS (LINN.), TEMM. **NORTHERN SANDHILL CRANE.** GROUP II. CLASS c.

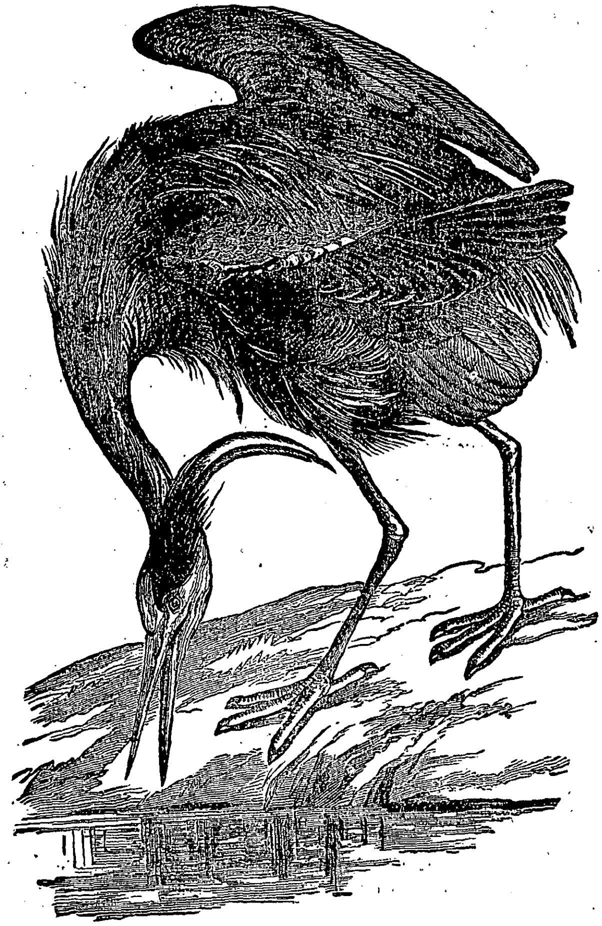
This species was formerly abundant in the state, and some used to breed here. It appears, however, to have taken the Dakota fever and gone west, like other people, to take up new claims.

It is rarely indeed now that we hear that cry, which only a Crane can make, come down through the still air from a mere mote floating in the sun, high above the clouds.

Food: "Sandhill Cranes stalk over the prairies to spear them (grasshoppers) by the thousands" (Coues). Am. Nat., Vol. VIII, p. 282.

Family ARDEIDÆ: Herons.

Fig. 144.



Great Blue Heron (*Ardea herodias*). From Tenney's Zoology.

228. **Ardea herodias**, Linn. GREAT BLUE HERON. Group II. Class c.

The Great Blue Heron is a common summer resident throughout the state, and is often, though incorrectly, called the Blue Crane. Its favorite resorts are slow streams and muddy lakes. Here it is known as an expert fisherman, who finds a ready market at no more distant port than his own capacious stomach, which is reached by a thoroughfare of alarming capabilities. I removed from the stomach of one of these birds a bullhead eight and one-half inches in length. The fish had been swallowed entire, and with those ridged side spines set at right angles to its body. Another bird had eaten two sunfish and five dragon-fly larvæ.

Food: Fish, mice, dragon-flies and seeds of spatter-dock. It has been known to eat fifty moderate sized dace and roach in one day. In a carp pond one has been known to eat one thousand stone carp in one year (Wilson). Crabs, eels, shellfish and various fishes (De Kay). Snakes, frogs, mice, fishes and insects (Samuels). Fish of all kinds, frogs, lizards, snakes, birds, shrews, meadow mice, young rats, aquatic insects, moths and dragon-flies. It destroys great numbers of Marsh Hens, Rails and other birds (Audubon).

229. HERODIAS EGRETTA (GM.), GR. **GREAT EGRET.** GROUP II. CLASS c.

This beautiful bird is a not uncommon summer resident, but much more retiring and shy than the last species.

Food: Frogs, lizards, small fish, mice, moles and insects (Wilson). Frogs, salamanders, mice, moles, snakes, etc. (De Kay).

230. BUTORIDES VIRESCENS (LINN.), CAB. **GREEN HERON.** GROUP II. CLASS c.

This is a common summer resident which frequents the banks of wooded streams more than any other situation.

The large number of dragon-fly larvæ observed in the stomachs of some of these birds is an unpleasant record to make.

Food: Of five specimens examined, two had eaten ten water scorpions; two, five beetles; one, two dragon-flies; two, fifteen dragon-fly larvæ; and two, four small fish.

Lizards, frogs, small fish, crabs, various worms and larvæ, particularly those of dragon-flies (Wilson). Reptiles and fishes (De Kay).

231. NYCTIARDEA GRISEA NÆVIA (BODD.), ALLEN. **AMERICAN NIGHT HERON.** GROUP II. CLASS c.

This species occurs in the state and is said to breed across the line in Lake county, Illinois. I have not met it alive. Mr. Thure Kumlien writes me that he received two specimens of this species from Stoughton, September 27, 1876.

Food: Small fish (Wilson). Fish, aquatic reptiles, grasshoppers, large insects and sea lettuce (De Kay). Herrings, pickerel, eels (Samuels). Fish, shrimps, tadpoles, frogs, water lizards, leeches, all kinds of water insects, moths, and even mice (Audubon).

232. BOTAURUS MUGITANS (BARTR.), COUES. **AMERICAN BITTERN.** GROUP II. CLASS c.

The American Bittern, or Stake-driver, as it is often called, is the most abundant of all our Herons and the least retiring. It is found in all meadows during the summer where there are small sloughs.

Food: Of four specimens examined, two had eaten eight small fish; one, a crawfish; one, a water-scorpion; one, a large water beetle; one, thirteen dragon-flies; one, a spider and its egg case; one, a meadow mouse; and four, six crawfish.

Meadow mice, aquatic reptiles and fish; also large winged insects (De Kay). Fish, frogs, other reptiles and insects (Samuels). Mollusks, lizards, frogs, small snakes, and fish as well as insects (Coues).

233. ARDETTA EXILIS (GM.) GR. **LEAST BITTERN.** GROUP II. CLASS c.

This is a common summer resident, but a very retired species, confining itself among the reeds of swamps and lakes.

Food: Of four specimens examined, one had eaten five beetles and two other insects; one, a water-scorpion and twenty water-boatmen; one, four insects and a dragon-fly; and one, a small fish.

Small fish (Wilson). Snails, slugs, tadpoles, water lizards, small shrews, and occasionally field-mice (Audubon).

FAMILY RALLIDÆ: RAILS.

234. RALLUS ELEGANS, AUD. **KING RAIL; FRESH MARSH HEN.** GROUP I. CLASS c.

I have seen but a single specimen of this species. It was observed among the reeds on Cold Spring pond, in Jefferson county.

Food: Grass seeds, insects, tadpoles, leeches, small cray-fish (Audubon).

235. RALLUS VIRGINIANUS, LINN. **VIRGINIA RAIL.** GROUP I. CLASS a.

This is a common summer resident, frequenting damp meadows and reedy ponds.

Food: One specimen examined had eaten five snails.

Small snails, worms, larvæ of insects (Wilson). Worms, aquatic insects, fresh-water shells and seeds of grasses (De Kay). Various insects and worms (Samuels). Small slugs, snails, aquatic insects, worms, crustaceans and seeds of grasses (Audubon).

236. PROZANA CAROLINA (LINN.), V. **CAROLINA RAIL; CAROLINA CRAKE.** GROUP I. CLASS c.

This species is very abundant in all suitable places throughout the summer. Its favorite haunts are the sloughs, reedy lakes and ponds and the marshy banks of streams.

Food: Of seven specimens examined, six had fed upon seeds; two had eaten six snails; two, two beetles; one, two leaf-hoppers. Two had fed upon duck-weed.

Seeds of reeds (Wilson).

237. PROZANA NOVEBORACENSIS (GM.), CASS. **YELLOW RAIL; YELLOW CRAKE.** GROUP I. CLASS c.

This species is mentioned by Mr. Nelson as not very rare in Northeastern Illinois, where it breeds. Dr. Hoy reports it as breeding in the state. I have not seen it.

Food: Aquatic insects and seeds (De Kay).

238. GALLINULA GALEATA (LICHT.), BP. **FLORIDA GALLINULE.** GROUP I. CLASS c.

A common summer resident. It frequents weedy ponds in various parts of the state.

Food: Of seven specimens examined six ate forty-two snails; one, three water-scorpions; and two, other insects. Six ate seeds; four, duck-weed; and four, water crowfoot.

239. IONORNIS MARTINICA (LINN.), REICH. **PURPLE GALLINULE.** GROUP I. CLASS c.

This species is introduced here on the authority of Mr. Nelson, who says: "Dr. Hoy informs me of its capture near Racine."

240. FULICA AMERICANA, GM. **AMERICAN COOT.** GROUP I. CLASS c.

The Coot, like the Florida Gallinule, is an abundant summer resident which frequents similar situations, but I have never observed the two species together.

Food: Of two specimens examined only algæ were noted as occurring in the stomachs.

Various aquatic plants, seeds, insects, and, it is said, small fish (Wilson).

FAMILY ANATIDÆ: SWAN, GEESE AND DUCKS.

241. CYGNUS BUCCINATOR, RICH. **TRUMPETER SWAN.** GROUP I. CLASS c.

A rather rare migrant.

242. CYGNUS COLUMBIANUS (ORD.), COUES. **AMERICAN SWAN.** GROUP I. CLASS c.

A rather common migrant.

243. ANSER ALBIFRONS GAMBELI (HARTL.), COUES. **AMERICAN WHITE-FRONTED GOOSE.** GROUP I. CLASS c.

An abundant migrant.

Food: Beech-nuts, corn, acorns, young blades of grass. In their gizzards I have found fishes, water lizards and snails (Audubon).

It frequents the corn-fields in Central Illinois, where hundreds are killed and shipped to the markets (E. W. Nelson).

244. CHEN CŒRULESCENS (LINN.), RIDG. **BLUE GOOSE.** GROUP I. CLASS c.

This species is introduced here on the authority of a statement of Mr. Nelson, who says many are sent to the Chicago markets with the preceding during the migrations.

245. CHEN HYPERBOREUS (PALL.), BOIE. **SNOW GOOSE.** GROUP I. CLASS c.

This species is common during the migrations.

Food: Rushes, insects in autumn, and berries, particularly *Empetrum nigrum* (Richardson). Roots of reeds (Wilson). It frequents the corn-fields in Central Illinois (E. W. Nelson).

246. CHEN HYPERBOREUS ALBATUS (CASS.), RIDG. **LESSER SNOW GOOSE.** GROUP I. CLASS c.

This Goose moves north and south with the last during the migrations, and in about equal numbers.

Food: It frequents the corn-fields in Central Illinois (E. W. Nelson). In speaking of the two varieties together, Dr. Coues says: "Various kinds of ordinary grass form a large part of this bird's food, at least during their winter residence in the United States. They also eat the bulbous roots and soft succulent culms of aquatic plants."

247. BERNICLA BRENTA (PALL.), STEPH. **BRANT GOOSE.** GROUP I. CLASS c.

Mr. Nelson states that the only instance known to him of the capture of this species in this portion of the country, is a specimen taken by Dr. Hoy near Racine, which is in his collection. Mr. Paul B. Wood writes me that he has taken this Goose near Peshtigo.

248. BERNICLA CANADENSIS (LINN.), BOIE. **CANADA GOOSE; COMMON WILD GOOSE.**

249. BERNICLA CANADENSIS HUTCHINSI (RICH.), COUES. **HUTCHINS' CANADA GOOSE.** GROUP I. CLASS c.

Both of these varieties are common migrants.

Food: Green leaves of sea cabbage, roots of sedges (Wilson). Fond of lighting in corn-fields and feeding on fresh blades, often committing great havoc; grass and earth-worms (Audubon).

250. ANAS BOSCAS, LINN. **MALLARD.** GROUP I. CLASS c.

A very abundant migrant and still a summer resident. They are becoming sensibly less numerous year by year, under the steady fire of sportsmen. Many breed about Lake Puckawa, and in many other similar places.

Food: Purely omnivorous. Putrid fish, garbage of all sorts, snakes, small quadrupeds, nuts and fruits of all kinds, rice, corn and other grains. They are expert fly-catchers (Audubon).

251. ANAS OBSCURA, GM. **DUSKY DUCK.** GROUP I. CLASS c.

The Dusky Duck is a rather uncommon migrant and probably breeds very sparingly.

Food: Small snails (Wilson).

252. DAFILA ACUTA (LINN.), JEN. **PINTAIL; SPRIGTAIL.** GROUP I. CLASS c.

A common migrant, often associated with the Mallards.

Food: Beech-nuts (Audubon).

253. CHAULELASMUS STREPERUS (LINN.), GR. **GADWALL.** GROUP I. CLASS c

A rather common migrant.

Food: Small fish, shells and aquatic plants (De Kay). Tender shoots and blades of grasses, beech-nuts and acorns, seeds of all kinds, tadpoles, small fish and leeches; sometimes alights in corn-fields for corn (Samuels from Audubon).

254. MARECA PENELOPE (LINN.), SELBY. **EUROPEAN WIDGEON.** GROUP I. CLASS c.

Mr. Nelson in his Birds of Northeastern Illinois has the following: "Exceedingly rare straggler. It has also been shot on Lake Mendota in Wisconsin by Mr. Kumlien (Hoy)."

255. MARECA AMERICANA (GM.), STEPH. **AMERICAN WIDGEON.** GROUP I. CLASS c.

A common migrant.

Food: Tender roots of aquatic plants (Wilson). Chiefly aquatic vegetables (De Kay). Principally tender roots and leaves of aquatic plants (Samuels).

256. QUERQUEDULA CAROLINENSIS (GM.), STEPH. **GREEN-WINGED TEAL.** GROUP I. CLASS c.

This exquisite Duck is a common migrant and summer resident. It breeds about Lake Puckawa, and near Berlin, and doubtless elsewhere in similar situations.

Food: Feeds on various kinds of grass; also leaves of tender vegetables (Wilson). Various water insects and their larvæ, seeds of aquatic plants, and tadpoles of different frogs (Samuels). Seeds of grasses, small acorns, fallen grapes and berries, aquatic insects, worms and snails (Audubon).

257. QUERQUEDULA DISCORS (LINN.), STEPH. **BLUE-WINGED TEAL.** GROUP I. CLASS c.

This is our most common summer resident, breeding in large numbers in most suitable places.

Food: Of four specimens examined, three had eaten sixty snails; one, vegetable matter; and one, seeds and duck-weed.

Seeds and vegetable food (Wilson). Aquatic insects and seeds of aquatic plants (Samuels).

258. SPATULA CLYPEATA (LINN.), BOIE. **SHOVELLER; SPOONBILL DUCK.** GROUP I. CLASS c.

A rather common migrant. It may also breed in the state, as it is said to do so in Illinois.

Food: Various aquatic insects and tadpoles, but eats but few seeds of aquatic plants; small crustaceans (Samuels).

259. AIX SPONSA (LINN.), BOIE. **WOOD DUCK; SUMMER DUCK.** GROUP I. CLASS c.

This handsome Duck breeds in abundance along Bark river and about small wooded lakes south and east of Whitewater, as well as along the wooded streams in Northern Wisconsin, and doubtless generally in similar situations.

Food: Of five specimens examined, one had eaten two dragon-flies and three water-larvæ; three, black cherries; one, burr oak acorns; and three, seeds.

Seeds of wild oats, acorns and insects (Wilson). Acorns, seeds of aquatic plants and insects (De Kay). Food of young, aquatic insects, flies, mosquitoes and seeds. When older they chase dragon-flies, or pick up locusts that have fallen into the stream. Old birds eat acorns, beech-nuts, grapes, berries and rice; insects, snails, tadpoles and lizards.

260. FULIGULA MARILA (LINN.), STEPH. **GREATER BLACK-HEAD; SCAUP DUCK.** GROUP I. CLASS c.

Not a common migrant.

Food: Shell-fish (Wilson). Small fry, cray-fish, grass that grows along river beds (Audubon).

261. FULIGULA AFFINIS (EYT.), **LESSER BLACK-HEAD; BLUE-BILL.** GROUP I. CLASS c.

This is an abundant migrant which breeds in small numbers about Berlin and doubtless in other parts of the state.

Food: Small fry, cray-fish, and grasses which grow along beds of rivers (Audubon from Samuels).

262. FULIGULA COLLARIS (DONOV.), BP. **RING-NECK; BLACK-HEAD.** GROUP I. CLASS c.

This Duck is also an abundant migrant which is associated with the last, and doubtless a few breed with us as they do in Northeastern Illinois.

263. FULIGULA FERINA AMERICANA (EYT.), COUES. **AMERICAN POCHARD; RED-HEAD.** GROUP I. CLASS c.

A rather common migrant.

Food: Stems and roots of Vallisneria, various aquatic plants, small fish, aquatic insects (Samuels).

264. FULIGULA VALLISNERIA (WILS.), STEPH. **CANVAS-BACK.** GROUP I. CLASS c.

A common migrant. Many are shot on Lake Puckawa.

Food: Roots of Vallisneria (Wils.) Vallisneria (De Kay).

265. CLANGULA GLAUCIUM (LINN.), BREHM. **GOLDEN-EYE; GANOT.** GROUP I. CLASS c.

A common migrant. Most abundant about the large lakes. Some are known to winter on Lake Michigan, north of Chicago.

Food: Shellfish and small fry (Wilson). Small fish and aquatic plants (Samuels).

266. CLANGULA ISLANDICA (GM.), BP. **BARROW'S GOLDEN-EYE.** GROUP I. CLASS c.

Mr. Nelson reports this species as a winter resident on Lake Michigan, and states that Dr. Hoy writes that a specimen was shot at Racine during the winter of 1860.

267. CLANGULA ALBEOLA (LINN.), STEPH. **BUFFLE-HEAD; BUTTER-BALL; SPIRIT DUCK.** GROUP I. CLASS c.

A common migrant and more abundant than the preceding members of this genus. It remains upon our streams until they are frozen over, and it is among the first to return in the spring.

Food: Shellfish, shrimps, etc. (Wilson). Aquatic vegetables and insects (De Kay). Small fish and crustaceans (Samuels).

268. Harelda glacialis (Linn.), Leach. **LONG-TAILED DUCK; OLD WIFE.** Group I. Class c.

An abundant migrant and winter resident upon Lake Michigan.

Food: One specimen obtained at Ithaca, New York, October 30th, had in its stomach only small mollusks.

Small shellfish (Wilson).

269. Histrionicus minutus (Linn.), Coues. **HARLEQUIN DUCK.** Group I. Class c.

Of this species Mr. Nelson says: "Rather rare winter resident upon Lake Michigan. Dr. Hoy has secured specimens at Racine."

Food: Shrimps, shellfish, roe, aquatic insects and mollusca (Audubon).

270. Somateria mollissima (Linn.), Boie. **EIDER DUCK.** Group I. Class c.

This species is included in Mr. Nelson's list, and he there states that Dr. Hoy informs him that a specimen was obtained at Racine in January, 1875.

271. Somateria spectabilis (Linn.), Boie. **KING EIDER.** Group I: Class c.

Mr. Nelson says: "A single specimen has been taken at Milwaukee, and is preserved at that place (Hoy)."

The three following species are reported by Mr. Nelson as winter residents in Illinois. From this it may be expected that they are at least migrants with us, unless in their movements they pass across the state without alighting, or go to the east of it: *Œdemia Americana*, Gro.; *Œdemia fusca* (Linn.), Flem.; *Œdemia perspicillata* (Linn.), Flem.

272. Erismatura rubida (Wils.), Bp. **RUDDY DUCK.** Group I. Class c.

A common migrant. Mr. Nelson mentions the occurrence of this species in Northeastern Illinois during the breeding season.

Food: Marine and fresh-water plants and seeds (De Kay). Shell-fish and mollusks (Samuels).

273. Nomonyx dominica (Linn.), Ridg. **ST. DOMINGO DUCK.** Group I. Class c.

Mr. Thure Kumlien has reported this species from Wisconsin (Coues).

274. Mergus merganser, Linn. **MERGANSER; GOOSANDER.** Group I. Class c.

A common migrant.

Food: Fish, aquatic reptiles, shells, cray-fish, etc. (De Kay).

275. Mergus serrator, Linn. **RED-BREASTED MERGANSER.** Group II. Class c.

Not a very common migrant.

Food: Small fry and shellfish (Wilson).

276. MERGUS CUCULLATUS, LINN. **HOODED MERGANSER.** GROUP II. CLASS c.

This handsome species is an abundant migrant. We met with small flocks of them upon the small lakes in Northeastern Wisconsin during the month of October, 1877.

Food: One specimen shot at Boulder Lake had in its stomach small seeds, shells and vegetable matter.

Fresh-water insects and their larvæ. It is an expert fisherman (Samuels). Snails, tadpoles and insects (Audubon).

FAMILY PELECANIDÆ: PELICANS.

277. PELECANUS TRACHYRHYNCHUS, LATH. **AMERICAN WHITE PELICAN.** GROUP II. CLASS c.

This large scoop-net fisherman was formerly a common migrant throughout the state, but at present moves north along the Mississippi and further west. There is a specimen in the cabinet of the River Falls State Normal School, which was obtained near St. Paul.

Food: A specimen shot on Cayuga Lake, N. Y., in the spring of 1864, had in its stomach two sunfish *(Pomotis vulgaris)*, one, six, and the other eight inches long, and two bullheads (W. J. Beal, Am. Nat.).

FAMILY GRACULIDÆ: CORMORANTS.

278. PHALACROCORAX DILOPHUS (SW.), NUTT. **DOUBLE CRESTED CORMORANT.** GROUP II. CLASS c.

A regular migrant, but not very common.

Food: Shrimps and various kinds of fish (Audubon).

FAMILY LARIDÆ: GULLS, ETC.

279. LARUS GLAUCUS, BRÜNN. **GLAUCUS GULL.** GROUP II. CLASS c.

Mr. Nelson speaks of this species as a rare winter visitant to Lake Michigan, and states that Dr. Hoy has killed three specimens upon the lake near Racine.

280. LARUS ARGENTATUS SMITHSONIANUS, COUES. **SMITHSONIAN HERRING GULL.** GROUP II. CLASS c.

A migrant and winter resident on Lake Michigan. Dr. Hoy records it as common on the lakes. Mr. Nelson states that a colony breed on an island between Green Bay and Lake Michigan.

Food: It consists principally of herrings, of which they destroy great numbers; also other fish, shrimps, crabs, shellfish, as well as young birds and small quadrupeds. They suck all the eggs they can find. The young are fed chiefly upon shrimps and small crustacea (Audubon).

281. LARUS DELAWARENSIS, ORD. RING-BILLED GULL. GROUP II. CLASS c.

A rather common migrant, and, with the last, was obtained at Whitewater.

282. RISSA TRIDACTYLA (LINN.), BP. KITTIWAKE GULL. GROUP II. CLASS c.

Of this species Mr. Nelson writes: "A rare winter visitant to Lake Michigan. Dr. Hoy writes that in the winter of 1870 a single specimen of this species kept about the harbor for several days, but was too shy to be shot."

283. CHROÏCOCEPHALUS FRANKLINI (RICH.), BRUCH. FRANKLIN'S ROSY GULL. GROUP II. CLASS c.

Dr. Hoy states that a specimen was obtained at Milwaukee and is preserved in a collection at that place (Nelson). Mr. E. S. Richmond writes me that he has obtained it at Whitewater.

284. CHROÏCOCEPHALUS PHILADELPHIA (ORD.), LAWR. BONAPARTE'S ROSY GULL. GROUP II. CLASS c.

An abundant migrant.

Larus leucopterus, *L, marinus*, *L. argentatus* and *Chroïcocephalus atricilla* are other Gulls included by Mr. Nelson in his "Birds of Northeastern Illinois." Both Dr. Hoy and Mr. Nelson allege they have seen specimens of *Xema Sabinii*, which they did not secure.

285. STERNA MAXIMA, BODD. ROYAL TERN. GROUP II. CLASS c.

A specimen was taken at Milwaukee many years since and preserved in a museum there (Hoy from Nelson).

286. STERNA HIRUNDO, LINN. COMMON TERN; SEA SWALLOW. GROUP II. CLASS c.

A rather common migrant.

287. STERNA FOSTERI, NUTT. FOSTER'S TERN. GROUP II. CLASS c.

This is a summer resident and not very rare. I am confident that I have seen it five times, though I have never obtained a specimen.

Sterna anglica and *Sterna caspia* are included in Mr. Nelson's list. I believe that I saw the first species at Berlin. *Sterna superciliaris* is also included.

288. HYDROCHELIDON LARIFORMIS (LINN.), COUES. BLACK TERN. GROUP I. CLASS c.

This is a very abundant summer resident and is to be found about most of our sloughs and weedy lakes in large numbers.

Food: Of six specimens examined, three had eaten six dragon-fly larvæ; three, six water-scorpions; one, eight dipterous insects; and three, twelve other insects.

Grasshoppers, crickets, beetles, spiders and other insects floating on the water (Samuels). Follows the plow for earth-worms and larvæ (E. W. Nelson.)

Family COLYMBIDÆ: Loons.

289. Colymbus torquatus, Brünn. **GREAT NORTHERN DIVER.** Group II. Class c.

This large species is still not uncommon, but is steadily retiring. It is a summer resident and breeds regularly.

Food: Fish (Wilson).

290. Colymbus arcticus. **BLACK-THROATED DIVER.** Group II. Class c.

In regard to this species Mr. Nelson says: "A very rare winter visitant on Lake Michigan. There is a specimen in Dr. Hoy's collection, taken at Racine, and a second specimen was captured and preserved at Milwaukee.

291. Colymbus septentrionalis, Linn. **RED-THROATED DIVER.** Group II. Class c.

Said to be not uncommon during the winter on Lake Michigan.

Family PODICIPIDÆ: Grebes.

292. Podicipes cornutus (Gm.), Lath. **HORNED GREBE.** Group II. Class c.

A migrant not very common. A specimen was taken at Berlin, May 4, 1874, and is now in the High School Cabinet.

Food: Insects, fishes, crabs, fresh and salt water shells (De Kay). On salt water, shrimps, fishes and crabs; on fresh water, insects, leeches, small frogs, tadpoles and aquatic insects (Audubon).

293. Podicipes griseigena holbœlli (Reinh.), Coues. **AMERICAN RED-NECKED GREBE.** Group II. Class c.

Said to be rare and found only in winter on Lake Michigan.

Food: Smallest fry, amphibians, reptiles, insects and vegetables (Audubon).

294. Podicipes auritus (Linn.), Lath. **EUROPEAN EARED GREBE.** Group II. Class c.

Mr. Nelson speaks of this species as rather common on Lake Michigan in winter, and Dr. Hoy states that it nests on the margin of small lakes, and is a common species.

Food: Fish, aquatic insects, small reptiles and seeds of aquatic plants (Audubon).

295. Podilymbus podicipes (Linn.), Lawr. **RED-BILLED GREBE; DAB-CHICK.** Group II. Class c.

This is a very common species. A pair or more is to be found upon almost every pond and stream.

Food: Of six specimens examined, two contained fifteen dragon-fly larvæ; four, fifteen water-scorpions; one, seven shells; one, nine insects; one, a small bone; and every one a rather large pellet of feathers.

Small fry, plants, seeds, aquatic insects and snails (Audubon).

PART III.

CHAPTER I.

IRON ORES.

By R. D. Irving.

Iron Industry of Wisconsin.

Iron mining and iron smelting are industries which are as yet in their infancy in Wisconsin, although the state already ranks sixth among the states of the Union in its total iron production. According to the census of 1870, when its total production was 42,234 tons, it was then twelfth in rank.[1] This production has thus far been largely from ores raised in the northern peninsula of Michigan. While these ores will continue to come to Wisconsin in increasing quantity, her own ores will in the future yield a larger and larger proportion of the total product. According to the census of 1880, Wisconsin had nine iron smelting establishments, with a total capital of $2,843,218, employing 2,153 hands, paying out $1,004,931 in wages, using $3,830,667 worth of raw materials, and producing 178,935 tons of iron, worth $6,580,391.[2]

Iron smelting had fairly begun in Wisconsin between the years 1850 and 1860. In 1859 there were three charcoal furnaces in the state, all built to use native ores. One of these was at Mayville, in Dodge county, where it is still in operation — having been rebuilt in 1872,— and is using still, as then, the Clinton red hematites of that vicinity. The second of these furnaces was a small one, at Ironton, in Sauk county, built in 1857 to produce both castings and pig iron from a hematite occurring in the immediate vicinity. This furnace is still in operation, using the same ore. The third of these furnaces was at Black River Falls, in Jackson county. It was very small and was soon abandoned, having been built to utilize the lean ferruginous schists of that vicinity. These schists occur about Black River Falls in great abundance, but no one at all conversant with iron ores or iron smelting, would have undertaken to base an enterprise upon them, or, rather, upon those exposed to view, for it is not impossible that good ores may lie concealed in the vicinity.

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[1] Statistics of the Iron and Steel Production of the United States, by James M. Swank, p. 12. Reports of the Tenth Census.

[2] Op. cit., p. 47.

No further advance was made in the iron industry in Wisconsin until 1865, when a charcoal furnace was built at Iron Ridge, in Dodge county, to use the Clinton hematites of that place. Subsequently two furnaces were built at West Depere, in Brown county (1869 and 1872); two at Depere, in the same county (1869 and 1872); one at Green Bay (1870); two at Bay View, near Milwaukee (1870 and 1871); two at Appleton (1871 and 1872); one at Milwaukee (1873); and one at Fond du Lac (1874). A furnace was also built at Cazenovia, in Richland county, in 1876, to smelt brown hematites of that vicinity, but was torn down in 1879. Most of these later furnaces were built to use charcoal and ores from the northern peninsula of Michigan. The three furnaces at Bay View and Milwaukee use anthracite coal and coke. Several of the furnaces smelt a mixture of Lake Superior ores and the red hematite from Dodge county. In 1880 there were thus fourteen furnaces in the state, eleven using charcoal and three anthracite coal and coke. The only rolling mill in Wisconsin is one at Bay View near Milwaukee. It is a large mill, and produces both new iron rails and merchant bar.

Nature and Principal Properties of the Several Kinds of Iron Ore Found in Wisconsin.[1]

All iron ores are made up of two portions. These are the mineral containing the iron, and the foreign minerals which are present as impurities. These two different portions are mechanically united with one another, and are mingled in all proportions, there being a complete graded series, from ores which are almost or quite free from foreign matter, to rocks in which the iron is a mere accessory or accidental ingredient. There is thus no sharp line between iron ores and ferruginous rocks. Any iron-bearing substance from which the iron may be profitably extracted is an iron ore, and as the percentage of metallic iron at which this may be done varies with the same kind of ore in different regions, and with different kinds of ore in the same region, it is not possible to lay down a figure at which an iron-bearing substance always becomes an iron ore. What would be a mere worthless rock in one region, would be a valuable ore in another.

Iron ores differ from one another, in the first place, as to the nature of the iron-bearing mineral present, and in the second, as to the nature of the foreign minerals. So far as Wisconsin iron ores are concerned, the iron mineral is always one of three kinds, namely:

[1] Such ores as do not occur in Wisconsin are not spoken of here.

magnetite, hematite, or limonite. Two of these minerals at times occur in the same ore. Ores in which the iron occurs as magnetite are known technically as "magnetic ores;" those in which it is in the shape of hematite, as "hematite ores;" and those in which it appears as limonite, as "brown ores." The hematites, however, embrace two strongly contrasted varieties, which are distinguished in the trade as "specular" ores, and "red hematites." In the former, the hematite is of the brilliantly metallic-lustered kind, and in the latter of the red, earthy kind. There are intermediate varieties, but these two phases are usually so strongly contrasted in the northwest, both as to occurrence and metallurgical properties, and are so generally distinguished in the iron trade, that it will be convenient to consider them separately here. The red hematites in turn present various gradation-varieties into the "brown" ores. We may, however, most conveniently class the Wisconsin ores under the four general heads of *magnetic ores, specular ores, red hematites,* and *brown ores.*

Magnetic Ores. The magnetic ores, as already indicated, are those in which the iron occurs in the form of the mineral magnetite. This mineral, whose physical properties are fully described in a previous chapter, is composed of sesquioxide of iron, 68.97 per cent., and protoxide of iron, 31.03 per cent. It contains, therefore, 27.6 per cent. of oxygen, and 72.4 per cent. of metallic iron. Since magnetic ores can never be richer than pure magnetite, the last figure is the extreme limit of the richness of such ores, and, indeed, since magnetite is the richest of iron-bearing minerals, for iron ores of any kind. All statements, then, as to the existence of iron ores of higher grade than this are without foundation. Experience shows, in fact, that magnetic ores very rarely exceed 65 per cent. of metallic iron. In Wisconsin a first class magnetic ore is one containing 60 per cent. or upwards. Below 50 per cent. magnetic ores are not now salable in the Wisconsin-Michigan region. Ores containing from 50 to 60 per cent. are second class. These high figures are demanded partly on account of the distance of the ore from mineral fuel and flux, but chiefly on account of the nature of the foreign matter present. This is, for the most part, quartz, which, on account of its great infusibility, requires a large proportion of fluxing material to produce a well molten slag.

The magnetic ores are to be recognized by their dark color, their high specific gravity, and their attractability by the magnet. It constantly occurs that explorers in the Wisconsin and Michigan woods, inexperienced in the recognition of iron ores, are deceived into supposing that dark colored and rather heavy rocks are such ores. Magnetite is not an uncommon constituent of such rocks, so that they often exert a marked influence upon the magnetic needle. It is thus desirable that the explorer should have some simple rules to guide him in distinguishing between iron ore and a mere ferruginous rock. In the first place, then, a small pocket magnet, which any explorer may readily carry, should pick up, not merely a few particles from the powder of the rock, but nearly the whole of the powder. This powder, moreover, should be black, or very nearly so. If it is white, or even distinctly gray, the substance is of no use as an iron ore. There should also be perceptible a more or less metal-like luster to the specimen.

The weight of the hand specimen also is an excellent guide to an experienced hand. Pure magnetite is 5.2 times as heavy as an equal bulk of water — that is, its specific gravity is 5.2,— and no magnetic ore is of value unless its specific gravity is upwards of 4.00. This difference affords a ready means of distinguishing magnetic ores from mere rocks, as these rarely exceed 3.0 in specific gravity. Between a lean and worthless magnetic ore, and a rich one, the distinction is often somewhat difficult to an inexperienced hand. Specific gravity determinations, close enough for practical purposes, may, however, be made by any one with a very inexpensive piece of apparatus. The following is the mode of procedure: "With an ordinary cheap swing balance, weigh the piece of ore first in the air, and afterwards while suspended in water. Divide the weight in air by the difference between the weight in air and the weight in water. The quotient will be the specific gravity of the specimen. This specific gravity, multiplied by 13, if the ore be apparently a rich one, or by 12, if it seem to be lean, will give approximately the percentage of metallic iron in the specimen."[1]

Two classes of magnetic ore are met with in Wisconsin. In one of these the structure of the ore is more or less fine granular, the individual crystalline particles crumbling apart readily. The other variety, which we may call slaty or flag ore, is very much more compact, and harder, and has, as the name implies, a more highly developed slaty structure. Such ores are more apt to be lean in iron than granular kinds. Not unfrequently, also, they contain a notable proportion of the specular oxide, in which case the black powder obtained from pure magnetite is exchanged for a purplish one.

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[1] See T. B. Brooks in Geol. Surv. Michigan, Part I, p. 202.

The lean flag ores of the Penokee Range, for instance, present all phases from hematite with a little magnetite, to magnetites in which there is no admixture of the specular oxide. Coarsely crystalline magnetites, like those of the Adirondack region of New York, are unknown among the Michigan and Wisconsin ores.

Of the foreign minerals mingled with these magnetites, quartz is always the principal one. When it materially exceeds ten per cent. of the whole mass, the ore is no longer a first class one. Besides quartz, some amphibolic material, such as actinolite or hornblende, is often present; but the quantity is always too small to have any material influence upon the metallurgical properties of the ore. Pyrolusite, or some other manganese oxide, is a not infrequent minor ingredient, its proportion at times reaching three or even four per cent. Pyrite and pyrrhotite — sulphides of iron — occur only in very minute quantity, the magnetic ores of the Lake Superior region generally being extraordinarily free from sulphur. Phosphorus is present in these ores in minute quantity in the shape of the mineral apatite or phosphate of lime. The quantity of this ingredient, however, is only very rarely sufficient to influence to any considerable degree the value of the ore. The phosphorus of the Wisconsin magnetites rarely exceeds 0.15 per cent.; while the sulphur reaches at the extreme, 0.20 per cent.

Specular Ores. The specular ores have the iron-bearing ingredient in the shape of iron sesquioxide, in which there is 70 per cent. of metallic iron and 30 per cent. of oxygen. The specular ores are distinguished from the magnetic by their more brilliant metallic luster, and the red color of the powder. So far as the richness of the different grades of the specular ore is concerned, as also their foreign impurities, and the use of the specific gravity test for the determination of their value, what has already been said for the magnetic ores will apply equally here. The specular ores are generally divided by the Lake Superior miners into the slate and granular varieties.[1] The two same varieties have already been recognized as characterizing the magnetic ores. But in the case of the specular ores the slaty structure is no indication of probable leanness, many of the very best specular ores being of this character. Such ores are not infrequently as perfectly and thinly laminated as a typical clay slate. The granular or massive specular ore shows, on the contrary, none of this lamination, and no tendency to split into slabs, being made up usually of minute crystalline grains. In

[1] Geol. Survey of Mich., Vol. I, Part I, p. 86.

some cases these grains are perceptibly of an octahedral form. This octahedral hematite, which is known to mineralogists under the variety name of martite, is plainly the result of a molecular change of magnetite. How far the other specular hematites of the Lake Superior region may be oxidized magnetites, is an open question. The granular specular ore is generally firm in texture, and never friable like the granular magnetic ores. The specular ores are only rarely without any admixture of magnetite.

In the Menominee river region there is found much of a peculiar soft, friable, blue specular ore, which is unlike the ores above described, constituting a distinct variety. It is a loose aggregate of minute particles of specular iron, and often shows some tendency to pass over to a red hematite.[1]

Red Hematites. The red or earthy hematites have the iron in the same chemical combination as in the specular varieties, that is to say, as the sesquioxide, but now in an earthy form, without metallic luster. These ores also commonly differ, so far as Wisconsin is concerned, in the nature of the foreign impurities, which are apt to be less refractory than in the specular ores. On this account, as also on account of their more open and porous character, the red hematites are often marketable at as low a figure as 40 per cent. of metallic iron. They are also more apt to be rich in manganese than the magnetic and specular ores, whilst at the same time they are more generally characterized by a notable proportion of phosphorus and sulphur. Among Wisconsin red hematites we have to note three principal varieties, coming from different regions, and different formations. One of these is the ore of the Clinton formation whose occurrence is described below. This ore is characterized commonly by a minute concretionary or oölitic structure, yields upwards of 50 per cent. of metallic iron, and 1 to 3 per cent. of phosphoric acid, and contains a mixture of clayey and calcareous matter as foreign impurities. Another class includes a part of the so-called "soft hematites" of the Huronian, though some of these ores fall under the next head. Still another class includes some of the ores of the Potsdam sandstone in Central Wisconsin, as for instance that smelted at Ironton in Sauk county. These ores are at times partially hydrated, but in other cases are chiefly red hematite.

Brown Ores. The brown ores are those in which the iron-bearing ingredient is the hydrated sesquioxide, in which there are contained

[1] Vol. III, pp. 504, 668.

of iron sesquioxide 85.6 per cent., and of water 14.4 per cent. The metallic iron of these ores, then, when they are free from foreign admixture, reaches 59.92 per cent., but they are very rarely obtained with more than 50 per cent. They are recognized by their light-brown to dark-brown color, and the light-brown to yellow color of their powder. They vary considerably in hardness, at times becoming very hard. They are without crystalline structure, being commonly—and this is precisely the same with the so-called "bog ores"—of a more or less open texture, to which, as also to the non-refractory nature of the foreign material, their ease of reduction is due. The foreign impurity is at times clayey, rarely is sandy, and not unfrequently is some partially decomposed silicated rock.

Three classes of the brown ores may be distinguished in Wisconsin. Of these, one includes a part of the so-called hematites of the Potsdam sandstone of Central Wisconsin, which appear to have been derived, mediately or immediately, from bodies of the sulphide. These ores always contain some non-hydrated sesquioxide admixed, and at times, as stated above, the red non-hydrated oxide predominates. Another class includes the bog ores which underlie certain marshes of Central Wisconsin. These are of limited extent, and are not yet utilized. The most important brown ores of Wisconsin, however, are the so-called "soft hematites of the Huronian" of the Menominee river region. They are earthy, brownish, and yellowish ores, often with much admixed red hematite, generally with from 40 to 50 per cent. of metallic iron, and are often rich in manganese.

Distribution and Occurrence of Iron Ores in Wisconsin.

At the present time, iron mining is carried on in Wisconsin in two important districts, and one of minor importance. These are the Iron Ridge region of Dodge county — where a Clinton red hematite is raised; the Menominee region of Florence county — where specular hematites and soft hematites are obtained from the Huronian schists; and the small district in the neighborhood of Ironton, Sauk county — where a brown hematite is found associated with the Potsdam sandstone. Besides these districts, that of the Penokee Huronian area, in Lincoln and Ashland counties, is not unlikely to produce largely in the near future. It will be convenient, then, to take up the Wisconsin ores, in the present connection, in the following order: The Huronian ores; the Clinton red hematite; and the ores of the Potsdam sandstone.

Huronian Ores.

The Huronian schists of the Menominee and Penokee regions are described in full in Vol. III of these reports.[1] Both are but continuations of the iron-bearing rocks of the Marquette region of Michigan.

Menominee Region. In the Menominee district the principal rocks of the Huronian are especially hornblendic and micaceous schist, clay-slate, chloritic schist, actinolite-schist, limestone, diorite, diabase and iron ores. The diorite and diabase are, in the writer's judgment, always of eruptive origin, occurring in part as interbedded contemporaneous flows, and in part as intrusions.

The Menominee schists are very intricately folded. They have been studied in detail by Brooks,[2] who thinks that he recognizes in them the same succession of beds that he had previously made out with great skill and labor in the Marquette region. In a region of such complicated folding, however, where the structure is yet more obscured by the occurrence of numerous faults, and of masses of eruptive material, as well as by a heavy drift-covering, the mapping of the folds has to be in large measure hypothetical. There are at least two horizons in the Menominee region at which iron occurs, if we accept Brooks' conclusions. One of these is the layer marked by him as VI, counting from the base of the series, and the other the one called by him XV.

As to the proper reference of the first-named of these horizons to the lower part of the series there can be little doubt. There are a number of mines along this horizon on the Michigan side of the Menominee river, near the boundary line, though none have as yet been opened on it in Wisconsin. This bed (VI) forms a strongly marked ridge trending N. 72° W., whose summit is not infrequently occupied by remnants of the horizontal Potsdam sandstone. The larger part of the bed is made up of ferruginous quartz-schists and quartzites, often running into lean "flag" ores, and now and then into ores of sufficient richness for working. The iron oxide in these rocks is in part the specular and in part the red, but, although in wholly subordinate quantity, enough of the magnetic oxide is present to affect the compass needle strongly as the bed is crossed. This bed is estimated by Brooks to have a total thickness of some 700 feet. Immediately beneath it is a very heavy and easily recognized bed of dolomite or crystalline limestone (V of Brooks' scheme).[3]

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[1] Parts III, IV, VII, and VIII. [2] Vol. III, Part VII. [3] Vol. III, p. 000.

The ore bodies of this range are irregular lens-shaped masses or portions of the belt richer than the rest. These lenses, with one or two exceptions, differ from most of those met with in the Marquette region, in that the latter are distinctly intercalated, the beds above and below them closing together about them, while in this case the iron oxide simply impregnates certain areas of the stratum, whose subordinate layers continue undeflected through the ore bodies.[1] The ores are of the peculiar "soft specular" variety, already noted as found only in the Menominee region. They lie midway between the true specular and red hematites.

As an illustration of the occurrence of these ores in the Menominee region, I may instance the ore-body of the Breen and Emmett mines, the easternmost on the range. I quote from Mr. C. E. Wright's description: "These mines adjoin one another, and are located on the north side of a swamp, and along the south side of a low ridge or plateau. The general trend or strike of the formation is about east and west, and the dip 60° to the south; the ore stratum therefore dips under the swamp." In the Breen mine the ore is of the blue "soft specular" variety just mentioned, while in the Emmett, this blue ore, with a thickness of twenty feet, is overlain, according to Mr. Wright, by fifty feet of brown ore. The blue ore carries 65.7 per cent. of metallic iron, and the brown 60.33 per cent., the latter figure proving that the so-called "brown ore" has much unhydrated iron oxide in its composition.

The stratigraphical position of the second ore horizon of the Menominee region is more doubtful, Brooks placing it as XV, Wright as XIII in the series. However this may be, the existence of a second horizon is unquestionable. It is opened upon at several points on the Wisconsin side of the Menominee river, and at the Commonwealth and Florence mines is yielding already on a large scale.

There are also several belts of magnetic attraction known on the Wisconsin side of the Menominee, along which no developments have as yet been made. The existence of these belts, the extraordinary developments already made in this region, and the great extent towards the south and west from the Menominee river of the Huronian schists, lead to the expectation that northeastern Wisconsin will become in the future one of the most prominent iron-producing areas of the United States.

Penokee Region. Passing now to the Huronian of the Penokee region in Ashland, Lincoln and Bayfield counties, we find the for-

[1] Vol. III, pp. 669, 670.

mation stretching all the way from Lake Numakagon, in Wisconsin, to Lake Agogebic in Michigan. Along the whole course of this belt the stratigraphical succession is practically the same, and the dip across the whole width of the belt, which is from half a mile to three miles, constantly to the northward. Several of the subdivisions have been traced uninterruptedly as much as fifty miles. About 540 feet above the base of the series comes in an iron-bearing belt from 800 to 900 feet wide. The rocks of this belt in Wisconsin are chiefly magnetic quartzites and quartz-slates, the magnetite in part concentrated into narrow and very rich seams, but also often uniformly spread through the mass, and then mingled with all sorts of proportions of specular hematite, up to a preponderating quantity, and often also with small quantities of actinolite or tremolite. Other less common kinds occur, and towards the west end of the belt there are interstratified hornblendic beds. Manganese oxide is always present in notable quantity, and the phosphorus and sulphur are always low. I have sampled considerable thicknesses of these magnetic ores containing upwards of 40 per cent. of iron, and numerous narrow bands with over 60 per cent., but, so far as I know, no quantity of magnetic ore, salable at the present standard of shipment, has yet been uncovered on the Penokee range.

In the neighborhood of the Michigan boundary, however, and thence eastward for about fourteen miles in Michigan, there have recently been some important developments of red hematite made. An examination of Atlas Plates XXIV, XXV, and XXVI, and the accompanying descriptions of Vol. III,[1] will show that the magnetic attractions observed in crossing the magnetic belt lessen rapidly in amount as one goes eastward from Potato river in T. 45, R. 1 E. Accompanying this change, which becomes first very pronounced in the vicinity of the Gogogashugun river, there is noticed, where the rocks are exposed, a lessening in the amount of magnetite, the belt becoming almost entirely quartzite, with here and there bunches and streaks of a very highly manganiferous red hematite, of a plainly secondary origin.[2] It is this manganiferous red hematite that has

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[1] pp. 118–132, 153–162.

[2] See especially in this connection pp. 131 and 132 of Vol. III, and the annual report for 1877. In the latter, after describing the subjacent formations, Prof. Chamberlin remarks as follows: "The schists are overlain by more massive beds of white and red quartzites, which occupy a belt at the surface about 200 feet in width. These graduate into a series of alternating layers of quartzite and iron ore, which are but partially exposed, and soon become entirely concealed by drift. The iron ore consists of red hematite and limonite.

"Where exposed, these have been largely eroded, owing to their softness, givsince been found in quantity by digging. On the Michigan side of the Montreal river a number of developments have been made, but in Wisconsin the only one is in Sec. 33, T. 46, R. 2 E., just west of the Gogogashugun river, where a bed of good ore 27 feet wide and 500 feet in length is said to have been uncovered.[1]

The stratigraphical arrangement of the Penokee Huronian resembles so nearly that of the Marquette Huronian, that there can be little doubt of the equivalency of the Penokee magnetic belt with Brooks' beds VI to XI of the Marquette region. If his reference of the Menominee iron belt to VI of his Marquette scheme is correct, then that belt finds its equivalent in the Penokee range magnetic belt.

The middle portion of the Penokee Huronian is so largely drift covered, that we are ignorant as to whether the equivalent of the Marquette ore horizon, XIII, is here ore-bearing or not. The rocks immediately above and below being so strikingly like those of the

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ing rise to intervals between the projecting layers of quartzite. The average resisting power of these alternating layers is less than that of the adjacent quartzites and silicious schists, to which fact is doubtless due their deeper erosion and limited exposure. Wherever they outcrop, the amount of quartzite is much greater than that of the associated ore, otherwise they would undoubtedly have been more deeply eroded and concealed. There is also present with the iron ores a considerable relative proportion of manganese.

"The special significance of these facts is this. To the westward, where the attractions are strong, magnetite and specular hematite are associated in a precisely similar way with quartz rock, and occupy a corresponding horizon. It becomes quite evident then that the loss of magnetism in this eastern portion is not due to the absence of iron ore, but to a replacement of the magnetic and specular ores by the softer red hematite and limonite. It is highly probable that all these ores were originally of the same character, and that their present variation is due to different degrees of oxidation and hydration. Oxidation of the magnetic ores would produce the hematites, and hydration of these the limonite. We may be justified then in suggesting that the eastern portion of the range has furnished, at some time in the history of the formation composing it, freer access of air and water, and is therefore presumably of more open texture. This harmonizes with the fact that the range in this portion has suffered more erosion, as shown by its flattening out eastward. It is also to be observed that the rock horizon of these hematites and limonites east of the meridian, does not project on the crest of the range, and sometimes occupies a more or less evident depression between the silicious schists on the south, and the magnetic slates on the north, where both outcrop, or approach the surface. It is along the line of this depression, and between the schists and slate, that the greatest probabilities of the existence of workable ore are presented, and the facts, in my judgment, justify a prudent and intelligent expenditure of means in testing the region by the interested parties." pp. 27–8.

[1] Report of J. M. Longyear to T. M. Davis, Pres. Lake Superior Ship Canal and Iron Co., Sept. 28, 1882.

Marquette series, we naturally look forward to the discovery of ore here in the future. Whatever discoveries are made, they are not likely to be of magnetic ore, to judge from the negative result of the magnetic observations made. It is well known that the rich specular and soft hematite ores do not outcrop.

Other Huronian Districts. Huronian rocks exist on the western side of the Chippewa river, and in Barron county, and iron ores in small quantities are known to occur here, some of them manganiferous.[1]

South and east from here, on Black river, the Huronian schists are highly ferruginous, carrying all of the iron oxides — magnetic, specular, red and brown,— but the iron content never exceeds 25 to 35 per cent. As already stated, an iron furnace was once erected here, and an attempt made to smelt the ores, of course without successful result. It is not impossible that marketable ores may be found here, though there is a lack of definite evidence justifying the expectation. Such rational grounds of hope as there are lie in the possibilities of secondary concentration of the lean schists such as occurs in the Menominee region.[2]

In the Baraboo region of Sauk county,[3] large bunches of brilliant specular iron in veins of white quartz are often met with, but no indication of the existence of ore in quantity in the Huronian of this region has been observed. It is a matter of great interest that while we have in the Penokee and Menominee Huronian the same kinds and succession of rocks as in the iron district of Marquette, in the Baraboo country, and to the northeast from there, we find a great development of the porphyry so characteristic of the Huronian iron district of Missouri. It is wholly within the possibilities that iron ores may yet be discovered in the Baraboo Huronian.

Iron Ores Associated with the Potsdam Sandstone.

In the counties lying immediately north of the Wisconsin river, along its final southwestward stretch to the Mississippi, certain places in the Potsdam sandstone are very highly charged with red hematite, and this at times nearly excludes the sand. A very good hematite ore occupying such a position has been opened on in the eastern part of the town of Westfield, T. 11, R. 4 E., but the deposit has not yet been fully developed.

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[1] Vol. IV, p. 578. [2] Vol. II, pp. 493–498. [3] Vol. II, pp. 504–519.

At a number of points in Richland, Crawford, Vernon and western Sauk counties, are other occurrences of red and brown ores in connection with the Potsdam sandstone.[1] In some cases these ores are plainly the result of the direct oxidation of bodies of iron sulphide, which is frequently found remaining in them in little cores, but in other cases — for instance, that of the vicinity of Ironton, in Sauk county — the ore is of a botryoidal and stalactitic nature, occupying irregular spaces between the blocks of a shattered belt of the sandstone, and can only have been derived indirectly from iron sulphide, the iron chiefly in the form of the red or non-hydrated oxide, but there is usually some of the brown or hydrated oxide, and occasionally the latter predominates. These deposits are always limited in size, and though likely to furnish a basis for a small industry for some time to come, they do not appear destined to assume any great importance. The small furnace at Ironton, Sauk county, has been working for more than twenty years past on an ore derived from one of these deposits — the one just referred to — on the S. W. ¼, Sec. 10, T. 12, R. 3 E. Some 25,000 tons of ore, yielding 11,000 tons of pig, had been raised here prior to 1873.

Clinton Iron Ore.

The well known "fossil," or "dyestone," ore, which occurs at so many points in the eastern states at the Clinton horizon, has also a large development in Wisconsin. The Clinton formation in the region of Lake Michigan merges into the great mass of limestone which forms nearly the whole of the Upper Silurian; but at the junction of this limestone mass with the underlying Cincinnati shales, the Clinton ore has been found at several points. This junction line has been indicated closely on the Atlas Plates X, XI and XII, Eastern Wisconsin, by Professor Chamberlin, who has shown that the ore certainly does not form a continuous band at the junction, though always occupying this position when found. Though not improbably existing at many points now unknown, it has as yet been developed in quantity at only one point.

At this, however, the deposit is of enormous dimensions. At Iron Ridge, in the town of Hubbard (T. 11, R. 11 E.), according to Professor Chamberlin, the ore is found with a thickness of 15 to 25 feet, lying horizontally underneath a west-facing ledge of the Niagara limestone. It is in more or less distinct layers, three to

[1] See Mr. Strong's descriptions in Vol. IV, pp. 49–56.

fourteen inches in thickness, most of which are made of lens-shaped concretionary grains, $\frac{1}{25}$ of an inch in diameter. Some of the lower layers are more or less hydrated, but the mass is ordinary red hem atite. Two small charcoal furnaces, one at Mayville, and one at Iron Ridge, smelt this ore in the vicinity, producing a pig exceed ingly rich in phosphorus, and using little or no flux. The average furnace yield is 45 per cent. Much the larger part of the ore, however, is sent away to mingle with the Lake Superior and Missouri Huronian ores, especially the former. It goes to Chicago, Joliet and Springfield, Illinois; St. Louis, Mo.; Wyandotte and Jackson, Mich.; and Appleton, Green Bay, and Milwaukee, Wisconsin. The Iron Ridge mine produced in 1872, 82,371 tons. The great extent of these deposits, their great accessibility from occurrence on the side of a ridge and in a thickly settled region, and the usefulness of the ore as an admixture for the silicious ore of Lake Superior, give it a very great value, notwithstanding the large content of phosphorus.

Composition of Wisconsin Iron Ores.

The following table of analyses, arranged in a convenient form for comparison, will give more definite ideas as to the composition of the various ores above described. Nos. 1 to 11 inclusive are samples from the Penokee iron range, and were made by Prof. W. W. Daniells, of the University of Wisconsin, and T. B. Bowman. Nos. 1 to 5 inclusive are samples taken from the west bluff at Penokee Gap, Sec. 14, T. 44, R. 3 W.; No. 1 represented a thickness of 19 feet; 2, of 18 feet; 3, of 10 feet; 4, a 10-inch seam of granular magnetite; 5, a 2-inch rich seam. No. 6 is of a sample from the N. E. quarter of Sec. 15, T. 44, R. 3 W., representing 41 inches; No. 7, of a sample from the N. E. quarter of Sec. 14, T. 44, R. 3 W., representing 50 inches; No. 8, of one from the S. E. quarter of Sec. 10, T. 46, R. 3 W., representing 58 feet; No. 9, of one from S. W. quarter of Sec. 1, T. 44, R. 2 W., representing a thickness of 20 feet; No. 10, of one from rich seams, S. E. quarter of Sec. 32, T. 45, R. 1 W.; and No. 11, of one representing a thickness of 25 feet, from near the Potato river, Sec. 19, T. 45, R. 1 E. Nos. 12 to 19 inclusive represent samples of the Menominee Huronian ores, and are taken from C. E. Wright's report on that region. No. 12 represents the 36-feet bed; No. 13, an overlying 10 feet of leaner ore; and No. 14, the 68-feet bed — all from the Commonwealth mine. No. 15 represents 10 feet of specular ore; No. 16, 15 feet of hard hematite; No. 17, 18 feet of soft hematite

ANALYSES OF WISCONSIN IRON ORES.

	1	2	3	4	5	6	7	8	9	10	11	12
Metallic iron	44.941	49.40	45.871	57.520	68.072	41.192	53.465	41,931	37.885	67.665	35.449	63.182
Protoxide of iron	19.173	....	19.479	24.602	....	8.460	8.332	16.797	12.331	27.488	5.112	....
Sesquioxide of iron	42.897	....	43.885	54.825	....	49.435	67.064	41.241	40.420	65.913	49.254	90.26
Silica	31.838	27.03	30.734	17.276	....	33.894	18.472	36.508	39.171	4.684	40.103	3.24
Organic matter	....	....	....	....	....	....	....	....	....	....	....	....
Alumina	0.384	....	none	none	....	1.151	0.305	1.025	1.139	none	2.059	..
Lime	1.373	....	1.910	2.043	....	3.156	2.483	1.383	1.373	1.786	1.687	....
Magnesia	1.293	....	1.632	0.660	....	2.403	2.280	2.156	1.890	none	1.586	....
Manganese oxide	1.126	....	0.873	0.625	....	0.337	1.050	0.193	0.553	0.563	0.183	....
Phosphoric acid	none	none	0.021	trace	....	none	0.127	trace	trace	none	none	0.53
Sulphur	none	....	none	trace	....	none	none	0.160	none	trace	0.199	0.02
Water	0.378	....	0.545	0.282	....	1.500	0.450	1.078	2.559	....	trace	....
Totals	98.462	....	99.079	100.313	....	100.336	100.613	100.541	99.436	100.431	100.183	....
Magnetic oxide	50.668	....	62.754	79.273	....	27.260	27.008	....	39.733	88.572	....	....
Specular oxide	11.402	....	0.610	0.154	....	30.635	48.438	....	13.018	4.829	....	....
Total	62.070	....	63.364	79.427	....	57.895	75.446	....	52.751	93.401	....	....

	13	14	15	16	17	18	19	20	21	22	23	24
Metallic iron	48.10	57.50	49.00	53.03	57.00	58.10	58.10	55.475	49.98	51.26	45.33	56.03
Protoxide of iron	....	....	....	....	....	....	....	....	....	....	....	....
Sesquioxide of iron	....	....	....	....	....	....	....	79.25	71.40	73.23	....	....
Silica	10.60	5.57	20.30	11.60	3.80	3.04	4.00	6.18	8.52	4.81	....	....
Organic matter	....	....	....	....	....	....	....	....	1.62	5.88	....	....
Alumina	....	....	....	....	....	....	....	2.49	3.77	1.00	....	..
Lime	....	....	....	....	....	....	....	[1]6.81	.58	0.11	....	....
Magnesia	....	....	....	.	....	....	....	[2]0.14	tr'ce	0.25	....	....
Manganese oxide	....	....	....	....	....	....	....	....	....	0.27	....	....
Phosphoric acid	[3].15	[3].21	[3].14	....	[3].40	....	[3].39	1.13	0.21	0.10	....	....
Sulphur	....	....	....	....	....	....	....	....	0.02	0.07	....	....
Water	....	....	....	....	....	....	....	4.00	13.46	14.24	....	....
Totals	....	....	....	....	....	....	....	100.00	99.85	99.69	....	....
Magnetic oxide	....	....	....	....	....	....	....	....	....	....	....	....
Specular oxide	....	....	....	....	....	....	....	....	....	....	....	....
Total	....	....	....	....	....	....	....	....	....	....	....	....

[1] Calcium carbonate. [2] Magnesium carbonate. [3] Phosphorus.

and limonite; No. 10, 9 feet of soft hematite; and No. 19, 6 feet of shaly specular ore — all from the Florence mine. No. 20, by Chilton, represents the Clinton ore of Iron Ridge, Dodge county. Nos. 21 and 22, by Oliver Matthews, represent bog ores, from Necedah, Juneau county, and Grand Rapids, Wood county, respectively. Nos. 23 and 24, by Prof. Daniells, are hematites from the Potsdam sandstone of Richland, Crawford and Vernon counties. No. 23 represents a good sized body of ore on the N. W. quarter Sec. 12 T. 10, R. 1 W., about three miles northwest of Richland Center. No. 24 is an ore occurring on the N. W. quarter Sec. 18, T. 13, R. 2 E.

The following analyses of Michigan Huronian ores are added because such ores are to be expected from the Huronian of Wisconsin. Nos. 1, 2, 3, and 4 of these analyses are from T. B. Brooks' report on the iron-bearing rocks of the northern peninsula of Michigan.[1] They are not the results of single analyses in each case, but give "an approximate general summary of the results" of a large number of analyses, "exhibiting the average composition of the four classes of ores now produced (1873) by the following mines of the Marquette region:

"1. *Red Specular Ores.* Barnum, Cleveland, Jackson, Lake Superior, New York, Republic, and Kloman.

"2. *Black Magnetic and Slate Ores.* Champion, Edwards, Michigan, Spurr, and Washington.

"3. *Soft Hematites.* Foster, Lake Superior, Lake Angeline, Tayler, Macomber, New England, Shenango, S. C. Smith, and Winthrop.

"4. *Flag Ore.* Cascade."

	1	2	3	4	5	6	7	8	9	10
Protoxide of iron	......	19.639	......	......	......	......	......	......	......	......
Sesquioxide of iron	90.520	67.761	75.75	70.98	93.850	81.570	83.863	85.200	93.28	95.90
Oxide of manganese	trace	0.130	0.800	trace	0.600	......	......	0.429	......	trace
Alumina	1.390	2.130	1.536	2.01	0.720	......	......	2.300	1.29	0.62
Lime	0.700	0.680	0.360	0.45	0.870	3.150	2.700	4.100	0.48	0.36
Magnesia	0.420	0.690	0.294	0.20	......	1.800	1.600	0.620	......	0.30
Sulphur	0.050	0.132	0.110	0.03	0.900	0.560	0.200	0.022	0.04	0.01
Phosphoric acid	0.258	0.199	0.185	0.13	0.110	0.295	0.100	0.040	0.08	0.04
Silica	5.892	7.828	14.035	25.12	1.400	5.550	6.760	7.500	4.36	1.80
Water, uncombined	......	......	1.180	......	......	......	......	......	......	......
Water, combined	......	......	3.940	......	......	......	......	......	......	......
Water, total	0.770	0.811	......	1.08	......	......	......	......	......	......
Volatile matter	......	......	1.810	......	......	......	......	......	......	......
Undetermined	......	......	......	......	......	......	......	......	......	1.47
Carbonic acid, water, etc.	......	......	......	......	2.360	7.579	4.960	......	......	......
	100.000	100.000	100.000	100.00	100.810	100.504	100 180	100.211	99.51	100.00
Metallic iron	62.995	62.930	52.649	49.332	65.700	60.330	58.700	59.640	65.300	67.130
Phosphorus	0.111	0.085	0.078	0.083	0.047	0.129	0.044	0.018	0.034	0.017
Metallic manganese	trace	0.091	0.56	trace	0.420	......	......	0.03	......	......
Specific gravity	4.74	4.19	3.88	4.09	......	......	......	......	......	......

[1] Geological Survey of Michigan, 1869–1873, Vol. I, p. 285.

Nos. 5 to 10 inclusive are Menominee range ores, all being, with one exception, of the "soft specular" variety. No. 5 is the soft specular ore of the Emmett mine; No. 6, that of the Breen;[1] No. 7 is a brown ore from the Emmett;[2] No. 8 is from the Norway;[3] No. 9 from the Quinnesec;[4] and No. 10 from the Cyclops.[5]

I add a few words in explanation of the effects of their foreign impurities upon the metallurgical properties of iron ores, for the benefit of those not especially acquainted with the subject. In this connection, these foreign ingredients may be considered under two heads, viz.: (1) those foreign constituents which make up the gangue matter, and are therefore commonly present in relatively large quantity; and (2) those accidental impurities, which, although occurring in relatively small proportion, are yet of great importance, because they enter into the pig iron produced in the smelting process, and affect its properties and value in a notable degree.

The most common gangue matter in the Wisconsin ores is silica, in the shape of the mineral quartz. The effect of this ingredient is to render the ores more difficult of fusion; a serious matter, especially in the case of those ores in which the iron oxide ingredient is magnetite, or specular hematite. A large quantity of silica in the ore renders necessary a large addition of flux, and a consequent reduction of the total iron content of the furnace charge. In the specular and magnetic varieties, ten per cent. is the outside limit of the silica content for a first class ore, while ores with 25 per cent. are hardly salable, save as they may serve as a fluxing material for calcareous ores. Besides silica, iron ores nearly always have among the gangue constituents lime, alumina, and magnesia. In the magnetic and specular ores of the northern part of the state, in which they occur as silicates, these ingredients are reduced to a minimum, and while they aid, as far as their amounts allow, in slagging the silica, they are yet commonly in too small proportion to exert much influence.

Blast furnace slags are silicates of alumina and lime, which last ingredient may be more or less largely replaced by magnesia. Since silica is commonly the predominating gangue constituent, limestones are in most cases used as the fluxing material. Besides lime these furnish often also to the slag, alumina and magnesia and some silica. The nature of the limestone to be used will then depend upon the com-

[1] Vol. III, p. 668.
[2] Vol. III, p. 668.
[3] Vol. III, p. 672.
[4] Vol. III, p. 676.
[5] Vol. III, p. 673.

position of the ores, and since the best composition for slags is well settled by experience, it is possible by a very simple calculation to arrive at the amount and character of the limestone to be added. Certain ores, as, for instance, the Clinton ore of Dodge county, have already a large amount of calcareous material, and may even be smelted without flux, the various slag-forming ingredients being present in the right proportion. In other cases, however, silicious matter has to be added to the furnace charge, and it is often very advantageous to do this in the shape of lean silicious ores such as occur in great abundance in the Lake Superior region, for in this way the iron product is increased, and ores otherwise useless may be treated alone.

The second class of impurities includes manganese, sulphur, and phosphorus, which occur respectively as oxide of manganese, sulphide of iron, and phosphate of lime. Manganese really belongs to both classes of impurities, since it often exerts an important influence on the slag, besides entering into the composition of the pig iron. Manganese oxide is present in many iron ores, and its presence is in general regarded as advantageous. It always tends to make the slag more readily fusible, a relatively very small proportion of manganese exerting a great influence. Pig iron containing manganese is especially adapted to conversion into wrought iron and steel.

Sulphur and phosphorus are the two chief hurtful impurities found in iron ores, and are the great bugbears of the makers of wrought iron and steel. Besides occurring in the iron ores, sulphur is also present in all mineral fuels used in iron smelting, and in many limestones used as fluxes, while not many limestones are completely free from phosphorus. Of the two, sulphur is the less objectionable ingredient in the furnace charge, because it may be in large measure gotten rid of in the smelting process, and again to some extent in the process of converting pig iron into wrought iron. The chief injurious effect of sulphur is the "redshortness," or brittleness at a red heat, which it imparts to both wrought iron and steel. The largest amount of sulphur that steel will stand without serious impairment of its malleability is 0.10 per cent., while wrought iron is perceptibly redshort with more than 0.05 per cent.

Phosphorus produces the contrary effect, i. e., renders iron and steel "coldshort," or brittle when cold. It also greatly increases the brittleness of cast iron. In wrought iron more than 0.10 per cent. of phosphorus tends to the production of a coarsely crystalline grain, whereby the strength and extensibility are decreased and the hardness increased, although a larger percentage has been found not to impair the strength, when the iron has been drawn out to such an extent that it exhibits a fibrous structure on a fracture.

Phosphorus has the same effect on steel, but the proportion that may be present without detriment is found to vary with the amount of carbon present, i. e., more phosphorus may be present as the carbon content is lowered. These same steels containing only 0.05 per cent. of phosphorus are unfit for rails, while others in which the carbon does not exceed 0.15 per cent. have been found to contain 0.35 per cent. of phosphorus without serious injury to the strength and ductility of the metal.

In the production of pig iron from its ores practically all of the phosphorus in the charge passes into the pig iron. In the conversion of the pig into wrought iron, phosphorus is in a measure eliminated, but in the steel-making processes, as still ordinarily carried out in this country, nearly all the phosphorus in the pig passes into the steel. Thus in the making of pig iron for steel making, ores exceedingly free from phosphorus are needed. One-tenth of one per cent. of phosphorus is commonly given as the outside limit for a pig iron from which Bessemer steel is to be made, and since all of the phosphorus in the furnace charge will pass into the pig, it is easy to foresee from the analysis of an ore whether it will produce so pure a pig. Of course it follows also that the leaner in iron the ores are, the less phosphorus they can stand.

In the future, however, phosphorus-bearing ores will be largely used in making steel, the new "basic" processes making possible the removal of a large percentage of phosphorus during the conversion of pig iron into steel. It should also be remembered that pig irons to be used for making castings may carry much larger quantities of sulphur and phosphorus than indicated by the figures above given, so that iron ores only very rarely contain enough of either of these elements to render them entirely worthless.

The Search for Iron Ores — Determination of the Value of Iron Deposits.

Iron ores of value very rarely outcrop in force, and hardly ever in such a way as to give any satisfactory answer to a question as to the probable extent and value of the deposits. Usually they are more or less deeply buried beneath surface debris, which is either glacial drift, or the immediate result of the degradation of the surrounding rocks. Rich iron ores are easily disintegrated, and in all those regions occupied by the glacial drift have offered so feeble a resistance to the glacial forces that their upper edges have been nearly always broken down and buried beneath loose material. Indeed, the mere fact that an iron ore outcrops at the surface in these glaciated regions — unless some special and obvious reasons for its protection appear — is a good indication of the presence in the ore of a large and hurtful content of quartz, to whose resistant power the appearance of the ore at the surface is to be attributed.

Thus it comes to be frequently the case that iron ore deposits have to be in the first place searched for by the aid of various surface indications, and next to be uncovered by digging away at least some of the overlying debris, before any satisfactory conclusion as to size and value can be reached. Since this digging is a costly matter, it is of course desirable to exhaust the surface indications before proceeding to excavation.

These surface indications may be classed under four different heads: (1) We may in the first place search for a definite geological horizon, as indicated by rock outcrops; (2) we may next make use of the evidence afforded by the appearance at surface of loose fragments of ore; (3) we may also gain some information by a careful observation of the topography of the region under examination; (4) and finally, in a search for magnetic ores or specular ores containing some magnetite, we may make use of the magnetic attractions as indicated by the disturbances of a compass needle.

Much the most important ores in Wisconsin are those of the Huronian regions of the northern and northeastern parts of the state, and it is especially with regard to these ores that this section of the chapter is designed to refer. The Potsdam and Clinton ores may be more rapidly dismissed in the present connection.

Potsdam Ores. With regard to the ores of the Potsdam sandstone it may be said, in the first place, that they are not expected to occur except within the driftless area of the state. Within this area, moreover, they are not likely to occur without the region included in Vernon, Crawford, Richland, and western Sauk counties. According to Mr. Strong,[1] these iron ores are to be especially looked for where the underlying rock is the upper portion of the Potsdam sandstone. The surface indication in the case of these deposits is an iron stain to the surface soil about them, and the occurrence upon the surface of numerous fragments of ore. Since there has been no

[1] Vol. IV, p. 56.

glacial action in the region in which these ores occur, the deposits are to be looked for up hill or up stream from where the fragments are found. Before one of these deposits can be shown to be of any considerable value, it must be uncovered sufficiently to render certain the possibility of obtaining at least several thousand tons of ore, containing over 40 per cent. of metallic iron, and this without the necessity of handling any large quantity of waste material.

Clinton Ores. In searching for deposits of the Clinton or "fossil" ore in Eastern Wisconsin, the explorer has first to place himself upon the correct geological horizon. This horizon has been very carefully mapped by Prof. Chamberlin on Atlas Plates X, XI, XII, and is generally sharply marked by the topography, lying at the foot of the steep western face of the ridge of Niagara limestone which forms the eastern side of the great valley of Eastern Wisconsin.[1] The occurrence at this horizon of loose surface fragments of ore, or of bodies of ore, penetrated in digging cellars or wells, are the only other indications that can be made use of. In order to be of value, a deposit of this ore must be capable of producing at least several thousand tons of ore with over 40 per cent. metallic iron.

Huronian Ores. One of the most prominent facts in regard to the Huronian ores of Wisconsin and Michigan, is the occurrence of the deposits in well-defined belts, parallel to the courses of the adjacent rock belts. In other words, these ore deposits are confined to certain geological horizons, or beds of rock. The series of rocks in which these ores occur is a succession of much folded layers, the complexity of whose arrangement has been still further increased by the introduction of eruptive matter. Great denudation having supervened upon the original folding of these rocks, the several beds present themselves in the shape of layers standing on end, and traversing the country in regular belts. The iron ores being confined to certain ones of these belts, it should become the explorer's first object to place himself upon one of the iron ore belts.

Although in a district distant from any known deposits of ore this becomes a difficult task, and one which calls for special geological experience, where there are openings on ore deposits within any reasonable distance it becomes an easy matter. Starting at any point where ore has been exposed, the explorer notes the courses of the exposed ore-body and of its adjoining rock beds. Projecting the line thus indicated into the adjacent territory, he then searches along it

[1] Vol. II, Plate IV.

for further indications of ore. Usually he is further aided, however, by the occurrence of more than one ore deposit in a line, or by outcrops of rock beds whose positions with reference to the ore horizons are well known. Frequently these ore belts, and the adjacent ones of rock, run on curving lines, so that one searching along a straight line projected at any great distance from a known deposit is apt to be working off to one side or another of the true position of the belt.

A constant reference, therefore, to ledges of a known and well marked horizon should be made whenever it is possible. In the Menominee river iron belt, for instance, immediately underlying the ore horizon (Formation VI), and forming a belt directly to the north of it, is a very marked belt of dolomitic limestone (Formation V), over a thousand feet in width. This limestone is in nearly continuous exposure for fifteen miles or more. Still lower in the series, and therefore more distantly removed from the ore horizon, is a very heavy bed of quartzite (Formation II), which, owing to its great thickness and resistant power, makes frequent outcrops and often rises into a bold ridge. Such strongly marked horizons as these serve as sure guides in the search for ore deposits.[1] West of the Menominee river, in Wisconsin, the exposures of rock become much rarer, and since it is certain that there are here a number of folds in the Huronian beds, it becomes very much more difficult to determine the horizon to which any outcrop of rock should be referred.

In the Penokee iron region, however, it is always an easy matter to determine one's position in the geological series, the rocks here being unfolded, dipping constantly to the north, and lying, all told, within a belt whose width rarely exceeds two miles, and is often less than one. All the discoveries of ore in this region, thus far made, are confined to a single belt (Formation IV). This belt, through much of its length, forms a bold ridge, so that the searcher for ore along its course should have little difficulty in locating himself correctly. Even where this ridge loses its prominence, there is no difficulty in determining the position of the ore belt, since immediately to the south of it is always a broad belt of a peculiar silicious schist, which makes very frequent exposures.[2]

In making use of the evidence of loose material on the surface in search of Huronian ores, two principles have to be kept in view,

[1] For a full exposition of the geological structure of the Menominee iron region, see Vol. III, Parts VII and VIII, and the accompanying Atlas Plates XXVII, XXVIII, and XXIX, by T. B. Brooks and C. E. Wright.

[2] For a full exposition of the geological structure of the Penokee region, see Vol. III, Part III, and the accompanying Atlas Plates XXI to XXVI, inclusive.

viz.: the loose fragments of ore should be angular, and the deposit from which they have come should be looked for to the northeast from where the fragments are found. Lack of angularity indicates in general that the fragments have come from so great a distance as to have no value as an indication of the proximity of an ore deposit. An exception to this would be where the fragments are found in the bed of a rapid and good-sized stream, in which case a certain amount of rounding may have been produced by the action of the running water. That the ore deposits lie to the northeast from the loose fragments that have been drifted from them, follows from the fact that the ice of the glacial period in both Menominee and Penokee regions had a northeast-southwest course. In the Menominee region, this course was indeed often well to the westward of southwest, or nearly due west. The only exceptions to this rule would be where the fragments had rolled down the steep north face of the ridge in which the ore deposits occur, or where they had been moved for short distances in abnormal directions by rapidly flowing streams.

In searching for these ores useful hints may often be obtained by a close observation of the topography. The surface irregularities are of especial use in aiding us to trace the different beds of rock.

The magnetic needle may often be used to great advantage in the search for these Huronian ores; but it needs to be used with a great deal of care in skilled hands, or else its indications may be worse than worthless. It may be used in two forms. In one of these the instrument is merely an ordinary compass, furnished with such attachments that the amount of variation of the needle from the true meridian may be determined at every point. The position of the true meridian is determined by an attached sun-dial, whence the name of dial-compass.[1] The other form of magnetic needle used in searching for ore is that of the old-fashioned dip-compass, in which the needle is hung so as to swing vertically. When there is no external attraction, the needle in this instrument is so balanced as to lie horizontally. From this horizon-

[1] The dial-compass is an instrument not ordinarily for sale by the instrument makers, and yet it is indispensable for all geological workers and mineral explorers in a region of magnetic attractions, like that of the basin of Lake Superior. This instrument was originally devised by T. B. Brooks, of the Michigan Geological Survey. It has recently been much improved by Brooks and Professor Pumpelly.

Very much the best form of the instrument (combining ordinary compass clinometer, dial-compass and protractor) is made by Franz Krœdel, 52 Nassau St., New York, at a cost of $40.00.

tal position it may be made to swing by magnetic attraction over a graduated circle, the amount of deviation from a normal horizontal position with the north end of the needle pointing to the north, indicating the amount of attraction. In sunny weather, the dial-compass is the only one of the two instruments necessary. Its indications are always much more delicate than those of the dipping needle, which in some cases, indeed—as for instance that of a magnetic belt trending north and south, and having but little magnetic influence—is of little use.

Two cases may now arise. The explorer may either be searching at random for belts of magnetic attraction, or he may simply wish to trace out the continuation of some already known ore belt. In the first case the best method of procedure is to follow the section lines, noting along them at every twenty-five or fifty steps the deviation of the needle of the dial-compass from the true meridian. If any deviations larger than usual are met with on these lines, other lines of observation crossing the section from north to south, or from east to west, as may appear preferable, should then be run. The same process may be carried on for the adjoining sections so far as appears desirable. The observations are then platted with a protractor. A line drawn through the points of maximum attraction will indicate the position of the magnetic belt.

In tracing out the continuation of an already known belt, or of a belt whose general direction is known, it is often desirable to make the lines of observation very close to one another—one or two hundred paces apart—and at right angles to the course of the belt; that is to say, if the belt trends northeast or northwest, these lines will be run obliquely to the section lines.[1]

In this connection the following points should be borne in mind: (1) Rich specular and soft hematite ores may occur without any admixture of magnetite, and so produce no effect whatever upon the magnetic needle. (2) Not infrequently, however, such ores do contain some little magnetite, and may be traced out by very carefully made observations. (3) Very powerful attractions are often exerted by magnetic ores or schists which are too lean to have any commercial value.[2]

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[1] For magnetic plats relating to the Menominee and Penokee regions by T. B. Brooks, C. E. Wright, and R. D. Irving, see Atlas Plates XXIII, XXIV, XXV, XXVI, and Plates XXIII to XXXI, inclusive, and XLIV of Vol. III.

[2] For a pretty full discussion of the use of the magnetic needle in exploring for iron ores, see T. B. Brooks, Geol. Surv. of Mich., Vol. I, Part I.

CHAPTER II.

LEAD AND ZINC ORES.

ESSENTIALLY PREPARED BY THE LATE MOSES STRONG.

LEAD.

The operations of mining conducted in the Lead Region since the year 1827 — now half a century — have resulted in the production of only two minerals containing lead, and of these, one only is sufficiently abundant to be regarded as an ore.

Galenite, more commonly known in the lead region as "Mineral," is the sulphide of lead, and consists of sulphur 13.4 per cent., and lead 86.6 per cent. Its specific gravity is about 7.5 per cent.; luster, metallic; color, pure lead-gray; surface of crystals usually tarnished. The most common forms of crystallization in which galenite is found in the Lead Region, are (1) the cube; (2) the cube with one or more angles or edges truncated; (3) the octahedron, which, with its modifications, is the least common form.

In common with all galenite, a trace of silver can be detected by chemical means in the ore of Wisconsin. It does not exist in sufficient quantity to be commercially valuable, being much less than is contained in the galenite of the English and German mines, where the proportion of silver varies from three- to five-hundredths of one per cent.

The appearance of cleavage surfaces of galenite varies considerably, and appears to depend largely on the conditions under which it was formed. When obtained from crevices in a very hard dolomitic rock, the cleavage surfaces are small and irregular. When the ore is from large crevices or openings, and in comparatively soft rock, the cleavage surfaces are usually large and regular in all the proper cleavage planes.

There are also many peculiarities of external appearance, by which persons who are accustomed to handle and deal in lead ore can readily distinguish the ore obtained in east and west crevices and ranges, from that of north and south ranges.

There are no minerals known in the Lead Region which bear a close resemblance to galenite. The mineral most similar to it is *blende*, but between them the following physical differences exist: blende is much harder, and not more than half as heavy, and its luster inclines to resinous or adamantine, while that of galenite is always metallic.

It appears from the writings of Pliny, who speaks of it as *galena*, that this ore has been known from ancient times under substantially the same name, the only change being one recently introduced in the termination *ite*, for the sake of uniformity in mineralogical names.

The impurities which are known to occur in galenite are antimony, iron, copper and zinc. Of these, the only ones occurring in the galenite of the Lead Region are iron and zinc, the former of which is found as iron pyrites, and the latter as blende or sphalerite, and smithsonite. As these impurities never exist in chemical combination, but always as a mechanical mixture, their removal by mechanical methods is easy, and they do not interfere with the chemical processes of reduction.

The workable deposits of lead ore in the Lead Region occur in the Trenton division of the Lower Silurian formation, and mainly within a vertical range of 125 feet above the base of the formation. Of this metalliferous stratum, the lower fifty feet include the Trenton limestone proper, which is locally subdivided into the Buff and Blue limestones, and above the Blue limestone there remains about 75 feet of Galena limestone, especially productive of lead ore, from which mineral this part of the formation derives its name.

The Galena limestone is characterized by fissures and crevices of various kinds, of which the greater number have either an east and west, or a north and south direction. Both kinds exist in every mining district, but the east and west crevices are by far the largest, longest and most productive of ore. The length of these crevices varies from a few yards to a mile or more, and their width from one inch to several feet. They are usually nearly vertical, but are sometimes slightly inclined in passing from one bed to another.

An examination of the fissures indicates that they were at one time courses of an extensive underground drainage, which is, to some extent, going on at the present time. In those portions of the crevices where softer rocks existed, erosion went on more rapidly, and a local enlargement of the crevice, which in mining language is termed an "opening," was the result. Similarly the flat openings, whose width is much greater than their height, appear to have been formed by the partial removal of a softer stratum of rock, contained between two harder ores.

Without entering upon a discussion of the origin of the lead ore, it seems most probable that the lead was deposited contemporaneously with the limestone, and that it was afterwards deposited as ore in the fissures by solution and segregation. The size and shape of these fissures, therefore, have given rise to the following forms of deposit:

The Sheet. This is the simplest and one of the most common forms of occurrence. It consists of a body of ore, seldom more than a few inches thick, contained between two walls of limestone, which remain approximately parallel for a distance varying from a few yards to several hundred feet. Their vertical extent is much greater than that of any other form of deposit, being sometimes more than 100 feet, but more frequently less. They are often intersected by other sheets crossing them at right angles, and in quartering directions, and are usually larger and more productive at such crossings.

The sheet is seldom accompanied by any regular gangue or veinstone, nor is there any concentric vein structure apparent, such as the alternation of several minerals, from the walls to the center, nor any striation of the walls. Sometimes a thin film of clay intervenes between the clay and the wall rock, but quite as often the ore is attached directly to the wall. The usual characteristics of true veins are not seen in the sheet deposits of the Lead Region.

The "Opening." The transition from the sheet to the "opening" is easy and natural, the latter being only an enlargement of the former. In the crevice opening, the galenite sometimes occurs attached to the wall rock, and sometimes in loose masses mixed with earth, stone, and ferruginous clay, most of which can be removed without the aid of blasting. Openings are frequently so large that they are termed caves, and often have the sides incrusted with large and well developed crystals of ore. In openings there is usually a greater accumulation of vein minerals than in sheets, the most common being calcite and pyrite. There are frequently two and sometimes three openings situated above one another and connected with the same crevice.

Galenite is also of frequent occurrence in flat sheets, contained in flat openings, especially in the central and northern portions of the Lead Region. Such sheets are confined to the lower part of the Galena limestone, and to the underlying Trenton. It is not improbable that they occur also in the southern part of the Lead Region, but as they there lie deeper below the surface, they are not so easily accessible.

In the flat openings the galenite is usually found in large, irregular bodies, many feet in width, often several hundred feet in length, and usually associated with ores of zinc. The thickness is very variable, being from a few inches to two or three feet, and seldom retaining the same thickness for any great distance. The galenite does not invariably occupy the same place in a flat opening, but is sometimes attached to the roof, sometimes to the floor, and at others near the middle of the opening. Frequently there are two sheets in the same opening, often connected with each other by inclined sheets of ore called "pitches." The pitches also frequently connect openings which are separated from each other vertically by several feet of unproductive rock.

Galenite is also often found in "pockets." These are irregular cavities varying from a few inches to several feet in diameter, contained in the limestone, and frequently have no apparent connection with the crevices. The limestone in which they are found is usually softer and more porous than the generality of the formation. The galenite is usually attached in crystals to the rock forming the pocket.

"Float Mineral" is galenite found scattered through the earth and clay near the surface of the ground. Such ore is readily distinguished by having the edges and angles of the crystals rounded and worn smooth, by being partially decomposed on the surface, and often covered with a white coating of carbonate of lead. The decomposition never extends through the entire mass, but proceeds from the surface to the interior, and wears away at the surface as fast as it decomposes.

The vein minerals which occur associated with galenite in the Lead Region are the following, given in the order of their most frequent occurrence, excepting the ores of zinc, which will be hereafter described:

Calcite. Generally known among miners as "tiff." This mineral is of very frequent occurrence in connection with galenite, and often forms small veins by itself. It usually occurs crystallized in various forms of the cube and scalenohedron. Its color is always nearly white, and it is readily distinguished by its easy cleavage and light specific gravity.

Pyrite. Sulphide of iron. Known in the mines as "sulphur." It occurs massive and in small irregular crystals. It is easily recognized by its brass-yellow color. It is often intimately associated with galenite, and is often found coating the surface of its crystals; also in sheets alternating with galenite and the zinc ores, and frequently in extensive deposits unassociated with other minerals.

Marcasite. This mineral has the same chemical composition as pyrite and is found in the same conditions. It is fully as common as pyrite. It is readily recognized by the decomposition which it undergoes when exposed to the air.

Barite. This mineral is not of frequent occurrence, but is sometimes found associated with galenite in the lower flat openings. It is distinguished from calcite, which it slightly resembles, by its greater specific gravity, and by its inferior cleavage. It seldom affords distinct crystals.

The method of occurrence of lead ore and its associate minerals has now been briefly described. After a few additional remarks on the occurrence of zinc ores, we shall proceed to the description of mining, ore dressing and smelting as practiced in the Lead Region.

ZINC.

There are two ores of this metal extensively mined in the Lead Region, both of which, previous to the year 1860, were rejected as worthless minerals, and esteemed of no commercial value. During the year 1860 the carbonate of zinc (drybone) first began to be utilized, and about 160 tons were exported from the Lead Region that year. This exportation continued to increase steadily until the year 1867, when *blende*, or the sulphide of zinc, was exported to the amount of about 420 tons. The experiment of manufacturing zinc from the blende proving successful, its exportation increased rapidly, and now greatly exceeds that of smithsonite (the carbonate).

The distinguishing characteristics of the two ores are as follows:

Blende, sulphide of zinc; commonly known as "Black-jack." It is usually deep-colored, nearly black, has a somewhat resinous luster, and a crystalline structure, but never forms perfect crystals, the nearest approach being small, irregular crystals, very much compounded with each other, found lining the inside of cavities. It is also often found in small, hemispherical masses having a radiate structure from a common center. The color of blende in other regions is sometimes white or yellow when pure, also black, red, green and brown.[1] In the Lead Region the color is nearly the same in all localities, and is almost black. This darkness of color is probably due to a small amount of iron which it contains.

It derives its name from the German *blend*, meaning blind or deceptive, because, while it slightly resembles galenite, it yields no lead.

[1] See Dana's System of Mineralogy, p. 50.

Smithsonite. Carbonate of Zinc. "Drybone" of the mines. This mineral occurs in various colors, among which white, yellow, gray, and light brown are the prevailing shades. In crystallized surfaces its luster is vitreous, inclining to pearly. By far the greatest amount is found in a massive uncrystallized condition, full of small cavities which are often lined with drusy surfaces.

It is probable that all the smithsonite in the Lead Region has resulted from the decomposition of blende. The oxidation of blende produces the sulphate of zinc, a soluble salt, which, in turn, being acted on by water containing carbonates of the alkalies and alkaline earths derived from the limestone, is changed to the carbonate of zinc. As the water contains but little silica in solution, the silicate of zinc, calamine, is seldom found. This view is further supported by the frequent occurrence of masses of ore in which the interior portion is undecomposed blende, and the exterior is smithsonite, still retaining the irregularly shaped crystals of blende, the middle portion frequently being in a transition state. Smithsonite is also found in small stalactitic crystallizations, and as pseudomorphs after calcite.

The ores of zinc occur almost entirely in the flat openings in the lower beds of the Galena limestone, and in the flat openings of the Trenton. Consequently the sheets are usually nearly horizontal, and frequently connected by pitching sheets.

The smithsonite or "drybone" is obtained chiefly from the Green rock and Brown rock openings of the Galena limestone, frequently, however, accompanied by blende. The strata in these openings, being more loose and porous, seem to have more readily permitted the circulation of water through the rock; and thereby to have facilitated the decomposition of blende. On the other hand, the Pipe-clay and Glass-rock openings, being more compact, and lying deeper below the surface, are chiefly productive of blende, the conditions for its decomposition not having been as favorable.

Proximity to the surface has also been favorable to the formation of smithsonite. It is frequently the case that a flat sheet of zinc ore, near its outcropping edge, will consist almost entirely of smithsonite, and on following it into the hill the ore will be found to change gradually to blende, and finally consist entirely of that mineral.

The minerals found associated with the ores of zinc are the same in kind as those found with galenite, but much greater in amount. They are chiefly calcite and the two kinds of pyrites. Calcite occurs in masses of irregular shape, intimately connected with the blende, and frequently penetrating the mass in all directions, filling small cavities and forming small veins. When pyrite is present, it usually presents a banded arrangement in connection with the sheet, forming sometimes the exterior, and at others the interior portion. Frequently, also, it is mixed through the sheet of blende in a very irregular manner.

Remunerative Quantity of Ore.

The quantity of ore which must be present to make mining operations remunerative is very various, and depends chiefly on such considerations as the price of ore, the price of labor, the amount of water and the accessibility of the ore, or the amount of unproductive rock which must be penetrated in order to obtain it; also on the amount of cleaning and separation it must undergo, and the distance it has to be hauled before it can be sold.

As the basis of calculations, it is estimated that a sheet of galenite six feet square and one inch thick will weigh 1,400 lbs. A sheet of blende six feet square and one inch thick weighs 750 lbs., and a sheet of smithsonite or "drybone" of the same dimensions weighs from 500 lbs. to 700 lbs., depending greatly on the density of the ore and the cavities contained in it. In practice, however, allowance must be made for the waste of ore in mining, and for the variations in the size of the sheet, which last constitutes the greatest element of uncertainty in mining operations.

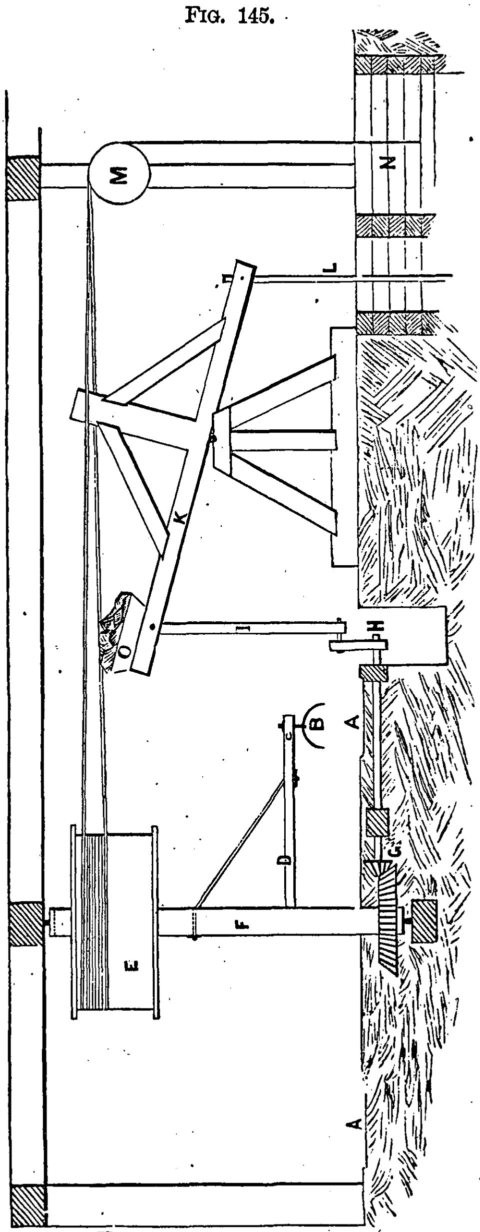
The price of labor in the Lead Region has generally ranged from $1.25 to $1.50 per day, a day being reckoned at eight hours for mining labor and ten hours for labor of other kinds.

Drainage of Mines and Hoisting of Ore.

The amount of water enters as a very important factor into the calculation of expense of mining operations. Where the amount is small, it is usually removed by bailing into a large tub or barrel, and hoisting it out with a windlass. It is estimated that a practiced laborer can hoist about 150 gallons per hour from a shaft 100 feet deep, when two tubs are employed, one of which descends and is filled while the other ascends and is emptied. When only one tub is employed, not more than two-thirds of this result is obtained, owing to the time consumed in lowering and filling the empty tub.

When the amount of water is too great to be bailed, a pump operated by horse power is often employed.

Fig. 145.



Horse Pump and Hoisting Gin.

The annexed figure represents a horse pump and hoisting gin, or "whim," as it is often called. As the two are frequently combined, it is convenient to describe them together. In practice, however, it is customary to build the machine so that the hoisting drum can be disconnected from the pump, and vice versa, as it is seldom desirable to carry on both operations at the same time. The essential parts of the machine are as follows: A A represents in section the circular walk around which the horse travels. He is attached by his harness to the semi-circle at B, which, by simple rotation on the swivel at C, permits him to walk around the circle in either direction when hoisting. In walking, the horse carries around the arm D, and thus imparts a circular motion to the drum E, and the shaft F. By means of level-gearing G, at the bottom of the shaft F, circular motion is imparted to the crank at H, and thence through the connecting rod I, and the walking beam K, to the pump-rod L, in the shaft. O is a box filled with rock to serve as a counter-poise to the weight of the pump rods. In hoisting, the gearing is disconnected from the shaft, and the drum is connected with it. A rope is wrapped around the drum, and passes over two pulleys at M, and thence down the shaft N, so that one bucket descends while the other ascends. In hoisting from the upper levels, the excess of rope is wrapped around the drum.

The load which a horse can raise, at once including ropes, buckets, and the friction of machinery, is as much greater than his own direct force, as the diameter of the horse-walk is greater than that of the winding drum, and the drum moves slower than he does in the same ratio. When a horse is not expected to work eight hours per day, the number of strokes of the pump per minute may be increased, or the diameter of the winding drum, to accelerate the work. In order that the horse may walk easily, and work to the best advantage, the diameter of the circular horse-walk should not be less than 25 feet. It may vary from 25 feet to 35 feet.

It is estimated that a fair average horse should pump in eight hours the quantities contained in the first three columns of the following table, to the height in the fourth column.

Cubic Feet.	Pounds.	Gallons.	Height Feet.	Cubic Feet.	Pounds.	Gallons.	Heig't Feet.
1,600	100,000	11,968	100	4,571	285,714	34,194	35
2,000	125,000	14,960	80	5,333	333,333	39,893	30
2,667	166,666	19,946	60	6,400	400,000	47,872	25
3,200	200,000	23,936	50	8,000	500,000	59,840	20
3,555	222,222	26,596	45	10,667	666,667	79,787	15
4,000	250,000	29,920	40	16,000	1,000,000	119,680	10

When the amount of water is too great to be removed by a horse pump, steam pumps of various sizes, patterns and capacities are employed, or the ground is drained by a level.

Indications of Ore Observed in Mining.

In seeking for veins and beds of ore, there are several circumstances and conditions more or less accepted among miners, as indications of the proximity of the metallic ores. One of the most reliable of these indications is the finding of "float ore," either of lead or zinc, occurring loosely in the soil as previously described. The value of this will be apparent when we reflect that the limestone has been, and is, continually undergoing disintegration on its surface, the soil being composed of such portions as were not so readily dissolved and removed. When this decomposition took place on the surface of an outcropping vein or flat sheet, the more insoluble parts of the vein, which are usually the metallic ores remain as loose pieces in the adjacent soil, and often serve to indicate the presence of an adjacent sheet of ore. This indication is the more valuable, because the Lead Region has never been subjected to glacial influence, and the consequent disturbance, transportation, and replacement of its surface clays. Therefore, except at or near the surface, the clay and its included rock materials or minerals have seldom been removed to any great distance from the beds from whose decomposition they were derived. It should, however, be borne in mind that all substances on the surface are liable to gradual displacement by running water, frost, etc. Similarly, "float ore" found in the bed of a stream cannot be regarded as a good indication of the proximity of a large mass. It may, however, be followed up stream, and by its increased frequency ultimately lead to the discovery of the bed from which it came.

The presence in the soil of minerals which usually accompany the metallic ores, such as calcite, pyrite, barite, etc., may be regarded as a good indication, although a less positive one than the occurrence of float ore. Their occurrence is to be explained in the same manner as above.

The presence of certain yellow or reddish ocherous clays, both in the soil and in crevices of the rock, is regarded as a favorable indication, and rightly, inasmuch as this ferruginous matter results probably from the decomposition of marcasite and pyrite, which so frequently occur in connection with the lead and zinc ore. These indications, however, can never be regarded as certain concomitants of the existence of valuable deposits of ore. In the case of the occurrence of associate minerals and clays in the soil, it is often true that the minerals from which they came occur in sheets and beds unassociated with these ores, and the pieces found may have been thus derived. Also in the case of the finding of the float ore, the deposit may have been small, as a pocket, or a sheet of small vertical extent, and the entire body may now be contained in the soil. It should be remembered, also, that on the sides of steep hills the surface soil and clay is liable to large displacements through sliding, and that the external or surface appearance of such slides in a few years becomes obliterated through the influence of vegetation and other causes.

In sinking a shaft it is one of the great aims of the miner to find a good crevice to follow in his course, because the useful ores are mainly found in them or beneath them, and because such crevices very materially facilitate the labor of sinking through the solid rock. The lines of small circular depressions in the ground known as "sinks" are almost unfailing guides to the position of subterranean crevices below them.

In former years, before the Lead Region became agriculturally valuable, the course and direction of the crevices was very clearly and distinctly marked, even to an unpracticed eye, by an excessive growth of grass and weeds in the soil immediately above them. This was especially perceptible on the prairies, where the crevices could be traced for long distances. This appearance may still be seen in some parts of the Lead Region where the soil has never been cultivated, especially in the vicinity of the Blue Mounds. In the earlier mining operations it was an index which was very frequently made use of.

The surface contour of the ground is greatly relied on by miners as an indication of the locality of mineral deposits. Certain slopes, hollows, ravines and hillside exposures have great influence in determining the location of their prospecting shafts.

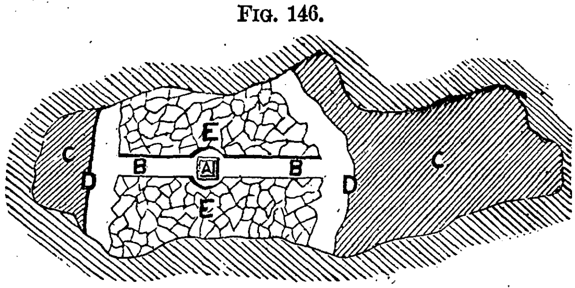
As yet, however, there is little unanimity of sentiment on this subject in any mining district, nor are any recognized rules of guidance generally observed. That too much importance is attached to the accidental surface contour is probable for the following reasons: 1st. The facts in the case do not seem to warrant it. In some mining districts, more especially in the southern part of the Lead Region, the largest, longest, best defined, and most productive crevices, and the mineral deposits contained in them, hold a nearly straight course from one end to the other, sometimes more than a mile in length, crossing hills and ravines, large and small, at all angles of intersection, and without undergoing changes in their productiveness, other than those found in the inequalities of the veins, which do not seem to be correlated with the surface contour. 2d. From the circumstance of no ore being found in the rocks newer than the Galena limestone, we infer that its deposition ceased with that formation. From the outliers that remain, we know that a deposition of from 200 to 400 feet of shales and limestones, constituting the Cincinnati (Hudson River) group and part of the Niagara formation, succeeded the Galena limestone; also that this amount has been removed by denudation, along lines of drainage, whose generally southern direction was determined by the east and west axis of elevation, and whose general details, such as the smaller streams and ravines, were dependent on slight flexures of the strata and their varying hardness and solubility. To effect this denudation then, the system of streams must have been well defined, and they must have occupied nearly their present positions before there was an outcrop of Galena limestone exposed in the Lead Region; and consequently we cannot suppose that the unexposed crevices or bodies of ore therein contained can have determined the direction of the water courses, or the consequent contour of the surface.

Methods of Mining in the Lead Region.

The manner of occurrence of the ores in the mines does not usually necessitate any very complicated system of mining, the general plan being to follow the sheets as long as they continue productive. As the vertical extent of the sheets is seldom very great, there is not often any necessity for a series of drifts situated at various levels, branching off from the main shaft and subdividing the vein into rectangular blocks; but whenever the sheet is sufficiently large to require it, the method of mining by "direct stopes" working in the floor, or by "reversed stopes" working in the roof, is employed, as is most suitable to the nature of the ground.

In the mining of the large flat sheets of ore, there is more opportunity for a systematic arrangement of the work. The general plan of operations is shown in Fig. 146. A shaft is first sunk upon the sheet as at A, and the work of excavation and removing the ore immediately commences at the shaft, proceeding in all directions until the limits of the deposit are reached. Care is taken to leave main drifts B B open, leading from the shaft to the unworked portions of the sheet C C. In this way the opening is excavated in its full thickness, which is from three to eight feet, and across its entire width. Fig. 146 shows a flat sheet being worked in two directions from the shaft. D D are the working faces. After being loosened by blasting, or with the pick, the ore is separated from the rock, and hoisted out of the shaft A. As much as possible of the unproductive rock is then piled in behind the miners, filling up the worked-out portions of the opening at E E, and the remainder is also hoisted out through the shaft A. This filling also serves to support the roof or "cap," and in some places it is necessary to leave pillars containing ore as supports.

Fig. 146.



Ground Plan Illustrating the Method of Mining on Large Flat Sheets.

Usually two or more shafts and excavations are worked at the same time on the sheet, and are connected for the purpose of ventilation.

The cost of rock excavation in mining operations, such as the dividing of levels and drifts and the excavation of shafts, is very various, and depends chiefly on the hardness of the rock and the distance to which the excavated materials have to be transported. In shaft excavations the cost varies from five to fifteen dollars per vertical foot for a shaft six feet by four. In drifts and levels six feet high by four feet wide, the cost is from five to thirty dollars per linear foot, the expense being materially increased by the length of the drift. The above estimates include everything except the cost of pumping, for which no allowance can be made.

The expense of blasting is an important factor in the cost of rock excavations. In the Lead Region common blasting powder is the material chiefly relied on, and the introduction of the various powerful explosives, discovered in the last quarter century, proceeds with great slowness. Accidents from the use of these are usually quite as rare as from the use of common powder, and considering the great economy of time and expense that attends their use, they ought to be more generally employed.

The occurrence of ore in flat sheets and openings with a wide working face affords opportunities in many places for the advantageous employment of steam or pneumatic drilling machines. They have as yet been introduced in the Lead Region to but limited extent. In mines where a large number of men are employed, the same amount of work can be done in much less time and with less expense.

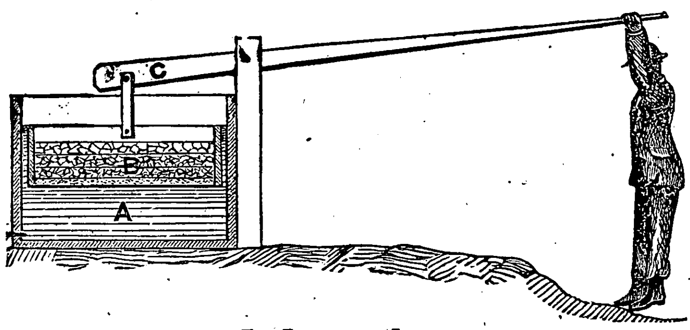
The introduction and use of diamond drills for prospecting would undoubtedly be attended with remunerative results. These drills operate by rotation, penetrating the rock with great rapidity, and removing an interior cylinder or core, thus exposing to direct ocular examination a section of the strata through which they pass. For discovering and proving the extent of flat sheets there is no instrument which is their equal. As they drill holes from 100 to 500 feet deep, it would be easy to prospect the Lower Magnesian limestone by their use.

Dressing and Separating Ores.

The ores of lead and zinc, as they arrive at the surface, are sometimes clean and pure, in large masses, and ready for market, but more frequently they have to undergo certain operations of dressing and cleaning. Lead ore in small pieces usually comes from the mine mixed with considerable clay and earth, and is known as "washdirt." It is cleaned by washing as follows: A long box about nine inches deep and open on the top and at the lower end is set in the ground at a moderate slope, and a stream of water is conducted into it over the headboard at the upper end. The ore to be washed is placed in the extremity so that the water falls upon it. The operation is completed by the miner shoveling the ore against the stream until all foreign substances are removed.

Frequently, however, a simple washing does not suffice for the preparation of ore, especially if more than one kind of ore is present in the mass, or if the ore is mixed with rock or vein minerals. In such cases it is customary to prepare and separate the ore by crushing and jigging. The crushing is effected either by a rock-breaking machine, such as "Blake's Rock-breaker," or by passing it through a pair of rollers operated by horse power. It is then washed and screened, the coarser portion re-crushed; and the operation of cleaning and separation concludes with jigging, which is effected by the contrivance shown in section in Fig. 147.

FIG. 147.



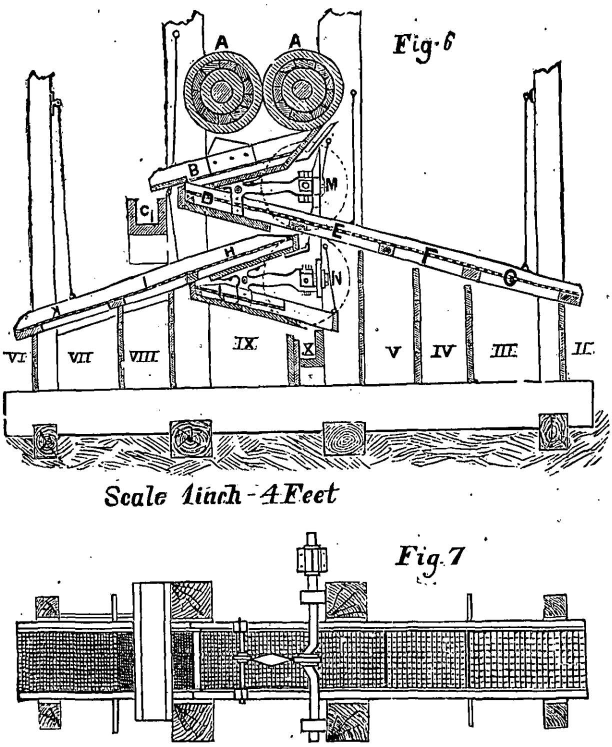
THE PROCESS OF JIGGING.

The jig used in the Lead Region consists usually of the following parts: An exterior deep box **A**, filled with water, and an interior shallow box **B**, in which the ore is placed; the bottom of which consists usually of an iron plate, pierced with fine holes to permit the passage of water through the mass. This box is connected with a long lever arm **C**, at the end of which the workman places himself, being able to reach it, standing on his toes, with his arms extended above his head. By alternately rising and falling on his feet, he produces a slight vertical movement of the interior box and its contents.

The contents of box **B**, being suspended in the water and agitated, immediately undergo a change of position, resulting in the deposition of the heaviest material at the bottom of the box, and the lightest, such as stone, at the top. After a short agitation, the box **B** is raised from the water by depressing and fastening the lever **C**, and the materials are removed. At the close of the operation, the water is drawn off from the box **A** through the plug **D**, and the fine ore which may have passed the sieve is collected from the bottom of the box.

This machine is simple, and to a certain extent effective. That it might be rendered still more efficient will be seen by the following considerations.

FIGS. 148, 149.



GERMAN MACHINE FOR ASSORTING ORES.

The fall of bodies in water, on which the action of the machine depends, is governed, first, by their *specific gravity*, and second, by the *relative size of the pieces*, the large pieces falling with the greatest rapidity, because their resisting surface is less in proportion to their weight. Therefore, when the materials to be separated are placed in the jig without sufficient previous classification according to size, the separation cannot be perfect. If, however, the material is first separated by sieves of various sizes, and each size treated by itself in the jig, the separation is much more perfect, as they then arrange themselves according to their different specific gravities.

Figs. 148 and 149 represent, in elevation and plan, one of the numerous machines commonly made use of in the German mining regions for the classification of ore before the operation of jigging. The ore, after passing through the crushing rollers **A A,** falls upon the crushing sieve **B.** All pieces of more than 45-100 in. diameter pass over the sieve to the receptacle **C,** and are passed through the rollers again. All pieces of less diameter than 45-100 in. pass through **B** and fall on the series of coarse sieves, **D, E, F, G,** the sizes of whose meshes are as follows: **D**=11-100 in.; **E**=16-100 in.; **F**=22-100 in.; and **G**=32-100 in. All pieces of less diameter than 11-100 in. pass through **D,** and fall on the series of five sieves; **H**=4-100 in.; **I**=6-100 in.; **K**=8-100 in. All particles of less than 4-100 in. in diameter pass through **H** and fall in compartment **IX,** except the dust, which is collected by the dust sieve **L,** and falls in the compartment **X.** From this separation there arise ten sizes, which fall in the compartments **I** to **X,** in Fig. 148. The sieve frames are supported by small iron rods and swing loose, motion being imparted to them by the eccentrics at **M** and **N.**[1]

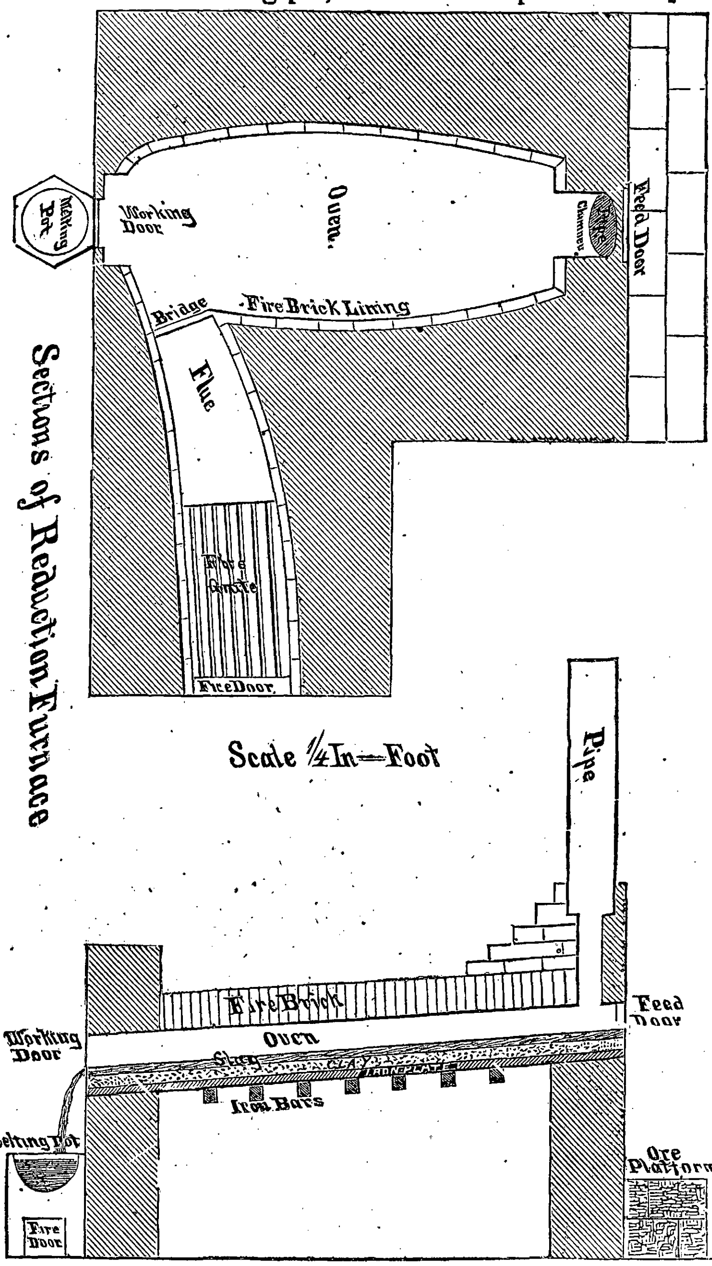
This machine, worked in connection with one of the continuous automatic jigs, whose effective work is about three times that of hand jigging, would effectually sort and separate all mixtures of ore and rock which occur in the Lead Region. In this way a large amount of poor zinc ore, which is now thrown away as unsalable on account of its intimate mixture with rock and pyrite, could be profitably worked, and as the pyrite also would be separated without extra expense, it could be brought into market, being worth at present from five to six dollars per ton in Chicago.

Reduction of Lead Ore.

Until within the last twenty years the American Hearth Blast Furnace was the only one used in the Lead Region for the reduction of ore. In some districts it has been entirely replaced by the Drummond Reverberatory Furnace, and in many localities both are used, the reverberatory for the reduction of fine ore, and the blast for the smelting of coarse ore and slag. By far the greater part of the ore in the Lead Region is smelted in a reverberatory furnace, similar to Figs. 150 and 151, which are sections through the oven. The ore is placed in the oven through the feed door, and is subjected to the action of the flame coming through the flue and over the bridge. While in the oven it is continually stirred with long iron rods

[1] See Rittinger's Aufbereitungskunde, p. 528, Taf. 12, Fig. 128.

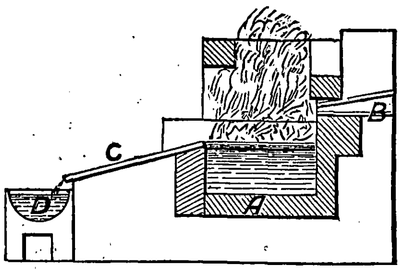
through the working door, and as it melts it runs out of this door and falls into the melting pot, where it is kept melted by a small



FIGS. 150, 151.

fire built under it. When the melting pot is full, the lead is ladled out into the molds and made into pigs. A furnace of this kind will smelt from 7,000 to 9,000 pounds of ore in twenty-four hours; consuming from 1¼ to 1¾ cords of oak wood, and requiring the labor of two men.

Fig. 152.



Scotch Hearth.

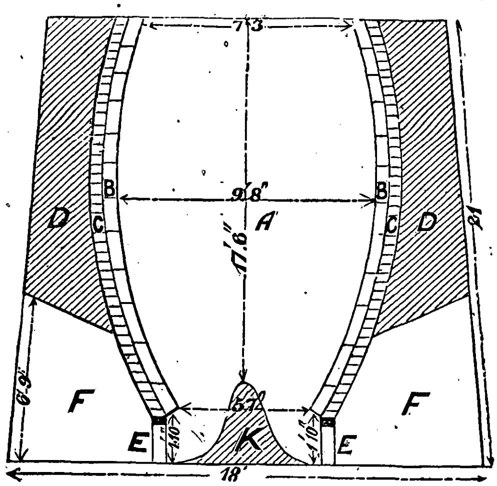
The Scotch Hearth, similar in construction to Fig. 152, is often used for the reduction of large ore and the smelting of slag. For fine ore it is objectionable, because so much of the fine ore dust is carried up the chimney by the draft. It consists of a cast iron box, set in masonry. At the rear is a tuyere **B**, through which the blast enters from a bellows, or air compressor, which is usually operated by a water-wheel in an adjoining room. Ore and fuel are charged together in small quantities in front of the tuyere, and when the box becomes filled with metallic lead it runs out over the working plate **C**, and into the smelting pot **D**, from which it is ladled out into the molds. The smoke escapes through a very large chimney, which is sometimes about thirty feet high. The finest and softest quality of lead ore is produced by this process, but the percentage of loss is greater than in the reverberatory furnace.

A furnace of this description will smelt from 10,000 to 12,000 pounds of ore in twenty-four hours, and requires the labor of six men; that is, two at a time working at eight hour shifts.

Reduction of Zinc Ore. The reduction of zinc ore in the Lead Region has not hitherto proved to be a remunerative business, although very profitable as conducted in Illinois, where all of our zinc ore is consumed. The reason is probably that it is less expensive to ship the ore to La Salle, where coal is obtained, than to ship the coal into the Lead Region, and then export the manufactured product.

The only process which the zinc ores of the Lead Region undergo previous to shipment, is the roasting of the carbonate. The

Fig. 153.



Furnace for Roasting Carbonatf of Zinc.

blende is never subjected to any roasting previous to shipment. The roasting of smithsonite is effected in a simple furnace, such as is represented in Fig. 153, and not unlike a lime-kiln in construction and working. It consists of a large oven, **A,** with an interior lining of fire-brick, **B,** which is separated from the masonry, **D,** of the furnace, by the lining of common brick, **C.**

After building a fire in the bottom of the furnace, and when it has become well warmed, layers of ore and bituminous coal are added gradually until the furnace is nearly full. As fast as the ore is calcined it is withdrawn through the doors **E, E,** access to which is had through the arched entrances **F, F.** **K** is a circular mass of masonry, to facilitate the descent and withdrawing of calcined ore. The object of this operation is to eliminate from the ore as much as possible of the carbonic acid which it contains. This is usually about thirty-five per cent., and of this about thirty per cent. is expelled. The small amount of water which is usually present in mechanical mixture is also driven off during the operation; and as a final result the ore loses about one-third of its entire weight, and the bulk is diminished in about the same ratio.

A furnace of the above description and size will contain about 60 tons of raw ore; and will roast about twenty-five tons in twenty-four hours, requiring the labor of six men working two at a time in eight-hour shifts. From 80 to 100 pounds of bituminous coal are required for each ton of ore. The cost of carrying the ore through this operation is from $50 to $60 per hundred tons. The cost of such a furnace with the requisite tools is about $300.

With calcination the treatment of zinc ore in the Lead Region ceases. It is then shipped to La Salle, Ill., and there reduced; forming a considerable portion of the spelter produced in the United States.

We have now sketched with as much minuteness as so brief an article will allow, the conditions under which our ores are found, and the manner of procuring, preparing and reducing them, which, taken together, form one of the most important industries of the State.

CHAPTER III.

ECONOMIC SUGGESTIONS IN REGARD TO COPPER, SILVER AND OTHER ORES.

BY T. C. CHAMBERLIN.

It is the purpose of this chapter to make such practical suggestions concerning ores not now actively mined in the State, as may perhaps be serviceable to parties who are or may become interested in them.

COPPER.

NOTE.— For details as to the occurrence of copper within the State, see Vol. II, pp. 27, 28 (Lapham), 210 (Chamberlin), 619 (Irving), 741–2 (Strong); Vol. III, pp. 203–6 (Irving), 343, 344, 348, 353, 357 and 362 (Sweet), 403–427 (Strong and Chamberlin); Vol. IV, pp. 56, 69–72 (Strong), 390, 405 and 507 (Chamberlin). For the characteristics of the copper ores, see this volume, pp. 311–314. For the origin of the copper deposits, see this volume, pp. 108–114, 141 and 164; and Vol. IV, p. 405.

Copper occurs in Wisconsin (1) in its native state; (2) in the form of the copper-iron sulphides, *Chalcopyrite* (copper-pyrites) and *Bornite;* (3) in the form of the copper carbonates, *Malachite* and *Azurite;* and (4) as the copper oxides, *Cuprite* and *Tetrahedrite.*

Tests. Not infrequently certain substances, especially those of a greenish color, are mistaken for copper ores, and are thus the occasion of false hopes, and sometimes of useless expenditures. A few of the simple methods of detecting copper may therefore prove serviceable. The native or metallic copper is of course so well known as to need no description. As found at the surface, it is usually coated with green copper carbonate, popularly but incorrectly known as verdigris.[1] This coating is *malachite*, and furnishes a convenient standard of comparison. Its color, when critically examined, is found to be different from that of most other green minerals, and as examples of it on copper and brass utensils are so readily accessible, most mistakes might be avoided by a simple comparison. It is very common to hear of water in pits, springs or quarries, in which, if tools are left, they will "turn green," and

[1] Verdigris is an acetate of copper.

confident hopes of a copper mine are not infrequently built upon this fact. A little attention to the exact color would probably undeceive in all such cases. The writer has never found this green coating to be anything but "frog spittle," or a similar vegetable growth. It is perfectly safe to say that all such supposed indications of copper are entirely fallacious.

A very simple test of green or blue minerals, suspected of being copper carbonates, is as follows: Powder some of the mineral, and apply a little nitric acid, and, after giving the acid a few moments to act, insert for an instant the point of a knife blade, or other article of steel or iron, made clean and bright, and if there is any notable quantity of copper present, the blade will be coated with a thin film of metallic copper. A more delicate test is to add ammonia to the nitric acid solution, when, if there is copper present, the liquid will assume a deep blue color. Only an extremely small quantity of copper is necessary to give this reaction. As these tests can be made by any one at the cost of a nickel, there is little need for doubt or deception.

The test for the carbonates may be made applicable to any common copper ore by powdering a small portion, mixing it with soda (common baking powder will answer), and heating it to redness (on a stove shovel, if nothing more suitable is at hand). After cooling, remove the fused mass and apply nitric acid, and test with knife blade or ammonia as above directed.

Relative Quantity. But it is one thing to discover copper and quite another to find it in paying quantities. Only a small percentage of the instances of the occurrence of copper would repay mining. It is impossible to lay down any general rules that can be safely applied, unless guided by considerable special knowledge; but some general statements may be helpful.

The amount of copper necessary to remunerative mining varies greatly, according to the form in which it occurs; the cost of mining, transportation, reduction, etc. Ores yielding not more than three or four per cent. are sometimes profitably worked. When the copper occurs in the metallic state it may be profitably wrought at an even less percentage. On the other hand, ores containing several times that amount may be unremunerative.

An important consideration is the proportion of the ore to that of the rock which must be mined and handled with it. A width of three or four feet along the vein must necessarily be mined out, and unless the ore bears a fair ratio to the whole of this it may be unprofitable, though in itself the vein may be a rich ore. It is clear that a very narrow vein, or even a thin seam of pure copper, might give less metal in proportion to the rock handled than a vein of quite lean ore or disseminated metal which has a good working width, so that little or no barren rock would need to be mined out with it. The concentrated ore has, however, the advantage in the extraction of the metal.

Again, there are considerable differences in the cost of reduction. Beyond doubt some of the sulphide ores of the southwestern part of the State would be quite remunerative, if the metal they contain occurred in the native state, as it does in the Lake Superior region. Its unfortunate combination with iron and sulphur increases the difficulty and expense of its reduction.

To these considerations are to be added, manifestly, the favorable or unfavorable situation of the deposit, the cost of power, labor and transportation; the facilities for marketing, etc.

These considerations may enable the intelligent land-owner or explorer to determine, in very many instances, that the deposit he may have found falls short of the remunerative limit, and the matter may be dismissed without further trouble or expense.

But may not a lode that is unremunerative at the surface grow richer below? It sometimes does. But the too prevalent dictum that "veins usually grow richer as you go down," is an *ignis fatuus* that has allured thousands into unprofitable expenditures. There is no such general rule that is a trustworthy guide. Deposits sometimes grow richer with depth, and sometimes poorer. The truth seems to be that there is a presumption of increasing richness in depth in certain classes of deposits, and, on the other hand, a presumption of decreasing richness (after moderate depths have been reached) in other classes, while in still others, there are no known grounds for presumption either way. In most cases, the richness is fluctuating, growing in turn richer and poorer. It is impracticable here to define these classes (even so far as it is now possible to define them at all), so as to make the discriminations practically serviceable to those for whom these suggestions are intended. The topic is here introduced for the purpose of guarding against attaching undue weight to a fallacious dictum. There are very many cases where the surface display of ore is small, which yet justify proving up by sinking shafts, but it is as important that undue stimulus shall be withheld, as that proper encouragement should be given. It is important to observe, however, that the immediate surface of outcropping veins or lodes may be altered by surface agencies and some excavation may be necessary to develop the true condition of the deposit. These remarks are made with reference to the more common forms of deposits. Those of the southwestern part of the State conform to the peculiar laws of the lead and zinc ores elsewhere discussed.

In case the land-owner or explorer has positively determined the existence of copper, either by finding it in the native state, or by a reliable identification of its ores, and by a careful estimate has found that its amount is considerable in proportion to the gangue or vein-rock that incloses it, and also to the amount of rock that must be removed in mining, his judicious course (the geological formation being favorable, or at least not adverse) will then be to procure a reliable assay of an average sample of the ore. It requires some moral courage to select samples which shall fairly represent the average of the lode in its length and width, but this is quite essential to a trustworthy judgment as to the prospective value of the deposit. A considerable quantity of fragments should be taken from all parts of the vein equally, and without regard to apparent richness. These the assayist will powder and mix and thus secure an average sample. If the result of a trustworthy assay prove encouraging, further excavation and additional assays will be justified, and exploration may proceed judiciously, basing operations on what is found and what is fairly indicated, or rendered reasonably probable.

There may, of course, be instances where the interests of communities, or corporations, may justify the proving of the *possibilities* of a formation, without much regard to the *probabilities*. The suggestions here made are intended only for those whose sole interest lies in the deposit under investigation, and whose only recompense is the return which it may make.

Favorable Territory. One of the notable results of the survey has been the demonstration that the Copper-bearing series of Lake Superior extends entirely across the northwestern part of the State from Michigan to the Minnesota border. This very much increases the area that, in a general sense, may be said to offer favorable ground for the discovery of mines, and there is a reasonable basis for the hope that valuable discoveries will be made in the course of the settlement of the country, and the excavations incidental thereto. Up to the present, the region has been covered largely with forest and surface drift, and has presented conditions unfavorable to exploration; but with the completion of the railroads now being constructed, its settlement, and the development of its resources will doubtless be speedy.

The other area of the State known to bear copper deposits that at least approach a remunerative richness lies in the southwestern part of the State, and is described in Vol. IV. The strata, the ores, and the method of their occurrence are quite different from those of the northern portion of the State, the embracing formations being magnesian limestones, the ores *chalcopyrite (copper pyrites)* and *malachite* and *azurite* resulting from its alteration, and the mode of occurrence, similar to that of the lead and zinc deposits. For details reference may be made to the discussion of the ore deposits of Southwestern Wisconsin in the preceding chapter and in Volume IV.

Concerning their utilization the following observation may be offered. In the present condition of the copper market, and with present facilities for shipment and reduction, they can be made but very slightly, if at all, remunerative, and little or no advantage to the owners or the community would accrue from their extraction. The present great mines of native copper in the north cannot be expected to maintain indefinitely their enormous yields, while the consumption of copper will surely increase with the continued development of mechanical appliances, and may perhaps be specially augmented by the more extensive use of electrical devices. With the decline of the mines of native copper, the sulphides must be more extensively reduced, and better facilities and more economical methods will result. Prices will probably also appreciate, and labor be cheaper. Under such conditions these deposits may come to be valuable. Our advice is, therefore, to reserve them to that time, which may not be distant.

These suggestions apply, in the main, to the copper region of the northern portion of the State. Both regions have agricultural and other productive resources upon which their permanent dependence may rest, and, in the long run, the greatest value from their mineral deposits can be realized by choosing the most advantageous time for their development, and by exercising prudence and discretion in their utilization.

Drift Copper. "Float" Copper. The occasional pieces of virgin copper that are found in the drift at various points, have been brought from the Lake Superior region by glacial agencies, and left where they are found, hap-hazard, so to speak. The finding of one piece offers no presumption that another may be found near it, and is, of course, no indication whatever of a copper deposit in the vicinity. The finding of one of these pieces is merely so much good luck. Hundreds, if not thousands of them, have been picked up in the State, especially in the eastern and northern portions.

Silver.

Note.—For details as to the occurrence of silver in the State, see this volume, p. 310; Vol. II, p. 27; Vol. III, pp. 201, 206, 358 and 669; Vol. IV, pp. 382–3.

Native silver occurs in association with the copper of the Lake Superior region, and in the drift derived from that region. The silver-bearing stratum of the Ontonagon, or more strictly Iron-river, region of Michigan, which a few years since created some excitement, and called forth considerable expenditures, was at that time traced by the survey across the Montreal river, into Wisconsin, and found to there contain small quantities of silver and copper. The unfavorable experience of the operations in Michigan, however, leaves little ground for expecting rich deposits in that horizon, though nothing is known to forbid it.

Silver occurs as a minute ingredient of the lead ores of the southwestern portion of the State, but the quantity is even less than is common to such ores, in which it is almost universally present.

While silver has very frequently been unauthoritatively reported from various parts of the State, and undoubtedly occurs not unfrequently in minute quantities, nothing is known that gives substantial grounds for expecting any valuable discoveries. Experience and observation give an adverse probability. Our judgment, therefore, is that, while inquiry into the composition of whatever mineral seems to possess any likelihood of being argentiferous is to be encouraged, there is no justification for fostering an expectation of rich results, or for incurring an expense beyond what the satisfaction of knowing, or the *possibilities*, rather than the *probabilities*, may warrant.

Gold.

Note.—For the occurrence of gold within the State, see this volume, p. 310; Vol. II, p. 27; Vol. III, p. 669.

Only minute quantities of gold have yet been proven to exist within the State. The crystalline rocks of the northern region are very similar to those in which gold-bearing veins occur elsewhere, but the lack of the discovery of notable quantities either in the veins, or the sands of that region, gives a quite adverse aspect to the probabilities of its discovery in quantity.

Manganese.

Manganese ores (see p. 317), mainly *pyrolusite*, occur in the Penokee Iron Range, in the Barron county quartzites, in the Lead Region, and in some of the bog deposits of the State. In none of these situations does it promise to be of available value, except as an ingredient of iron ores, though some of the last class of deposits may prove to be so. Its blackness and soft nature are its most conspicuous characters, and by these it may usually be recognized.

CHAPTER IV.

BUILDING MATERIAL.

By T. C. Chamberlin.

The older portions of the State are already entering upon the second stage of their architectural history, that in which the pioneer structures are replaced by the more ample and enduring ones that mark the attainment of an assured prosperity. It may not be altogether unfortunate that so many of the buildings constructed under the stress and limitations of early settlement are of perishable materials, and that they so readily and necessarily give place to a better class of structures. But as the era of larger and more expensive buildings, public and private, is entered upon, and ampler means are at command, it is important that attention should be turned toward the employment of more imperishable and non-combustible material.

The native architectural material which falls within the geological purview may be grouped under three heads: 1st, material formed and solidified by nature, as building and ornamental stone; 2d, material adapted to artificial solidification, as brick and ceramic clays; 3d, material adapted to the preparation of cements, as common and hydraulic limes.

I. Building Stone.

Among the leading desirable qualities of building stone are endurance, agreeable color, ease of working, and adaptability to required dimensions. Prominent among these is endurance. Our climate is not of the least trying character. Not only are the extremes of heat and cold measurably great, but the transitions of temperature are somewhat frequent and sudden. Experience in northern Europe has shown the instability of several classes of otherwise desirable rocks, when submitted to the test of centuries. The entire classes of limestones and sandstones are placed under ban. This is doubtless an extreme view of endurance, which, as the people of a new and rapidly evolving state, we are not yet prepared to fully accept as a working basis, and in these reports the term enduring has been used in a somewhat more limited sense. But in the construction of our great bridges, piers and permanent public works, if not in our more expensive dwellings and business blocks, a more liberal respect for the influence of time may be altogether wholesome.

Perishableness in rock arises mainly from two sources, a tendency to solution or disintegration under the influence of air and moisture, and a liability to be affected by changes of temperature, and especially by frost. Among the common rock constituents least affected by the former agencies is quartz, and next in rank, perhaps, the feldspars. Among those most affected are limestones, and the pyroxenes and amphiboles (whose most frequent forms are augite and hornblende). Those most affected by the latter agencies are rocks of a porous, absorptive nature, or of a fissile character. When moisture is freely absorbed, it matters little what the character of the rock, it must at length yield to the irresistible power of freezing water. The disintegrating effects of frost greatly aid dissolution by chemical agencies, and the actual results observed are largely due to their combined action. One of the practical benefits to be derived from full and careful descriptions of the texture and composition of rocks is suggested by these considerations.

To those unskilled in the detection of the constituents of rocks, there is an easier and more obvious line of observation, leading to very decisive results. The larger portion of our State is strewn with scattered bowlders, representing essentially all the formations that lie north of us for three hundred miles or more. These were detached from their parent ledges, borne southward, and deposited where they now are, with freshly rubbed and rounded surfaces, in a recent geological epoch, but still one antedating the historical period. While many of these bowlders may have only been uncovered in the later times, the most of those which are fully exposed on the surface present the results of the severest tests of many centuries. By an examination of these, it may be observed that all the limestones show an eroded surface. Some have been deeply eaten into irregular and, occasionally, fantastic forms; some riven to fragments, and largely dissolved; while some, though surface-etched, are still sound and firm in the interior. The sandstones have usually suffered fracture and surface disintegration, and some have wholly crumbled away. The gneisses are disintegrated in varying degrees, and are occasionally crumbled to fragments; the granites have sometimes admirably endured, and sometimes as notably succumbed; the quartzites are rarely much affected, and stand as the type of extreme resistance; the quartz-porphyries are in like manner little affected, for the most part, while the dark class of rocks of igneous aspect are universally altered on the surface, and sometimes greatly disintegrated.

A similar class of observations may be made on rock-ledges, or any natural exposure of rock. It is safe to assume that whatever has taken place in the native ledge, will take place in the artificial wall, in proportion to the degree of its exposure. A layer of rock that is disintegrated or split into chipstone, as it comes to the surface in the hillside or outcropping ledge, will suffer like degradation in an exposed wall. A rock that stands forth at the natural surface, firm and unriven, may be safely trusted in any construction. In making these observations, we are but reading the teachings of Nature's experience with our rock and in our climate. We may, of course, make serviceable, temporarily, material that fails in these severer trials, but they are none the less instructive. The manner in which a rock weathers also furnishes a valuable indication of the changes of color that it will suffer, and is especially to be considered in respect to monumental uses.

Granites. First among the valuable rocks of the State are to be reckoned its granites, both on account of their extent and variety and their excellence. The great Laurentian area of the northern part of the State is occupied largely by granites and gneisses, among which are some of exceptional excellence. Some specimens exhibited at the Centennial Exposition received very high commendation from foreign experts, as material for monumental and ornamental purposes, as well as for massive construction. Granitic rocks of greater or less excellence outcrop along the upper reaches and tributaries of the Menominee, the Peshtigo, the Oconto, the Wolf, the Wisconsin, the Yellow, the Black, the Chippewa, the Flambeau, the Bad, and the Montreal rivers. These are now being rapidly brought within the reach of cheap transportation, and should be utilized to the mutual benefit of those who work and those who use them. In the central part of the State, there are a few outliers nearer to market, as those of Montello, Spring Lake, Marion, Waupaca and Mukwa.[1] That at Montello has been recently extensively utilized.

The attention of interested parties is invited to the Wisconsin granites, not only as affording suitable material for ordinary architectural purposes, piers, paving, and similar uses, but also for monumental and ornamental uses.

Porphyries. In Central Wisconsin there are several outliers of quartz-porphyry that furnish a hard and enduring material of dark

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[1] Vol. II, pp. 248–9, 521–2.

rich color, more or less mottled by interspersed crystals of lighter hue. Some of the knobs that are entirely bare and appear to have been so ever since the glacial period, still retain the glacial groovings, and sometimes even spots of glacial polishing, indicating a remarkable endurance. They are capable of receiving a high and beautiful polish, though they are wrought with difficulty. They are capable of sustaining great pressure, or enduring long continued wear. They have recently been introduced into Chicago as paving material. The outcrops of this rock and their characteristics are described in Vol. II, pp. 249, 252, 519–521.

Quartzites. Quartzites, when pure and thoroughly metamorphosed, furnish a material of the greatest endurance. An obstacle to their use, however, lies in their extreme hardness, brittleness, and want of cleavage. In some portions of the quartzite ranges of the State, however, the alteration from sandstone, to which they owe their origin, is not of the extreme character, and the rock still retains something of the workable nature of the original sandstone and is then a very serviceable rock. In other cases, scales of aluminous minerals are present, and give the rock a sufficient cleavage to be worked without serious difficulty, as in the case of the Portland rock, where the accessory ingredients are sufficient to give some portions a somewhat granitic appearance, and the rock is popularly termed a granite.

At certain horizons in the Baraboo and Barron county quartzite series, there is enough of aluminous and ferruginous material intermingled, to give the rock a finer grained, and a more highly colored character, verging toward pipestone or jasper. Some of this would make a most beautiful building stone. These modifications most abound in the pipestone region of Barron county. The leading quartzite localities are as follows, and are described on the pages referred to: Baraboo, Vol. II, pp. 427, 504–519; Portland, Vol. II, pp. 252–256; Wausau, Vol. II, pp. 486–488; Vol. IV, p. 661; Menominee Range, Vol. III, pp. 459, 460, 466–7, 481, 491, 507–511; Penokee Range, Vol. III, pp. 108–110, 123, 134, 142–4, 164; Barron and Chippewa counties, Vol. IV, pp. 575–581; Necedah, Vol. II, pp. 523–4; and on and adjacent to the Peshtigo river.

Gabbros. It is perhaps worthy of note in this connection that rock identical with that known as "Duluth granite" occurs in massive formation in Ashland county, adjacent to the Wisconsin Central Railway, and elsewhere. It is not a true granite, but a gabbro; is tougher, less hard and less enduring than the best granites, but possesses fair powers of resistance. It is perhaps the only rock of the diabase class likely to meet with much acceptance as a building stone, the class being generally dull in color, and subject to surface changes.

Sandstones. The reddish-brown sandstones of Lake Superior afford a building material quite comparable in excellence to the favorite brownstones of the east, which they greatly resemble in color and texture. They occur along the lake shore in Ashland, Bayfield and Douglas counties, and are finely exposed in the Apostle Islands. They, and their equivalents in Michigan, rank among the best architectural sandstones of the interior. The light-colored Potsdam sandstone, so widely distributed across the central portion of the State, is usually too soft and friable to furnish a first class rock, but portions of it are not unfrequently rendered firm by a calcareous, ferruginous, or silicious cement, and yield a handsome, easily wrought, and quite durable stone. Some of the more indurated portions are excellent for the heaviest class of masonry, bridge piers, etc. Some of the partially calcareous strata near the upper surface of the formation have a fine grain, pleasant color, moderate strength, are easily wrought and considerably used. The Madison sandstone, much used at the Capital, is perhaps the best known example.

With rare exceptions, the St. Peters sandstone is too incoherent for building purposes. Indeed it is much more frequently a direct source of mortar-sand. At Red Rock, near Darlington, it is impregnated with much iron-oxide, and locally indurated, and affords a serviceable reddish-brown stone. At a few other localities, it is locally solidified, but its use as building stone is limited.

Limestones. While the limestones of Wisconsin furnish a large amount of widely accessible rock, serviceable for ordinary masonry and common coursing work, and are thus a resource of wide availibility, it is only in selected portions that heavy beds of fine grain, uniform texture, and agreeable color, suited to the higher architectural uses, are found. Of such the Niagara limestone furnishes a considerable number. At Waukesha, Genessee and other locations on the same stratum, a compact, fine-grained, white limestone, excellent for cutting, is found, and somewhat extensively utilized. The Byron beds that stretch from near Fond du Lac to the extremity of the Green Bay peninsula, afford a very similar, fine-grained, white limestone of like excellence. Similar stone also occurs in the towns of Manitowoc Rapids, Cooperstown, Rockland and adjoining regions. Near Cedarburg, east of Fond du Lac, in Ashippun, and elsewhere, there are granular dolomites that cut into dimension stone with great facility, have a warm, cream color, and are serviceable where great strength is not indispensable. In the town of Brillion, and to some extent elsewhere, there are fine-grained, marble-like beds, that are lined and flecked with pink, which give the rock a handsome appearance. It takes a fair polish, and might be utilized to good purpose as an ornamental stone.

The Galena limestone rarely has a grain that adapts it to the higher classes of masonry. In the modified form which it takes in the Fox river valley, it has furnished heavy blocks that have been extensively used for piers, locks and similar heavy work. It is there characterized by argillaceous seams that might be thought to unfavorably affect its endurance, but the drift blocks that have apparently been exposed for ages, seem to testify to the contrary.

The greater portion of the Trenton limestone is affected by shaly seams and partings, which lead to splitting and disintegration, especially where exposed to moisture and freezing, and this renders it unsuited to trying situations. Selected portions have fair endurance. The most peculiar development of the Trenton series is the Glass rock of the Lead Region, a very fine-grained, dark-gray rock of glassy fracture. It furnishes a good coursing stone, the Platteville Normal School building being constructed of it.

The Lower Magnesian limestone is, in the main, coarse, rough, thick-bedded, and suited only for rough, heavy work. Certain exceptional portions, however, possess an excellent, even texture, and a soft, uniform color, that is quite in contrast with the body of the formation. The quarries of the town of Westport, near Madison, from which the material of the Insane Asylum and other public buildings was obtained, are examples (Vol. II, p. 602).

For specific descriptions of the rocks of the State, reference may be made to the descriptive portions of the report in Volumes II, III, and IV.

II. Clays.

In their utilization in the manufacture of brick, tile, pottery, or similar products, the several ingredients of clays and clayey earths have different properties, and perform distinct functions. The true clay (i. e., the hydrous silicate of alumina) is the main ingredient that gives plasticity and adhesiveness, and is the element upon which the strength of the product is generally regarded as dependent. But it has the unfortunate property of shrinking, warping and cracking in the process of drying, and this must be obviated. The corrective commonly used is silica, in the form of common sand, or a silicious earth. While this corrects measurably the tendency to contract, it lessens the cohesive strength, and tends to give weakness and brittleness. Its too large use makes the brick "rotten," in popular phrase.

The most obvious effect of the presence of iron is upon the coloration of the product. The redness of most clay products is due to this ingredient. In the clay, the iron is usually in the form of protoxide or hydrous peroxide, whose colors are bluish or yellowish; but on heating, the water is expelled, and the iron fully oxidized to the red peroxide. This result is obviated when much lime and magnesia are present, as will be presently noted. Another function of the iron ingredient is to cement together the other constituents, and, to the extent of its presence, it tends to give strength.

Lime and magnesia, when present in the form of a comminuted, clay-like constituent — a common form in glacial clays,— act as fluxes at a high temperature, fusing and binding the silicious and aluminous ingredients into a hard and firm product. They have also the remarkable property of uniting with the iron ingredient to form a light-colored alumina-lime-magnesia-iron silicate, and thus the product is cream-colored, instead of red. Mr. Sweet has shown by analysis that the Milwaukee light-colored brick contain even more iron than the Madison red brick. At numerous points in the Lake region, and in the Fox river valley, *cream-colored* brick are made from *red* clays. In nearly or quite all cases, whatever the original color of the clay, the brick are reddish when partially burned. The explanation seems to be that, at a comparatively moderate temperature, the iron constituent is deprived of its water and fully oxidized, and is, therefore, red, while it is only at a relatively high heat that the union with the lime and magnesia takes place, giving rise to the light color. The calcareous and magnesian clays are, therefore, a valuable substitute for true aluminous clays, for they not only bind the mass together more firmly, but give a color which is very generally admired. They have also this practical advantage, that the effects of inadequate burning are made evident in the imperfect development of the cream color, and hence a more carefully burned product is usually secured. It is possible to make a light-colored brick from a clay which usually burns red, by adding lime. The amount of lime and magnesia in the Milwaukee brick is about twenty-five per cent. In the original clays in the form of carbonates, they make up about forty per cent.

The effect of what soda and potash may be present in the clays (the amount is usually small) is undoubtedly similar to that of the lime and magnesia. They fuse at a lower temperature, and unite more readily with the silica, iron, etc.

The presence of lime in the form of pebbles or concretions is to be avoided, for in such cases it only fuses with other constituents on the exterior of the lumps, and the remainder is reduced to quicklime, which subsequently absorbs moisture, slacks, swells and cracks the brick.

While light-colored brick have been general favorites, and probably always will be, handsome red brick are now much demanded, and the tendency of present taste is turning somewhat in that direction. Probably there will always be a fluctuating preference for the one or the other, and both will probably always be in demand. The color of red brick, when dull, may be improved by the judicious addition of an iron-earth. Earth of this character, apparently well suited to the purpose, may be found at Iron Ridge and at several other localities. In the Red Clay region, superficial clays that have been rewrought by surface drainage, and from which the calcareous element has been mainly removed, probably also furnish an excellent material for bright red brick. Of course the calcareous clays must be avoided if red brick are desired.

In the older countries, specially colored brick, as black, blue, green, etc., are in considerable use. Doubtless our white brick, with their fusible tendencies, would furnish an excellent basis for special coloring, which is usually accomplished by fusing into the exterior a suitable pigment, much as is done in glazing pottery.

As above indicated, fusible ingredients are, within certain limits, advantageous in the manufacture of common brick, but of course precisely the opposite is true when a refractory brick is desired. A fire-brick of the first quality must be entirely free from any ingredient that will either fuse by itself, or in association with other constituents of the clay, at any attainable temperature. Lime and magnesia, while extremely infusible in themselves, flux with silica, and vitiate the refractoriness of any clay in which they occur. Potash and soda, and to a less extent iron, have a similar effect. The practical absence of these ingredients is, therefore, essential. Some of the clays of Wood, Jackson and other counties afford material of this class (Vol. II, pp. 469–471).

The clays of Wisconsin, considered with reference to the foregoing characteristics, fall mainly into three general classes: 1st. Those which are highly calcareous, and produce light-colored brick; 2d. Those which contain but little lime and magnesia, and, by virtue of the iron oxide present, yield a red product; and, 3d. Kaolin clays, or those which are nearly free from all ingredients except silica and alumina, and produce a white, highly refractory product.

1. The first class owe their origin mainly, as we hold, to the mechanical grinding of glacial ice upon strata of limestone, sandstone and shale, resulting in a comminuted product that now contains from 25 per cent. to 50 per cent. of carbonates of lime and magnesia. This product of glacial grinding was separated from the mixed stony clays produced by the same action, by water, either immediately upon its formation, or in the lacustrine epoch closely following. The process of separation must have been rapid and comparatively free from the agency of carbonated waters, otherwise the lime and magnesia would have been leached out. Where these glacial clays have been rewrought by drainage waters and surface agencies in recent times, the carbonates of lime and magnesia have been mainly removed from them and they pass into the second class. This change may be appreciated by a very simple observation. Selecting a point where the drift hills are composed of stony clay (which is true of most hills in the limestone districts of the drift-bearing area), and where recent gullies by the roadside or in the field have cut down into the drift below the leached surface portion, apply a little diluted hydrochloric or other strong acid, and the clay will respond with prompt and vigorous effervescence. Follow down the gully into the valley to a point where, by the lessening of the slope, the clay washed from above has been deposited, and test again, and no effervescence (so far as my experience goes) will result. The effervescence in this case is due to the escape of carbonic acid, which is displaced from its union with lime and magnesia by the stronger acid applied. This shows that the original clay of the hills is mainly deprived of its calcareous and magnesian ingredients in being washed to the valley. While the original clay might but for its stoniness give a good white brick, the secondary valley deposit would burn red. For a like reason there are localities where the upper portion of the clay bed burns red, while the lower, unleached portion gives a light-colored product. With the growing demand for both white and red brick, this phenomenon can probably be turned to practical advantage. For example, in the extensive red clay district bordering Lakes Michigan and Winnebago (the red clays of Lake Superior are much less calcareous, containing from four to twelve per cent., Vol. III, p. 213), the original clay is highly calcareous, and burns light-colored, notwithstanding the large amount of iron which gives the clay its high, native color. The surface portion, and such parts as have been reworked by surface waters,

are but slightly calcareous, and (though I am not aware that the experiment has been tried) would doubtless burn red, and from the amount and uniform distribution of the iron oxide, as indicated by the natural color of the clay, it might be expected to give a deep rich color. Of course the calcareous portion would have to be carefully excluded. The simple acid test above indicated would distinguish between the two. I know of no common clay which fails to give effervescence that will produce white brick.

It is not uncommon for the brick of some yards to present much variety of color, some being white, some quite red, with various intermediate grades, and with blotched and mottled specimens. This is probably due, in some instances, to the mingling of the surface leached clays with the deeper calcareous ones, and in such cases might be easily avoided, the acid test serving as a guide to distinguish between the two. Differences of color, varying from white to light red, may also be due, as already indicated, to different degrees of burning. This might be clearly determined by the position of the brick with reference to the fire.

The area in which the calcareous brick clays abound may be defined as the limestone district of the later drift region, or, mainly, the eastern portion of the State. They do not occur in the driftless region, because the clays of that district were derived from the *disintegration*, not grinding, of the rock, and the calcareous and magnesian portion were removed, and the silicious and aluminous left. They are not mechanically-formed, but residuary clays.

Very highly calcareous clays cannot be expected to occur in the Archæan, or sandstone areas, except so far as limestone drift has been borne onto them; since the crystalline rocks of the State are not rich in lime.

Calcareous clays occur in the older drift area, but are rather rare. They are likewise not common in the central part of the State, within the later drift limits.

2. *Slightly Calcareous Clays.* The second class, the slightly calcareous clays, are widely distributed throughout the State, occurring as superficial deposits in districts of calcareous clays, and as the main body of clay deposits elsewhere.

3. *Kaolin Clays.* The third class, or the Kaolin clays, are, of course, of much rarer occurrence. They originated from the disintegration of gneissoid rocks (mainly from the feldspar contained in them), and may have been more prevalent in the granitic regions before the drift period, but, for obvious reasons, rarely survived in the region actively over-ridden by the ice. In coincidence with this

fact, the deposits, so far as known, lie on the southern edge of the granitic area, along the margin of the glaciated area, mainly in Wood county. As the proper utilization of these clays is dependent upon a special knowledge of the precise character of each deposit, general suggestions are of little value. Those interested are referred directly to the local descriptions and analyses given in Vol. II, pp. 468, 469, 471 and 476, and to the special paper of Prof. Irving on the "Kaolin Clays of Wisconsin," published in the Transactions of the Wisconsin Academy of Sciences, 1880.

While it is convenient and customary to speak of the crude material of brick as clay, that which is really made use of is a mixture of clay and sand, or, in the cream-colored brick, of aluminous clay, calcareous clay or marl, and sand. This mixture is really a loam, and but for the appropriation of that term as the designation of a soil, it would doubtless be more generally applied to such mixtures. Very many deposits present the right proportions of clay and sand, either already mixed or in interstratified layers readily mixed in the handling.

Pottery clays, suitable for pottery, common tile, etc., abound at various localities, and some of the finer classes are apparently suited for higher ceramic purposes.

III. Limes and Cements.

The several limestone series of Wisconsin furnish superabundant material for the manufacture of quicklime, suitable for common constructive purposes. The main practical question, therefore, that claims attention here, relates to the selection of the best available material, a matter too much neglected.

Chemical Composition. It was formerly supposed that pure carbonate of lime afforded the best material for the purpose, and that the magnesian limestones were inferior; but extensive experience seems to have satisfactorily demonstrated that the reverse is true. At least, the great markets of this country are said to be now supplied almost wholly by magnesian limes, to the exclusion of the simple limes, even though the latter may be obtained nearer at hand. It is possible that this may be in part due to greater freedom from impurities, and to texture, but at any rate the former prejudice against magnesia seems to have been ill-founded.

The presence of silica (sand) and alumina (clay) are objectionable, not only as impurities, but because, by fusing with the lime, they neutralize an equivalent portion of that, and are therefore more than simple inert impurities. Iron is especially objectionable, if it discolor the product. It may, however, unite with silica and lime in proper proportion, and form a light-colored lime-iron silicate, as in white brick, as before noted.

In view of the fact that the impurities of limestones that have been actually used range from fifteeen or more per cent. down to less than one per cent., some convenient test that can be applied by lime-burners, even though it give only approximate results, would prove serviceable. I have seen kilns of approved construction, and favorably located, lying idle and abandoned, within a short distance of as fine beds of magnesian limestone as the country is known to afford, while a quite inferior rock had been used.

A test capable of giving even but a rude approximation to the composition would guard against the more serious errors, and be of particular service where the different beds of a locality vary in character. Such a test may be made by simply dissolving a portion of the rock in dilute hydrochloric (muriatic) acid, and estimating the amount of the residue. Chippings from the rock, sufficient to represent a fair average, may be pounded up together, and a portion of the powdered rock transferred to a glass. To this, add gradually the acid (if it be concentrated, it is well to dilute it somewhat with water). Bubbles of carbonic acid gas, displaced from the limestone by the stronger acid applied, will rise through the liquid in the glass. Continue to add acid until bubbles cease to rise. The carbonates of lime and magnesia will then have been dissolved, and a small, but not very important, part of the impurities. The main and most objectionable part of the impurities will remain as dregs, and an approximate estimate of their amount may be made. If the rock belongs to the higher grade of purity, the amount will be very small, not more than about one one-hundredth of the powdered rock used in the experiment. Different beds may thus be compared, and the best afforded by any locality selected.[1]

[1] By the use of apothecary's scales, even a rude determination of the percentage of insoluble impurities may be made. In this case, dry thoroughly the powdered limestone in an oven or otherwise, weigh out carefully the quantity to be used (say 200 grains), dissolve the soluble portion in hydrochloric acid, pour the whole, both liquid and residue, upon a filter made by adjusting filter paper in a funnel in a manner familiar to all druggists, and, after the liquid has drained away, pour pure water into the glass used in dissolving, and stir it so as to wash out all the sediment, and pour this into the filter, and repeat the operation until the sediment has all been transferred and until that on the filter has been cleansed of the acid solution. Then remove the filter paper, together with the

The Niagara formation affords an abundance of magnesian limestone, well distributed, in which the total impurity is only about one per cent., and, in some instances, only about one-half of one per cent. While there may be special reasons which render it profitable to the burner and serviceable to the consumer to reduce a somewhat less pure rock in certain localities, it is in general possible to secure limestone whose average impurity does not much exceed one or one and a half per cent. Two per cent. should generally be regarded as the outside limit. In the central and western parts of the State, where transportation from the Niagara district is an important item, recourse may advantageously be had to the lower limestones. From the Galena limestone it is possible to select portions whose impurities shall fall below two per cent., and this is, in many localities, the best available formation. In the Lead Region, portions of the Blue limestone can be obtained whose impurities fall below two per cent.; indeed in some instances nearly as low as one per cent. Elsewhere, it is less pure. The Lower Magnesian limestone is usually quite silicious, but varies much, which makes judicious selection a matter of importance. There are portions of the formation, rather exceptional it is true, in which the percentage of impurities does not exceed one or one and a half per cent., and which take rank among our purest magnesian limestones; and this, while it is not uncommon that rock in which there are six or eight per cent. of objectionable ingredients is burned. Most regions dependent upon this formation can probably be supplied by judicious selection from beds of not more than three or four per cent. impurity, and indeed much less, in some favored localities.

The area of crystalline rocks in the northern portion of the State can have no local supply, for want of limestone, and will find its best supply, in the main, from the Niagara limestone, whose edge nearest to that region is readily accessible on the eastern margin of the Fox-River-Green-Bay valley from the vicinity of Lake Winnebago northward. The northwestern region can be supplied with a fair product from the Lower St. Croix and Chippewa river limestone districts.

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insoluble residue upon it, and, after carefully drying, the sediment may be removed and weighed. Chemists usually burn the filter paper and include the ash with the residue, so as to save the fine particles that adhere to the paper, and then make a deduction for the weight of the ash of the paper, the amount of which is known. Having obtained, as accurately as possible, the weight of the insoluble portion, it will only remain to divide its weight by that of the original powdered rock to give the percentage.

To go into details as to localities and special beds on this broad subject of lime-supply, would far transcend our present limits. Attention has been given to it in the description of the several limestone strata in Volumes II and IV, to which reference may be made.

Texture. The discussion has thus far had reference only to the chemical composition of the rock, but its texture is a consideration not to be overlooked. A certain degree of porosity is desirable, since it permits the ready escape of the liberated gases, and secures a uniform and complete reduction without an excessive heat and its attendant deleterious effects. It likewise facilitates complete slacking when used, and tends to prevent the introduction into the wall of unslacked lumps, whose subsequent swelling injures it. A uniform, porous, granular texture best meets this requirement. Some of our dolomites are composed of minute crystals, rather loosely aggregated, leaving minute interstitial pores which furnish, in almost ideal perfection, the desired quality. In some cases this granular condition is so marked that the rock is regarded as a sandstone and seemingly avoided. On the contrary, it is the very rock to be sought, unless too loose and crumbling.

Pure Limestone. There are occasional special uses for lime, in which magnesia is detrimental. In the interest of such industries, attention may be called to the simple limestones of the Trenton series in the Lead Region, especially to the peculiar layers known as *Glass rock*, which have their most typical development on the Platte and Fever rivers and their tributaries, and may be well seen near Platteville, Quimby's Mills, and elsewhere. An analysis reported by Prof. Whitney gives the composition of a specimen as, carbonate of lime, 97.92; carbonate of magnesia, 1.60; peroxide of iron and magnesia, 0.28; insoluble residue, 0.82.

Flux. The Glass rock, but for the occasional presence of particles of pyrites, and its distance from most furnaces, would be admirably adapted to use as a flux for iron ores, but practically is not now available. The pure granular magnesian limestones of the Niagara formation are, everything considered, the best and most available which the State affords, and these have been practically demonstrated to be reasonably satisfactory.

Hydraulic Cements. An important class of constructions require a cement whose qualities will not be affected, except beneficially, by contact with water. It was long since found that certain natural and artificial mixtures of lime, magnesia, alumina and silica, prepared by moderate burning and grinding, give this desired quality. The precise explanation of this has not yet been certainly arrived at. Quite various compositions have been found to give good results. In general terms, it may doubtless safely be said to be due to the formation, chemically, of an aluminous-lime-magnesian silicate.

Hydraulic limestones are to be sought among the impure magnesian limestones and highly calcareous shales. Some of these are known to possess hydraulic properties in a measurable degree, and the constitution of others makes it highly probable that they do also. There is little reason to expect, however, that a stratum possessing an excellence equal to that now utilized near Milwaukee will be found, though the variation in character of hydraulic cements renders a judgment in advance of actual tests of uncertain value. The Milwaukee cement is quite fully described in Volume II, to which reference is invited. Experience, so far as I am informed, justifies the high estimates which the early tests encouraged.

CHAPTER V.

SOILS AND SUBSOILS OF WISCONSIN.

By T. C. Chamberlin.

Note.—For special descriptions of soils, see Vol. II, pp. 188–198, 449–451, 663; Vol. III, 324–6, 375–381; Vol. IV, 156–9. For geographical distribution, see Atlas Plate II, B.

Only a portion of the complicated questions that are involved in the highest utilization of the soil fall within the field of the geologist. Almost the entire range of natural and commercial science is in some degree involved, directly or indirectly, in the industries dependent on the soil, and a correspondingly wide range of knowledge is tributary to farming in its widest and highest sense. The geological aspects relate mainly to (1) the origin and nature of the soil, (2) to its waste and reproduction by natural means, (3) drainage, and (4) natural fertilizers.

Origin of Soils. Allusion has been briefly made, in the closing portion of the Historical Geology (pp. 294–5), to the manner in which our soils originated. As a broad general proposition, it may be stated that the mineral portions of soils originate from the disintegration of rock, and the organic portions from the decomposition of animal and vegetable matter. As the latter is largely that which the soil has itself produced, and is partly due to the character of its mineral ingredients, a consideration of these will embrace the essential geological phases of the subject. The character of the soil derived from a rock depends mainly (1) upon the nature of the rock, (2) upon the manner and degree of its reduction to the fine, earthy condition, and (3) upon the degree of retention or loss of the finer constituents.

The rocks of Wisconsin, as already abundantly set forth, belong to four chief classes: (a) the limestones; (b) the sandstones; (c) the clay shales, and (d) the mixed crystalline rocks. The more common agencies by which these are reduced to an earthy condition are water, the atmosphere, especially the ingredients, carbonic acid and oxygen, changes of temperature, including especially frost, the action of plants and plant products, and that of animals, especially the agency of earthworms, as lately shown by Darwin. The reduction effected by these agencies is partly of a chemical and partly of a physical nature, and the result is a comminution of a part of the rock-substance, and the solution and removal of another portion, while sometimes a third portion is left in unreduced lumps or masses, of greater or less size.

In the case of limestones, the lime and magnesia are mainly dissolved and carried away by the agency of water charged with carbonic acid, while the alumina and silica that were distributed through the rock as impurities are left, because mainly insoluble. These last form the body of the soil, which, in this case, usually has a fine texture of the loamy or clayey character. There is usually retained a portion of the other ingredients of the limestone, the lime, magnesia, potash, soda, iron, and in smaller quantities, sulphur and phosphorus. These ingredients were originally derived, as already explained in the General Geology, from oceanic sediments, formed largely from the remains of animal and vegetable life; with which were also entrapped some oceanic salts. The decomposition of the limestones is, in favorable situations, continually going on beneath the subsoil, furnishing new soil-earth and fresh mineral solutions that can be taken up directly by deep-rooted plants, and which are drawn surface-ward by capillary action, particularly in times of drought.

Soils of this character prevail in all the areas of the driftless tract of Western and Southwestern Wisconsin, and, to a limited extent, in the limestone areas of the drift-bearing districts. In the latter regions, however, for the greater part, the soils are derived in a somewhat different manner, presently to be explained.

Where the underlying rock is a sandstone, the action of the same agencies gives rise to a sandy soil, formed from the grains of sand that mainly made up the rock; with which are mingled also earthy matter, derived from the cement of the sandstone, and perhaps to some extent from the decomposition of the sand itself. If the sandstone is composed almost entirely of grains of quartz, the resulting soil will be poor; if composed in considerable part of grains of feldspar, mica, or other silicates, or of minute crystals of calcite, or particles of limestone, or of clayey or limey admixtures, the resulting soil may be a sandy loam of considerable fertility.

Sandy soils so derived, in part fertile and in part sterile, occupy the area underlain by the Potsdam and St. Peters sandstones in the central and western portions of the State, where these are not covered by drift or wash. Sandy soils do not, however, occupy the entire areas of these formations. The sandstones, being more easily eroded than the limestones, have been more largely removed, and hence generally occupy valleys and lower tracts, while the limestones crown the hills. The superior soil from the latter has washed down and covered up or mingled with the sandy soil, improving its quality. Again, alluvial deposits from streams frequently cover the bottom lands, and marshy tracts are overspread by peat and muck.

Where the underlying formation is a clay shale, it is usually readily disintegrated to a clay soil, which is heavier or lighter according to the character of the original rock. The Hudson River (Cincinnati) shales, which occupy a narrow belt on the east of the Green-Bay-Rock-River valley, and some limited patches in the southwestern part of the State, represent this class. These shales are usually somewhat calcareous and arenaceous, so that the resulting soil is a clayey loam, and occasionally, even a sandy loam.

The crystalline silicate rocks, of which the granites and traps are types, being quite various in composition, give origin to correspondingly different soils, which vary from the sandy, through the loams, to the clayey. But as the areas of these rocks are mainly covered with drift, it is unnecessary to consider the several classes in detail.

In the preceding cases, the soils have been derived directly from the rocks on which they lie, and depend immediately on them for their character. In pre-glacial times, such soils undoubtedly covered the entire area of the State, and there was then a close correspondence between the underlying rock and the soil, as there is now in the driftless district. But the glaciers that moved over all the eastern and northern portions of the State, largely scraped this old soil away, and ground off the face of the rock, producing a new kind of rock-flour, mixed with pebbles and bowlders, all of which were left in a confused, irregular sheet over the surface of the rock, constituting what is known as *the drift*. Two things are especially to be noted of this, considered as soil-matter: First, the material of the various formations was commingled. As the ice passed over the several strata in succession, it bore along more or less material from all, and mixed and ground it together, producing a highly composite product. Material from the limestone belts was borne onto and mixed with that of the sandy tracts, matter from the crystalline rocks was mingled with that of the limestones, and so on, the result being a commingling of ingredients, and a soil-material of complex constitution, and in that regard favorably constituted to meet the complex demands of the various kinds of vegetation.

The second characteristic to be noted is that the finely comminuted material was *mechanically* produced,— was the result of rubbing and grinding. This difference is most strikingly displayed in the limestone products. It has been remarked above that in the decomposition of the limestones the lime and magnesia (for our limestones are nearly all magnesian) were mainly dissolved out, and the residual earth is chiefly composed of finely divided silica and alumina. While there is a little lime and magnesia present, these soils and subsoils rarely give any effervescence, on the application of acid, which would take place if the carbonates were present in any considerable quantity. The clays produced by glacial action, on the contrary, are ground limestone, in considerable part, and show their calcareous character by prompt and vigorous action when acid is applied.

These calcareous clays are not, however, in their crude state, in the most favorable condition for supplying the wants of plants. They need first to undergo the reducing action of the atmospheric and other agencies above noted. The result of this action (which has supervened since the glacial period) is a surface soil from which nearly all calcareous material has been removed, and whose characteristics are very similar to those of the limestone regions not acted on by glacial agencies. But the deeper subsoil is a highly calcareous clay, and this is usually within reach of most cereals. Calcareous drift clays occupy nearly all the eastern part of Wisconsin, and a considerable area in the northwestern part.

The drift of the area of crystalline rocks in the northern region is mainly composed of ground crystalline rock and rock-fragments. The material, being in general harder, and containing a larger ingredient of quartz, than the limestone, was much less comminuted by glacial grinding, and remains coarser and more stony. But still a large amount of clay was produced, mingled with much sand and gravel. By the wash of glacial streams, and those that have drained the region since, much of this sand was sorted out, and strewn along their courses in great sand-streams and flats, forming the "plains" or "barrens" of that region. As these lie mainly along the valleys, and are level, dry, and scantily clothed with timber, the earlier lines of travel were, for obvious reasons, along them, and, as a consequence, an impression of barrenness has gone forth that is quite untrue of the region as a whole. The unmodified, mixed drift embraces a great variety of clayey and sandy loams of much fertility, as the heavy growths of mixed timber amply testify. To some extent, calcareous clays were borne onto the crystalline region, and the fertility of the soil thereby increased.

Another result of glacial action was the carrying of calcareous clays onto areas underlain by sandstone, and so covering them with material for a more productive soil than they would otherwise have possessed.

In the later stages of the glacial period considerable districts bordering the Great Lakes, and smaller areas in other parts of the drift region, were occupied by lakes. Beneath these were deposited clays from the drift. Of these, the most important are the red clays that border Lakes Michigan, Winnebago and Superior. These lacustrine clays, like the original glacial clays, are calcareous; those of Lakes Michigan and Winnebago and the Fox river valley, highly so; those of Lake Superior in a less degree. The disintegration of the surface of these has given rise to a marly-clay soil of medium, or rather heavy, character and enduring fertility. Surface action has mainly removed the calcareous ingredient from the upper soil, but it is abundant in the deeper subsoil.

The glacial agencies left the upper surface of the drift uneven, presenting many shallow depressions, which furnished the most favorable conditions for the accumulation of muck and peat deposits. These lie scattered in thousands of isolated areas throughout the drift area. Many of them have been subsequently drained by natural means, through the cutting down of the edge of the basin by the out-flowing water, while many remain as undrained marshes and swamps. The soil of these is, for the most part, humus, and belongs to a class quite distinct from those previously discussed. Some of it is sufficiently dry and firm and free from hurtful acidity to be excellent meadow land. Some of it is of exceptional value for special kinds of culture, as that of the cranberry, while some of it has its main value as a source of fertilization for adjoining lands.

We have thus far considered the derivation of soil, without regard to the accidents of surface contour. Were the surface essentially plane, the soil would quite closely correspond to the formation beneath; but the irregularities of the surface have an important modifying influence. Where the slope is considerable, as on hillsides, much of the finer material is washed down into the valleys, leaving the soil above thinner and coarser. Of the material washed down, the coarser portion lodges first, while the finer is carried onto the flatter bottoms, or perhaps borne entirely away. The different constituents of the soil become thereby separated, and different kinds of soil come to occupy different topographical situations. In this way soil derived from one formation is transported to the ground of another, as in the case of limestone soil being borne down onto sandstone territory, a common occurrence in the western half of the State. The reverse is occasionally, but more rarely, true. In this way, also, clay deposits are sometimes formed in valleys and depressions in sandstone regions where limestones and clay rocks are wanting, the fine material of the sandy soil being washed from the surface, and redeposited in the depressions by the slackened stream or the embayed waters, thus recovering in part the loss of the original washing.

The winds also produce analogous modifications of soils, by blowing away some of the finer and lighter material from exposed situations, and depositing it in protected places. The winds probably produce a somewhat greater effect upon cultivated fields than we commonly realize, as one may perhaps convince himself by observing the discoloration of snow on a partially covered field, even though unstirred and frozen. The effect of wind drift in sandy regions is quite marked.

By these and similar surface agencies, almost innumerable local variations of soil are produced, among which are many of those minor varieties observable on nearly every farm.

Waste of Soils. What has just been said introduces us to the subject of the waste of soils. The surface drainage bears away a not inconsiderable portion of the soil. A part of this is only too apparent in the muddy streams that flow from cultivated fields in times of flood and freshet, and even of more moderate rains. Another portion is borne away invisibly in solution by surface waters, and by underground drainage. There is still another phase of the action not to be overlooked. Every shower disturbs and moves over some little space the surface particles on cultivated fields, even when it is not competent to wash them any considerable distance. The movement will obviously be mainly down hill, and as it affects almost the entire surface, even though the movement of any portion is small, the total effect is not inconsiderable. Thus the surface is moved, little by little, toward the valley, where either the stronger floods carry it away, or it accumulates to a depth which practically amounts to the burial of the greater portion beyond available reach. It has been estimated from the amount of material being borne out into the Gulf of Mexico, that the whole surface of the Mississippi valley is being lowered at the average rate of one foot in about 6,000 years. This is certainly not a very startling rate, but of course it must be considered that the lower part of the valley is filling, rather than wasting, and that at our expense. It must also be noted that the waste from cultivated fields is great, as compared with sod and timber land, so that the burden of this waste falls upon the tilled lands. Upon these also falls the loss from the removal of crops, so that they are doubly subjected to wastage.

Reproduction of Soils. Whatever may be the precise measure of the natural soil wastage, it certainly is not unimportant, and gives interest to the question of a compensating natural reproduction of soil. In so far as the surface is lowered by wastage, the atmospheric agencies are brought within reach of the underlying rock, or crude drift, from which they develop a subsoil to compensate for the surface loss, and this new soil will, in the process of ages, itself become the surface soil. There is thus a renewal below, as the direct result of waste above. This renewal does not always proceed at the same rate as the waste, but wide observation seems to render it certain that the agencies of renewal are competent, in the general average, to reproduce the soil faster than surface agencies carry it away. The exceptions are found on very steep slopes, and in special situations where wash is rapid, or where disintegration proceeds with unusual slowness.

Surface Drainage. While there are numerous small undrained areas occupied by wet meadows, sedge marshes, or tamarack, cedar, or spruce swamps, these are confined mainly to circumscribed depressions in a gently rolling surface, the most of which is well drained. There is little of the State that suffers from excessive flatness, or is damaged by excessive hilliness. The highest utilization of the marshes, and of occasional flats and bottom lands, will require artificial drainage, and the protection of some hillside slopes against wash deserves attention; but for the greater part, nature has herself prepared a satisfactory drainage system.

Underground Drainage. The facility with which subsoils and underlying strata are penetrated by water, and the character of the underground drainage, are not unimportant considerations. If the substratum is very close and impervious, underdrainage will be impeded, resulting in injury to the crops in very wet weather, and the rise of water from below, in dry seasons, will be retarded to the detriment of the crops. On the other hand, too great porosity permits surface waters to sink away too readily, and, from the coarseness of the pores, capillary action is less efficient in dry seasons. These qualities also affect the aeration of the soil — an important consideration. A medium degree of porosity is most to be desired. Wisconsin soils present nearly all grades of porosity, as do also the subsoils and underlying strata. Some of the sandy soils, resting on the Potsdam sandstone, suffer from too great porosity, both of soil and substratum. The rainfall is quickly absorbed and passes down into the open sandstone, whence it is led away beneath the deeper strata, as perhaps best explained in the chapter on artesian wells following. On the other hand, some of the more clayey soils, resting upon a compact drift clay, would be better for a less impervious bottom. This, however, is not a prevalent case. Few Wisconsin soils are very objectionably heavy, or underlain by a too compact base. The greater portion belong to intermediate classes, consisting of medium and lighter clayey loams, and the finer sandy loams, resting upon a limestone, or mixed drift base, which is neither excessively porous, on the one hand, nor injuriously impervious on the other.

The character of the underground water is a not unimportant consideration. In dry seasons, when the surface evaporation greatly exceeds the rainfall, water is brought to the surface by capillary action, and evaporated, leaving in the soil such mineral constituents as it contained. An inspection of the analyses of natural waters, given on pages 307 and 308 of this volume, will show the large extent to which valuable constituents are carried by the deeper waters. Nearly all the underground water in the limestone regions of the State, and these embrace by far the larger portion now under cultivation, contains notable quantities of lime, magnesia, potash, soda, iron, sulphur and frequently phosphorus, in some of their combinations. A portion of the surface enrichment which is observed to be the result of protracted drought, is to be attributed to the drawing of these waters to the surface, and their evaporation thence, leaving their mineral content in the upper soil.

Natural Fertilizers.

Peat. Among the natural fertilizers of Wisconsin, peat is most abundant, occurring in innumerable deposits, scattered over the larger portion of the State. Some account of the method of formation and character of these deposits may be found in Volume II, pp. 240–246. By reference to the Soil Map of the Atlas, it will be seen that its distribution renders it widely and conveniently accessible. Its leading functions as a fertilizer are the following: (1) It has a remarkable power of absorbing and retaining moisture, which it may imbibe directly from the vaporous condition in the atmosphere. This property makes it a valuable corrective for dry soils. (2) It also absorbs ammonia from the atmosphere, and thus furnishes it to the plants. (3) By its own decay it generates ammonia, and perhaps other nitrogen compounds, as well as carbonic acid. (4) By its decomposition, it assists in the disintegration of other soil constituents. (5) It improves the texture of the soil, giving greater compactness to porous, sandy soils, and less adhesiveness and stiffness to clay soils. (6) Being dark in color, it is especially fitted to absorb heat from the sun, and thus increase the temperature of the soil.

Peat, however, does not give a quick and conspicuous return. Indeed, if put on in a sour condition, it may be temporarily harmful. In any case it yields its products slowly, and is hence less appreciated than fertilizers that give a more ready and manifest response, even though they are more quickly exhausted. But for sandy soils especially, its slowness of action and endurance are desirable qualities, and its more extensive use is to be recommended. It is well adapted to the absorption and retention of the more valuable portions of liquid manure, which is now almost universally allowed to run to waste.

Shell Marl. Many of our present marshes were formerly lakelets, in which mollusks and other forms of life flourished. Their shells in time accumulated in considerable quantities, forming layers of shell marl. Beds of this are quite common, underlying the peat marshes, several of which will be found described in these reports. In most instances, the marl is mixed with peat and other organic matter. The marl itself is mainly carbonate of lime, and is serviceable for those lands that need a calcareous fertilizer. There are usually present small quantities of accessory mineral ingredients, including sulphur, potash and phosphorus, that add to its value according to their abundance. Peaty matter is mixed in varying proportions, giving rise to numerous grades of peaty marls and marly or shelly peat. These mixtures are especially beneficial for sandy soils.

Glauconite, a greensand, occurs in considerable quantities in the Potsdam sandstone, especially in certain of the upper layers. It is essentially a potash-iron silicate, and its value as a fertilizer arises from the first named constituent. It varies much in composition, and, in the Wisconsin formations, is mixed with common sand. I am not aware that its fertilizing value has been practically tested, but it is worthy of an intelligent trial. The true glauconite is, however, to be distinguished from mere greenish sand which is common in the same formation. The glauconite is dark green, opaque, and somewhat earthy, while the green sand is paler, and transparent or translucent.

Gypsum (the crude material of "plaster") occurs in small quantities in the Hudson River (Cincinnati) shales, but is scattered through the clayey rock in too small quantities to be utilized, and our supplies of this material must be imported from our neighboring states, Michigan, Iowa, and elsewhere.

Apatite, a phosphatic mineral, occurs as small crystals disseminated through some of the crystalline rocks of the northern part of the State, but it is impracticable to utilize it, except as Nature does so by the slow disintegration of the rock.

Of *Lime*, which is very much used in the older countries, it is unnecessary to remark that there is an abundance, widely accessible and cheaply reduced. Its magnesian character is held to be an advantage, since magnesia forms a larger percentage of the ash of grains and fruits than does lime, while the opposite is true of the fiber of the plants, seeming to indicate that magnesia is especially concerned in fruit and grain production, and lime in fiber-making. (See Vol. II, pp. 197–8.)

We are not yet arrived at that stage in which the *claying* of sandy soils, or the opposite, can be generally carried out with profit, but there are special instances in which this is practicable and advisable, as in gardens and orchards. In sandy districts, clayey beds not infrequently occur in the depressions where the finer material of muddy waters has been permitted to accumulate. Many of the little marshes have a clayey or marly bottom, serviceable for such purposes. Where shell marl and peaty material is mixed with this, an additional advantage may be secured.

Map of Soils. There are few natural formations more difficult to map than soils. There is an almost infinite gradation of varieties between which there are no hard-and-fast lines, and it is nearly or quite impossible to represent these gradations on a map. Moreover these gradations run through more or less of their minor changes on almost every farm, and to attempt to represent these for the more than 50,000 square miles of land embraced within the limits of Wisconsin would be an undertaking of no small magnitude, and would require maps of very large scale and elaborate execution, and when executed, while extremely valuable for certain uses, the very confusion of details would be a source of inconvenience in the more general studies.

One of the more important uses of a soil map is to furnish a basis for the *comparison of practical results in farming.* The experience of one farmer is valuable as a guide to another, only when considered in connection with the conditions which affect both farms. Among these conditions, the nature of the soil is an important one.

This is especially true when results at distant points are compared, as is the commendable practice at State Conventions, and through the agency of agricultural publications. The general maps of Soils, Native Vegetation, Rainfall, Temperature, Topography, Drift, and General Geology, given in the Atlas, are designed to constitute a series that shall form a basis for such a comparison. By their use, it is hoped that some of the errors that arise from inconsiderately following the practice of others, without regard to the conditions that determine success or failure, may be obviated, and, on the other hand, some valuable general deductions be made from a rational comparison of experience.

CHAPTER VI.

ARTESIAN WELLS

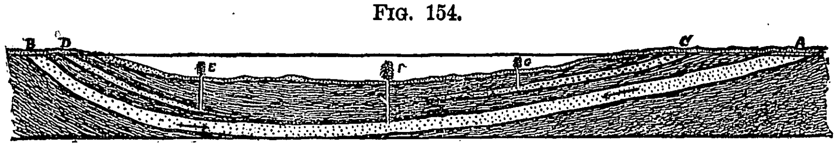
BY T. C. CHAMBERLIN.

NOTE.— For special descriptions and discussions of artesian wells, see Vol. II, pp. 149–171 (Chamberlin); Vol. III, p. 88 (Irving); Vol. IV, pp. 57–62 (Strong).

The subject of flowing wells is one of prime importance to the people of Wisconsin. On the one hand, many thousand dollars have in the past been uselessly expended in attempts to secure fountains where the necessary conditions were entirely wanting; and on the other, very great possibilities have lain unutilized, to the great industrial and sanitary loss of our citizens. It is the purpose of this chapter to gather into a convenient form such serviceable information as may be capable of brief, general statement. Special descriptions and discussions may be found under the references above given, and the descriptive volumes of the report will furnish the data necessary for the special study of any given problem.

To obtain a simple and clear idea of the nature of most of our Wisconsin artesian wells, picture to the mind an open, porous stratum, through which water can readily pass, lying between two others that are essentially water-tight. Suppose these beds to be moderately inclined, so that on one side their edges come to the surface (except that they are usually covered with soil and other loose surface material), and that on the other they dip down to great depths, and either come up again to the surface at a distant point, or else terminate in such a way, or take on such a nature, that water cannot escape in that direction, as illustrated in the accompanying

FIG. 154.



IDEAL SECTION ILLUSTRATING THE NATURE OF ARTESIAN WELLS. *A B*, a porous stratum lying between impervious beds. *C*, a porous layer changing below into an impervious bed. *D*, a porous stratum terminating below. *E*, *F* and *G*, fountains derived from the porous strata.

figure. Now picture the surface waters derived from rainfall as penetrating the porous bed and filling it to the brim. That all such beds are full to within a comparatively few feet of the surface, we know from our ordinary wells, which find an inexhaustible supply in them without usually going below the main valleys. Now it is manifest that if such an inclined bed, so filled with water, be tapped at some lower point by a boring, the water will rise and flow at the surface because of the higher head in the upper edge of the bed, and if the surface waters continually supply the upper edge as fast as the water is drawn off below, the flow will be constant.

From this simple conception we may draw out the leading conditions upon which artesian flows depend, which may be stated as follows:

1st. There must be a stratum sufficiently porous to permit a ready entrance and flow of water through it.

2d. There must be an impervious bed below to prevent escape of water downward.

3d. There must be a like impervious bed above to prevent escape upward, for the water, being under pressure from the head, would otherwise find relief in that direction.

4th. All these beds must form a basin, or at least be inclined, so that the edge at which the waters enter will be higher than the surface at the well.

5th. The edge of the porous stratum must be suitably exposed so as to take in a sufficient quantity of water to afford an adequate supply.

6th. To furnish this supply, there must be an adequate rainfall.

7th. There must be no escape for the water at a lower level than the surface of the proposed well.

These may be considered severally, and we may then pass to some of the special practical questions involved.

1. *The Porous Beds.* The porous stratum in Wisconsin is usually a sandstone. In a few instances flows are derived from limestone strata, as in the case of the wells at Manitowoc. In such cases the water has probably formed underground channels by solution — "veins" of water in quite an appropriate sense. As the position of these cannot be determined beforehand, there is no certainty of striking them, and hence they cannot be relied upon as sources of flow. Experience seems to show that the chances of striking them are quite small. The sandstone beds, on the contrary, are continuous sheets underspreading large areas, and may almost certainly be struck at the proper depth. They are, furthermore, usually so porous that there is little liability of passing through them without encountering at least a moderate supply of water, where other conditions are favorable. The St. Peters and Potsdam sandstones are

our great water-bearing strata. The latter is fortunately divided into three separate water-bearing horizons by the Mendota limestone and shales, and by a stratum of shale lying lower down. These are not always present, however, but, on the other hand, there are, at some localities, other impervious beds that serve a like purpose.

Besides these ancient sandstones there are porous beds of sand and gravel in the drift deposits above the rock, some of which are available as sources of flow; but these are local, and cannot here be well treated, and our discussion will be confined to the rock beds which alone are available over any considerable tract.

2. *The Confining Stratum Below.* Usually this does not need consideration, for if the bed next below any given porous stratum is not water-tight, some lower one is, and manifestly the water cannot sink indefinitely downward. It is rarely the case that any lower porous bed is so exposed that it can drain a higher one, yet a case of the kind might occur.

FIG. 155.

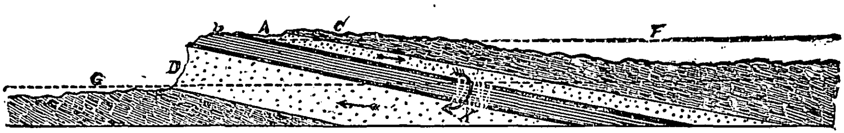


DIAGRAM ILLUSTRATING THE POSSIBLE EFFECTS OF A DEFECTIVE CONFINING STRATUM. In the annexed diagram, *C*, *B* and *G* represent impervious strata, and *A* and *D* porous beds interstratified between them. It is manifest that if the stratum *B* is perfect, a flow may be derived from the bed *A* at any point under the line *F*; but if the stratum *B* is broken at any point, as at *X*, the bed *A* would be drained through the porous stratum *D*, as indicated by the arrows, and no flow could be secured at *F*.

3. *The Confining Stratum Above.* It is much more important to give careful attention to the strata that overlie the water-bearing bed than to those below, for the water, being under pressure, tends to rise through them, and if they are in any degree penetrable, the water will, to that extent, escape and relieve the pressure and reduce or prevent the flow. Our most nearly impervious rocks are clay shales, such as those of the Hudson River formation. Our limestones, where they are present in considerable thickness, serve as reasonably good confining beds. No rock is, however, entirely impenetrable to water, and the question of the amount to be allowed for leakage is an important one in many cases where conditions are closely balanced. It thus becomes apparent that the character of the strata overlying the water-bearing bed between the proposed well and the fountain-head needs to be considered. If they are thick and compact, the leakage will be small. If otherwise, it may be large.

There is another element to be recognized here, that has never, so far as I know, found place in discussions of the subject, viz.: *the height of the common underground water-surface between the proposed well and the fountain-head.* Everyone who has given any thought to the subject is familiar with the fact that the surface of the underground water, as shown by wells, stands at varying heights. It is almost invariably higher than the adjacent streams, though when the substratum is sand or gravel, the difference is usually slight. In general, the surface of the underground water rises and falls somewhat as the land surface does, only less in amount,-i. e., the water stands higher under ridges and swells of land than under valleys, though of course usually farther from the surface. Now, if the underground water between the proposed well and the fountain-head stands as high as the latter, as may be the case (except at and near the well, where, of course, the surface must be lower), there *will be no leakage,* not even if the strata be somewhat porous, for the underground water presses down as much as the fountain-head causes that of the porous bed to press up, since both have the same height. Under these conditions a flow may sometimes be obtained where it would be impossible if the intermediate water level were lower.

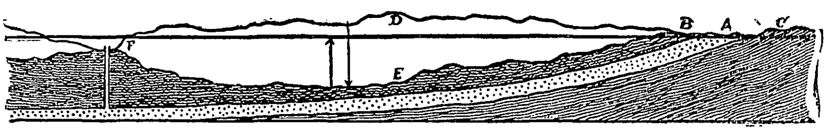
If the water between the well and fountain-head is actually higher than the latter, it will tend to penetrate the water-bearing stratum, so far as the overlying beds permit, and will, to that extent, increase the supply of water seeking passage through the porous bed, and will, by reaction, tend to elevate the fountain-head, if the situation permit; but the effect of this is altogether trivial.

If, on the other hand, the underground water-surface between the proposed well and the source of supply is much lower than the fountain-head, there will be considerable leakage, unless the confining beds are very close textured, and free from fissures. For example, if it be 100 feet lower, there will be a theoretical pressure of nearly three atmospheres, or about 45 pounds to the square inch, upward, greater than that of the underground water downward, and this will be competent to cause more or less penetration of the water upward through the pores and crevices of the rocks, and consequent loss of head and forcing power.

This may be illustrated by the accompanying profile, in which *A* represents a porous stratum inclosed between the impervious beds *B* and *C.* The source of water-supply is at *A*, and the proposed well at *F.* Let *E* be supposed to represent the surface of the ground (and, for convenience, also the surface of the common ground water) in one of the two supposed cases, and *D* the surface in the other

The arrow springing from the surface *E* represents the upward tendency of the water in the porous bed owing to pressure from the fountain-head, while the arrow depending from the line *D* represents the downward pressure of the ground water whose surface is represented

FIG. 156.



by *D*, and is, it will be observed, more than equivalent to the upward tendency due to pressure from the fountain-head. A flow at *F* could very safely be predicted if the surface were as represented by *D*, while it might be doubtful whether one could be secured if the surface were as represented by *E*.

My attention was first directed to this consideration by observing that where the intermediate country was elevated and had a high-water-level, wells flowed at heights surprisingly near theoretical estimates, almost no deduction for obstruction and leakage being necessary, whereas in those cases where the opposite is true, there is a very considerable falling short of theoretical estimates.

4. *The Inclination of the Beds.* The water-bearing bed and the confining strata above and below must be inclined so that the edge that comes to the surface shall be higher than the portion under the proposed well, else there could be no elevated source of supply for the flow. The ideal conditions are furnished when the strata sag in the center with upturned edges so as to form a basin. The water then enters the edges of the porous stratum and fills it up to the level of surface drainage at its edges. If, now, this be penetrated somewhere toward the center of the basin, at a point lower than the edges of the strata, the water will rise to the surface.

But it is not really necessary that the beds form a basin. If they are inclined so as to expose their edges on one side, and if the porous bed is blocked up by any means in the other direction, so that the water cannot escape, a flow may be obtained without regard to what may be the position of the opposite edge. It is highly probable that our sandstone beds as they pass off from the old shore belt along which they were formed into what was then the deeper part of the ocean, gradually change from coarse open sandstone to fine-grained rock, clay, shale, and possibly limestone, and so cease to be readily permeable to water.

Practically, in Wisconsin, we have to deal only with such inclined strata. Our beds dip eastward, southward and westward from the Archæan core and central axis of the State, as explained in the Historical Geology, and only reappear at distant points, as in Canada, the Alleghanies, Missouri, or the Rocky Mountains. But it is scarcely probable that our sandstone strata continue as open porous beds throughout such an extent, unless perhaps in the case of the Potsdam sandstone. However that may be, experience shows that we may safely neglect the opposite side of the basin, and consider the problems presented as if the porous beds became impermeable somewhere in their downward extension.

The height of the outcropping edge of the water-bearing stratum is a consideration of the first importance. This edge must be sufficiently elevated so that when the stratum is filled with water it will stand high enough above the site of the proposed well to force an efficient flow, after deduction is made for leakage and the obstruction and friction of the sandstone. How much higher than the well it must be is a practical rather than a theoretical question, and depends much on the character of the confining strata, and the underground water-surface between the well and the edge of the water-bearing beds, as previously explained, and upon the distance from the well to the source of supply. From the data furnished by Wisconsin wells, it would seem to be a general rule that the loss of efficient force from the fountain-head is about equal to one foot per mile; or, in other words, that the source should be as many feet higher than the well as the two are miles apart, in order to give a flow at the surface. A higher elevation is necessary to give force to the flow. Such a general estimate must, of course, be modified to suit the special conditions of any given proposed well.

5. *The Reservoir, or Fountain-head.* It is often convenient to speak of the source of the supply as the *reservoir*. But an erroneous impression is quite likely to arise from the use of the term. It is quite common to think of the reservoir as a surface lake, or as an under ground cavernous cistern, as it were. These are incorrect impressions. A surface lake is an extremely improbable source of an artesian flow. Lakes usually owe their existence to the fact that they have *impervious bottoms*, which prevent the water from flowing away beneath, and that very fact prevents them from being sources of supply for flowing wells. The reservoir is simply the water contained in the porous stratum above the level of the point of flow, or, in other words, the water in the elevated marginal portion of the water-filled stratum. To illustrate, if a piece of lead tube be inclined, and filled with sand (the lower end being closed),

and then water be poured in until the sand is completely saturated, a miniature flowing well may be formed by drilling a small hole near the lower end. The water in the sand will run out, and if renewed at the upper end, the flow will be continuous. This would be analogous to an artesian well, save that here there is a cylinder of water-filled sand, instead of a sheet. Now the reservoir, in this case, is the *water in the sand* in the upper part of the tube. In like manner, in artesian wells the reservoir, so-called, or the fountain-head, is *the water contained in* the elevated edge of the porous stratum. This is supplied by the surface rainfall, and this leads us to the consideration of two additional topics, (1) the collecting area, and (2) the rainfall.

6. *The Collecting Area.* If the porous bed is thin, and comes to the surface at a considerable angle, its edge will not occupy much area at the surface, and will, consequently, not receive a large supply of water from rainfall, and cannot be depended upon to deliver large quantities. On the other hand, if the thickness is considerable, and if the stratum comes to the surface at a low angle, so that its beveled edge is wide, it will have a considerable extension at the surface, and will consequently present a large collecting area, and, so far as that condition is concerned, will be competent to deliver a large supply of water. The Potsdam sandstone of our State has a very large surface extent on the central arch of the State, and it is exceptionally well situated for receiving into itself an enormous supply of water. Hence any well so situated as to draw upon this supply will not lack for a sufficient accumulation at the fountain-head. If it fails, it will be for other reasons. The St. Peters sandstone is much thinner and occupies less space at the surface, but with our moderately large rainfall it takes in a very considerable supply, one which is adequate for all ordinary purposes.

7. *Rainfall.* With an average precipitation of about thirty inches per annum, fairly well distributed throughout the year, the strata are kept full to overflowing, as the surplus that finds its way out to the surface in springs, or through porous soil, testifies, as do also ordinary wells in the collecting area. In our region, it is safe to assume an adequate atmospheric supply. In the somewhat arid western regions, this element of the problem becomes a more serious one.

8. *Escape at Lower Levels.* It is clear that if the strata be pierced (naturally or artificially) at a point lower than the surface of the well, the water may find relief from pressure by escaping there, and fail to flow from the well. This is not often a source of failure, but

two or three wells in the State seem to owe their want of success to this cause. It is also manifest that, where several wells are sunk near each other, the lowest may take the flow from the rest, if the supply is limited. In some of the drift wells of Waushara and Winnebago counties, it is necessary to bring all the penstocks to the same level to prevent this interference. In the great sandstone beds, however, the supply is often so generous, and the pressure so great, that little or no interference is noticeable, even where the wells are near each other.

We have now considered the conditions connected with the pervious and impervious strata, their inclination, the elevation of their outcropping edges, the collecting area and the water supply. We now turn to some of the questions more directly connected with the well itself.

The Rate of Delivery to the Well. It is manifest that, however great the supply at the fountain-head, if the water must pass through a thin sheet of close-grained rock, the rate of delivery at the well will be slow. If, on the other hand, the texture of the rock be open, and the bed deep, the supply will be, other things being favorable, very abundant. The depth of the Potsdam sandstone is great, sometimes reaching 1,000 feet. Three-fourths or more of this is quite porous, the lower portion usually exceptionally so. The drillings from wells at Prairie du Chien, La Crosse, and elsewhere, show a deep bed of quartzose sand, the grains of which are almost the size of peas, furnishing unusual facility for the ready passage of water. The St. Peters sandstone is perhaps, on the average, about 80 feet thick, and is usually very porous, so that it is competent to furnish passage for a very considerable supply, but it must not be too much relied upon where an exceptional quantity is desired at a great distance from the source, especially if the difference in elevation is not great. The quantity it does supply in some cases, however, is surprisingly great.

A second condition of delivery relates to the well itself. It is clear that if the well merely touches the upper portion of the sandstone, only a small quantity can flow in through the porous rock into the extremity of the bore. If, on the other hand, the well penetrates the formation deeply, the water can run in all along its sides, and though the inflow at any one point may be moderate, the total amount from the large surface presented by the sides of the bore may be great. When necessary, the surface may be increased by firing an explosive in the bore within the water-bearing bed. This has the advantage of fissuring and loosening the rock for considerable distances about the well. This method is extensively practiced in the oil wells of Pennsylvania and elsewhere to promote an inflow.

Height of Flow. Theoretically, the water will rise at the well to the same height as the fountain-head, and will flow at any height below that. But the obstruction offered by the rock, and the leakage of the confining strata, are important factors, and often considerably reduce the height at which a flow of any serviceable amount can be secured. As before stated, an allowance of about one foot for every mile between the collecting area, or fountain-head, and the site of the well, may be stated as a general estimate for our region, subject to considerable modification in special situations.

Areas in which Success is Probable. The height of the outcropping edges of the Potsdam and St. Peters sandstone having been ascertained by the Survey, it is possible to map the State off, as it were, into districts (1) in which the probabilities of securing flowing wells are sufficiently great to justify the attempt to secure them, and (2) into others in which the probabilities are so small as to make the expenditure of time and means in such attempts altogether unjustifiable. Between these are regions in which the favorable and unfavorable conditions are nearly balanced, and no very decided opinion as to the result can be expressed beforehand, because a sufficiently exact knowledge of all the conditions cannot be secured.

The areas of favorable probabilities are as follows: 1st, a belt along Lake Michigan. In Vol. II, the following opinion was expressed (p. 168): "Near the Lake level the chances will be good for the whole of the Lake border. From Manitowoc county southward, they may be said to hold good for elevations not exceeding 100 feet above the lake, to be fair up to 140 feet, and but slight above 150 feet, though perhaps possible in some locations at 200 feet or more."

2d. "The second area consists of the Green Bay valley, from Fond du Lac northward. In the vicinity of Lake Winnebago, a flow from either the St. Peters or Potsdam sandstones cannot be relied on at an elevation exceeding 15 feet above the lake surface, though Mr. Wild's well has demonstrated that it is possible at 50 feet. On the other hand, however, the wells at Oshkosh show that the limit given is the extreme one that is reasonably trustworthy. To the north of Lake Winnebago the limit in altitude descends at about the same rate as the general surface of the valley. It must be remembered, however, that the St. Peters sandstone is not so reliable in this region as farther south, where its thickness is more uniform. The Potsdam should, however, present reasonable probabilities for the region along the bay, at elevations not exceeding 25 or 30 feet above its surface, with slight chances for greater altitudes."

3d. "The third district lies in the valley of Rock river. An elevation of 250 feet may be taken as the upper limit of favorable chances. That a flow at this altitude is attainable is shown by the wells at Watertown, Palmyra and Janesville. The St. Peters sandstone is available for only a portion of the area that falls below that altitude, since, in some parts of it, this formation is deeply eroded by the streams, and its fountain-forming possibilities destroyed. Success in these portions will be chiefly dependent on the Potsdam sandstone."

4th. The fourth district lies along the Mississippi river. In the southwestern part of the State the probabilities are fair for success at elevations not more than 100 feet above Lake Michigan. (The elevation of the Mississippi is here nearly the same as that of Lake Michigan.) The deep valleys of the streams in this region have cut extensively into the confining strata above, and have made success less certain than on the eastern margin of the State. Were it not for this, flows could probably be obtained up to 200 feet, and even higher, and such are even now locally secured, as at Sparta. But success at such elevations cannot be relied upon unless the local conditions are exceptionally favorable. Even within 100 feet of the Lake level, partial or total failure has been experienced, apparently through local defects in the confining stratum above the water-bearing beds.

Farther up along the Mississippi the probabilities are less, and attempts to secure flows are not generally to be encouraged. At low elevations some success may be expected, but the special situation should be carefully considered in each case attempted.

5th. In the sandstone along the shore of Lake Superior it is not impossible that occasional success may be met with.

Doubtful Regions. In belts bordering these areas, at elevations 25 to 50 feet higher, occasional success may be expected, but the probabilities are poor, and attempts should be made, if made at all, with this distinctly in mind.

Drift Wells. The foregoing, as previously indicated, relates to wells in the rock beds. There is quite a large class of wells that derive their flow from the drift and depend for their existence upon beds of sand or gravel sandwiched between those of clay, or between clay and the rock below. These are local, and cannot well be treated here. A considerable number of them have been described in Vol. II, to which reference may be made. They are cheaply obtained and are very serviceable. These are not confined to the districts above indicated, and are quite independent of the conditions to which the deeper class of wells owe their origin.

Areas of Adverse Probabilities. In all the higher regions of the State, the general conditions are so adverse as to make any attempt to secure a flow altogether injudicious, unless there are known to be special local conditions that are favorable, which are very rare, except, of course, in the drift. As a general rule, no attempt should be made at an elevation of more than 300 feet above Lake Michigan, unless exceptionally favorable conditions are known to exist. Indeed, there is no general ground for encouragement above 250 feet. The situation of the proposed well ought always to be considered, even though the elevation be less than this.

Limit in Depth. There is a popular impression that the deeper the well is sunk the greater the chances, and a vague impression is gained that sufficient depth would bring success anywhere. This is altogether fallacious. The formations below the Potsdam sandstone are quite unfavorable, and both reason and experience forbid any attempt to penetrate them. No flow has ever been secured from them, though repeatedly attempted. Our State (previous to the survey) needlessly spent considerable sums in such attempts, and would, perhaps, have repeated the mistake since, but for advice to the contrary. If the figures given are correct, an amount was expended in a single attempt, after all reasonable chances had been exhausted, more than equal to the entire expense of the geological field-work on an area of 4,000 square miles about it.

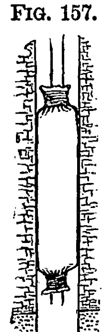
When the Archæan rocks are struck, all work should cease. Below that point the drilling is very hard and expensive, and the probabilities of flow almost zero. It cannot be said to be impossible to secure a flow, but it is altogether too unlikely to warrant any further work. In making contracts for drilling, a stipulation that the work shall cease when the Archæan rocks are struck will be in the interest of both parties. Such a stipulation is now commonly inserted in contracts by some of our drillers, acting upon advice, and some useless expenditure has thereby been saved.

Down to the base of the Potsdam sandstone, the amount and height of flow usually increase, and, as before indicated, the increase in the surface of the bore increases the facilities for the inflow of water into the well. There are, however, some special cases where the chances of securing a flow at some higher elevation are greater than those below, and it is even possible to lose a flow by going deeper; but this is rare. In general, it is advisable to go down to the base of the Potsdam sandstone, unless a sufficient supply is sooner obtained.

Detection of a Flow. It is a matter of some practical consequence to know when a stream is struck that may give a surface flow when put under proper control. The water does not always rise and overflow without such control. It may merely rise part way, and flow off laterally through the upper strata. In such instances there is usually a rise of water in the well, but even this is not always the case. But in any instance of a strong flow, the drillings are apt to be carried away, and when the sand pump fails to bring these up, there is good reason to believe that a strong stream has been struck, and the proper tests should be made. Some influence on the action of the drill rods is also liable to be felt. Tests should usually be made when such indications appear, unless it is desired to prove the full capacity of the stratum without regard to the amount of such partial flow.

Testing a Flow. To test a flow it is merely necessary to shut off any side leakage in the strata above the water-bearing bed. This may be done by inserting a tube (gas-pipe) nearly down to the water-bearing stratum, with suitable packing near its lower extremity. A simple method frequently employed is known as the "seed-bag" test. A stout leather bag is made in the form of a cylinder of the size of the well bore. The pipe is run through this, and the lower end of the bag securely fastened about the pipe. It is then filled with dried seed (usually flax-seed), and the upper end securely closed around the tube, when it is lowered into the well, and the seed allowed to swell by absorbing water. This enlarges the bag so as to tightly fit the bore, and shut off all water from rising except through the pipe. The latter can be extended above the surface so as to determine how high the water will rise, or that may be determined by a pressure gauge. Instead of the seed-bag, rubber discs, like the "washers" of a carriage, may be fitted about a section of the pipe, so adjusted that, after being put down, they can be screwed together, and so caused to expand laterally, and fill the bore. This, for permanent packing, is considered much better than the other method.

FIG. 157.



SEED-BAG TEST.

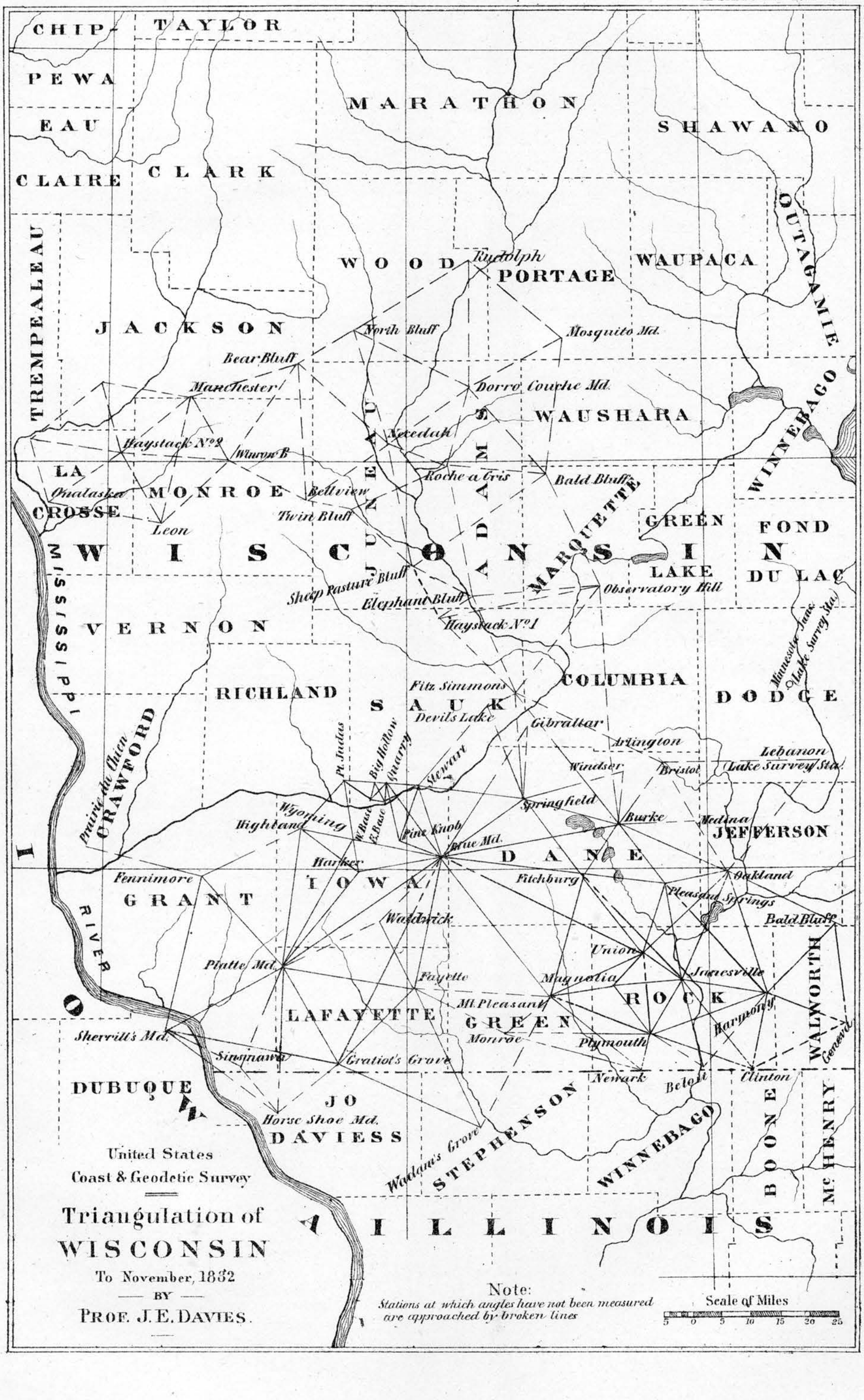
Persons desiring only a moderate flow will do well to contract that satisfactory tests be made when reasonable indications that a competent stream has been struck first present themselves, as the expense of sinking deeper may thus be saved. Indeed, it is wise to do this in any case.

Special Study. It is always best to make a special study of any proposed well in a locality not previously proven. There may be local conditions that will determine success or failure, independently of the general rules here laid down. The volumes of the report give quite ample data for determining the character and dip of the strata and the elevation at any point, as well as other necessary data for such a study.

APPENDIX.

THE GEODETIC SURVEY.

By virtue of the prosecution of a geological survey by the State, and in response to a request from the first Director, the United States Coast and Geodetic Survey has commenced a system of triangulation of the State under the charge of Professor J. E. Davies of the State University. A brief sketch of the character and methods of this survey is given in Volume IV. One of its leading objects is to furnish almost absolutely exact determinations of the positions of the principal points in the State, and of the distances between them, and thus to furnish a reliable basis for more accurate land and linear surveys, which the continued appreciation of property will render important. As a matter of general interest a sketch map showing the progress of this work is here given.


United States
Coast & Geodetic Survey
Triangulation of
WISCONSIN
To November, 1832
BY
PROF. J. E. DAVIES.
Note:
Stations at which angles have not been measured are approached by broken lines
Scale of Miles
5 0 5 10 15 20 25
WISCONSIN
ILLINOIS
IOWA
MISSISSIPPI RIVER
CHIPPEWA
TAYLOR
EAU CLAIRE
CLARK
MARATHON
SHAWANO
OUTAGAMIE
WOOD
PORTAGE
WAUPACA
TREMPEALEAU
JACKSON
WAUSHARA
WINNEBAGO
LA CROSSE
MONROE
JUNEAU
ADAMS
MARQUETTE
GREEN LAKE
FOND DU LAC
VERNON
RICHLAND
SAUK
COLUMBIA
DODGE
CRAWFORD
JEFFERSON
DANE
GRANT
IOWA
LAFAYETTE
GREEN
ROCK
WALWORTH
DUBUQUE
JO DAVIESS
STEPHENSON
WINNEBAGO
BOONE
McHENRY
Rudolph
North Bluff
Mosquito Md.
Bear Bluff
Manchester
Dorro Couche Md.
Haystack No. 2
Wuwon B
Necedah
Roche a Cris
Bald Bluff
Onalaska
Bellview
Twin Bluff
Leon
Sheep Pasture Bluff
Elephant Bluff
Observatory Hill
Haystack No. 1
Minnesota Junc. (Lake Survey Sta.)
Fitz Simmons
Devils Lake
Gibraltar
Arlington
Windsor
Bristol
Lebanon (Lake Survey Sta.)
Prairie du Chien
Pt. Judas
Big Hollow
Quarry
Stewart
Springfield
Burke
Medina
Wyoming
Highland
W. Base
E. Base
Pine Knob
Blue Md.
Harker
Fitchburg
Oakland
Fennimore
Pleasant Springs
Waldwick
Bald Bluff
Union
Platte Md.
Fayette
Magnolia
Janesville
Mt. Pleasant
Harmony
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Sinsinawa
Gratiot's Grove
Newark
Beloit
Clinton
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