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Report on the geology of the Lake Superior Land District: by J. W. Foster and J. D. Whitney, United States Geologists

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SPECIAL SESSION,
March, 1851.

[SENATE.]

EXECUTIVE,
No. 4.

REPORT

ON THE

GEOLOGY

OF THE

LAKE SUPERIOR LAND DISTRICT:

BY

J. W. FOSTER AND J. D. WHITNEY,

UNITED STATES GEOLOGISTS.

[U.S. General land office]

PART II.

THE IRON REGION,

TOGETHER WITH THE

GENERAL GEOLOGY.

MARCH 13, 1851: Ordered to be printed.

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INTRODUCTION.

Department of the Interior,
Washington, November 21, 1851.

Sir: For reasons stated by the Commissioner of the General Land Office, in his letter of the 20th instant, which accompanies this, and with a view to such action by you as he suggests, I herewith transmit the second and final report of Messrs. Foster and Whitney, United States Geologists, on the geology of the Lake Superior Land District in Michigan, accompanied by sections and illustrations, and a general map, on which are defined the range and extent of the several systems of rocks.

I am, sir, very respectfully, your obedient servant,

ALEX. H. H. STUART, *Secretary.*

Asbury Dickins, Esq.,
Secretary of the Senate of the United States.

General Land Office, *November* 20, 1851.

Sir: I have the honor herewith to submit to you the second and final report of Messrs. Foster and Whitney, United States Geologists, on the geology of the Lake Superior Land District in Michigan, (the first part of which was published last year,) accompanied with sections and illustrations, and a general map, on which the range and extent of the several systems of rocks are defined. This report was ordered to be printed, by a resolution of the Senate of the United States, at the last session, under the direction of this office. The resolution, however, having omitted to make any special appropriation for the work, or to indicate the number of copies to be printed, it is suggested, in order to gain time, and with your approbation, to have the work contracted for by the Secretary of the Senate, in the usual manner, and to the usual extent authorized by law, and await the pleasure of Congress as to the further extent of the publication.

In all matters connected with the accuracy of execution, this office will exercise the discretion contemplated by the resolution.

I have the honor to be, very respectfully, your obedient servant,

J. BUTTERFIELD, *Commissioner.*

Hon. A. H. H. Stuart,
Secretary of the Interior.

PHILADELPHIA, *November* 12, 1851.

SIR: We transmit to you our second and final report on the geology of the Lake Superior Land District, accompanied with sections and illustrations, and a general map on which the range and extent of the several systems of rocks are defined. Our observations have been extended over an area of little less than one hundred thousand square miles; and, although the whole of this area is not strictly within the limits of the district, yet a description of it is deemed necessary to its complete elucidation.

Nearly the whole of this area is an unbroken wilderness, interspersed with tangled thickets, almost impassable marshes and inland lakes, which retard the progress of the explorer; and, even along the mountain ranges where the rocks approach the surface, their presence is often concealed by a thick covering of moss. It is only on the precipitous cliffs, or along the beds of streams, that their true characters are revealed. Even in a densely populated district, every road that is constructed, every shaft that is sunk, and every quarry that is opened, reveals some interesting fact in geology; and it is by an attentive observance of these artificial excavations, rather than of the accidents of the soil, that the geologist is enabled to draw correct conclusions. In the prosecution of our labors, we have been enabled to avail ourselves of few of these extraneous aids. Passing weeks in succession in the midst of the forest, with no trace of the works of man around us, except the surveyors' lines, we have encountered difficulties unknown and unappreciated by geologists in a more civilized and less inhospitable region. Under these circumstances, it would not be surprising, if, hereafter, when the country becomes more thoroughly opened, and the means of communication more direct, it were found necessary to alter, in some respects, the boundaries of the several systems of rocks. Each year will develop new facts and fresh materials for illustration.

There is another circumstance to which we deem it proper in this connection to allude. It was the desire of the department to be placed in possession of the results of these explorations at the earliest period practicable. We were instructed to press forward the work with all due diligence to completion. We have been in charge of the survey a little more than two years. During the first year, we prepared a report on the "Geology of the Copper Region," in which we endeavored to define the boundaries of the cupriferous belts, and exhibit the principal phenomena of veins. We now transmit the concluding portion of the work, embracing in the main the results of our explorations during the second year.

It will be seen that there are, in this region, two great metalliferous belts, distinct in age and in the character of the products; to wit, COPPER and IRON.

There is already a large interest invested in the copper mines, and their products are to be found in the principal markets of the United States. It is believed that the supply from this source will soon meet the national consumption.

The Iron Region will ultimately prove of equal value. From the details incorporated in this report, it will be seen that the specular and magnetic ores are here developed on a scale of magnitude, and in a state of purity, almost unprecedented.

While our main object has been to trace out the boundaries and determine the quality of these economic materials, we have also endeavored to incorporate the scientific results of our explorations, such as the relative ages of the different groups of rocks, the character of the fossils entombed in a portion of them, and the conditions of the ocean in which they were deposited.

In the prosecution of this work, we have been aided by Messrs. James Hall, of New York, E. Desor, of Massachusetts, and Charles Whittlesey, of Ohio, whose contributions will be found incorporated in the pages of this report.

In the exploration of a portion of this region, we were also aided by Mr. S. W. Hill, of Michigan. Mr. John Burt, for many years a surveyor in this region, kindly placed his notes at our disposal.

In concluding this letter, allow us to express our thanks to you personally for the disposition manifested, in the progress of the survey, to facilitate our labors, and enable us to carry them to completion.

We are, sir, with great respect,

Your obedient servants,

J. W. FOSTER,
J. D. WHITNEY,
U. S. Geologists for the Lake Superior District.

Hon. Justin Butterfield,
Commissioner of the General Land Office.

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GEOLOGY

OF THE

LAKE SUPERIOR LAND DISTRICT.

PART II.

CHAPTER I.

CLASSIFICATION AND NOMENCLATURE OF THE ROCKS.

Tabular Arrangement of the different Formations.— Terms defined.— Relations of the Igneous and Aqueous Formations.— The Azoic System.— The Silurian System.— Confusion in Nomenclature.— Synonomy of the Groups in different Regions.— Explanation of the General Map and Section.

In Part I. of this Report, communicated to the Commissioner of the General Land Office in 1850, and published in 1851, we have given a historical sketch of the exploration of the country bordering on Lake Superior, a description of its physical geography and climate, and so much of its geology as was necessary to the full elucidation of the copper-bearing rocks and their relation to the sedimentary formations; this being the subject to which that part of the report was principally devoted. The two concluding chapters contained an account of the drift phenomena so conspicuously displayed in the region of the great lakes.

In Part II. of this Report, we shall proceed to the detailed and systematic description, so far as our materials will enable us, of the geology of the whole of the Lake Superior Land District, commencing with those formations which are the lowest in the scale of geological succession, or those which were the first formed, and ascending to those which are now in the progress of accumulation. We shall only allude to the results of the former part of the report, so far as it may be necessary to enable the reader to form a connected idea of the geology of the whole region.

The following table exhibits the names and the order of succession of the geological groups which have been recognized as existing within the limits of our district.

CLASSIFICATION OF THE ROCKS.

FORMATIONS.	IGNEOUS.	OF VARIOUS AGES.	Plutonic Rocks.	Granite, Syenite, Feldspar and Quartz rock.
			Trappean, or Volcanic Rocks.	Greenstone, or Dolerite, Porphyry, Basalt, Amygdaloid, Hornblende and Serpentine Rocks, Masses of Specular and Magnetic Oxide of Iron.
	METAMORPHIC.	AZOIC SYSTEM.		Gneiss, Mica and Hornblende Slate, Chlorite, Talcose and Argillaceous Slate, Beds of Quartz and Saccharoidal Marble.
	AQUEOUS.	SILURIAN SYSTEM.	Lower.	Potsdam Sandstone. Calciferous Sandstone. Chazy Limestone. Birds-eye Limestone. Black-River Limestone. Trenton Limestone. Galena Limestone. Hudson-River Group.
			Upper.	Clinton Group. Niagara Group. Onondaga Salt Group.
		DEVONIAN SYSTEM.		Upper Helderberg Series.
		DRIFT SYSTEM.		Beds of Sand, Clay and Gravel rudely stratified, Transported Blocks of Granite, Greenstone, &c.
		ALLUVIAL DEPOSITS.		Sand and Pebble Beaches, Marshes, Flats, Hooks, Spits, Dunes, &c.

The term *rock*, according to the arrangement of M. Constant Prevost,* is applied to masses, or beds, whether the elements composing them be homogenous, or complex: *formation* explains their origin, while *system* designates the relative ages of the different parts.

Two sets of causes have operated simultaneously to produce the various compounds which compose the crust of the earth: these are the IGNEOUS and the AQUEOUS. The rocks resulting from the first, or igneous set, have a crystalline aspect, and contain certain mineral substances, such as feldspar, mica, hornblende, pyroxene, &c., constituting great irregular masses, and traversed by divisional planes, pursuing, for the most part, a uniform direction.

The rocks resulting from the second, or aqueous set, are arranged in sedimentary deposits, divided into strata, beds, layers, &c., composed, for the most part, of argillaceous, calcareous and arenaceous particles, and often contain numerous organic remains.

* Article "FORMATION" Dictionnaire Universel d' Histoire Naturelle.

In addition to the two grand classes of formations, igneous and aqueous it is necessary to establish two orders of mixed formations. Where the materials were formed in the interior of the earth, and ejected by the action of fire, but subsequently modified by the action of water, which transported and deposited them in stratified beds, such as *trap-tuff*, *peperino*, &c., often enclosing organic remains; these are called PLUTO-NEPTUNIAN

On the other hand, those rocks which were deposited by water, and afterwards modified by the action of heat, changing their character and causing them to resemble igneous formations, such as the *crystalline schists*, *saccharoidal marbles*, &c., these are called METAMORPHIC. Thus far the arrangement of M. Prevost.

Each system of detrital rocks in this district, if we except the drift, is characterized by the presence of igneous products, which differ as much, one from another, as the sedimentary systems. Thus, the oldest class of igneous products consists of hornblende and feldspar rocks, and serpentine rocks, and may be regarded as contemporary with the azoic system. Next in order are the granites and syenites, which are intermediate in age between the azoic and Silurian systems. These are traversed by at least two systems of greenstone dykes which are anterior to the purely sedimentary deposits. Contemporaneous with the lower portion of the Silurian system, are the bedded traps and amygdaloids of Keweenaw Point, Isle Royale and the Ontonagon region; and, although composed of nearly the same constituents as many of the older igneous rocks, there is no difficulty, from the diversity in external characters, in drawing the line of demarcation between them,—the older being compact or crystalline, but never amygdaloidal.

Below all the fossiliferous groups of this region, there is a class of rocks, consisting of various crystalline schists, beds of quartz and saccharoidal marble, more or less metamorphosed, which we denominate the AZOIC system. This term was first applied by Murchison and de Verneuil to designate those crystalline masses which preceded the palæozoic strata. In it, they include not only gneiss, but the granitic and plutonic rocks by which it has been invaded. We adopt the term, but limit its signification to those rocks which were detrital in their origin, and which were supposed to have been formed before the dawn of organized existence. This, however, is a mooted point. Lyell, on the one hand, maintains that animal organisms may yet be detected below what is now regarded as the oldest fossiliferous group; while, on the other hand, Murchison contends that it is highly probable we have reached the point where organized existence first started. We incline to the latter view; and are disposed to regard these deposits as having been accumulated before the dawn of animal life, rather than that organisms flourished, died and were entombed in the rocks, and that their remains have become obliterated by the long-continued action of heat.

The Silurian, or protozoic system, as it is sometimes called, since here we find the first traces of organized existence, is represented in this district from its summit to its base. Much confusion prevails with regard to the nomenclature of the different groups composing it. The various State surveys, while they have developed many valuable facts, have, also, originated a multitude of local names. They started about the time that Murchison first promulgated his subdivision of the *Transition* rocks; and while American geologists recognized the great leading features of that subdivision, they failed to detect subordinate groups. There existed in this country, no standard of comparison, and hence arose a variety of names, local in their application, and often founded on the lithological, instead of the zöological characters of the rocks. Unfortunately, few of these surveys were carried to completion, so that the geologists in charge were unable to adopt a national nomenclature.

The New York geologists have divided the Silurian system, as developed in that state, into eleven groups, while some of the Western geologists recognize, in its western extension, but five. Between the two systems of classification there is no community of names.

The geographical position of our district is such as to form a connecting link between the East and the West. While, on the one hand, the New York and Canadian geologists have traced the Silurian groups up to the eastern borders of our district; on the other hand, the geologists of Michigan, Iowa, Wisconsin and other states, have traced the same groups, though under different names, along their southern and western prolongation, without having attempted to identify them with their eastern equivalents, or to subdivide them according to the palæontological evidence.

Under these circumstances, we have endeavored to connect the two sets of observations and blend them into one harmonious whole. As the New York survey is the only instance in which the matured results have been communicated to the public, and as the volumes on the palæontology—a monument of the research and perseverance of the author, Mr. Hall—will form the standard of reference for the whole country, in determining the succession of the Silurian groups, we have deemed it advisable to adopt that nomenclature, so far as the same groups described by the New York geologists could be recognized in our district.

The designation of groups of strata by names derived from their geographical position, or from the locality in which the rocks are first investigated and their relative position clearly defined, seems to be of all the methods of nomenclature that which, for the present at least, is liable to the least objection. Names given solely with reference to lithological character, or to the presumed predominance at any particular point of a certain genus or class of organic remains, seem much more likely to lead to misunderstanding and confusion; and, however desirable it may be that a universal system of nomenclature and arrangement should be introduced, it seems quite impossible to hope for any such thing in the present state of geological science, a science which is so rapidly developing, and liable to such constant changes. The names introduced by the New York geologists, are in most instances derived from the locality where the group designated is particularly well developed, and the fact that those groups have, in their continuation through Canada, been described by Mr. Logan, the Provincial Geologist, under the names recognized by the New York survey, seems an additional reason for their adoption, as far as possible, by us.

It will be seen from the details incorporated in a subsequent part of this report, that many members of the Silurian series, particularly the grits and conglomerates, which are clearly defined in New York, have but a limited range, and disappear altogether before reaching the limits of our district. These are conditions which we ought to expect would exist in deposits made along a shelving ocean-shore; but so far as these are persistent, it seems desirable that they should bear the same names throughout their whole extent.

The following is the synonomy of the groups of the systems developed in this region, according to the nomenclatures adopted in the reports of the different surveys.

New York and Lake Superior.	*Pennsylvania and Virginia.*	*Ohio Iowa and Wisconsin.*
	AZOIC SYSTEM.	
AZOIC SYSTEM, (Not classified in New York.)	AZOIC SCHISTOSE SERIES.	METAMORPHIC ROCKS. (Wanting in Ohio and Iowa.)
	SILURIAN SYSTEM.	
Potsdam Sandstone.	Primal Sandstone, or Formation No. I.	Lower Sandstone, or Formation 1, wanting in Ohio.
Calciferous Sandstone.	Lower part of the Matinal Series, or part of No. II.	Lower Magnesian Limestone, F. 2, wanting in Ohio.
Trenton Group (including Chazy, Birds-eye, and Black-river Limestone.)	Middle part of Matinal Series, or part of No. II.	Fossiliferous Limestone, No. 3. Blue Limestone and Marls of the West.
Galena Limestone (not recognized in New York.)	Not recognized in Pennsylvania and Virginia.	Erroneously regarded as the equivalent of the Cliff, or Upper Magnesian Limestone.
Hudson-river Group.	Matinal Shales, or No. III.	Associated with No. 3, or the Blue Limestone and Marls of Ohio.
Medina Sandstone and Clinton Group.	Part of the Levant Series, or part of No. V.	Not recognized at the West.
Niagara Group.	Part of the Levant Series, or part of No. V.	Cliff Limestone of Ohio and Indiana. Upper Magnesian Limestone.
Onondaga Salt Group.	Summit of the Levant Series.	
	DEVONIAN SYSTEM.	
Upper Helderberg Limestone.		Upper portion of the Cliff Limestone.

EXPLANATION OF THE MAP.

Accompanying this report, will be found a general Geological Map of the region over which our observations have extended, on which we have attempted to delineate by a system of colors, so far as practicable, the boundaries of the several groups of rocks embraced in the above table. Although we have succeeded in recognizing most of the minor groups, such as the Chazy, Birds-eye, Black-river limestones, and also the Medina sandstone and Clinton groups, not only by their lithological characters, but by their fossil contents, yet their geographical range is so limited that they cannot well be represented on a map of this contracted scale. By adopting a set of symbols, we have endeavored to represent minor phenomena, such as the bearing and inclination of the strata, and in many instances their mineral associations.

In preparing the geology of the northern coast of Lake Superior, we have availed ourselves of the labors of Mr. Logan, the distinguished Provincial Geologist of Canada. We have had less reluctance in presenting an epitome of his investigations, for the reason that his reports of progress have had but a limited circulation in the United States, and for the additional reason that they tend to elucidate the geology of our own district.

EXPLANATION OF THE GENERAL SECTION.

The General Section appended to this report has been constructed for the purpose of exhibiting not only the different systems of stratified rocks which prevail in this district, and the relative positions of the granitic and trappean formations; but is also designed to represent a geognostic profile of the route traversed, in which the relative heights of the most prominent points above the level of Lake Superior are given. We have, also, constructed a ground plan on which the topographical features of the region, along the line of the section, are delineated—a feature not hitherto introduced into works of this character, but which is calculated to afford the inquirer essential aid.

This section commences at the head of Thunder Bay, on the north-west coast of Lake Superior, and terminates at the mouth of the Menomonee river of Green Bay, pursuing a course of about N. 18° W. and S. 18° E. Its entire length in a direct line is nearly 260 miles. The scale of height has been made to conform as closely as possible to that of length, with a due regard to the representation of all the phenomena.

We have not attempted to represent the drift deposits which are plentifully distributed over nearly the entire region.

We propose to give a brief explanation of the phenomena delineated on the section.

Commencing a few miles inland from Thunder Bay, we meet with a range of granite, belonging to the oldest system of upheaval, around which the upper beds of the azoic system are deposited in a horizontal position. At Thunder Cape and Pie island, these slates are exposed in a nearly vertical section a thousand feet in thickness, with a crowning overflow of trap of about 300 feet.

The greater portion of Isle Royale is composed of trappean rocks of the Silurian epoch, which do not rise in great irregular masses, but present a bedded structure. On the southern slope of the island, we meet with intercalations of sandstone and conglomerate, dipping with considerable uniformity to the south-east. The southern margin of the island, between Siskawit Bay and the point south of Washington Harbor, as well as the various reefs, consists of conglomerate passing into sandstone; and we have no evidence of the invasion of the trap between this line and the southern coast.

Keweenaw Point is the counterpart of Isle Royale, except that the dip of the sedimentary rocks is reversed; thus, rendering it highly probable that between these two points there is a great curvature in the strata, caused by an elevation along the lines of two volcanic fissures. The alternations of conglomerate and trap are much more numerous on the northern slope of Keweenaw Point than on Isle Royale, and the latter attain a much greater thickness. The *productive* veins of copper are restricted to the trap, although in many instances the fissures traverse the conglomerate. This conglomerate is not, strictly speaking, a sedimentary rock, but in the nature of a tuff or peperino, and is due to the joint action of fire and water. On the southern slope of the axis, the sandstone which is here a purely sedimentary rock, and the equivalent of the Potsdam, is seen dipping away from the crystalline trap at a high angle; but at a short distance from the line of igneous outburst, it verges towards horizontality; and all along the coast to near the head of Keweenaw Bay, it presents a series of gentle undulations. A short distance above the Methodist Mission at L'Anse, it is seen reposing unconformably on the slates of the azoic system.

From this point to Chippewa island, in the Menomonee river—a distance in a direct line of more than 80 miles—the country is occupied by rocks of the azoic system, consisting of various crystalline schists, beds of quartz, saccharoidal marble, and immense deposits of specular and magnetic oxide of iron. They are invaded at numerous points by igneous rocks, both granitic and trappean.

At Chippewa island, the Potsdam sandstone is seen reposing upon the upturned edges of the slates, or occupying the preëxisting depressions in the igneous rocks. To this succeed the calciferous sandstone, and the Trenton limestone. The bed of Green Bay has been excavated in the Hudson-river group, while the Niagara and Onondaga limestones, being more indestructible, form a barrier reef on the east, known as the peninsula of Green Bay.

CHAPTER II.

AZOIC SYSTEM.

Various crystalline Schists, forming the primeval Crust of the Earth.—Contortions to which they have been subjected.—Presence of Igneous Rocks.—Condition of the Earth at the time of their Formation.—Effects of Metamorphism.—This System characterized by an entire Absence of Organic Remains.—Supposed Causes of their Absence.—Geographical Distribution of these Rocks on the northern Coast of Lake Superior.—Divided into two Groups.—Associated Igneous Rocks.—Metallic Contents.—Their Relation to the Silurian Strata.—Their Distribution on the southern Shore.—External Characters.—Igneous Products.—Lines of Lamination in Slates.—Prevalence of Iron.—Difficulty in estimating the Thickness of this Group.—Contortions of the Strata.—Remarks on the existence of this System in other parts of the World.

The Azoic System—so called from the entire absence of organic remains—comprises the most ancient of the strata which form the crust of the earth. They consist for the most part of gneiss, hornblende, chlorite, talcose and argillaceous slates, interstratified with beds of quartz, saccharoidal marble and immense deposits of specular and magnetic oxide of iron. Most of these rocks appear to have been of detrital origin, but greatly transformed by long-continued exposure to heat. They are sub-crystalline or compact in their structure, and rarely present unequivocal signs of stratification. They exhibit the most violent dislocations; in one place the beds are vertical, in another, reversed, and in another, present a succession of folded axes.

Intermingled with them is a class of rocks whose igneous origin can hardly be doubted, and to whose presence the metamorphism so characteristic of this series, is in some measure to be ascribed. They consist of various proportions of hornblende and feldspar forming traps and basalts, or where magnesia abounds, pass into serpentine rocks. They appear in some instances to have been protruded through the preëxisting strata in the form of dykes or elvans; in others to have flowed in broad lava streams over the ancient surface; and in others to have risen up through some wide-expanding fissure, forming axes of elevation.

Most geologists, at this day, admit that the earth was originally in a fluid state and refer to heat as the solvent power; that the earth gradually parted with portions of this heat so as to allow the materials to crystallize and form a crust around the incandescent nucleus; that the waters acting on this crust detatched particles of matter and carried them far into the ocean, where they were deposited in extensive beds, or strata; and that by long-continued exposure to heat, they assumed the crystalline character which they now present. Their transformation in aggregation, structure and chemical composition, has not resulted from mere contact with plutonic or volcanic masses, but from gaseous sublimations which accompany erupted rocks, intense pressure and electro-chemical agencies generated in the vast laboratory of nature.

"If we consider our planet as a cooling mass of matter," observes De la Beche—the great practical and theoretical geologist of England—"the present condition of its surface being chiefly due to such a loss of its original heat by long-continued radiation into the surrounding space, that, from having been wholly gaseous, then fluid and gaseous, and subsequently solid, fluid and gaseous, the surface at last became so reduced in temperature, and so little affected by the remaining internal heat, as to have its heat chiefly regulated by the sun,—there must have been a time when solid rock was first formed, and also a time when heated fluids rested upon it. The latter would be conditions highly favorable to the production of crystalline substances, and the state of the earth's surface would then be so totally different from that which now exists, that mineral matter, even abraded from any part of the earth's crust, which may have been solid, would be placed under very different conditions, at these different periods: we could scarcely expect that there would not be a mass of crystalline rocks produced at first, which, however they may vary in minor points, should still preserve a general character and aspect; the result of the first changes of fluid into solid matter, crystalline and sub-crystalline substances prevailing, intermingled with detached portions of the same substances, abraded by the movements of the first-formed aqueous fluids."

Chemists have shown that similar materials, when fused, yield dissimilar products, dependent on the rapidity or slowness with which they cooled, and the degree of pressure to which they have been subjected. The researches of Mitscherlich and Gustav Rose have thrown much light on the process of metamorphism. The artificial mineral products, such as garnet, idocrase, magnetic oxide of iron, &c., and even some of the rarer gems which have been produced in the laboratory of the chemist, or found among the scoriæ of furnaces, afford us an insight as to the manner in which nature has operated on a grander scale.

Since the theory of metamorphism has been generally recognized, many of the rocks which were formerly regarded as igneous, are now referred to aqueous agency, and the transformations which they may have undergone traced to the presence of erupted rocks.

Von Buch has shown that the gneiss around the Gulf of Finland has been produced by the metamorphic action of granite.

Hoffman points out an instance in the Fichtelgebirge, in which argillaceous schist, which can be traced for sixteen miles, is transformed into gneiss only at the two extremities, where they come in contact with granite.

In the Pyrenees, compact limestone is changed into granular limestone, where it comes in contact with the erupted rocks. The dolomite of the southern Tyrol and of the Italian side of the Alps, is but a metamorphism of calcareous beds, exhibiting no signs of stratification, and no vestiges of organic remains.

The marbles of Carrara and Siena, which have afforded so many blocks for sculpture, and which were formerly cited as examples of "primitive limestone," are as recent as the öolite, while the sandstones which flank the Appenines, and were once supposed to rest at the base of the fossiliferous series, are proved to belong to the tertiary. So too, the slates of Glaris, which were formerly regarded as transition, have been proved by Agassiz, from the fishes, to belong to a period as recent as the chalk.

The vast beds of quartz in South America, which rise in mountains 7000 or 8000 feet in height, are, probably, but transformed beds of sandstone.

The ribboned jaspers of Orsk, in the Ural, according to Gustav Rose, are, in all instances, in direct contact with greenstone porphyry, and are but highly silicified schists.

Murchison and de Verneuil have observed, in the Ural, the sandstones, limestones and shales of the Silurian and carboniferous systems passing into chlorite, talcose, and quartzose rocks, with beds of crystalline marble, as they approach the lines of eruptive agency.

It is needless to cite further examples of metamorphism. From the countless analogies which exist, we are authorized in the inference that gneiss is a highly metamorphosed form of shale, quartz of sandstone, and saccharoidal marble of calcareous beds. We shall, therefore, in treating of the various schists, marbles and quartzose rocks, regard them as sedimentary deposits, transmuted by eruptive agency. We shall recognize no rock as purely igneous, unless it occur in vast, irregular masses, like granite; in dome-shaped, or crater-like summits, like basalt, or trachyte; in long lines, like dykes, or elvans, cutting through the incumbent strata; in ramifying veins, like granite; or broad lava sheets, like trap. Yet, with these restrictions, there are many rocks in this district which almost defy classification.

In the earlier periods of the earth's history, igneous causes operated with greater force and intensity, and hence it is, that the ancient sedimentary deposits differ so widely from those belonging to more recent epochs.

This system, as its name implies, is characterized by an entire absence of the remains of animal, or vegetable life. It is reasonable to suppose that there was a time in the history of our planet, when its crust was subject to constantly-recurring volcanic paroxysms, when mephitic vapors were escaping through extensive fissures communicating with the interior, and when the waters were in a heated condition, and differed perhaps chemically from those of the existing oceans. Under such conditions, we ought not to look for any types of animal, or vegetable life.

Many eminent geologists maintain that the lowest stratified rocks are but portions of the Silurian, or Cambrian system; and that, from long-continued exposure to heat, the lines of stratification have become obscure, and all traces of organic remains obliterated. Our investigations in this district have led us to a different conclusion. If the Potsdam sandstone rests at the base of the palæozoic series, if from that epoch we are to date the dawn of animal creation, there is in this district a class of obscurely stratified rocks interposed between the Silurian system and the granite,—rocks distinct in character, unconformable in dip and destitute of organic remains. They have been so far transformed by direct or transmitted heat as to exhibit few traces of their original character. Sandstone has been converted into massive quartz, limestone into saccharoidal marble and shales into hard crystalline schists. If we found these rocks graduating into stratified deposits of sandstone, shale and limestone, as we receded from the lines of igneous outburst, and enveloping the remains of animals and plants, we should be led to a different conclusion; but, so far from it, the evidence is ample that the strata which form the base of the Silurian system repose on the upturned edges of the metamorphosed rocks, and that the causes by which their metamorphism was effected had ceased to operate before the deposition of the fossiliferous strata. Between the two systems there is a clear and well-defined line of demarcation. It forms one of those great epochs in the history of the earth, where the geologist can pause and satisfy himself of the correctness of his conclusions. On the one hand, he sees evidence of intense and long continued igneous action; on the other, of comparative tranquility and repose.

Few regions, perhaps, afford ampler facilities than this, for the investigation of the early history of our planet, or at least of that portion extending back from the termination of the Silurian epoch to the first-formed or azoic schists, "when the waters were gathered together unto one place and the dry land appeared," and although a few leaves may be wanting, enough remain to form a connected and intelligible record.*

Having thus taken a general view of the origin of the azoic system we will now proceed to describe its geographical distribution.

AZOIC SERIES ON THE NORTHERN SHORE.

The rocks of which it is composed are developed on an extensive scale, both on the northern and southern margin of the Lake Superior basin. Commencing on the northern shore of the lake, we find a series of talcose and chlorite slates with occasional beds of coarser grits, in immediate contact with the granite and gneiss. They have been divided by Mr. Logan, the distinguished Provincial Geologist of Canada, into two groups—a division which we have failed to recognize on the southern shore—the lowest of which consists of slates partially chloritic and talcose, and occasionally holding a sufficient number of pebbles derived from the hypogene rocks to constitute conglomerates. "These slates," he remarks, "are of a dark-green color, often dark-grey in fresh fractures, which at the base, appear to be occasionally interstratified with beds of a feldspathic quality, of the reddish color belonging to the subjacent granite and gneiss: sometimes they are a combination of feldspar and quartz, occasionally with the addition of hornblende, making syenitic beds, and in some the hornblende predominating gives the syenite a general green tinge. Some of the beds have the quality of a greenstone, others that of mica slate, and a few present the character of a quartz rock."† These slates, he conjectures, attain a thickness of several thousand feet, and are well exposed at the mouth of the river Doré, about five miles from the Michipicoten river. The strike of the beds is very irregular and their dip highly inclined.

The upper group rests *unconformably* on the preceding, and towards the base presents conglomerate beds of no great thickness, the pebbles of which consist of white quartz, red jasper and occasionally slate, the whole enclosed in an arenaceous matrix. Higher up are found layers of chert,

* Lyell and others, as remarked in a previous chapter, maintain that the rocks composing the azoic system, may once have been fossiliferous, and that their crystalline character is not due to a peculiar and nascent condition of our planet at the period of their formation.

We can hardly conceive it possible that causes of sufficient intensity to elevate continents above the level of the waters, could have operated without having left unmistakeable evidences of their action. At a period when the earth was passing from a chaotic to a habitable state, we may suppose that the two great antagonistical forces of fire and water were actively excited, and the result would be a vast accumulation of igneous and detrital materials; the whole so metamorphosed as to render it difficult in all cases to distinguish between them: and although in the subsequent history of the earth, there is abundant evidence of the repeated and conjoint operations of these causes, yet the azoic age was emphatically one of METAMORPHISM.

† Report of Progress, 1846-7, p. 10.

occasionally approaching chalcedony. The plates are separated by thin calcareous seams, presenting a ribbon-like appearance.

In the vicinity of the disturbed parts, the chert sometimes passes into chalcedony and agate, and small cracks are filled with anthracite, which is also found forming the centre of minute globules, enclosed in a silicious matrix.

Higher up in the series, the argillaceous slates become interstratified with argillaceous sandstones, in such an altered condition that it is often difficult, at first sight, to say whether the latter may not be trap layers. Calcareous bands occasionally occur of sufficient purity to be called limestone. Interlaminated masses of trap are found near the base and overlying the summits. They are composed of a black hornblende and greenish-white, horny-looking feldspar, in no instance assuming an amygdaloidal character, but occasionally presenting a porphyritic appearance. It exhibits a sub-columnar structure, and the crowning overflow of trap communicates a peculiar aspect to the whole region occupied by this formation. It attains a thickness of nearly 2000 feet, and, where it comes to the lake, rises in bold, overhanging cliffs.*

"Beginning at Pigeon Bay—the boundary between the United States and the British Possessions"—according to Prof. Mather, who has kindly placed his notes at our disposal—" we find the eastern portion of the peninsula lined with bold, rocky cliffs, consisting of trap and red granite. The latter is composed of red feldspar and quartz, with no mica, and is intersected by heavy dykes of trap, and veins of trap and calc-spar, containing iron pyrites. The whole southern shore of the bay, wherever examined, presents this character.

The falls of Pigeon river, eighty or ninety feet in height—are occasioned by a trap dyke which cuts through a series of slate rocks highly indurated and very similar in mineralogical characters to the old greywacke group. Trap dykes and interlaminated masses of trap were observed in the slate near the falls. These slates, brown and grey in color, form beds of stratified rock, nearly horizontal in position, around the granite, exhibiting no marks of derangement or upheaval through which the latter rocks emerge like islands.

Both of these rocks are traversed by dykes, belonging to a common system.

The base of nearly all the ridges and cliffs between Pigeon river and Fort William is made up of these slates, and the overlying trap. Some of the low islands exhibit only the grey grits and slates. Welcome islands in Thunder Bay display no traps, although, in the distance, they resemble igneous products, the joints being more obvious than the planes of stratification, thus giving a rude semi-columnar aspect to the cliffs."

At Prince's Bay, and also along the chain of islands which line the coast, including Spar, Victoria and Pie island, the slates with the crowning traps are admirably displayed. At the British and North American Company's works, the slates are traversed by a heavy vein of calc-spar and amethystine quartz, yielding grey sulphuret and pyritous copper, and galena. From the vein, where it cuts the overlying trap on the main shore, considerable silver has been extracted.

At Thunder Cape, the slates form one of the most picturesque headlands

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* Vide Report before referred to, pp. 13–14.

on the whole coast of Lake Superior. They are made up of variously colored beds, such as compose the upper group of Mr. Logan, and repose in a nearly horizontal position. These detrital rocks attain a thickness of nearly a thousand feet and are crowned with a sheet of trappean rocks, three hundred feet in thickness.

At L'Anse a la Bouteille, the slates rëappear, with the granite protruding through them, and occupy the coast for about fifteen miles: numerous dykes of greenstone, bearing east and west, are seen cutting the rocks vertically. The Slate islands form a part of this group, and derive their name from their geological structure.

They are next seen, according to Mr. Logan, for about seven miles on each side of the Old Pic river. Near Otter Head, a gneissoidal rock forms the coast, which presents a remarkably regular set of strata, in which the constituents of syenite are arranged in thin sheets and in a highly crystalline condition. From this point to the Michipicoten river, the slates and granite occupy alternate reaches along the coast, for the distance of fifty miles. "With the exception of a few square miles of the upper trap of Gargantua, these two rocks appear to hold the coast all the way to the vicinity of Pointe aux Mines, at the extremity of which they separate from the shore, maintaining a nearly straight south-easterly line across the Batchewauaung Bay, leaving the trap of Mamainse between them and the lake. Thence, they reach the northern part of Goulais Bay, and finally attain the promontory of Gros Cap, where they constitute a moderately bold range of hills, running eastwardly towards Lake Huron."*

This range, according to the same authority,† in its easterly prolongation, where it bounds the St. Mary's river on the north, consists of purely silicious masses of quartz rock, the bedding sometimes well-defined, and the surfaces not unfrequently ripple-marked; of conglomerate bands, containing pebbles of vitreous quartz and variously-colored jaspers; and of limestones of a compact texture and colored green, buff and grey, the whole reposing on granite. Interstratified beds of chert and chlorite slate are not wanting.

The bedded masses of igneous rock consist, for the most part, of greenstone trap, which in some instances attains the thickness of a thousand feet.

The limestone in different parts of the range varies in thickness from fifty to one hundred and fifty feet, and, wherever seen, is found in contact with quartz rock, or syenitic conglomerate. On Thessalon lake, great mountain masses of quartz, with subordinate masses of jasper conglomerates, appear to underlie the limestone, and at La Cloche, a band from 3000 to 4000 feet rests upon it. The scale upon which these older rocks are here developed, seems almost incredible.

The associated bands are traversed by several systems of dykes both of greenstone and granite, and, at the points of contact, afford numerous evidences of metamorphism and disturbance. They are also intersected by veins more recent in their origin, which contain several forms of the sulphurets of copper, and afford promise of profitable exploitation.‡

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* Canada Report, 1846–7, p. 25. † Report, 1848–9.

‡ Professor Agassiz, in his work on Lake Superior, has described many of the igneous belts and metamorphic rocks which occur on the north shore, and has called attention to the interesting fact that its outlines have been determined in a great measure by these belts. As that work is readily accessible to the American reader, we deem it unnecessary to present the views of the distinguished author in a more extended form.

This formation does not here invade the American shore. The Potsdam sandstone has been deposited in the sinuosities of the more ancient quartz, or rests unconformably on its upturned edges. The channel of the St. Mary's has been excavated along the line of junction between the azoic and Silurian systems, thus affording a striking coincidence in the political and geological divisions the country.

AZOIC SERIES ON THE SOUTHERN SHORE.

In the region included between the two great lakes, known as the northern peninsula of Michigan, this group constitutes the fundamental rock. The materials of which it is composed appear to have been thrown down in a comminuted state, since we rarely meet with those grits or conglomerates which occur on the north shore. They constitute alternating beds of great thickness, known as gneiss, hornblende chlorite, argillaceous, silicious and talcose slates, quartz, saccharoidal, and crystalline limestones. They are highly inclined and much contorted, and nowhere exhibit the characters of a purely sedimentary rock, but the evidences of metamorphism are more striking as we approach the lines of igneous outburst. Gneiss generally flanks the granite, succeeded by dark masses of hornblende, with numerous joints, but obscure lines of bedding, which often graduates into hornblende slate or chlorite slate, as we recede from the purely igneous products.

The outlines of this class of rocks are extremely irregular, and a reference to the general map will give a clearer idea of their range and extent than a mere verbal description. The great mass, it will be seen, occupies nearly half of township 48, between ranges 30 and 36; thence, they stretch uninterruptedly south to the Brulè river; on the east they are bounded by the granite and sandstone, and on the west by the granite. From the main mass there are numerous projecting arms. One starts from township 48, ranges 25 and 26, and trending in a north-easterly direction, intersects the head of Keweenaw bay, and terminates in township 51, range 30. It flanks the Huron mountains on the north and west, and is separated from Lake Superior by a narrow and irregular belt of sandstone. The length of this arm is nearly eighty miles, with a width of eight or ten miles.

Another arm starts near Machi-gummi, or Big Lake, and runs nearly due east, intersecting the main lake between Presqu'isle and Carp river. Its length is about thirty miles, varying in width from six to fifteen miles. It is included between two granite bosses, the one on the north and the other on the south. This portion is characterized by vast deposits of specular and magnetic oxide of iron in a state of considerable purity.

Another arm about eighteen miles in length and ten in breadth extends easterly into townships 42 and 43, range 28; while another shoots off in a southerly direction, occupying the valley of the Menomonee as low down as Pike river, in township 35. Their western termination is in Wisconsin.

In this district, the area occupied by these rocks exceeds eighty townships, or more than three thousand square miles. The configuration of the slates and granites may be compared to the contours of a rugged coast. The main granite masses form numerous projecting headlands, while the subordinate patches rise up like islands. The slates sweep round the promontories and form numerous narrow and deeply-indented bays.

The topographical features of the region occupied by the slates are striking. It is diversified by bold, rocky cliffs and narrow and intricate valleys, with lakes and water-falls, with luxuriant forests and natural meadows. The culminating points reach nearly twelve hundred feet above Lake Superior or eighteen hundred feet above the ocean-level.*

We commence our description of the local phenomena of this system of rocks where they intersect the lake shore between Riviere du Mort† and Chocolate river. The sketch entitled "View near Carp river" forming the frontispiece may serve to convey an idea of the contours of this region better than a written description. The lake here forms a spacious bay with gently-curving shores. A range of quartzose hills rising to the height of six hundred feet terminates abruptly by the coast and forms the background of the picture. The extremity of the point consists of sand-dunes rising to the height of fifty or sixty feet, with rounded outlines and highly inclined slopes towards the lake. Along its margin are to be seen the remains of ancient terraces which indicate its former limits. The middle ground is occupied by a range of trappean rocks interlaminated with the slates. The settlement here represented, has been named Marquette, in honor of the early missionary, and has already become the main outlet of the Iron region. The foreground is composed of another rocky promontory which projects for some distance into the lake, and serves as a shelter to vessels against a west and north-west wind; while by the shore, vestiges of the Silurian sandstone are seen reposing upon the upturned edges of the azoic rocks. It would be difficult to select another spot, along the whole coast, where the rocks of so many epochs, from the oldest to the most recent, are represented. It contains an epitome of nearly the whole geology of the district.

The quartz zone exhibits two distinct ridges, where it approaches the lake, hemming in the valley of Carp river with rocky walls, from two to six hundred feet in height. As we trace it westwardly, it presents but a single ridge, and after having passed Teal lake, sinks down and becomes lost. Where exposed by the lake shore, it exhibits lines of bedding and obscure traces of ripple marks. These lines bear east and west, and dip 86° to the south, while the Potsdam sandstone abuts against the quartz, in a nearly horizontal position. Some of the quartz beds in this vicinity enclose fragments of jasper and slate, showing that they contain vestiges of prior-formed rocks. The southern ridge—using the notes of Mr. Hill—presents a number of conical knobs rising from two to three hundred feet above the surrounding country. In section 2, township 47, range 25, a granite boss rises above the quartz, over which the strata are folded like a mantle. In the north-east quarter of this section, a band of slaty limestone, somewhat silicious, is seen beneath the quartz, bearing north-east and south-west, with an inclination of 44° to the south-east. In the northern part of section 3, the quartz is observed, with another band of limestone interstratified, bearing nearly west north-west. The protrusion of the granite has displaced the beds and broken their continuity; one portion shifted to the south, was traced as far as the line between sections 9 and 10, while

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* For a list of heights determined barometrically, see Appendix, C.

† This river is generally called *Dead* river. It cannot be from the sluggishness of its current, for in the distance of thirty miles, it falls more than a thousand feet, abounding in rapids and cascades. Its true name is the River of Death. There is a local tradition as to some act of violence here perpetrated, which we cannot now recall, and from which the river derives its name.

another portion, shifted to the north, was traced westward into section 4. The northern beds were found to be associated with a layer of limestone, or compact marble, only a few feet in thickness. The northern ridge attains a higher elevation than the southern, the highest point in section 6, being five hundred and ninety-two feet above the lake. The quartz has been so far metamorphosed as to destroy the lines of bedding, but in other portions of the range, for instance, near the Jackson Forge, it assumes the character of a quartzose conglomerate, and exhibits distinct lines of bedding. A granite protrusion occurs along the line between townships 47 and 48, range 25, which has caused a displacement of the strata, many thousands of feet in a linear direction, throwing one portion of the ridge to the south-west, and another portion to the north; and it is instructive to observe how far the course of the Carp river has been determined by this dislocation. The main branch curves around the southern outlier, while the affluent, known as Alder creek, finds its way between the granite and the quartz.

In section 31, township 48, range 25, near the west line, another band of compact limestone was observed, and thence traced westward, by Mr. Hill, through sections 33 and 36, being well exposed in the escarpments of the ridges. It is less silicious than that before described, variously colored, white, ash-grey and flesh-red, and beautifully veined with tints of a deeper hue. It calcines readily into lime, and affords beautiful ornamental materials.

Along the valley of the Carp, between Jackson Forge and Teal lake, beds of novaculite, or fine-grained silicious slate, are found interstratified with beds of quartz. It has been already quarried at several points, for hones, and there is, even now, a considerable demand for them. The beds are exceedingly fissile, and full of flaws at the surface, so that much of the mass is comparatively worthless; but it is believed that the blocks taken from a greater depth, and beyond the action of atmospheric agents, will be free from these imperfections. Messrs. Smith & Pratt have established a actory for the purpose of sawing these blocks, at the mouth of a small stream, near the Marquette landing, and are driving a thrifty business.

Between the quartz range and Dead river, the underlying rock consists, in the main, of chlorite and talcose slates, intersected by three belts of igneous rocks, ranging nearly east and west.

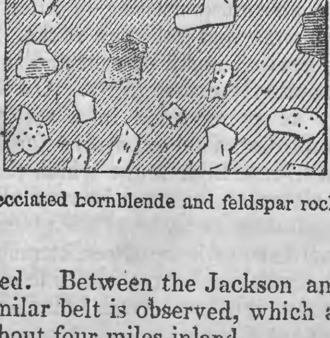
De la Beche, in reference to the greenstones and schistose rocks of Bossiney, Cornwall, remarks that, "there is so intimate a mixture of compact and schistose trappean rocks with the argillaceous slates, that the whole may be regarded as one system, the two kinds of trappean rocks having been probably erupted, one in a state of igneous fusion, and the other in that of an ash, during the time that the mud, now forming slates, was deposited; the mixture being irregular from the irregular action of the respective causes which produced them; so that one may have been derived from igneous action, and the other from the ordinary abrasion of preëxisting solid rocks, they were geologically contemporaneous."

This description is applicable to many of the igneous rocks of this region. They form neither long lines of dykes, nor axes of elevation, but broad sheets, bearing the same relation to the slates that the trappean bands of Keweenaw Point do to the conglomerates. Many of the slates appear to be composed of pulverulent greenstone, as though they might originally have been ejected as an ash, and subsequently deposited as a sediment, and pass by imperceptible gradations, from a highly fissile to a highly compact state. In some places, for example, at Marquette and Presqu'isle, they assume a spheroidal structure, as though after their deposition they had been so far operated on by heat as to allow a rearrangement of the particles. Along the lines of volcanic action, we frequently find, throughout this district, a green pulverulent substance, somewhat resembling chlorite, and containing a large amount of magnesia and lime, which is probably in the nature of an ash. The same ingredients enter largely into the composition of many of the trappean rocks, for they possess a soapy feel, and when reduced to a powder, effervesce feebly with acids.

There are undoubtedly, at this day, beneath the bed of the ocean, numerous "salses," which, from time to time, pour forth streams of pulverulent materials, but whose operation is concealed from human sight. We know that for weeks in succession, there flowed streams of chocolate-colored mud from the crater of Graham's island, before it finally sank below the surface. The contributions from this source, to the first formed stratified deposits, have not been duly appreciated. This volcanic mud is nothing more than the comminuted particles of trappean rocks, reduced by friction; and in the early history of our planet, when the fissures communicating with the interior were unfilled and volcanic energy was manifested more intensely than at this day, it would be reasonable to expect that igneous causes contributed as powerfully to the reduction of the preexisting rocks, as the ordinary abrading action of water. The slates are composed essentially of the same ingredients as the trappean rocks with which they are associated, and the main difference between them may be, that the one was the product of salses, ejected in the form of mud, while the other was the product of volcanoes, ejected in molten streams. It has been supposed that the talcose nature of the slates associated with the igneous rocks was the result of metamorphism, but the supposition that they have resulted in some instances from the destruction of the latter, is quite as reasonable.

About a mile from the lake shore, on the road leading to the Jackson Forge, a low range of trappean rocks, of a compact texture, and of a dark-

(Fig. 1.)



Brecciated hornblende and feldspar rock.

green color, is intersected. Between the Jackson and Marquette landings, by the lake shore, a similar belt is observed, which again appears near the junction of the roads, about four miles inland.

Another belt intersects the coast a short distance above the Marquette landing, which does not differ essentially from those before described. The slates in the vicinity of these belts are compact, of a greenish color, and traversed by different systems of joints, more distinct than the lines of bedding, cutting the mass into cuboidal blocks.

At Little Presqu'isle, another band of igneous rocks, of a highly crystalline character, projects into the lake. Distinct acicular crystals of hornblende are distributed in places through a paste of pure-white feldspar, while in others, these two minerals are disconnected, the latter forming beds of considerable thickness. Angular fragments of hornblende slate, chlorite slate; jasper and a green magnesian mineral, are seen enclosed in the mass near the water's edge, as represented in the preceding illustration, (Fig. 1,) which may be regarded as a volcanic breccia. These fragments seldom exceed a few inches in diamete..

Like most of the rocks of this region, its surface is smoothed and striated in a wonderful manner. Below the mouth of Dead river, a highly crystalline mass of this character emerges in the form of an island fifty or sixty feet in height.

The main Presqu'isle consists of a dark-green trappean rock, rising in overhanging cliffs to the height of a hundred feet. A description of this rock and the relations which it bears to the sandstone will be given when we come to treat of the Silurian system. Over this is deposited a volcanic tuff, imperfectly stratified, filling up the previous depressions, and attaining a thickness of twenty or thirty feet. It presents a complete net-work of veins, a few lines only in width, which penetrate but a short distance into the subjacent basalt. At one place, on the north-west side of the point, an irregular vein bearing north and south is seen for two hundred feet in a linear direction, in this obscurely stratified tuff, which yields the sulphurets of lead, copper and iron, but not in sufficient quantities to render its exploitation profitable. Asbestus is also sparingly distributed, and may be regarded as a metamorphic product resulting from the presence of lime. Traces of magnetic oxide of iron and black oxide of manganese are detected in some of the veins farther eastward.

Proceeding up the valley of Dead river, between sections 7 and 18, township 48, range 25, the stream is precipitated from a height of twenty feet over a ledge of schistose rocks, which exhibit distinct lines of bedding and abrupt convolutions of the strata.

In the next range west (27,) the trappean and schistose rocks are frequently exposed in the bed of the stream, consisting of alternations of talcose and chlorite slates, and hornblende and feldspar rocks. They stretch out in numerous parallel ridges, bearing north of east and south of west, and present, for the most part, southerly escarpments. On the north-west quarter of section 16, the river is precipitated in a series of rapids over the former class of rocks, affording fine exposures for observation. On the west boundary of section 6, in a high ledge which rises from the northern bank of the stream, the slates are again observed dipping to the south at an angle of 70°.

The stream here bears west-north-west, conforming to the direction of the strata. After flowing along the northern line of township 48, nearly through range 27, it divides into numerous branches whose sources lie to the north-west, in the region of the granite.

Proceeding southward from Teal lake, we first encounter a ridge of trappean rocks which skirt its southern shore and rise abruptly to the height of two hundred feet above the lake-level, succeeded by chlorite slates and vast masses of specular and magnetic oxide of iron. As we shall devote a special chapter to the character of these masses and their relations to the associated rocks, a more minute description is here deemed unnecessary. We would merely observe that in this region the iron masses are invariably found in this association—never occurring in the granite.

These alternations of trappean and schistose rocks continue, to near the southern boundary of township 47, and are characterized in many places by the ores above described.

SECTION FROM LAKE SUPERIOR TO LAKE MICHIGAN.

The coast near the head of Keweenaw Bay (L'Anse) affords an admirable section of the slates and the overlying sandstone. (Vide Plate XXI., Figure 1.)*

The following is the descending order of succession:

1 and 2. Fissile sandstone—the equivalent of the Potsdam—dipping slightly to the west-north-west, of a reddish color, and coarse-grained, passing into a conglomerate composed of pebbles of milk-white quartz, and occasionally trappean pebbles—13 feet, resting *unconformably* on the azoic rocks, consisting of

3. Chlorite slate and novaculite, or silicious slate, variously colored, and much contorted—in places folded over

4. A dark hornblende and feldspar rock evidently trappean in its origin. Formations 3, and 4, are traversed by veins of quartz which in no case penetrate the overlying sandstone. The slates are also occasionally intersected by dykes of trap. (5)

This section is exceedingly instructive, inasmuch as it enables us to draw a line of demarcation between two formations different in age and external characters. While the newer formation—the Potsdam sandstone—is but slightly if at all disturbed and little changed by metamorphism, the older, or azoic slates, are contorted and folded into numerous arches, and in several places, invaded by igneous rocks. Their structure has been changed from granular to sub-crystalline, and the whole mass is intersected by numerous planes of lamination.

These slates are displayed for three miles along the south-eastern coast of Keweenaw Bay, and, within that distance, exhibit several distinct convolutions, alternately convex and concave. This structure is probably characteristic of the whole of the azoic series, but it is nowhere so beautifully shown as along this coast, for the reason that it is impossible to meet with equally extended sections inland. Even where, at the surface, the strata are apparently vertical, if we could trace them downward, they would probably be found to form parts of flexures more or less abrupt. The upper portions of these flexures are, for the most part, imperfectly traced, for the reason that they have been removed by denudation.

The section displays in a very remarkable degree those planes designated as planes of lamination, represented by the highly inclined lines. (Plate XXI., Figure 1-6.) However great the foldings of the strata, which may

* The geology and topography on a southerly line between Lake Superior and Lake Michigan is illustrated on the General Section. It is but justice to add that in the exploration of this region, as well as in the preparation of the section, we were assisted by Mr. S. W. Hill.

be traced by the variety of colors, these lines pursue a parallel direction, only an inch or two asunder, sometimes coinciding with those of stratification, and sometimes intersecting them at greater or less angles; thus showing that the materials composing the mass have undergone a rëarrangement since they were first deposited,—a result probably due to the operation of some great law of crystallization, as yet but imperfectly understood.

The lines of lamination dip towards the south, or away from the axis of elevation, and the separation of the blocks is more easily effected in this direction than along those of stratification.

Professor Sedgwick was the first geologist to describe these lines, and their uniformity of strike. In the gorge of the Wye, they were observed to cut mountain masses from the summit to the base, preserving throughout a strict geometrical parallelism. He is of the opinion that no retreat of parts, no contraction in dimensions in passing to a solid state can account for the phenomenon, but that it must be referred to crystalline or polar forces, acting simultaneously and somewhat uniformly in given directions, on large masses, having a homogeneous composition.*

At the head of the bay, the slates reappear and exhibit the same folded structure. They are somewhat changed in their lithological character, taking into their composition a larger amount of chlorite. For a mile or more, they are exposed along the bed of Fall river, and, in places, are sufficiently fissile to be employed for roofing purposes.

The silicious beds noticed as occurring on section 25, form a very tolerable material for the coarser kind of hones, or whetstones; although the substance is somewhat friable, it has a sharp grit. The Indians frequently resort here to obtain pipe-stones, which they work into curious and fantastic forms.

Along the northern flank of the granite, the slates are obscurely traced, their presence being indicated only by occasional fragments strown over the surface, or by low ledges in the beds of rills. As we approach the granite axis, the detrital rocks become more crystalline and exhibit in a more marked degree the effects of metamorphism. About a mile and a half south of the line between townships 50 and 49, range 32, (vide the general section appended to the report,) gneiss was observed flanking a range of well characterized granite. Between this point and the head of Keweenaw Bay, about eight miles distant, the following is the order of succession of the rocks.

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* The experiments of Mr. Robert Were Fox seem to point to voltaic agency as the cause of these phenomena. He succeeded in producing lines of lamination in clay by long-continued voltaic action, the planes of the laminæ being formed at right angles to the electric forces. He considers that the general laminated structure of the clay in these experiments appeared to indicate that a series of voltaic poles were produced throughout the clay, the symmetrical arrangement of which had a corresponding effect on the structure of the clay, and that this view was confirmed by the occurrence in several instances of veins, or rather laminæ of oxide of iron or copper, according to the manner in which the experiments were conducted. He considers the prevailing direction of the electrical forces, depending often on local causes, to have determined that of cleavage, and the more or less heterogeneous nature of the rock to have modified the extent of their influence.—*Report of the Polytechnic Society of Cornwall, quoted by De la Beche.*

Mr. Darwin states that the ore of the gold mines of Yaquil in Chili is ground into an impalpable powder, which is washed and the sediment collected in a pool, which after having subsided is thrown into a heap. Chemical action then ensues, various salts effloresce on the surface, the mass hardens and divides into concretionary fragments. These fragments were observed to possess an even and well-defined slaty structure, but the laminæ were not inclined at any uniform angle.— *Travels in South America.*

1. Granite rising in a ridge over a thousand feet in height, and bearing north of east and south of west.
2. Gneiss, with a large amount of mica.
3. Compact hornblende, with silex in places predominating.
4. Chloritic, argillaceous and silicious slates.

Passing over the granite which forms a zone ten miles in width, and rises in places to the height of twelve hundred feet, being the culminating point between the two lakes, the azoic rocks rëappear. Near the centre of township 48, range 21, on the southern flank, the following was the order of succession observed.

1. Granite, ranging nearly east and west.
2. Quartz and feldspar passing into granular quartz.
3. Compact hornblende, traversed by numerous joints.
4. Magnetic and specular oxide of iron, with thin laminæ of white, granular quartz.

This association of rocks was observed north of a small lake known as Sagiagāns, which forms the first link in a chain extending as far east as range 30. It is one of the sources of the Menomonee and lies one thousand and forty-nine feet above its embouchure. On the north, the granite rises in precipitous ridges, with rounded summits, while to the south, the country occupied by the slates stretches out in low, marshy plains. On a rocky island near the northern border of this lake, there occurs a hornblende and silicious slate with thin laminæ of magnetic oxide of iron. Passing through a tortuous channel, bordered on either side by marshes, we emerge into a a second lake of about the same dimensions. Granite is observed on the north in conical hills, three and four hundred feet above its surface. Between the second and third lake, there occurs a portage (No. 1,) where the stream descends twenty-four feet in the distance of three-fourths of a mile. Aside from the descent, the channel is obstructed by numerous boulders of hornblende and granite. In section 21, township 48, range 31, loose masses of hornblende were observed containing a large amount of magnetic iron. The compass here exhibited great perturbation, and in one instance the poles were reversed. In passing over this portage, numerous blocks of compact and slaty iron ore were seen strown over the surface, but nowhere in place.

Portage No. 2, is a short distance east of the entrance to Machi-gummi, or Big Lake, and the trail winds around the base of an elevated knob for three-fourths of a mile.

Machi-gummi is among the most beautiful of the inland lakes of this region. It is in the form of a crescent, and elevated 1014 feet above Lake Superior. The numerous islands which dot its surface consist of dark-green, compact hornblende, jointed, and perhaps bedded. A range of similar rocks borders its northern margin, cropping out in mural cliffs, two and three hundred feet high, crowned with stunted cedars and spruces. The southern shore is lined with similar rocks, intermingled with patches of dark-green slates, corrugated on their surfaces, and displaying distinct lines of bedding, which dip nearly vertically.

All along this chain of lakes, the aberrations of the needle are great, and indications of iron abundant. To William A. Burt, Esq., is due the credit of having first determined the existence of these beds and proclaimed their value.* On the north side of Machi-gummi, in numerous places, an impure variety of magnetic iron is seen associated with hornblende or quartz, presenting a banded structure. On the southern shore, Mr. Burt observed a bed along the south boundary of township 48, range 30, section 34, having a granular structure, a dark brown color, and bearing south-west; but it was exposed to no great extent. Another bed associated with a rock in which quartz largely predominates, was observed on the south side of section 35, forming a knob twenty feet in height. It was laminated and jointed, the laminæ bearing W. S. W., and dipping 80° E. S. E. In range 29, on the south side of section 32, a ledge of iron ore eight feet in height crops out for the distance of nearly seventy-five chains; course W. N. W. Mr. Burt describes it as variable in richness, structure granular, lustre in fresh fractures metallic, highly magnetic and sometimes possessing polarity.

Another bed is described by him as occurring in range 28, on the south line of section 33, in the form of a knob fifty feet in height, jointed and banded, resembling a brown hematite with a large admixture of quartz.

At the outlet of the lake, the stream, increased by numerous affluents, expands to the width of sixty feet, with an average depth of two and a half feet, and takes the name of Machi-gāmig,—or, *The river flowing from a large lake.* It winds its way through superficial deposits which conceal all traces of the subjacent rocks, until it reaches township 46, range 29 and 30, where it forms a lake-like expansion. A chain of hills two hundred feet above its surface, approaches from the left to near the water's edge. On exploring this range, we found that it consisted of a mass of specular oxide of iron, portions of which were of sufficient purity to be profitably wrought. For the distance of eighty feet from the water, the rock is concealed by soil supporting a dense growth of trees; it then shoots up in a perpendicular cliff to the height of one hundred and thirteen feet. We passed along the base of this cliff for a quarter of a mile seeking for some gap through which we might ascend to the summit, until at length, after much toil and by clambering from one projecting point to another, we succeeded. Passing back from the brow of the cliff for fifty feet, the mass was found to consist of micaceous and granular oxide of iron: to this succeded a band of white, granular quartz, with particles of iron, disseminated, and, also, large rounded masses of the same material in the nature of a conglomerate, or perhaps, a breccia, fifteen feet in thickness, succeeded by specular iron exposed in places to the width of one hundred feet, to where the soil and trees concealed all further traces. This iron for the most part, contains thin laminæ of quartz arranged in parallel plates, bearing, so near as we could judge,—for the day was dark and rainy and a compass was of no avail,—north of west and inclining 82° north-east,—corresponding with the strike and dip of the quartz rock. Other portions present a granular structure and are highly magnetic. Veins of quartz, with iron glance, cut through the mass, presenting external characters altogether different from those of the containing rock. This ridge crosses section 1, township 46, range 30, and rises eleven hundred and nine feet

* Vide his report on Township Lines, for 1846. Land Office Documents for 1849–50.

above Lake Superior. Here, in this cliff, is sufficient iron, though not as rich as that of the Carp river region, to supply the world for centuries.

Above portage No. 4, in sections 1 and 6, according to Mr. Burt, on the right bank of the river, a similar ore appears in a ledge from twenty to fifty feet in height, dipping 80° to the south-south-east, of an iron-black color, passing into steel-gray, often resembling very fine cast iron. Another bed of similar character, was observed by him on the east boundary of township 47, range 29, twelve chains in length, rising in a cliff to the heighth of fifty feet.

After leaving this portage there is an interval of several miles along which no rock is exposed. The talcose slates probably here prevail, which are more easily denuded than the closely-grained and firmly-cemented hornblende rocks, but on approaching section 31, township 46, range 29, the latter reappear in dark-green masses. Their external characters indicate the proximity to a line of igneous outburst, and on the adjoining section south (section 5, township 46 range 21,) the granite appears in low, rounded outcrops, and occupies a belt five miles in width, flanked on the south by hornblende, presenting the same lithological characters as that on the north.

A short distance below the mouth of Fence river, (township 44, range 27 and 28), the left bank of the Machi-gāmig is lined with ledges of compact and crystalline limestone, rising in places to the height of thirty feet. The lines of bedding bear north-east and south-west, and incline 36° to the south-east. Its prevailing tint is flesh-red, inclining to bluish or ash-grey, intermingled with irregular veins of a deeper hue. It is well adapted to ornamental purposes, and for richness of effect is not surpassed by the highly prized foreign marbles. Irregular bunches of quartz are scattered through portions of the mass; but, with suitable care in the selection, slabs of considerable dimensions may be obtained. Three-fourths of a mile below, it is again exposed in the left bank of the stream, bearing north 48° east, and dipping nearly vertically, flanked on the south by a bed of argillaceous slate. This slate again appears about a mile below the mouth of Night-watching river, so highly indurated that the lines of bedding are very indistinct, while those of lamination are very conspicuous. At portage No. 7, the slates rise in cliffs one hundred and fifty or two hundred feet above the stream, presenting precipitous escarpments to the south.

On the north boundary of this township (43) Mr. John Burt observed a bed of specular iron of considerable thickness and purity, but we failed to detect its presence in the river banks.

Below portage No. 7, the rocks consist of alternate bands of argillaceous and hornblende slates. At portage No. 8, the latter rocks are admirably exposed in a nearly vertical position, bearing north 80° east. They are fissile, of a dark-brown color and contain acicular crystals of amphibole.

At portage No. 9, (near the south boundary of township 42, range 31), the granite pierces through the incumbent strata, forming an axis of elevation in an east and west direction. On either side, corresponding alternations of hornblende and mica slate are observed, and altogether this section affords one of the most beautiful examples of flexures in the strata to be found in the district.

At portage No. 10, a mile and a half below, mica slate is exposed dipping south 60°, and is again succeeded by hornblende slate which continues to the junction of the Machi-gāmig and Brulé rivers, where the united streams take the name of the Menomonee, (Indian, *Wild-rice river.*) The water of the former river is here precipitated from a height of twenty-four feet over a ledge of this rock which rises in sharp ridges on the adjacent banks. The direction of the laminæ, at this point, is north 72° west; dip 69° south-east.

As we descend the Menomonee, the hornblende and mica slates are found to graduate into chlorite and argillaceous slates. At portage No. 1, alternations of these rocks are observed—course north of west with a southerly inclination. At portage No. 2, the chlorite slate forms an abrupt ridge; the mass contains numerous vesicles filled with calc-spar—one of the few instances observed where the slates assume a porphyritic appearance—course north 75° east,—dip 75° southerly. The Twin falls break through two parallel ridges of these slates. Here, they are of a dark-green color, in some places fissile, and much plicated, but in others compact. Associated with them are seams of quartz ranging and dipping with the enclosing rocks. They often contain scapolite, and the sulphuret of iron and copper. The metallic contents, however, of these seams were regarded as worthless. Aside from their conformable inclination and bearing, there can be no doubt that they are contemporaneous with the slates and in the nature of beds, not veins; for, among the loose fragments in this vicinity we procured specimens of quartz whose surfaces were beautifully ripple-marked, while on cross-fracture they presented a compact or sub-crystalline structure throughout. These water-lines are so beautiful and regular that we have thought proper to append a sketch of them, (Plate XXI., Figure 2.) They clearly prove the mechanical origin of the rock, and do they not, also, throw much light on the origin of the associated schists? The compact texture may be regarded as the result of metamorphism; and while this agency has thus modified its internal structure, it has failed to deface the mould, or flask, in which it was encased.

At the Upper falls the strike of the rocks is nearly at right angles to the course of the stream; but at the Lower falls the contortions are so great as to bring the strike parallel to its direction.

The whole of this region bears upon its surface the marks of powerful abrasion, resulting from the drift agency. The rocks are worn bare, rounded, polished and scratched. Sand, gravel, clay, angular fragments of rock and boulders, are mingled together confusedly, and piled up in ridges a hundred and fifty feet in height. At this point the striæ on the rocks bore north 65° east.

Between the Twin falls and the mouth of Muskos river, the compact hornblende prevails; but, at the rapids above the latter point, the fissile slates appear with occasional plications. A short distance below, are seen, along the banks of the Menomonee and in its bed, angular blocks of ash-grey limestone, some of which contain 2000 or 3000 cubic feet, and continue for the distance of half a mile. From their magnitude and angularity, and from their limited distribution, we inferred that the parent mass must exist in this vicinity; but the hills, which here rise to the height of two hundred feet, are covered with drift, and their summits are strown with boulders arranged in lines, among which Mr. Desor recognised blocks of limestone similar to those in the bed of the river.

Within township 39, range 30, occur two of the most beautiful cascades of the Menomonee, the Great and Little Bekuenesec. (For a sketch of the former, see Part I. of our Report.) Above the Upper falls, the rocks consist of black, compact masses of serpentine, exhibiting few signs of bedding, but traversed by several systems of joints. They take into their composition a large amount of magnesia, and appear under different forms, such as hornblende, steatite, serpentine, &c.

At the head of Great Bekuenesec falls, is seen a rock which bears marked evidences of igneous protrusion. It does not appear to have cut the strata, like basalt or greenstone, in long dykes; or to have flowed over the surface, like the bedded trap; but, rather, like granite, to have been elevated in a pasty condition through a widely-extending fissure. Like the granite, too, it presents a highly crystalline aspect, and is cleft by numerous divisional lines into cuboidal blocks. Mineralogically, it might be classed as *protogine*, being composed of feldspar, quartz and talc, arranged in minute crystalline plates; but geologically, perhaps this classification might not be recognized, since the protogine of the Alps belongs to a much more recent epoch. Occasionally, hornblende replaces the talc, when it passes into well-characterized syenite.

Near the foot of the falls, a bed of drab-colored, talcose slate, in a nearly vertical position, is seen ranging north 70° west: to this succeed dark masses of hornblende, or, perhaps, the term serpentine would be more appropriate. Its texture is compact, and in other respects different from the crystalline mass before described.

These serpentine rocks reäppear at the head of Little Bekuenesec falls, while at the foot, the drab-colored and silicious slates are exposed, bearing east and west with a southerly dip of 80°. Beds of quartz, containing brown spar and chlorite and magnetic oxide of iron, in octohedral crystals, and copper and iron pyrites, are here observed, but they offer no inducements for mining enterprise.

Between this point and Sandy portage, the dark-colored slates appear on the left, in vertical cliffs, rising in places to the height of two hundred feet, and where they assume a compact structure, resemble basalts. The trail across the portage winds around hills of drift-sand one hundred and fifty feet in height, but along the river-banks the slates are occasionally exposed in a nearly vertical position.

The serpentine rocks largely predominate between Sandy portage and Sturgeon falls, often appearing in masses having rounded outlines, and traversed only by divisional planes; but, at other times,—for example, near the head of the falls, — they display a bedded structure and pass into steatite.

In passing this portage, a ridge is intersected bearing north of east and south of west, having very much the external characters of granite, but mineralogically, it approaches protogine. It is traversed by different systems of joints, which cleave the mass into cuboidal blocks; here are also irregular fissures filled with magnesian carbonate of lime and serpentine, with traces of carbonate of copper, but they have not the regularity or the productiveness of true veins. Near the foot of the falls, is seen an entangled mass of slates, cuneiform and about twenty feet in thickness.

Similar patches of slate are seen intercalated among the dark-green igneous rocks, as we descend the stream. The gradations between the crystalline, massive, porphyritic and fissile varieties of rocks are infinite, and seem to set at defiance all attempts at classification.

At Quiver falls, the rocks in the main are finely granular, but occasionally, crystals of red feldspar are seen disseminated through a light-green

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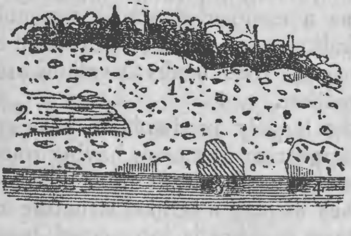
base. At the head of the first island below, a highly crystalline greenstone is seen, and to this succeed the compact varieties.

At Pemenee falls, the rocks assume a basaltic structure, being dark-green, close-grained, and possessing a high specific gravity. They are traversed by numerous lines of division, dividing the mass into cubic blocks. Veins of quartz are observed near the foot of the falls, three or four inches in thickness, associated with brown oxide of iron, bearing nearly east and west, and dipping 28° to the north.

This rock, occasionally porphyritic, prevails as far down as Chippewa island, where it comes in contact with talcose slates, of a light red and grey color, beautifully variegated, bearing north 85° west, and inclining but a few degrees from a perpendicular. Between the two, there is a pretty distinct line of demarcation. At the immediate point of contact, the lines of bedding are destroyed, but a foot or two removed, they become conspicuous. There is much sulphuret of iron, in the form of cubic crystals, disseminated through the serpentine rocks. Near the foot of Chippewa island, the slates become porphyritic, containing large crystals of red feldspar, and the dark serpentine rocks are seen in proximity. Numerous alternations of these compact and fissile rocks are observed in this vicinity, the former occasionally changing to a crystalline structure.

Near here, on the left bank of the river, the Potsdam sandstone is seen reposing in a horizontal position upon the upturned edges of the slates and filling the preexisting depressions in the serpentine rocks. A detailed description of this point will be given when we come to treat of the Silurian system. A few miles further down, the following section (Fig. 2,) was observed by Messrs. Whittlesey and Desor.

Fig. 2.



Junction of the Azoic and Silurian Series.

1. Drift. 2. Sandstone, horizontal. 3. A mass of brittle, red oxide of iron, or red chalk. 4. Serpentine rock.

The drift here forms a bank sixty feet in height, and although the sandstone is not seen in immediate contact with the other rocks, there can be no doubt of the order of superposition. The layers are nearly horizontal, and consist of coarse-grained silicious particles, of a yellow color, and slightly coherent. At the water's edge, a reddish slaty rock, impregnated with the peroxide of iron, is observed, the laminæ inclining slightly from perpendicular, while a little farther removed, a mass of serpentine rock is displayed in the same position.

Below this point, the compact serpentine rocks largely predominate over the schistose, and are seen at short intervals in the bed of the stream, as far down as the mouth of Pike river. Bands of quartz are, also, found intercalated. The underlying rock at the White Rapids, according to Mr. Desor, is of this character, with the Potsdam sandstone reposing unconformably upon it, and filling up a preëxisting depression in its surface.

The beds of sandstone above described may be regarded as outliers of the great zone which encircles all of the granitc and azoic rocks of this region. On the geological map we have extended it as high up as Chippewa island, where it was first observed. Here, probably, were its ancient limits, and the underlying rocks were laid bare during the drift epoch, when the whole of this region was powerfully abraded.

From the White Rapids to the mouth of the Menomonee, about thirty miles distant in a linear direction, the country is successively occupied by the lower groups of the Silurian system; first, by the Potsdam sandstone, extending to near the Grand Rapids; next, by the calciferous sandstone, reaching within sixteen miles of Green Bay; and next, by the Trenton limestone, occupying the intervening space. They repose conformably upon one another and incline at a very slight angle to the south-east. A description of these rocks forms no part of the subject matter of this chapter.

The topographical features of the region, along the line of the section just described, are somewhat striking. The explorer, leaving the waters of Lake Superior, passes over a succession of parallel ridges, with rounded outlines, rising higher and higher, until he attains the summit level—1200 feet—within about twelve miles of Keweenaw bay, when he strikes the sources of the Menomonee. Following along a londitudinal valley occupied by a series of beautiful lakes and meadows, he comes to where the waters are accumulated in one great resorvoir, 1014 feet above the level of Green Bay — whose outlet is through a transverse fissure in the hills. With a frail canoe and a couple of attendants, he commences the descent of the Machi-gämig. Day after day, he glides along the wooded banks, without encountering a trace of man; running, with race-horse speed, the numerous rapids; or, where too formidable, he lands and makes the portage. At night, he draws up his canoe, and camps beneath the shelter of a clump of pines. Occasionally, he observes traces of the otter and beaver, and the tracks of the bear, the wolf, or the deer, impressed upon the sands by the river margin.

The valley of the Menomonee has an uninviting aspect. The fires of the Indian have repeatedly swept through the woods, destroying the primeval growth, and the charred and branchless trunks rise up above the birch and aspen which have subsequently taken root. Abrupt ridges, attaining no great elevation, traverse the country in an easterly and westerly direction, and serve to relieve the dreary monotony of the scene.

The river itself abounds in rapids, cascades and water-falls; and these are so numerous and formidable that it can never be navigated, except by canoes. It drains an area of not less than 1200 square miles which offers few inducements to the agriculturalist.

To illustrate still farther the relations of the different formations, we append the following:

Fig. 3.

Profile of the Rocks from Section 35, Township 42 north, Range 30 west, in a southerly direction, to Section 14, Township 39 north, Range 30 west, near Little Bekuenesec Falls on the Menomonee River:—from the notes of Mr. Charles Whittlesey.

Distance, sixteen miles: the Base Line about two hundred feet above Lake Michigan.

1 & 2. Alternations of Gneiss, Hornblende and Quartz. 3. Compact Quartz. 4. Talcose and Chlorite Slates.
5. Saccharoidal Limestone. 6. Specular Iron. 7. Potsdam Sandstone. 8. Calciferous Sandstone.

The subjoined information is quoted from the MS. of Mr. Whittlesey.

"On the elevation about a mile north of the line between townships 41 and 42, are seen very large blocks of saccharoidal limestone, quartz, granite, greenstone, and specular oxide of iron. One composed of quartz and feldspar was 8 by 10 by 12 feet.—One of variegated marble, green and white, was 4 by 12 by 8. I saw but two exposures of the latter rock, one on section 35, the other on section 36, due east. The beds were nearly covered with debris and scarcely observable at the distance of a rod. The iron represented by the large blocks cannot be far distant, although I saw none in place, nor did the surveyor, Mr. Burt, in running the township lines. The needle is not as much affected here as is usual in the vicinity of iron, in fact, the pieces which I broke from the blocks did not sensibly disturb it. The variations given by Mr. John Burt, in 1849, were as follows: At the S. W. corner of section 34, 0° 5′ E.; one half of a mile N. along the W. side of 34, 6° E.: which is near the average variation of the place without disturbance. At the middle of the west line of section 35, or one mile east of the last station, it was 15° 15′ E., and one mile farther E. 9° 30′ W. On the S. E. quarter of section 36, it was 3° 5′ E. and a few rods N., 18° 30′ E.; but both of the above extreme variations were taken near large blocks of iron.

Most of the iron is of a dull-black color, massive and tough, containing silex in the form of chert, approaching hornstone; but much of it is quite pure yielding from fifty to seventy-five per cent. of ore.

The limestone is sometimes of a yellowish tinge, resembling the calciferous sandstone, or lower magnesian limestone; but at other times, it is pure white and green, beautifully mingled, and is adapted to ornamental purposes.

The space between this iron and marble ridge and the next elevation south is covered with a swamp which is drained by the waters of Cedar river, near its source. It is doubtless underlaid by a confused mass of hornblende, quartz and granite. These rocks are exposed for several miles to the south: in fact, I saw them about a half mile to the east of the swamp. The alternations of these rocks represented in the section for three miles present features strongly contrasting with the surrounding country. They are for the most part, denuded, and show sharp, steep faces from twenty to eighty feet in height, bearing east and west, the escarpments being on the south side. Red and smoky quartz are abundant. There are, also, quartz veins and masses of quartz within the hornblende and granite. The northern portion of these crags is generally hornblende, fibrous or compact: the granite contains silvery mica and occasionally passes into syenite.

From these rugged rocks, we passed to a region of pines, growing upon rolling land, composed of sand and drift, which conceal the rocks for three miles, consisting probably of talcose slates, as seen a few miles west. These slates have been more powerfully abraded than the other rocks, from their fissile structure and their yielding nature.

On the Correction line between townships 40 and 41, is a mass of vesicular quartz which presents a remarkable appearance, resembling the fibres of fossil wood. The dip is N. W. by W. at a high angle. It is of a red, or yellow color, and at first was mistaken for sandstone. "On the north side of the stream," quoting from the notes of Mr. Desor, "it forms a ledge twenty-five feet in height; but on the opposite side, bluffs of pure white quartz rise from one hundred to two hundred feet in height. It is apparently bedded and cut through by joints, extending from the summit to the base. At one place near the line, it may be seen passing into a hornblende slate, and still farther north, into gneissoid rock. Proceeding east, we found the rock assuming a gneissoid appearance, sometimes in layers and sometimes compact. As a general result, it seems to me that the quartz rock and hornblende are but a variation of the same thing. At the second section corner the rocks rise high, smooth and rounded to the north, but precipitous to the south. One fourth of a mile farther east, is a ridge of black hornblende with intercalated seams of quartz."

About three-fourths of a mile further south, on the line of the profile, the quartz is again observed in thick beds dipping west at an angle of 25°, portions of which possess a remarkable fibrous structure.

Ascending from the Sturgeon river to the south, the slope is covered to an unknown depth with large water-worn boulders of igneous rocks, and some few of metamorphic origin, *with very little earth intermingled.* We had before observed this phenomenon, but never in so marked a degree. This collection covered the northern face of two successive ranges. The subjacent rock is doubtless the slaty talc seen near some small lakes, two miles west.

On the north side of Lac Fumée, or Smoke lake,* in section 23, township 40, range 30, there is a sharp and elevated ridge rising apparently to

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* For the want of a better name, I call this sheet of water Smoke lake. It was a dark and rainy day when we made our examinations. Following the section line to its northern shore, we were obliged to build a large fire on a terrace about one hundred feet above its surface, in order that, after we had made the tour of the west end, we might know by setting the compass when we were opposite the line. The Canadian voyageurs as they looked back and saw the ascending column of smoke, exclaimed "*Lac Fumée! Lac Fumée!*"

the height of three hundred and fifty feet above the lake, which I estimate at two hundred feet above the Little Bekuenesec falls. This ridge is an outlier of the lower portion of the Silurian rocks; the Potsdam sandstone and calciferous sandstone are found resting undisturbed upon the azoic rocks below. The junction is not seen, but there can be no doubt that this is their relative position. Farther to the south-east, I saw the sandstone in two places in the same position, the talcose slates existing not far distant. The slopes of the hills on both sides of the lake are composed of heavy masses of coarse drift effectually concealing the rocks. The summit on the south is more elevated than the base of the Potsdam sandstone, but shows no trace of that rock. In its lithological characters, it may be described as a soft rock, composed of grains of silex, of a reddish-brown color, with a few black and red jaspery pebbles interspersed. Notwithstanding its softness, arising from the want of adhesion between the particles, it resists the weather perfectly well. The exposure is slight, but distinct, and extends along the northern slope of the ridge for a quarter of mile.

The calciferous sandstone, which reposes conformably upon it, is here about one hundred feet in thickness, and comes to the surface at the summit. This does not represent the entire thickness, the top having been denuded. It is impossible to determine the thickness of the Potsdam sandstone here, but, about two miles to the south, I saw at least one hundred and fifty feet of it exposed. The calciferous corresponds perfectly, in external characters, with that of the Wolf and Oconto rivers, in Dr. Owen's district. No traces of organic remains were observed.

On sections 34 and 35, the compact marble belonging to the azoic system appears in ledges from ten to sixty feet in height, dipping N. E. by E 70°, but there is little uniformity in its strike or inclination, and but slight traces of bedding. Its prevailing color is a pale blue, like that at Muskos river, beautifully marked with white, green and red stripes. It can be quarried in large and solid blocks, is susceptible of a high polish, and would afford a highly ornamental material for many architectural purposes.

Here the fluctuations of the needle are so great as to indicate the proximity of a large mass of magnetic iron, although none was observed within three or four miles to the west. At a point one mile west, the variation is given by Mr. Mullet, the linear surveyor, at 90° 30′ E.; one half mile farther west, at 35° 50′ E., and thence, being frequently taken for the next half mile, gives 164° E., 48° 30′ W., 22° 45′ W., 47° 30′ W., 17° 25′ W. and 10° 30′ W.; turning north one half a mile, it was 0° 45′ E.

On section 30, about four miles north-west by west, from where the profile cuts the line between townships 39 and 40, is a conspicuous iron mountain, which extends towards the seat of these variations. There is, also, near the north-west side of Lac Fumée, on the huge drift hills, which cover the rocks to the depth of one or two hundred feet, a great local disturbance. The state of the country is such as to render geological explorations difficult, being covered with bushes and burnt logs.

There are, on the upper Menominee, large tracts of land originally covered with pine, which have been prostrated by hurricanes and afterwards burnt. These districts are called "brulés." The second growth consists of white birch, aspen, pine and hazel. The fires of the Indians frequently sweep through the new growth, destroying it, and giving room for another growth. The explorer, therefore, commands a view of little more ground than that on which he stands, and may pass very near a low exposure of rock and not see it.

The "Iron ridge" to the south-west of Antoine's lake, is the only exposure of ore I saw in place, and this, for the most part, is covered with drift. It probably extends along the range south of Lake Antoine and Lac Fumée, to near the meridian of the profile, between sections 34 and 35. The variation at the iron ridge is 17° E., and proceeding one mile east, it is successively 0° 00′, 18° W., 22° W. and 15° 30′ W. I do not consider fluctuations in the needle as an infallible sign of the proximity of iron, but a very good sign. There are other rocks which affect the needle, and there are beds of iron which do not affect it.*

Between this exposure of limestone and the Menomonee river is an extensive plain of sand-drift covered with dwarf pines. On the east and next to the river, this heavy deposit of loose materials assumes the form of hills, and water-worn gullies, and rests upon the talcose rocks which appear in the river banks, especially at the Twin falls, the Great and Little Bekuenesec falls and at the Sandy rapids. There are patches where the rock is more ferruginous and compact, like greenstone, but the mass is either slaty or compact talc.

The mass of specular and magnetic oxide of iron in the south part of township 40, range 30, is believed to be the most southerly of all the beds of this region. It is exposed at the west end of a hill about one hundred feet high, rising to the east one hundred and fifty feet, and occupying a width of from one hundred to two hundred feet. Nothing but slaty ore is seen for the distance of forty rods on the summit. At the sides, as we descend, the drift and boulders have been piled up around the mass. It is a specular ore, of a bluish-black color, fine-grained, and gives a red streak. On the south and east, there is an abundance of wood for charcoal, and the water-power of the stream near the ore is unlimited. The Menomonee is not fitted for navigation, and hence the outlet for these ores should be through Bay des Noquets, forty-two miles distant."

Thickness of this System. Foldings of the Strata.—All attempts to estimate the thickness of the various schistose, calcareous and quartzose beds, must prove merely approximative. They occupy a belt which in its widest expansion reaches not less than eighty miles in width, and wherever exposed, have an inclination approaching verticality. If we were to deduct the spaces occupied by the purely igneous rocks, and then measure across the basset edges of those supposed to be sedimentary, the result would give us an incredible thickness—a thickness far surpassing that of the whole series of rocks heretofore observed, from the base of the Silurian to the crowning member of the tertiary. It is highly probable that the beds are arranged in a series of flexures resembling those represented in Plate XXI., Figure 1, but with broader and deeper curvatures, and that the observer, in passing over the outcropping edges, beholds numerous repetitions of the same beds; they have, however, been so repeatedly shattered by earthquakes, so disturbed and forced asunder by igneous protrusions, and so metamorphosed by direct and transmitted heat, that it is impossible to

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* Mr. William A. Burt states, that in passing from the Machi-gamig falls to Fort river, in 1846, he intersected a low ridge of iron, not far from the cornet of township 41 and 42, between ranges 29 and 30. The mass was very pure, banded and jointed, of a granular or micaceous structure, and having a metallic lustre. This was not subsequently met with in running the township lines.

place their continuity except over limited areas. If we could unfold these beds, and stretch them out in a nearly horizontal position, as when first deposited, they would require a far greater space than they now occupy. The causes by which these foldings have been effected, will be discussed in a subsequent chapter.

We have thus described the range, extent, and mineral peculiarities of a series of rocks, detrital in their origin, interposed between the granite and the base of the Silurian system. Throughout their whole extent, they are more or less metamorphosed, presenting a series of gradations, represented at one extreme by crystalline gneiss and compact hornblende, and at the other by bedded limestone and ripple-marked quartz. To the presence of granitic and trappean rocks this transformation is, in a great degree, to be attributed. Much of the compact hornblende presents the external characters of an igneous product; but, since it is found to occupy an almost invariable relation to the granite axes—flanking their slopes—and to assume a fissile structure as it recedes from the lines of igneous outburst, we cannot but regard it as the more highly metamorphosed portions of the dark-green chlorite slates. This compact hornblende is not to be confounded with those lenticular-shaped masses observed in the slates, which, we doubt not, are trappean in their nature.

We have seen that those igneous causes which produced numerous axes of elevation, and folded the strata into a series of flexures, had ceased to operate before the deposition of the Silurian groups, since they are found to repose in a nearly horizontal position upon the upturned edges of the slates, or to occupy the sinuosities in the granite, nowhere exhibiting traces of metamorphism or derangement of the strata. We do not now allude to the renewal of those igneous causes as manifested on Keweenaw Point and Isle Royale during the Silurian epoch, producing a class of igneous products widely different from those associated with the rocks of the azoic system. In a former report (Part I.) we have described the igneous rocks of the Silurian epoch as appearing under a variety of aspects, such as crystalline greenstone, porphyry, granular trap, and a highly cellular amygdaloid, differing little from modern lava, except that the cells are filled with various zeolitic minerals.

From the local details above given, it will be seen that the igneous rocks of the azoic period, though crystalline, compact, and occasionally porphyritic in their texture, are never amygdaloidal; and hence we infer that they were produced under widely different conditions. The latter may have been consolidated beneath the pressure of a deep ocean, while from the former a greater part of this pressure may have been removed; or it may be that both were, in the first instance, equally vesicular, but that the latter assumed a crystalline or compact structure from long-continued exposure to heat, under immense pressure. All the phenomena would seem to indicate that the eruption of the trappean rocks of this period took place beneath an ocean of great depth; or, at least, under conditions widely different from those which prevailed during the formation of the trappean belts of Keweenaw Point and Isle Royale.

REMARKS.

The investigations of geologists in different parts of the world, within the last few years, have clearly demonstrated the existence of a series of non-fossiliferous rocks below the Silurian or Cambrian systems, and there can be no doubt that they are destined to occupy a conspicuous place in the classification of the rocks both of Europe and America. At the meeting of the American Association at Cincinnati, in the spring of 1851, we made the development of this system in the northern portion of the United States and Canada the special subject of a communication. Professor Mather, after having confirmed the accuracy of our views, from personal observation, stated that he had observed the continuation of this system near the sources of the Mississippi, and on the waters of the St. Peter's. Its existence in Missouri, where it is associated, as on Lake Superior, with immense beds of magnetic and specular iron ore, is rendered certain by the observations of Mr. Mersch, which will be found incorporated in the subsequent pages of this report. At this meeting, Dr. King, who has examined this region with much care, confirmed these views, and we regret that the proceedings have not yet been made public, that we might quote his remarks in full.

Dr. Engelman, also, on that occasion, described a series of azoic rocks, as occurring in Arkansas, between Little Rock and the Hot Springs, which present a striking analogy with those of Missouri and Lake Superior, consisting of talcose, silicious and crystalline hornblende slates, often highly inclined, with beds of dark-blue limestone. On these older rocks, rests unconformably a sandstone, probably analogous to that of Lake Superior. Within this district of non-fossiliferous, stratified rocks, occurs a beautiful syenite. The vast masses of micaceous, or sub-magnetic oxide of iron, which occur in Missouri, find their representative in the well known "Arkansas Magnets," or, in the iron ore of Magnet Cove. It is here associated with the interesting titaniferous minerals, schorlamite, arkansite, or Brookite, and also, elæolite. Dr. E. thinks he has traced this series on the northern branches of the Colorado in Texas.

In the eastern portions of the United States, there can be no doubt of the existence of this system.

We are satisfied from personal observation that it flanks the Adirondack range in New York, where it is associated with hypersthene rocks and with masses of sub-magnetic oxide of iron, below the Potsdam sandstone.

The Messieurs Rogers describe a series of obscurely stratified rocks in Pennsylvania and Virginia occupying the same relative position, known as the gneissoid series. They undoubtedly flank the Appalachian chain on the east, throughout their entire range, and will probably be found well developed in Tennessee and North Carolina.

In Europe, the existence of this series has been established beyond controversy. It has been shown by eminent geologists, especially by Murchison and de Verneuil,* that the lowest beds in Scandinavia, containing the least traces of organic life, are the exact equivalents of the Lower Silurian strata of the British Isles, and that these have been distinctly formed out of, and rest upon, slaty and other rocks which had undergone crystallization before their particles were ground up and cemented together again to compose the earliest beds in which organic life is traceable. To this most ancient system of rocks in Scandinavia, they have given the name of azoic. By this term, they do not mean dogmatically to assert that nothing organic could have been in existence during the earliest times, when those rocks were in the process of formation, but simply to express the great fact, that, as far as our present state of knowledge goes, we look in vain for any traces of organic life, and it seems probable that they were formed under such physical conditions that nothing living could have flourished during that period.

The great mass of rocks in Scandinavia is made up of a crystalline, granitic gneiss, presenting an almost infinite succession of feldspathic, quartzose, micaceous and hornblendic laminæ, which are often highly contorted, though a general strike or direction may be traced over a large tract of country. These rocks are by no means to be confounded with the metamorphic Silurian strata, occurring under a similar and analogous form in the same country. These azoic rocks are often disturbed and cut through by dykes of greenstone and traversed by countless veins of granite.

It is evident from the direct comparison of the more ancient azoic with newer metamorphic Silurian, that, from lithological characters alone, no distinction could be drawn between them, and it is only where the most conclusive evidence is afforded, by superposition of the latter unconformably upon the former, that they can be clearly recognized and defined as belonging to different ages.

De la Beche remarks that, although alterations in the mineral character of the fossiliferous rocks, from the influence of intruded igneous matter in a molten state, or arising from other modifying causes, often produce mica slates, hornblende slates, gneiss and other forms of laminated and stratified deposits, with a peculiar aspect, there appears, nevertheless, evidence in Scandinavia and the British Isles, and also in other parts of Europe, to show that, beneath all the fossiliferous rocks, there are mica and chlorite slates, quartz rocks, crystalline limestones, gneiss, hornblende, and other rocks of earlier production. These may be, indeed, merely altered, or met-

* Russia and the Ural Mountains, Vol. 1, p 10.

amorphosed, detrital and chemical deposits of earlier times, and *possibly* organic remains may eventually be discovered in them; but until this shall happen, it seems desirable to keep them asunder, for the convenience of showing previous accumulations to those known as the Cambrian group. He, therefore, proposes the name of *Mona Series* for the reception of these older rocks, which are well displayed in the island of Anglesea, in connection with those of the succeeding group.*

In the admirable and detailed examinations of the Geological Survey of Wales, where the numerous intercalated beds of trappean rocks and the complicated series of faults have rendered the task of unravelling the geology one of great difficulty, the surveyors have clearly shown the existence of this azoic series below the lowest Silurian strata, which is there represented by the sandstone of Barmouth and Harlech.

Barrande, also, in his investigations of the Bohemian basin, has recognized a series of semi-crystalline slates alternating with compact argillaceous slates, below the lowest Silurian strata, in which he has failed to detect any trace of organic life; hence he has applied the name azoic to these rocks without meaning to assert positively, that the series is absolutely destitute of all traces, but simply as indicating the great fact that, thus far, none have been discovered.

* Geological Observer, pp. 31, 32.

CHAPTER III.

GRANITE ROCKS OF THE AZOIC PERIOD.

Granite.—Its Composition.—Mode of Formation.—Character of the Scenery where it prevails.—Peculiarities of Structure.—Range and Extent on the Northern Shore.—Its External Characters.—Range and Extent on the Southern Shore.—Greenstone Dykes.—Section between Lake Superior and the Mouth of the Escanäba River.—Section from Keweenaw Bay to the Mouth of the Menomonee.—Character of the Granite in the Western Portion of the District.—Age of the Granite of this Region.—Mineralogical Composition.—Economic Value.—Trappean Rocks.—Intensity of Igneous Action during this Epoch.

We shall use the term granite in an extended sense, as comprehending not only those compounds of feldspar, quartz, and mica, which form granite proper; but those compounds consisting of feldspar and quartz, to which the specific name of pegmatite has been assigned by the French, and those of feldspar, quartz and hornblende, usually known as syenite.

The gradations between the most ancient granites and the products of existing volcanoes are innumerable. There appears, however, this difference between them, that while the latter have been poured out in lava currents, the former have been elevated in a softened condition, forming vast, irregular masses, or bosses, over which the incumbent strata are often folded. They have not been protruded from narrow apertures, like the basalts, but from widely-extending gorges.*

The granites often occur in long, narrow lines, termed *elvans*, which appear to differ in no respect from greenstone dykes, except in composition, and also in ramifying veins, filling up the preëxisting fissures.

In most regions where granite constitutes the prevailing rock, the hills assume a rounded outline, and afford few scenes of picturesque beauty. We meet with no over-hanging cliffs, no needle-shaped peaks shooting up into the sky, no narrow and intricate defiles, where the sunlight rarely penetrates. All of the angular points are smoothed off, as though the plough and the harrow had passed over the region.

The granite masses are characterized by tabular divisions, which often communicate to them a stratiform appearance. Where it occurs, says Von Buch, in large insulated masses of a faintly arched ellipsoid form, it is covered by a crust, or shell, cleft into blocks—instances of which are met with, alike in the Harz district, the Mysore, and lower Peru.

* Humboldt. Cosmos, Vol. I p. 258. To use the language of an eminent observer, "imagine a large wedge forced from below through a sheet of thick ice on a river, or pond. First, the ice rises in an angle that becomes sharper and higher, as the wedge rises: then it cracks and opens, presenting its upturned edges on both sides, and through comes the wedge. And this is a very different process from what takes place when the ice merely cracks and the water issues through the crack. In the one case there is a rent, and water diffused over the surface: in the other there is the projecting wedge, flanked by the upturned edges of the ice."—Hugh Miller.

At the cataracts of the Orinoco, Humboldt saw granite in large flattened spherical masses, which could be divided, like basalt, into concentric layers.

GRANITIC ROCKS OF THE NORTHERN SHORE.

Granite forms, for the most part, the rim of the Lake Superior basin. The culminating points between the lake and Hudson's bay, on the north, the branches of the Mississippi on the south-west, and Green Bay on the south, are of this formation.

It appears in low, undulating hills, nowhere attaining a greater elevation than 2500 feet above the ocean. On the northern shore, it is more widely distributed than on the southern; but its geographical boundaries have been imperfectly determined. We propose to give, in a condensed form, a brief description of its distribution on both shores of the lake.

Beginning at Pigeon river, in the north-western extremity of the lake, we find, according to Professor Mather, a mass of granite forming the eastern extremity of the peninsula, where it appears in high ridges. It is composed of the two minerals, red feldspar and quartz, closely aggregated, and is traversed by heavy dykes of greenstone, and veins of quartz and calc-spar, containing the bi-sulphuret of iron.

A range, according to Mr. Logan, commences at Fort William, and, keeping north of the Kaministiquia river, is prolonged in a north-easterly direction, flanked on either side by beds of gneiss and chlorite slate. It intersects the coast about ten miles below the mouth of the stream, and is seen at intervals along the shore, for a considerable distance; it then recedes inland, and, crossing the isthmus between Thunder and Black bays, regains the water, about nine miles from the bight of the latter, in a spur terminating at Granite islet. The main range is protracted in a northerly direction, intersecting the Neepigon river some distance above the second rapid, and again approaches the lake near the mouth of Jack river, which falls into a deeply-indented cove in Neepigon bay. Farther on, it emerges from the overlying sandstone and trap, and appears on the bay at a point a little west of north from the entrance to the Chenal Ecarté—the strait between Simpson's island and St. Ignace. Cutting across a projecting point of sand, it forms a bold, rocky coast, crowned by occasional masses of trap, along the north side of Grand Detroit, as far as Les Petits Ecrits, where it is intersected by trap dykes, running in an easterly and westerly direction.

In the north-eastern extremity of the lake, the coast from Pic river to Otter Cove is formed by a gneissoid rock, which a few miles inland attains, according to Bayfield, an elevation of eight hundred feet above the lake. From Otter Cove to Michipicoten river, the coast is occupied by alternate reaches of granite and slate.

With the exception of a few square miles of trap at Gargantua, granite and gneiss are the only rocks exposed along the shore until we arrive in the vicinity of Pointe aux Mines, a distance of about fifty miles, at the extremity of which they separate from the shore, maintaining a nearly straight south-easterly line across the eastern part of Batcheewauaung Bay, leaving the trap of Mamainse between them and the lake. Thence, they strike the northern part of Goulais Bay, and finally attain the promontory of Gros Cap, where they form a moderately bold range of hills, running eastwardly towards Lake Huron.*

With regard to the composition of this rock, Mr. Logan remarks, that the base is granite occasionally passing into syenite by the addition of hornblende; but the latter does not appear to be often present wholly without the mica. Both the mica and hornblende are, in general, black, the quartz, either opake or translucent-white, or colorless, or transparent. The color of the feldspar is usually some shade of red, and, being the prevailing mineral, gives in most cases a reddish tinge to the mass.

GRANITIC ROCKS OF THE SOUTHERN SHORE.

Crossing over to the southern shore, we find the coast intersected at rare intervals, by granite masses. Between Huron Bay and Carp river, a few points composed of this rock are observed, generally connected with the main-land by a neck of sandstone—as for instance, at Granite Point, and Dead river. There are several islands in this vicinity composed in the main of granite; but, on the lee-side, patches of sandstone are seen, which have escaped the general denudation to which this region has been subjected. The Huron islands, according to Mr. Hill's observations, rise from eighty to one hundred feet above the lake, and are composed of granite. It is not improbable that, at no very remote epoch, they were connected with the main shore by a neck of sandstone, as is seen at this time at Granite Point.

The surface of these islands is bare and polished, and traversed by numerous striæ, bearing N. 20° E. and S. 20° W. Nowhere on the southern coast, have we seen these evidences of the drift epoch so well defined. It is only in the fissures of the rock that trees take root and grow with a stinted growth, and hence these islands present an inhospitable appearance. This granite, unlike most of that found on the southern shore, contains considerable mica, and is intersected by several systems of joints cutting it into tabular plates, which will materially aid the quarry-man in his labors. It affords admirable materials for construction, and the day may not be far distant when quarries will be opened to supply the cities of the lakes. The rock may be quarried almost by the water's edge, and vessels can approach within a few yards and be protected from every wind.

Granite island is a nearly bare mass of rock—comprising an area of two or three hundred square feet—on the top of which a few straggling cedars maintain a sickly growth. It is situated about six miles from the main-land, and three or four degrees east of north from Granite Point.

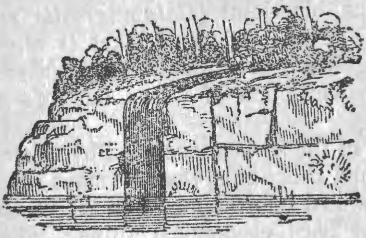
Middle island also belongs to this class of formations. The granite consists of the binary compound of feldspar and quartz. Powerful dykes of greenstone intersect the mass, some of which are ninety feet in width, and we counted no less than six within the distance of forty rods.

They cut the granite in remarkably straight lines, (see Fig. 4,) leaving clean, smooth edges, as though the shock by which the original fissures were formed, had been suddenly applied. In the smaller dykes, the greenstone is very compact and fine-grained; but in the larger, while it exhibits this texture near the edges, towards the centre it becomes highly crystal-

* Canada Report for 1846–47, p. 22 *Et Seq.*

line,—differences which may have resulted from the relative slowness, or rapidity, with which portions of the mass parted with their heat, in the process of consolidation. There are two systems of dykes; one set bears nearly east and west, while the other bears north-east and south-west; these, in their turn, are intersected by veins of quartz, as seen on the northern side of the island. The contour of the mass is rounded, and nu

Fig. 4.



Greenstone Dyke at Middle Island.

merous deep striæ, some of which are two feet in depth and four feet in width, were observed, bearing N. 20° W., S. 20° E.

Several granite islets appear off Presqu'isle, but as they differ in no respect in structure from Middle island, a farther description is deemed unnecessary.

These islands are but the outliers of a mass which, in our district, is spread over an area of more than 2000 square miles. It has an extremely irregular outline, which cannot well be defined by a verbal description. The reader, therefore, is referred to the general Map of the region for a representation of its boundaries.

Granite forms the coast between Presqu'isle and Granite Point. Proceeding westwardly, it expands rapidly until it attains a width of twenty-five miles—a spur shooting off to the north-west, known as the Huron mountains—and, after having passed the Machi-gummi, contracts equally rapidly, and terminates on the sources of the Sturgeon river. The extreme length of this granite axis is about sixty miles, and its culminating points rise 1200 feet above the lake.

Another granite boss rises to the south of that above described, and ranges in a nearly parallel direction for about thirty-six miles. The interval between them is from twelve to fifteen miles in width, occupied by crystalline schists, marbles, beds of quartz, and specular iron.

Farther west, another granite belt starts from the head waters of the Ontonagon river, and thence extends to the western limits of the district, intersecting the head of Agogebic lake, and crossing the Montreal river about fifteen miles from its mouth. Southward, it forms the water-shed between the rivers of Lake Superior and the Mississippi, and passes beyond the limits of this district into Wisconsin. It is probable that this belt is a continuation of that first described, but we have not been able to trace the continuity. There is an interval of twenty miles, where the surface of the country becomes nearly horizontal, and is strown with accumulations of clay and gravel, burying up the subjacent rocks.

There are, also, numerous, insulated patches of granite scattered through the crystalline schists, the positions of which are indicated on the accompanying map.

The granite, for the most part, forms numerous parallel ridges, bearing east and west, which are rounded and featureless. The rocks rarely emerge to the surface in mural escarpments, but are concealed by the debris of ages. Dense forests of maple and yellow birch, interspersed with pine and hemlock, clothe the ridges, while the intervals are occupied by almost impassable marshes, filled with tamarack, cedar, and alder, or by natural meadows, in which the blue-joint (*Calamagrostis canadensis*) flourishes with rank luxuriance. A chain of small lakes is often observed, hemmed in by the parallel ridges, whose outlet is through some tranverse gorge, formed, not by the erosive action of water, but by a fissure in the rocky barrier.

The greater portion of the surface occupied by this class of rocks has not yet been sub-divided, and hence it is, that the maps representing its area are so deficient in topographical information. Of the whole district, the granitic region possesses the least economical value. There appear to be no metallic veins worthy of exploration, and from the broken and rugged character of the surface, it is ill adapted to agricultural purposes. Besides, its remoteness from navigable water will retard its immediate settlement.

Local Details.—We do not propose to make a transcript of our note-books. Such a transcript would encumber the report with unnecessary details, and serve no useful purpose. We shall extract such portions only as illustrate some interesting problem in geology, or furnish facts of economical value. Sections extending through the different systems of rocks of this region, possess great uniformity, wherever taken, and their multiplication would throw little additional light upon its geological structure. We shall, therefore, content ourselves with a few illustrations of this nature.

Besides, in a region so vast as this, where the physical obstructions to its successful exploration are so formidable, it has been found impossible, with the means placed at our disposal, to make but little more than a general reconnoissance. We have only attempted to delineate its more prominent features, while to those who succeed us, we leave the more difficult task of sketching in the individual lineaments. That task cannot be successfully executed, until the country shall become intersected by roads and dotted with human habitations; until portions of the forests, which now cover the whole surface, become levelled by the axe, and the underlying rocks exposed in pits and quarries. Practical geologists alone can appreciate the aid afforded by these artificial excavations. It is not from wandering over the hills, or drift-covered plains, that he arrives at the structural relations of a country; but, by following up the beds of small streams, where the superficial covering has been removed, by examining quarries, where the fresh surfaces of the rocks are exposed to the day, and by scrutinizing the materials thrown out from wells and pits.

The subjoined section will serve to illustrate the order of position in the different groups of rocks, between Lake Superior and Lake Michigan. It commences on the township line between ranges 36 and 38, and extends thence, in a southerly direction to the mouth of the Escanāba river, a distance of about seventy miles.

Fig. 5. *Section from the mouth of Garlic River, Lake Superior, to the mouth of the Escanāba River, Lake Michigan. Distance,—Seventy Miles.*

Proceeding inland from the shore of Lake Superior, our route for the first six miles is over low, marshy ground, supposed to be underlaid by the Potsdam sandstone, in a nearly horizontal position. Occasionally vestiges of ancient terraces are observed, indicating the former boundaries of the lake. Where the sandstone is exposed by the lake shore, it is of a dark-red color, and contains numerous white blotches, like those at Tobacco river and Granite Point. A low granite ridge is first observed, according to Mr. Hill, a mile west of the corner of sections 34 and 33, along the south boundary of township 50, range 26. Fragments of slate are seen at its base, so that it is not improbable that a portion of the azoic system is interposed, at this point, as at many others, between the granite and the Potsdam sandstone. In section 1, along the east boundary of township 49, range 27, a ridge of granite four hundred and seventy-two feet in height is observed, bearing N. 20° E. It consists for the most part of the ternary compound of feldspar, quartz and mica, differing in this respect from that seen by the lake shore. Hornblende occasionally replaces the mica, forming syenite, the prevailing color being light-grey. Powerful dykes of greenstone traverse the mass in a direction parallel to its prolongation. There are also seen numerous granite veins, seldom exceeding eight inches in width, ramifying through the granite, and occasionally through the greenstone. Mica is more abundantly disseminated through these veins than in the adjoining walls, — an interesting fact, since it tends to confirm its volcanic origin; for this substance has been detected not only in the ancient basalts but in the products of existing volcanoes. Gneiss is observed to flank the granite both on the north and on the south, with intercalated beds of quartz and feldspar, and imperfectly laminated hornblende,—the whole dipping uniformly from the axis of elevation. These might with propriety be regarded as the more highly metamorphosed portions of the azoic system.

On section 7, another range of granite is passed, four hundred and ninety feet in height, bearing nearly east and west, which rises rapidly to the westward of the line of section; but to the eastward verges to a level. Gneiss is seen along its flanks to near the summit, which consists of a dark-colored, crystalline mass.

In section 18, numerous low ridges of granite occur, flanked by gneiss and hornblende.

Near the north line of section 19, a ridge of granite is seen which attains an altitude of seven hundred and seventy feet, and bears nearly east and west, with gneiss and slaty hornblende along its slopes. The greater portion of the line through this section passes over hornblende slate; but, near the southern boundary, the granite breaks through the incumbent rocks and rises to the height of eight hundred and sixty-seven feet above the lake. The mass consists of feldspar, quartz and black mica, the latter so far predominating as to communicate to it a dark color.

We here reach the boundary between the igneous and the metamorphic rocks, and it will be seen that as we recede from that line, the rocks become less crystalline in their texture and exhibit more distinct traces of bedding. The gneiss, the compact hornblende, and the quartz and feldspar rocks, exhibiting a massive structure, will be found passing into, or succeeded by, beds of argillaceous, talcose and chlorite slate; and quartzose rocks, enveloping pebbles and displaying obscure lines of stratification.

To the south of the last described ridge, along the western boundary of section 30, the line passes over hornblende rocks somewhat fissile, containing seams of quartz conformable in dip and bearing to the enclosing mass. About one-fourth of a mile south of the northern boundary of township 48, the talcose slates, with planes of bedding, are seen for the first time. The surface here attains an altitude of 1004 feet, which is higher than any of the granite ridges along the line of the section. The valley of Dead river sinks down nearly seven hundred feet, and the underlying rock consists apparently of talcose and argillaceous slates. To the south, in sections 13 and 24, hornblende slates reäppear and occupy a width of about a mile and a half. In section 24, they are succeeded by talcose slates; but, in section 25, the hornblende slates are again observed, and there is no marked change in the rocks until we arrive in section 36, when the talcose schists reäppear, dipping to the south at an angle of 68°.

About a fourth of a mile north of Teal lake, a quartz range is intersected, bearing nearly east and west, which forms one of the most striking topographical features of the country. Its altitude is nine hundred and forty-four feet above the level of Lake Superior, and throughout its entire range, it rises sharp and well-defined. The quartz exhibits imperfect lines of bedding, and displays a slightly granular texture. Beneath this is a bed of novaculite ten feet in thickness, which possesses a fine grit and affords an admirable material for hones. To this succeed talcose slates, the whole dipping 66° to the south.

In section 32, township 48, range 26, a quartzose conglomerate is observed ten feet in thickness, the included pebbles consisting of quartz from the size of a buck-shot to that of a hen's egg.

A few yards to the south-west of the Jackson Company's Forge, this same quartzose conglomerate is seen; but the pebbles do not attain so large a size.

These beds, although greatly transformed by reason of their proximity to igneous rocks, still retain traces of their mechanical origin.

Not far from the southern margin of Teal lake, there rises a range of hills composed of dark-colored and compact hornblende rocks, which here forms the "divortia aquarum" between the river systems of the two great lakes. The sources of the Escanaba approach within a quarter of a mile of Teal lake, which is drained by the Carp river of Lake Superior.

In following the line of our section to the southward, still continuing between ranges 26 and 27, we find a belt of about five miles in width, extending to near the north-east corner of section 36, township 47, range 27, occupied by the slates of the azoic series, and the intercalated beds of trappean rock. The latter, however, largely predominate in apparent thickness, the ridges being numerous, and mostly of a dark-green hornblendic trap. Near the line between sections 1 and 12, a ridge of green crystalline trap occurs, flanked on the south by hornblende slates, somewhat talcose in their composition, and dipping to the south at an angle of 65°. A mile farther south, the country gradually rises, with alternate ridges of trappean rock, and bands of hornblende slates, which have a finely schistose structure.

On the north side of section 13, the slates become more silicious, and stand nearly vertically; and, then again, are suceeeded by low ridges and rounded crests of a hard, compact, greenish, trappean rock. At the corner between sections 13 and 24, the hornblende slates are highly impregnated with oxide of iron, which occasionally forms quite pure bands in the slaty rock. The ground continues elevated along the eastern line of section 13, being about 1000 feet above Lake Superior, and is partially covered by drift; two miles farther west, however, the rock is exposed along the whole length of the line between sections 14 and 15, and presents a constant succession of steep ridges of a dark and crystalline greenstone, no slates being visible in the depression between the ridges. Near the corner of sections 24 and 25, we find an abundance of angular fragments of slaty hornblende-rock, containing iron, and masses of quartz, with specular iron. These rocks rise into a dome-shaped protuberance a little to the east of the line of section 25, and have, here, an elevation of about 1200 feet above Lake Superior. The slaty rocks are so impregnated with iron, at this point, as to become very good ores.

On the line between sections 29 and 32, is a remarkable knob of conglomerate, alike interesting from the fact that such a form of rock is of rare occurrence among the azoic series of this district, and from its intimate connection with the origin of the masses of iron in its vicinity. The conglomerate forms here an isolated, rounded elevation rising at least a hundred feet above the general level. It is made up of coarse blocks of various sorts which belong to the neighboring trappean and slaty beds, and are o very considerable dimensions. Among them we recognized, not only fragments of the rock associated with the iron; but masses of the iron itself, and of the banded and jaspery varieties. Most of the fragments of this remarkable breccia are but slightly rounded and worn on their edges, having in this respect much more the appearance of a friction-conglomerate than of one in which the long-continued action of water had played a part The blocks are cemented together by a very hard, ferruginous paste. The nature of the surrounding country, covered with soil and forest-trees, prevented us from satisfactorily tracing its connection with the adjoining rocks. We are inclined, however, to regard it as connected with the eruption of the adjacent granite, and rather as the effect of the crushing and elevating forces which such an elevation must have called into play. If this is the case, it may be considered as analogous in its mode of formation to the conglomerates of Keweenaw Point. A fact worthy of notice in this connection is, that, in spite of the heterogeneous structure of the mass, it exhibits a distinct tendency to separate, or flake off, in thick concentric layers, like some eruptive granites.

The nature of the fragments composing this breccia, and of the cement by which they are united, proves conclusively that the process of formation of the ores of iron, and the impregnation of the slaty rocks with metallic matter, must have been one of long continuance, and not a merely momentary operation. The various kinds of ore must have been in existence before the formation of this mass, but they were subsequently broken off and mingled together in confusion. Emanations of metallic matter must still have been issuing from beneath, since we find the whole deposit thoroughly impregnated with it, and converted into one firmly coherent mass.

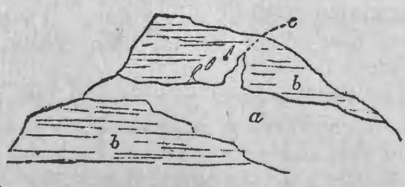
Near the south-eastern corner of section 25, (township 47, range 27,) we reach the southern boundary of the slaty and trappean rocks, and strike the belt of granite which intervenes between them and the Potsdam sandstone, on the south side of the axis. The width of the granitic belt along this line of section is about ten miles, since it extends south as far as the centre of township 45, where it was first seen in place by Mr. Hall, in ascending the Escanāba. The height of the land at the point of junction of the granite and slates, is about six hundred and fifty feet above Lake Superior.

The whole surface covered by this belt of granite is low and swampy, the rock rising out of the ground in narrow and precipitous ridges, a number of which are crossed by this line of section. They vary from twenty to fifty feet in height above the adjacent surface, and have an elevation of from six to seven hundred feet above Lake Superior. These ridges frequently present almost vertical and bare walls on both sides; and the desolate and forbidding character of the region, consisting mainly of low and tangled swamps, and barren ridges, can hardly be exaggerated.

The mineralogical constituents of the granite, on this side of the axis, are mainly reddish feldspar and quartz, with but little mica.

At the junction of the granite with the azoic slates on the southern side, the relation of the former to the latter is clearly seen. The slaty rocks are traversed by injected veins of granite, which gradually increase in number and dimensions as we approach the granitic nucleus. On an almost vertical wall of rock, about forty feet in height, near the south-east

Fig. 6.



a. Granite. *b.* Hornblende-slate. *c.* Vein of granite.

corner of section 25, (township 47, range 27,) the granite is seen penetrating the hornblende-slate like an immense wedge, and shooting out in ramifying branches. The preceding figure (Fig. 6,) shows the appearance of the two rocks at this place.

Around the portion of the granitic mass, indicated by the letter c, the slaty rock has all the appearance of having been bent and twisted by the injection of the granite vein. The following figure (Fig. 7,) represents this portion of the rock on a larger scale than the preceding:

Fig. 7.

This contorted structure seems to be due, not to an actual crowding back of the schistose rock, but rather to a rëarrangement of its particles, occasioned by the presence of the granitic mass.

Section from Keweenaw Bay to the mouth of the Menomonee. (*See General Section.*)—In ascending the first granite axis back of Keweenaw bay, its northern limits are observed to extend to within two miles of the boundary between townships 48 and 49, range 33, approaching within six miles of the lake shore. It is exposed in a mural cliff facing the south, about thirty feet high; it is of a light-grey color, and composed of an infinite number of crystalline plates, confusedly aggregated, in which the three constituents feldspar, quartz and mica, may be recognized. The altitude of this ridge is 1064 feet above Lake Superior. Descending into a longitudinal valley, the granite is occasionally exposed in low ledges, having a rounded form. Crossing the range line, it rëappears in a cliff fifteen or twenty feet in height, traversed by numerous and remarkably regular divisional lines. At the outlet of a small lake which is one of the reservoirs of Sturgeon river—near the east part of township 49, range 33—it is again seen, under the form of well-characterized syenite. Near the centre of township 49, range 33, we ascended an abrupt ridge, three hundred feet above the surrounding level, composed of rose-colored feldspar and quartz, and traversed by numerous veins of quartz and chlorite. Syenite rëappears along the north line of township 48, range 32. A mile farther south the granite rises to the height of 1198 feet above Lake Superior, forming the culminating point of this region. The southern boundary of this belt, which is here about ten miles in width, occurs north of Sagiagāns.

One of the sources of the Sturgeon river crosses this belt twice in this vicinity. It rises near the northern group of azoic slates and, flowing south, cuts through the main axis and sweeps around its base; then recrosses it, traversing the whole belt in a northwesterly direction. The course of this stream has probably been determined by transverse fissures extending across the entire axis.

The granite, it will be seen, forms a series of parallel ridges, bearing nearly east and west. The gentler slopes verge towards the north, while the precipitous escarpments front the south. The longitudinal valleys contain numerous natural meadows, or small wet prairies, destitute of trees and clothed with a rank growth of blue-joint grass. They appear to have been the beds of ancient lakes which have been filled by the débris of the surrounding hills, or drained by the abrasion of their former barriers. The prevailing growth on the ridges is maple, yellow birch and ash, interspersed with colossal pines, sometimes one hundred and fifty feet in height and six feet in diameter. The low grounds are occupied by dense thickets of alder, cedar and spruce, which are hung with long festoons of moss.

The second granite axis, where it crosses the Machi-gāmig (township 45, range 29,) is much contracted in dimensions, being only about five miles in width, and attaining but a slight elevation above the surrounding country. It consists of quartz and feldspar in large crystals, presenting, in many places, the aspect of graphic granite. In crossing portage No. 5, it is seen in low ridges running east and west, having a rounded contour. Mr. Hill explored this zone further east, and from his notes we gather the following information.

Starting on the line between ranges 28 and 29, in township 43, and proceeding north, he describes the country as low and marshy, and so thoroughly covered with transported materials that the underlying rocks are almost entirely concealed. The line of junction between the granite and sandstone was not observed; but is supposed to occur near the northern part of the township, since here, for the first time, loose blocks of sandstone were noticed, which were supposed to have been derived from the immediate vicinity. The granite is first observed on the line between sections 13 and 12, in a low exposure. Near the south-east corner of section 36, township 44, a low, rounded ledge is seen, rising up through the surrounding swamp. Along this line, through the whole township, frequent exposures of this character are observed.

The southern portion of township 45, range 29, is low and marshy; but the northern portion is broken, and the granite appears in numerous knobs and ridges. In sections 1, 11 and 12, dykes of greenstone are seen to cut the granite in numerous places. In section 13, a large dyke occurs, bearing east and west, and varying but little from a perpendicular in its downward course. Its mineral components are hornblende and feldspar intimately mixed, with crystals of glassy feldspar disseminated.

There seem to be, according to the observations of Mr. Hill, two general systems of dykes in this region, though subject to minor deviations; one bears N. from 70° to 80° W., the other N. 10° E. The east and west dykes are the main ones, being the widest, longest and best defined. Lines of division were everywhere noticed, one set bearing N. 75° or 80° W. and another from S. 10° E. to S. 10° W.

Near the north boundary of township 46, range 28, gneiss is seen supported by granite on the south: on sections 3 and 4, heavy dykes of greenstone, ranging east and west, traverse the mass. Some chlorite slate is seen between sections 46 and 47, where the Escanāba river crosses the line, flanking the hornblende ridges to the east and north.

Along the line between sections 27 and 28, township 47, and in sections 30 and 31, the granite is traversed by two greenstone dykes, bearing east and west, each of which is nearly eight hundred feet in width, composed of a base of compact hornblende and feldspar, with glassy crystals of the latter disseminated. The granite in this vicinity consists of a highly crystalline compound of feldspar and quartz, with an occasional admixture of hornblende.

On following the granite region westwardly from the Escanaba river, where it crosses township 46, range 27 and 28, we find it possessing nearly the same mineralogical character, and similar in its mode of occurrence to that already described. This belt of igneous rock crosses the Machi-gamig river in township 46, range 29, and pursues a westerly course, bending to the southward, for about twelve miles to the west of that stream. Beyond this point, it can no longer be traced, except in occasional knobs and ridges which rise out of the predominating slaty rocks.

There are numerous intrusive masses of granite scattered through the azoic series of the southern portion of the district; indeed, so numerous are the successions, and so complicated the relations of the two rocks with the accompanying trappean belts, and so great the diversity of character, that it would require much more time than we were able to devote to this part of the region, even under the most favourable circumstances of exposure of the rocks, to make out its detailed structure. We must content ourselves, therefore, with a general outline of the most conspicuous points.

The granite rises in low ridges from amidst the talcose, hornblende, and chlorite slates, in townships 41, 42, 43 and 44, through the whole district westward to 45. It is more quartzose than in the northern townships; mica is generally present in small quantity, and often arranged in parallel layers, so that the mass assumes a gneissoid structure. This mineral is generally very dark-colored, sometimes black, and, for the most part, occurs in minute plates.

In the extreme western portion of the district, west of range 40, granite is the predominating rock below the southern boundary of township 47, and is associated with a hornblende-rock, which sometimes assumes a slaty structure. The granite is mostly a binary compound of feldspar and quartz, the former largely predominating, and giving a reddish tinge to the whole rock; mica is present only in very small quantity, while hornblende and chlorite are occasionally scattered in minute particles through it. Nearly the whole of the granitic region in this part of the district presents the most forbidding and desolate aspect. Though it forms the most elevated portion of the country, being the water-shed between Lake Superior and the Mississippi, it is low and swampy, and filled with numerous lakes, of which over fifty were crossed by Mr. Burt, in surveying the boundary-line between Lac Vieux Desert and the Montreal river. There are occasional elevations, which are dry, and wooded with sugar-maple, and which, undoubtedly, are covered with a good soil; but, the larger portion of the region presents almost interminable cedar-swamps, in the midst of which the granite and hornblende ridges rise, with precipitous walls, rarely to more than fifty feet in height above the surrounding country. These ridges are generally very narrow, and their sides are covered with a thick coating of moss and lichens. Nothing can exceed the desolate solitude of this region. Not even the Indian traverses it; it is destitute of game, and its stillness is never broken, except by the crashing of the tornado through the dense forest, tearing up the trees, and piling them together, so as to present an almost impassable barrier, as if still farther to repel the intrusion of man into a region, so little fitted for his reception.

The granite of the whole of this portion of the district is very coarse-grained and crystalline, and is characterized by a predominance of feldspar, and an almost entire absence of mica.

Age of the Granites.—The granites of the Lake Superior region evidently belong to two different epochs of upheaval. That of the north-western coast of the lake, in the vicinity of Pigeon river, was elevated before the close of the azoic period, since the upper portion of the slates reposes horizontally around it; while that of the north-eastern coast, and that which forms the axis between the river systems of the two lakes, was elevated after the termination of the azoic period, and before the dawn of the Silurian, since the granite has disturbed the upper beds of slates, while the lower beds of the Potsdam sandstone rest undisturbed around it.

Mineralogical Composition of the Granite.—The granite, south of the belt of azoic rocks in township 46, ranges 25, 26, 27, and 28, is generally made up of feldspar and quartz, mica being almost always wanting, or only present in very small quantity. The feldspar is by far the predominating mineral; in fact, whole ledges in the granitic region are composed almost wholly of it. It has generally a pale, flesh-red color. On the west side of section 30, township 47, range 27, occurs a beautiful granite, made up principally of large tabular masses of red feldspar, with a little milky quartz, and occasionally a few specks of chlorite.

Of the feldspar an analysis was made, to acquire a more definite knowledge of the nature of the alkalies present in this mineral associated with the granite. This analysis gave on 2.0709 grammes of the substance, carefully dried at 100° C.

		Oxygen.
Silica	66.70	34.66
Alumina and a little iron	18.68	8.64
Lime	.30	
Potash	9.57	2.53
Soda	3.58	
Water	.70	.62
	99.53	

This is, as will be seen from the ratio of the oxygen of the silica of the bases, the common feldspar, (orthoclase,) in which the oxygen ratio of the protoxide bases, the peroxide bases, and the silica, is 1 : 3 : 12.

The water is undoubtedly in chemical combination in the mineral, playing the part of a base. All the feldspars which we have examined, contain more or less water, from one-half to one per cent., which water is not removed by drying, at a temperature of 100° to 120° C.; but which requires a full red heat for its expulsion.

Economic Value of the Granites.—Many of the feldspathic varieties which occur in the interior readily disintegrate on exposure, and are ill-adapted to building purposes. Besides, their remoteness from water communication would prevent their extensive use.

There are numerous ledges of almost pure feldspar in this region, which might be advantageously employed in the manufacture of porcelain ware, were they nearer to a manufacturing region.

The granite of the Huron islands, as before remarked, is admirably adapted to the purposes of construction, separating readily into large tabular masses, and resisting the action of atmospheric agents.

Trappean Rocks. — In the preceding chapter, we have described, with some minuteness, the interlaminated masses of igneous rocks which occur in connection with the slates, throughout their entire range; and, in the present chapter, have noted the occurrence of different systems of dykes traversing the granite. It is, therefore, deemed unnecessary to enter into farther details as to their mode of occurrence, or their range and extent. In a subsequent chapter, will be found the results of a chemical examination of many of these igneous products.

From the commencement to the termination of the azoic period, as indicated by the presence of these igneous products, the primeval crust was subject to constantly recurring convulsive movements, manifested under far different conditions, and with far greater intensity, than what we now behold, even in those districts which are the foci of the volcano and the earthquake. Sometimes the molten materials rose through the deeply-seated fissures in long lines of elevation, again they cut through the incumbent strata in the form of dykes, and again flowed over the surface in lava-like sheets.

Accustomed as we are at this day to witness the calm operations of nature, — operations apparently controlled by fixed and uniform laws, and rarely invaded by catastrophes, — we find it difficult fully to appreciate the turbulence which characterized this period of transition, when first the crust emerged from the watery abyss, and assumed the distinctive forms of continents and islands.

CHAPTER IV.

THE IRON ORES AND ASSOCIATED ROCKS.

Reference to the General Map and Section as to the Extent and Charac of the Iron-bearing Rocks.— Map of the Iron Region.— General D tribution of the Localities of Iron.— Description of particular Depos — The Iron Cascade.— Jackson Company's Location.— The Clevel Location.— The Iron Beds of the Machi-gamig.— Near the Menomo River.— Occurrence of the Ores of Iron in other Districts.— In Sc dinavia.— On the Island of Elba.— In the Ural Mountains.— In Mi souri.— In northern New York.— In Massachusetts and Canada Ea — Theoretical Considerations.— Resumè.

Having, in the preceding chapters, given a description of the geologic relations of the azoic system, we now proceed to consider the mode in whi the iron ores are associated with that system; and, in order to illustrate mo fully many of the phenomena exhibited in this district, we shall refer some of the principal deposits of a similar character, in other portions the earth.

The extent and boundaries of the azoic system, of which these depos constitute a part, have been fully set forth in the preceding chapters.- They are, also, delineated on the general map of the district; while, on t general section, the relations of the different groups, one to another, a portrayed. On the map of the district between Keweenaw Bay and Ch colate river, we have indicated the most important and valuable beds of or by an appropriate symbol, thus (♁).

From the results of our examinations, it will be seen that this district unprecedently rich in the specular and magnetic oxides of iron, and tha so far as relates to the magnitude of the masses and the purity of the ores it stands unrivalled.

Thus far, the principal deposits have been found connected with a be of crystalline schists and intercalated trappean rocks, bounded on eithe side, by a belt of granite. This belt extends in an easterly and wester direction for more than thirty miles, and, in its widest expansion, exceed eight miles.

Proceeding south, for forty miles, along the eastern limits of the azoi system, there are numerous evidences of the existence of these ores, bu nowhere are they observed to be developed on a scale of such magnitude or in such a state of purity, as those of the belt first alluded to.

The physical obstacles are not of such a character as to interpose formidable barrier to the successful working of these mines. Elevated from eight hundred to twelve hundred feet above the lake, the ground affords gradual and easy descent; the streams furnish an unlimited amount of wat power for the propulsion of machinery, and the magnificent forests of yello birch and maple will yield an ample supply of charcoal for the reduction the ores; while, at the landing by the lake shore, the lee of Little Presqu'isl forms a shelter for vessels in all but north-east storms. The cities along the shores of the lower lakes will, at all times, afford a market for these products, whether wrought into the finer varieties of bar iron and steel, or in the form of blooms and pigs. When we consider the natural advantages which these localities present, it seems reasonable to suppose, that the day is not distant, when the fabrication of iron will be successfully and extensively prosecuted in this region.

GENERAL DISTRIBUTION OF THE ORES OF IRON.

Starting from the shore of Lake Superior, near the mouth of Carp river, and proceeding westwardly, near the line between townships 47 and 48, we strike the first deposit of iron in the north-east corner of section 1, in township 47, range 27. This is distant about twelve miles from the lake shore, and, so far as we know, is the most accessible point to navigable water. Throughout the northern, and especially the north-eastern, portion of this township, the iron ores exist in inexhaustible quantity, and under conditions favorable to their development.

The only township which, in point of accessibility, and in the abundance and purity of these ores, compares with that just mentioned, is that adjoining on the east, (township 47, range 26.) Here, however, the deposits, thus far discovered, are situated near its southern boundary; and, although in reality a litle nearer the lake than those before alluded to, they are inferior in the purity of the ore.

In townships 47, range 28, but few deposits of iron are known to exist, the surface being comparatively low and covered with drift. One or two quarter sections on the northern boundary have been marked with the symbol of iron (♂), in accordance with the notes of the linear surveyors, though we failed to find any beds of value. On the northern side of section 18, in this township, we found specimens which indicated the existence of ore of a good quality in the neighborhood.

In township 47, range 29, several localities of ore have been observed, in a line nearly due west from the great deposits described as occurring in range 27.

Proceeding still further west, in the next range (townships 48, range 30.) there are abundant traces of iron associated with hornblende rocks, along the northern shore of Machi-gummi, while in the adjoing township south, on section 1, and in the adjoining township east, on sections 6, 7 and 12, on the borders of the Machi-gamig river, these deposits are largely developed and possess a considerable degree of purity.

It is presumed that these ores are prolonged in their range beyond the Machi-gamig, and in fact their existence, to a limited extent, has been ascertained by the linear surveyors; but the general surface of the region is here intersected by few ridges, and covered over with transported materials, effectually concealing the underlying rocks.

Farther west, on the sources of the Bad river, Mr. Whittlesey, while connected with the survey of the Chippewa district, discovered numerous deposits of iron, in the azoic series, and under conditions similar to those which prevail here.

Crossing the Machi-gamig, the belt of azoic schists sweeps to the south and southwest, intersecting the Menomonee river, along the south-western boundary of our district. Throughout this portion of their range, the occurrence of these ores is by no means rare, but they are nowhere develop on such a scale, or exhibit so great a degree of purity, as those in t vicinity of Teal lake; some of the beds, however, are valuable, and ma ultimately be made available. The most southerly deposits are in townsh 40, range 30, a few miles east of the Twin falls on the Menomonee rive and are among the most extensive and valuable in this portion of the distric

When it is remembered that nearly the whole of this region is a unbroken wilderness—without a human habitation, if we except the set tlements along the valley of the Carp, or a trace of the labors of ma if we except the surveyor's lines, or the few blind Indian trails—it seem reasonable to suppose that, at this time, we have but an imperfect idea the extent of these iron-bearing deposits. The more important masse have been discovered; but there are, undoubtedly, subordinate beds, equ in purity, and susceptible of being wrought, which will not be reveale until the axe shall level the forests, or the plough strip off the superfici covering.

From the above sketch of the geographical range of the princip deposits of iron, it will be noticed that, in the belt of azoic rocks as f west as the Machi-gāmig river, they predominate along the northern si of township 47; so that, if we take a line running due east and we between this township and that of 48, for a distance of about eighteen miles in length, we shall find nearly all of the valuable deposits concen trated within a short distance to the north and south of that line. A ten dency to the formation of a similar belt may be noticed along the southe side of township 47, where the azoic schists are in close proximity to th granite.

PARTICULAR LOCALITIES OF ORE.

We now proceed to a more detailed description of some of the mor important iron-deposits of this region. The great similarity which exist among the different localities, renders it unnecessary to describe all whic have been examined in detail; but, as a guide to the explorer, we shal insert in the appendix a table of the sections and quarter-sections on whic iron ores are known to occur.

Township 47, *Range* 26.—The principal deposits of specular and mag netic oxide of iron are on and near the line between sections 27, 28, 2 and 30, and sections 31, 32, 33 and 34; they are arranged in a meta liferous belt, bearing nearly east and west. In section 31, the iron ore i finely displayed in the bed, and along the banks, of a small stream whic is one of the sources of the Escanāba river. At one point, it is precipi tated over a ledge of this ore, from a height of 27 feet, to which fall we have given the name of the "Iron Cascade." The stream is of sufficien size to furnish water-power, in case a forge should be established here.

This ore is a peroxide of iron, mixed with considerable silicious matte (see analysis,) and seems to exhibit indistinct lines of bedding which di at a high angle, and are intersected, at nearly right angles, by joints whic cut the mass into large tabular blocks. The quantity of the ore is evi dently very great, even at this one locality; but its limits and thickness coul not be ascertained, owing to the heavy accumulations of drift which line the stream on either side above the cascade, forming steep banks some fifty feet in height.

Proceeding eastward, we find, at the north-east corner of the section, and along the section line for the distance of a mile or two, at various points, the apparent prolongation of the same metalliferous band; but differing in character from that just described. The ore resembles the banded, jaspery deposit, on sections 10 and 11 of the same township, in the next range westerly, known as the Cleveland location. In fact, throughout the whole extent of the azoic series, up to the granite, which makes its appearance a little north of the south line of the township,—the line of demarcation running nearly east and west along the whole of the township,—the slaty rocks are so associated with the iron, that it is evident some great, general cause has operated throughout their whole extent to impregnate the entire mass with this metal. The relation of the schistose rocks and the associated ore may be seen from the following section, (Fig. 8,) near the north-east corner of section 31:

Fig. 8.

a is a compact, quartzose mass, highly charged with peroxide of iron, so as to be perfectly black, although distinct grains of quartz can be easily recognized in it.

b is a somewhat slaty rock, resembling hornblende slate, also impregnated with iron, which occasionally forms in it bands of quite pure ore, and in some places alternates with jaspery matter, as at numerous other localities.

The presence of the peroxide of iron, in two adjacent rocks of so different mineralogical composition, proves that its diffusion through them must be ascribed to some general cause, quite independent of the nature of the rock itself.

We do not regard these ores as equal in value to the purely eruptive ones: an abundance, however, may be obtained, which will probably yield as high as forty, or fifty, per cent of metallic iron.

Along the line between sections 32 and 33, near the junction of the azoic schists with the granite, the relations of the iron and the slaty and quartzose rocks are finely displayed, in a ravine which extends for a considerable distance to the east and west of this line. The phenomena, here, are of the most complicated and interesting character. On the north side of the ravine, we have the slaty and quartzose rocks dipping at a high angle to the north, and presenting a great variety of mineralogical structure. Quartzose bands, composed of fine grains of silicious matter, impregnated with peroxide of iron, with occasional wide bands of pure ore, alternate with a hornblende rock, having a schistose structure, and equally charged with ferruginous matter. The whole appearance of the mass is that of a series of beds of quartzose and hornblendic matter, thoroughly impregnated with iron and greatly disturbed, and changed from their original structure and position. On the south side of the ravine, at a distance of a couple of hundred feet, a complicated succession of trappean and granitic belts, crossed by numerous veins of igneous rock, is presented. Here, however the rock is no longer charged with iron.

Township 47, *Range* 27.—Here, the deposits of iron, as before stated, are displayed on a grander scale than in any other portion of the district, and merit a special description; since they are not only preëminent in quantity and purity, but are situated so favorably with regard to facility of working and proximity to the lake shore.

The location of the Jackson Company embraces section 1, of the above township; but their forges are situated in township 48, range 26, near the corner of sections 28, 29, 32 and 33 on Carp river, which affords excellent water-power.

The ferriferous band here forms a ridge about a thousand feet in width, and from a few feet to fifty in height, above the general level of the surrounding country, and can be traced almost continuously across the section in an easterly and westerly direction. On the northern side of the belt, the ore is compact, and of great purity; near the centre it exhibits a banded structure, while, to the south, it passes again into the compact variety. The annexed section (Fig. 9,) by Mr. Hill, will serve to illustrate these changes, and show the connection of the iron with the associated rocks.

Fig. 9

N.  S.

Section of the Jackson Ore Bed. Width 1000 *feet.*

1. Chlorite slate. 2. Compact iron ore. 3. Iron and jasper, in alternating bands. 4. Hornblende and feldspar rock, highly crystalline. 5. Veins of quartz, containing iron glance, cutting the mass.

Thus, it will be seen that this deposit is bounded on the south by a purely igneous rock (4), and on the north by slaty, chloritic beds (1), the dip being about 62° to the north. Towards the centre of the mass, the ore is less pure, and passes into the banded variety. Numerous veins of quartz (5) cut the great mass of ore, and contain specular oxide in large, brilliant plates, which present quite a different appearance from the ore which they traverse.

The character of the ore of this locality is somewhat various at different points; but, in general, it possesses a remarkable degree of purity — for a description and analysis of which, see the chemical composition of the iron ores in the succeeding chapter. The iron has been worked to a limited extent in an open quarry, but there are loose blocks enough scattered along the base of the cliff to supply a furnace for many years.

The same deposit, above described on section 1, continues westerly into section 2; but this latter section is far less valuable. The trappean rocks here form a bold ridge along its northern boundary, being a continuation of the ridge on section 1. In the sections still farther west of this tier nothing of value has been discovered.

In the north-east corner of section 12, next south of section 1, there are evidences of a deposit of iron in the deep red soil and large masses of ore, which lie near the surface on the side of a hill, of which the summit is a crystalline trappean rock. No part of this section, however, has been reported as containing a workable deposit of ore.

In the next adjoining sections west, (10 and 11,) are deposits of ore on a scale of great magnitude; they are, in fact, unrivalled in the abundance and almost absolute purity of the ore. The purest ore occurs in a ridge, or elongated knob, which extends across the line between these two sections, about an eighth of a mile south of their northern boundary. It rises with precipitous walls to the height of at least fifty feet above the surrounding surface, and is made up of an almost chemically pure ore. It exhibits many of the characters of an igneous, eruptive rock, and cannot be regarded in any other light than as a huge lenticular mass, which has been elevated to its present position from beneath, while in a semi-fluid state, exactly in the same way as the trappean ridges which accompany it, and which it so strikingly resembles in general outline and position. The ores of this ridge, though in the highest degree of purity, differ somewhat in appearance at different points. The purest portions are a very compact and fine-grained specular ore, having an imperfect slaty structure, and traversed by joints, like the slates in the neighborhood. Through this fine-grained base are scattered numerous, minute crystals of the magnetic oxide. In other places, the ore is almost entirely made up of an aggregate of crystals of the magnetic oxide, sometimes very minute, and rarely larger than a pin's head. Abundance of ore may be obtained in loose blocks, around the base of the ridge, and of a quality unrivalled for purity, containing between sixty-nine and seventy per cent. of metallic iron. (See analyses of ores from this locality.)

The emanations of metallic matter have penetrated the adjoining slaty rocks in the vicinity of this locality, and filled them with crystals of magnetic oxide and occasional streaks and bands of fine-grained peroxide of iron. The thickness of the mass described above, or its linear extent, cannot be given with accuracy, as its limits are concealed by the heavy covering of drift which extends over the greater portion of this region; but it may be safely stated that this single locality is capable of furnishing an inexhaustible supply of ore; and that, too, without recourse being had to expensive underground mining.

Farther south, we find another deposit of ore crossing the line between the same sections (10 and 11), on a scale of still greater magnitude, though not equal in point of purity, to the ore last described; this is known as the Cleveland location. It rises in the form of an elongated knob, or ridge, to the height of one hundred and eighty feet above the small stream in the valley at its base, and one hundred and fifty-two feet above the drift terrace, over which the road passes near its northern slope. Its height above Lake Superior is 1039 feet, and it forms the culminating point on this line, between the two lakes. This mountain of ore, for such it may be called, is no less remarkable for its magnitude, than for its extraordinary structure. It is made up, as far as it is exposed on its sides, which rise irregularly, and in some places with vertical walls, of alternate bands of pure fine-grained peroxide of iron and of jaspery ore. The thickness of the bands varies from that of a sheet of paper up to one-fourth of an inch. They are not arranged in a constant position, with regard to the general disposition of the mass; but are twisted and contorted in every variety of form and outline; the curvatures are, however, mostly on a very small scale, the radius of curvature in the concentrically folded layers being never as great as one foot in length. The deep-red color of the jaspery portion contrasts admirably with the steel-gray of the less silicious bands; indeed, the singular beauty presented to the eye on stripping off the mossy covering of a vertical wall thus decorated by innumerable, fantastically-interwoven stripes of harmonizing and brilliant colors, can hardly be exaggerated. We know of nothing resembling it elsewhere. This peculiarity of structure, as well as the convolutions, is represented in Plate XXI., Fig. 3.

The width of this deposit of ore cannot be less, at its base, than a thousand feet, and it may be traced for considerably over a mile in length. It is probable that the deposit which occurs on the western line of this section, south of the trail, is a continuation of that just described. It appears in the form of a rounded knob, portions of which are of very pure ore, while in other places, it exhibits the same banded structure as the more easterly portion of the ridge.

In the line of sections next south of 10, 11 and 12, namely, 13, 14 and 15, there is a large quantity of iron at numerous localities; but so far as we have examined them, they are much inferior in quality and purity to those just described. The metallic matter has apparently not been thrown up bodily in a fluid, or semi-fluid, state; but has permeated the slaty, silicious rocks in the form of a sublimation from below, and is, therefore, not pure, being mixed with more or less foreign matter. At the south-eastern corner of section 13, the hornblende slate is thus impregnated with iron, which occasionally forms in it streaks of quite pure ore, but not of any considerable thickness.

The same may be said of numerous localities along the line between sections 13, 14 and 15, and sections 22, 23 and 24. In proportion, however, as we recede to the north, or south, of a band about a mile in width, occupying the northern portion of the township, we find the quantity and purity of the ore deteriorating.

Township 48, *Range* 30.—On the northern shore of Machi-gummi, iron has been observed at several localities, but it possesses no great purity. It is associated with compact hornblende and feldspar rocks, which may be eruptive in their origin. In some instances, it occurs in slates, when it partakes of the laminated structure characteristic of these deposits. In other instances, for example along the south boundary of section 32, township 48, range 30, it is associated with a rock in which quartz largely predominates: an association very common in the Adirondack ores of New York.

Township 46, *Ranges* 29 *and* 30.—The largest mass observed by us in this region occurs on the left bank of the Machi-gämig, in section 7, of township 46, range 29, and traces of it are to be observed on several of the adjoining sections. It here rises in a nearly vertical cliff to the height of one hundred and thirteen feet, and is somewhat variable in purity. For the most part, it has a slaty cleavage, and, on close inspection, is observed to be composed of alternating bands of micaceous specular iron and quartz, tinged red by the peroxide of iron; but there are occasional belts which display a granular texture, and apparently possess a greater degree of purity. These laminæ are nearly vertical, exhibiting few contortions, and range with so much uniformity, that the observer would be inclined to refer both the slates and the iron to a common origin. Interlaminated with it, is a band of rock composed mainly of white, granular quartz, with traces of feldspar, through which are disseminated particles, as well as rounded masses, of specular iron. It is difficult to pronounce whether this is a conglomerate, or a breccia. Notwithstanding the immense development of this iron, it was found impossible to determine its relations to the surrounding rocks, a fact of much importance in judging of its igneous, or metamorphic, origin. At several points, veins of pure white quartz were seen traversing the cliff, which contained iron glance, a form of this mineral which was no where noticed except in this association.

In the vicinity of portage No. 4, and on the right bank of the river, according to Mr. Burt, the same kind of specular iron is seen in ledges twenty and fifty feet in height; and another exposure of equal magnitude was noticed on the north boundary of township 46, range 29; but in both instances, the associated rocks were not recognized.

On the north boundary of township 43, range 31, Mr. John Burt observed a bed of iron possessing a considerable degree of purity, but of inconsiderable extent.

Township 40, *Range* 30.— This, as far as known, is the most southern position of the iron, and of course nearest to the navigable waters of Lake Michigan. Its position, however, as will be seen, is far less favorable than that of the deposits in the vicinity of Lake Superior, and we do not, therefore, believe the iron will become of practical value, at least within a reasonable time. According to Mr. Whittlesey's notes, the bed is exposed near the south-west corner of the township, at several points along the west side of a hill which is about one hundred feet in height; its breadth is from one to two hundred feet, showing nothing but slaty iron ore on its summit for a distance of forty rods. The real extent of this deposit is concealed by heavy accumulations of drift and boulders along its base and on the summit of the ridge; but it probably extends eastward for a considerable distance. The distance from this deposit to the Menomonee river is only two or three miles; this river would furnish a great amout of water-power in the neighborhood of the ore, but is not navigable except for canoes, which can be carried round the numerous falls by portages. The quality of the ore does not appear, from the specimens collected, to be very good, it being mixed with more than half its weight of silicious matter. The surface of the township is so covered by burnt and fallen timber and a thick undergrowth of maple and poplar, that it is difficult to ascertain much with regard to the character of the subjacent rocks.

Township 40, *Range* 28.—In the south part of this township, on the line between sections 28 and 29, there is, according to Mr. Burt, a deposit of iron of considerable extent. It is at least a hundred feet in breadth, and extends probably three-fourths of a mile in a linear direction. The specimens of the ore show a very high degree of purity, as they contain but little silicious matter, and are a mixture of the peroxide and magnetic oxide, yielding from 63 to 68 per cent. of metallic iron. (See analysis.) The course of the bed is N. 80° E. S. 80° W., and the dip is 80° to the north. This is probably the most valuable deposit of ore in the southern portion of the district, thus far observed.

Township 42, *Range* 30.— In the southern part of this township large blocks of ore have been observed, but the bed was not discovered.

Townships 42 *and* 43, *Range* 32.—In these townships, several localities of ore are reported by Mr. John Burt; but, as he remarks in his notes, they are not generally of sufficiently good quality, or extensive enough, to make them of much value. The ores of this portion of the district are generally much mixed with silicious matter, and far inferior to those of the deposits farther to the north-east. (See analysis.)

OCCURRENCE OF IRON ORES IN OTHER DISTRICTS.

Having thus briefly indicated some of the principal localities of iron in our district, and given an account of their association with the slates and trappean rocks of the azoic system; for the purpose of enabling the reader to form a clearer idea of their probable origin, geological position, and mode of occurrence, we propose to allude to some of the most extensive and important deposits in other parts of the world; excluding from our notice those ores which occur chiefly in the form of an impure carbonate, in the carboniferous series, and which are of such great importance from their immense development in connection with the coal. With these ores, those of Lake Superior have no analogy, either in their mineralogical composition, or their mode of occurrence. It is to those great deposits of the *oxides* of iron which occur in various parts of the world, that we are to look for the means of comparison. Among these, the best known and most extensive, in Europe, are those of Sweden, of Elba and Russia; and, in our own country, those of northern New York, and Missouri. They are of great extent and of remarkable purity.

Mines of Scandinavia.—According to the best authorities, and especially Durocher, who has given a very detailed and careful description of the metalliferous deposits of Scandinavia, the ores of iron may be arranged in the following scheme.

I. DIVISION. Deposits in the azoic system, (gneiss and argillaceous slates.)	A. Deposits of pure magnetic oxide.	*a*. In gneiss alone, or accompanied by granite, and in the allied slates, talcose, micaceous and calcareous. *b*. In hornblende rocks, intercalated or interposed, in the gneiss.
	B. Specular iron, sometimes pure, and sometimes mixed with magnetic iron.	In gneiss and associated quartzose and micaceous slates.
	C. Magnetic oxide.	In the argillaceous slates.
II. DIVISION. Deposits in the palæozoic series.	Masses of magnetic and, rarely, of specular oxide, near the contact of the palæozoic rocks and the granite.	
III. DIVISION. Recent deposits.	Bog ore in lakes, swamps, &c.	

The deposits of the first division are by far the most important; those in the palæozoic rocks the least so. It will be noticed particularly that the former are enclosed in the azoic series, which in Sweden and Norway is made up principally of a crystalline, granitic gneiss, presenting an almost infinite succession of feldspathic, quartzose, micaceous and hornblende laminæ, and often cut through and disturbed by dykes of greenstone and granite. The researches of Murchison and de Verneuil show conclusively that these rocks had taken their present form before the deposition of the lowest Silurian strata. There are several localities where the magnetic oxide occurs nearly pure and without gangue; of this, the mine of Bispberg furnishes a good example. It has the form of a lenticular mass, and its longest axis coincides with the direction of the schistose structure of the slates in which it is enclosed. The mines of Danemora are in a ferriferous band of about 600 feet in width, and 7000 feet in length. In the neighbourhood gneiss is the prevailing rock; but, in the immediate proximity of the mines, the rock exposed is a greyish limestone, slightly magnesian, accompanied by talcose and chloritic slates, which probably are subordinate to the gneiss. The deposits of iron form imperfectly cylindrical masses, their axes almost vertical, and their bases much elongated in the direction of the schistose structure of the rock.

The mines of Utö, which are especially interesting to the mineralogist on account of the quantity of lithia minerals which are found there, are of great importance. The ore is principally the specular oxide mixed with the magnetic oxide. It is in the form of lenticular masses, enclosed in micaceous slates and quartz-rock; at the point of contact of the ferriferous mass, the quartzose beds predominate, and the silica is often colored red by the peroxide of iron. The principal deposit is about one hundred and twenty feet in its widest part, forming an enormous, lenticular mass of an irregular contour, and with a vertical axis.

At Gellivara, the magnetic oxide forms a mountain mass three or four miles in length, and a mile and a half in width, a great portion of which is very pure, some portions containing specular ore mixed with magnetic. The principal reason why this enormous deposit has not been worked to a great extent, is its remoteness from navigable water, and its very high northern latitude, (67°).

These deposits are called, in Sweden and Norway, *veins;* but they differ materially in character from what is generally understood by true veins. With a few exceptions, they appear to have been deposited in the midst of schistose, or massive rocks, in forms which approach more nearly to beds, or elongated bands and irregular masses; and they have evidently not filled previously-existing fissures which cross the strata at an angle, but almost uniformly coincide in the direction of their greatest elongation with the strata of the schistose rocks.

The micaceous, specular ores are generally associated with the quartzose and mica slates, but rarely with the calcareous rocks. Where there is calcareous matter near the junction of the ore and the enclosing rock, there is a great variety of minerals in the gangue, indicating that they were formed, under certain conditions, by the metamorphic action of the ferriferous mass upon the adjacent rocks. The mine of Hassel, in Norway, offers a good instance of the tendency of the specular ore to associate itself with the quartzose and slaty rocks. The deposit is not a vein, but rather a series of slaty beds impregnated with peroxide of iron, to the amount of twenty or thirty per cent.

The Mines of Elba.— The mines of Elba, which have been so long known as to have acquired a classic celebrity, afford abundant proof of the igneous origin of the specular ores of iron; and, on that account, are of great interest to the geologist. The deposits of iron are principally concentrated in the eastern part of the island, where they are associated with serpentine. The sedimentary rocks in that vicinity have been metamorphosed and intermingled with serpentine, so as to give rise to an abundance of beautifully variegated marbles. The mass of specular ore near Rio has all the appearance of having been formed by sublimation, with pressure from below upwards, through the strata, which are highly metamorphosed at the contact of the ferriferous mass and into which these metallic emanations have penetrated in every direction. The nature of the gangue varies with the rock in which it is contained. In the quartzose slates, it is mostly crystallized quartz, and in the calcareous strata, actinolite and yenite; so that it is evident that these effects could only have arisen from intense igneous action.

The appearance and relations of the mass of magnetic oxide and hematite of Monte Calamita, are such as to leave no doubt as to its igneous origin. This deposit, which is much more extensive than that of Rio, has uplifted the incumbent strata and produced all the effects of metamorphic action upon them. For instance, the compact limestone which lies adjacent to the ferriferous mass, is changed into a saccharoidal dolomite, and, along the line of contact, silicates of lime, magnesia and iron have been developed. The whole appearance of the mass is, according to Burat, that of an immense wedge driven upwards from below into the calcareous and schistose rocks, producing all the effects to be expected from the intrusion of such a mass by igneous agency.

The age of the deposits of the island of Elba is probably later than the Jurassic epoch; but it must be observed that, although these mines have become very celebrated, from the great length of time during which they have been worked, yet the deposits are by no means on a scale of such magnitude as those of the azoic system, though highly interesting from the evidences of igneous action which they present.

Russian Mines.—The iron ores of Nijny Tagi'sk, in the Ural mountains, occur in immense masses, which are thus described by Murchison and de Verneuil, in their Geology of Russia. From this, it will be seen that the associated rocks of the two regions (Lake Superior and the Ural) are somewhat similar, though differing in age.

"On the summits and slopes of the Vissokaya-gora, patches of ore (usually compact, and with a conchoidal fracture,) have been extracted from a very remote period; but, whether these metallic masses are merely the upper portions of veins which traverse the surrounding rock, or mere adherent superficial patches, which occupy cavities and clefts in the greenstone, we could not ascertain. However this may be, the chief mass of the ore is now seen to occupy the valley on the western side of the hill, for it has been deeply cut into by open quarries. The refuse stuff, or capping of decomposed feldspar and mixed matter, with hydrate of iron, having been cleared away, an enormous body of the iron ore, (fer oxydulé,) rudely bedded, and traversed by numerous joints, is exposed by great works along a face which, including the useless overlying materials, has a height of nearly a hundred feet, and a length of several hundred.

When on the spot, it seemed to us possible to account for the appearance presented by this metallic accumulation, most of which is now but little solidified, either by supposing it to have been of plutonic origin, and that, issuing from fissures on the hill-side, it had flowed, when in a molten state, into the hollow where it lies; or, that it was formerly a mass of sedimentary materials, which had been altered and mineralized by heat and vapors, which, making use of parts of the surrounding limestone as a flux, had elaborated the metallic substance. A feature pointed out to us by M. Schwetzoff, may serve to throw some light on the question of the origin of the iron. In opening out the side of the valley, nearest to the hill of greenstone, irregular knobs, or points, of that rock were met with, on stripping which, it was found that the iron ore had accommodated itself to the inequalities of the surface, and that, at such points of contact, the ore was not only harder and more crystalline than usual,—in fact, almost unmanageable by the workmen—but, also, much more magnetic than at a short distance from the greenstone.

Now, if the observer were furnished with no other data than these, he might, reasoning from the countless analogies of metamorphism which result from the eruption of igneous through sedimentary matter, infer that the greenstone, intruding into ancient materials, had, in producing a change throughout their whole mass, rendered those parts only which were in contact with it, most crystalline and metallic, by the development at such points of the most powerful electrical action.

We leaned, we confess, when on the spot, to this opinion; but, after having read the memoir of Colonel Helmersen, upon the origin of the magnetic iron ore of Blagodat, we are bound to admit, that the phenomena at Nijny Tagilsk may possibly be explicable in accordance with his views, and that the metallic iron ore may have penetrated the preëxisting greenstone of the hill, and thence have flowed, as submarine lava, or volcanic mud, into the contiguous depressions. The fact, that the ore expands in width, thickness and dimensions, as it is followed into the lower parts of the valley, and that it fills up the sinuosities of the subjacent rock, seem, on the whole, to favor this view."*

At Blagodat, the chief eruptive rock is feldspathic augite porphyry. Upright masses with metallic surfaces are seen to rise out, as is were, from the porphyry, indicating the ancient quarries from which the iron ore has been extracted. When on the spot, we were rather disposed, they remark, to view the great lateral and rudely stratified accumulations as sediments which had been metamorphosed by the influence of the contiguous eruptive rocks; we were then ignorant of the fact, that dykes of really intrusive character, made up of crystalline and igneously-formed minerals, and clearly formed posterior to the mountain, contained similar iron ore.

If we turn from the foreign localities of this class of deposits to those of our own country, we shall find that they possess many features in common, and that they were all derived, probably, from a common origin.

Iron region of Missouri.—From Mr. Charles F. Mersch, an intelligent German metallurgist, who was employed for several years at the Iron mountain of Missouri in superintending the erection of furnaces and directing their operation, we derive the following information:

"The specular and magnetic iron ores in this portion of Missouri are found in the porphyritic rocks which constitute all this part of the region. The Iron mountain proper is a conical hill at the western extremity of one of these porphyritic ridges, its base covering an area of about three quarters of a square mile. Its height is very nearly two hundred feet above the surrounding plain, and its summit is an isolated cone; but on the eastern side, some thirty feet towards a narrow wall of porphyritic rock which connects it with the ridge forming the western extremity, the junction of the iron ore and porphyry is very plainly seen, along the line of intersection of the surfaces of the two mountains. The specimens along that line contain the two rocks mechanically mixed. At a short distance on either side of this line, the iron ore and the porphyry are pure.

This Iron mountain seems to consist of one single mass of compact oxide of iron, almost pure peroxide, with not more than two or three per cent. of silicious, or aluminous matter. Its top presents some large fragments, but without any indications of stratification.

This same specular ore is found in several places in other parts of the

* Russia and the Ural Mountains, Vol. I., p. 371.

mountains; but nowhere in such an extensive mass. It seems to form bed coeval with the porphyry which encloses it.

Some four or five miles south of this iron mountain is situated another of a much larger size, known in the country as the Pilot knob. Here the ore, though not very different in its chemical composition, is different in its physical characters, and is known as the magnetic ore.

Its altitude may be five or six hundred feet; its summit being about on the same level as the highest points of the porphyritic ridges. This, too, is an isolated cone, and the ore occurs from the summit to the base, apparently forming an immense dyke bisecting the mountain, which is porphyritic, like the surrounding ridges. This ore not only occurs in laminæ, like the slates, but varies also with regard to its purity—in general becoming more slaty as it becomes purer. When the impurities increase, the mass loses this slaty structure, and constitutes a rock similar in appearance to porphyry.

As to the relation of this porphyritic formation to the granite, I can only add that, to my knowledge, there is no real black, or grey, granite in the country; but about two or three miles to the south-west of the Iron mountain, commences a very remarkable formation of syenitic granite, in boulder-like masses, resembling in its external characters that of the Nile. These rest on dome-like formations of the same nature, with divided lines of stratification, or division, running more or less parallel with the surface.

As to the relative age of this formation and the porphyry, I have no facts to found an opinion upon.

With regard to the sedimentary formations, the only one I ever saw immediately connected with the porphyry is a sandstone (Potsdam ?) which has been almost entirely destroyed by subsequent aqueous action; but which is posterior in age to the porphyry and iron; since, wherever the layers of the latter come in contact with the porphyry, they repose in a nearly horizontal position—a fact the more important, since there are portions of this formation in other parts of the district, with different dips, produced in my opinion, by the action of water.

En resumè, I have never observed in the iron region of Missouri, to which the preceding remarks refer, one single feature which would authorize me to infer, or suspect, any volcanic or plutonic action posterior to the formation of the first sandstones, except such action as might have caused the absolute change of level in the *whole* country, of which there are abundant marks."

In a subsequent communication, in reply to additional queries propounded by us, he remarks:—"With regard to the rocks which mark the intersection of the porphyry and iron ore, at the Iron mountain, they are really somewhat like breccias, though fused into a homogeneous mass; one rock containing fragments of the other, though less angular than is generally the case with breccias. My impression is that the specimens rather indicate that the porphyry contains fragments of iron, than the contrary: at any rate, I have never seen any which I would have considered as fragments of the two rocks merely *cemented* together.

With regard to the direction of the ridges, I dare say but little about it, although my impressions are that they run, at least in the vicinity of the Iron mountain, north-east and south-west.

There are some features about the Iron mountain which I did not communicate in my former letter; but, in order that you may be able to determine how far the geological events of this region agree with those of Lake Superior, I add here a section of the Iron mountain. (Fig. 10.) This section has actually been made, and there is, therefore, nothing theoretical, or rather, hypothetical, about it, except the relative thicknesses of the different masses.

Fig. 1

Section of the Iron Mountain.

1. Porphyritic mountain.
2. Iron mountain, of solid ore of great purity, all over the summit, apparently of unfathomable depth.

a. Fragments of iron ore, derived from No. 2, rounded as if by the action of water, varying in size from a man's head to that of a pea, closely aggregated, the interstices being filled with a red, or brownish clay, rich in iron and manganese. This stratum has an average thickness of six feet.

b. A bed of red clay, without any iron ore mechanically mixed.

c. A slaty rock of clay-like nature, called, in the country, *hard-pan.*

d. Sandstone, not identical, in my opinion, with that before mentioned.

These deposits are evidently of comparatively recent date, and have some connection with the history of the Iron mountain.

It is from the bed *a*, that the American Iron Mountain Company derive their ore. Not only this bed, but the underlying one, *b*, extends some distance up the mountain. With regard to the two subjacent ones, I can say no more. How deep the sandstone extends has not been determined."

Ores of the State of New York.—Our information with regard to these extensive and important deposits of the ores of iron in New York, is principally derived from Professor Emmons's Report on the Geology of the District, and from our own examination of a portion of this region.

In the nature of the ores and their mode of occurrence, as well as the character of the associated rocks, there is a considerable similarity to those of the Lake Superior district, but the analogy with the Swedish deposits is still more striking. The New York ores are chiefly the magnetic oxide, with some specular ore, or peroxide. They are included within gneiss, quartzose, and hypersthene rocks, and associated, not unfrequently, with serpentine. The gneiss seems to be an obscurely stratified rock, similar in position to the azoic slates of the Lake Superior region, the upward range of the ores in both districts being limited by the Potsdam sandstone.

By far the larger portion of both the magnetic and specular ores of the iron region of New York occurs in the form of masses, apparently due to igneous agency. These masses appear to be contemporaneous with the rock which encloses them, and, like the trappean rocks, they exhibit a jointed structure. The extent of many of these deposits is so great, that the ore can only be considered as a *rock*, and the deposits classed like greenstone, porphyry, or serpentine, among rock formations. These eruptive masses almost invariably coincide in their line of greatest linear development, with the line of strike of the associated rocks, but are exceedingly irregular in their dimensions, expanding to a great width, and then contracting again within very narrow limits, or disappearing for some distance entirely. Although thus coinciding in their strike, they do not invariably agree in dip, with the planes of the rock enclosing them.

Among the most extensive of these deposits, are those of the Adirondack mountains, which consist of the magnetic oxide, showing in their mode of occurrence a striking resemblance to the Swedish deposits before described, of the same class. Nothing like the appearance of regular veins is observed in them, except the small ramifications which are subordinate to the large masses. They have often a jointed structure, and break into tabular blocks. Some of them are slaty, having parallel lines of separation, a structure which may, with probability, be referred to the action of crystallizing forces. The width of these deposits seems to be very great in proportion to the length through which they have been traced. Thus, the "Sanford bed," according to Dr. Emmons, is exposed for a length of 1667 feet, and its width is 514 feet.

In describing these deposits, Dr. Emmons appears to have been satisfied of their igneous origin, and of their being by no means veins. In his description of the ores of Clinton county, however, he seems to recognize, in their mode of occurrence, all the phenomena of true veins,* in corroboration of which, he cites the celebrated "Arnold vein."

In our examination of this locality, we gave a different interpretation of the phenomena here displayed. So far from regarding the containing rock as granite, we thought we saw abundant evidences of its metamorphic origin. It does not appear in the form of a vast, irregular, compact mass; but presents well-defined lines, like those of bedding, having a uniform dip and bearing. The ore is arranged in bands, conformable to these lines, and although it is slightly variable in thickness, it was not observed in any instance, to cross the mineral planes. It has none of the characters of a true vein. There are no well defined walls, grooved and striated — no distinct lines of separation between the metallic and silicious matter, and no gangue, different from the wall-rock: so far from it, there is a gradual passage from one into the other, and, even where there is the greatest concentration of the ore, we find disseminated particles of silicious matter which do not differ in mineralogical character from the exterior rock. From the phenomena here displayed, most geologists would at once recognize the deposit as a bed, and not a vein. It is true, this bed does not pursue a uniform direction; but when it is observed that the quartzose rocks are here traversed by powerful trappean dykes, we are not at loss to account for the dislocation.

Ores of Massachusetts.— Canada East. —In Massachusetts, according to Professor Hitchcock, the micaceous oxide occurs in beds. At Hawley, it is included in the talcose slates, and at Chester, in the hornblende slates, interstratified with talcose slates.†

Mr. Logan has described numerous deposits of specular and magnetic oxide of iron, in the townships of Sutton and Brome,‡ Canada East, in a prolongation of the Green Mountains. They occur between two dolomitic belts on the west side of the anticlinal axis, in a highly metamorphosed formation, supposed to be the equivalent of the Hudson-river group. He describes the deposits as beds, ranging and dipping with the associated strata. "The

* Report on the Second Geological District of New York.
† Geology of Massachusetts, 612.
‡ Report of Progress, 1847–8, p. 60 *et seq.*

ore of the whole of the localities that have been described is of a thinly laminated or slaty character, often splitting into curved plates where corrugations exist, and in the bluff in question the laminæ throughout the whole face present a most complicated and fantastic set of contortions, but closely compacted together, in so smooth and polished a transverse section that it was not practicable to ascertain whether there was a tendency to separation in the lines of supposed deposit; a few parallel joints, independent of these lines, were observed, but giving thick plates." These ores are more or less titaniferous, of a finely granular structure and contain an admixture of chlorite. There are, however, in this vicinity, transverse veins of nearly pure specular iron, with a quartzose gangue, cutting chlorite slates.

THEORETICAL CONSIDERATIONS.

Having thus indicated some of the most interesting localities of the ores of iron, analogous in their geological position and mode of occurrence to those of the Lake Superior district, we are naturally led to the consideration of the theory of their origin: a question of the highest scientific interest, with regard to which the opinions of eminent geologists are at variance. These differences principally relate to the questions,

I. Are they Veins, or Beds?

II. Are they of Igneous, or Metamorphic origin?

To the consideration of these questions, we propose to devote a few pages.

I. These deposits, so far as investigated by us, display few of the phenomena of veins. A vein we understand to be a fissure of indefinite length and depth, running, in most instances, across the lines of stratification, and filled with mineral or metallic matter, differing from the enclosing walls. The contents of a vein are generally separated from the walls on either side by selvages of decomposed earthy matter, so that the gangue and mineral matter are easily distinguished and detached from the accompanying rock; moreover, there is generally evidence that the fissure is subsequent in age to the rock which it traverses. In all of these characteristics of a true vein, the great deposits of iron, whether observed on Lake Superior, in Missouri, New York, or Scandinavia, will be found to differ essentially.

We do not intend to imply that there may not be veins formed secondary to, and dependent on, the existence of larger masses. These appear in some of the deposits of the New York iron region in the form of ramifying and branching strings, shooting out from the great body of ore. So at the Jackson location, and on the Machi-gämig, we have numerous quartz veins, secondary to the main ferriferous mass, into which the iron has been sublimed; but it is worthy of remark, that in those veins, which never exceed an inch or two in width, the ore is in the form of brilliant plates, or proper *specular* ore associated with a quartzose gangue, which is not the case in the main body at all. The great deposits of this metal, however, as we have seen, occur under conditions widely different. The Iron mountain of Missouri rises up from the surrounding plain like a great dome, or protuberance, while the ferriferous belts of the Lake Superior district expand to the width of more than a thousand feet. In Scandinavia, they assume the form of flattened, cylindrical masses, and the same is true with regard to their occurrence in northern New York, their width, in some cases, being nearly as great as their extent.

In regard to the junction of the ferriferous belt with the enclosing rocky masses, it may be said, in general, that there are no selvages and no abrupt lines of demarcation between the two; but that they are, as it were, soldered together, or else the amount of metallic matter gradually decreases and is replaced by rock. In most of the Lake Superior deposits, there is a total absence of any appearance of selvages, and, moreover, there is no gangue, or peculiar mineral matter, connected with the ore. Where there is a tendency to a parallel structure of the metalliferous belts, the bands of rock enclosed by them are in no way different in their nature from the formation itself in which the whole system is contained. Neither do we find any appearance of rubbed and polished surfaces, indicating a subsequent intrusion of the metallic mass, as if it had been driven in between the strata like a wedge. This is an important point, since we can hardly conceive of such enormous quantities of matter having been forced up from beneath, along the line of least resistance of the strata, without some evidence of such a powerful disruption of the rock, and of the immense friction of the uplifted mass against the rocky walls. The almost universally observed coincidence of the line of bearing, or line of greatest extent, with the lines of bedding of the adjacent rock formation, is another essential point of difference between the mode of occurrence of the iron deposits, and that of other ores occurring in regular veins. If there had been a set of previously existing fissures, analogy with the metalliferous veins of the great mining districts would lead us to expect to find them, in the greater number of instances, crossing the formation at an angle with the line of direction of the strata. This is not the case with any of the deposits of ore in the Lake Superior region, and very rarely, if ever, in the other districts. We find, on the contrary, that the great iron beds of this region preserve in their direction a perfect harmony with the slates of the azoic series, which forbids the supposition of there ever having been a set of fissures formed by any disruption of the strata.

Having thus shown that these deposits are essentially different from veins, we proceed to discuss the second branch of the enquiry.

II. Are they of Igneous, or Metamorphic origin? Or, in other words, have they been forced up through some widely expanding fissure and flowed over the ancient surface in broad sheets; have they penetrated the prior-formed strata in the form of metallic emanations from below; or, were they originally deposited by aqueous causes, but subsequently modified by direct, or transmitted heat?

The occurrence in nature of specular and magnetic oxide of iron, and especially of the former variety, is such as to leave no doubt of its having been an original igneous product; but, whether it is so, in all cases, cannot, perhaps, be demonstrated. If, however, it appears, that this theory of its formation is analogous to what we know to be true, in many cases, and does not controvert any known fact, and that it is the only one by which the phenomena of these deposits can be explained, we should not hesitate to adopt it. We know that the sublimation of specular iron is a phenomenon frequently exhibited, on a large scale, in volcanic craters. In that of Vesuvius, for instance, the clefts and cavities are often found lined with delicate and beautiful crystals of specular iron, deposited in such a manner as to leave no doubt of its having been sublimed from the seat of igneous action beneath. It is related, by Italian authors, that at the time of the eruption by which Torre de l'Annunziata was overwhelmed, numerous well-defined crystals of this substance were gathered from the walls and doors of the convent.

We consider that the evidence is sufficient, as shown in the preceding pages, to prove that the slates and quartzose rocks of the azoic period were originally deposited from water, and that, since their deposition, they have undergone great changes in their structure. These belts, we have also shown, alternate throughout the iron region with undoubted igneous products, which, in all probability, were poured out during the accumulation of the sedimentary deposits, in lava-like sheets, over the bottom of the sea. Intercalated among these mixed products, we find the immense masses of ore, and to one or the other of these classes, we have no alternative but to refer their origin.

In many districts, there is an intimate association between the iron masses and the trappean, porphyritic and serpentine rocks. The Iron mountain of Missouri occurs in connection with porphyry, without any vestiges of metamorphic rocks; at Blagodat, upright masses, with metallic surfaces, are seen to rise out of the augitic porphyry; at Monte Calamita, Elba, the iron mass has uplifted and metamorphosed the incumbent strata; while, in the Lake Superior region, the trappean rocks very often, but not invariably, occur in close proximity to the great deposits of ore. On the other hand, the ores at Danemora are associated with metamorphic products, and the same is true, to some extent, of the specular ores of New York, Canada and Massachusetts.

Were the trappean rocks found to be an invariable accompaniment of these deposits, there would be little hesitancy in assigning to all of them a purely eruptive origin; but when we find them under the form of beds, in clearly metamorphic strata, having a common bearing and inclination, we are disposed to regard them as having been derived from the destruction of previously-formed igneous masses, and their present association to have resulted from aqueous deposition.

The azoic period having been one of long continued and violent mechanical action, there is no reason to doubt that many of the strata of which it is composed may have been derived from the ruins of previously formed rocks of the same age, both sedimentary and igneous. This is clearly shown to be the case in the remarkable knob of conglomerate, described on page 43, which contains rounded fragments of the various kinds of ore found in the adjacent region.

These ores in many districts, assume a banded structure. This is the case in the Lake Superior region, where we frequently find them interlaminated with jasper, chert, quartz and talcose slate. At the Pilot knob, in Missouri, they become lamellar as they increase in purity; at the Sanford bed in the Adirondack, the same structure is displayed: and, at Nijny Tagilsk, they resemble a rudely stratified mass.

At first glance, this banded structure might be regarded by some as the result of aqueous deposition, by which alternate seams of quartzose and ferruginous matter were spread over each other, and the whole subsequently solidified and welded together by heat; but, if we examine the circumstances more closely, it will be found more difficult to account for all of the facts, under this hypothesis, than might at first appear. The extreme tenuity of these bands, which are often no thicker than a sheet of paper, renders this supposition of their analogy to strata highly improbable. In fact, this banded structure in many of the Lake Superior ores—for example, at the Cleveland iron knob, will be hardly apparent to the eye, on fresh fracture of a specimen, the weathered surface of which may present a beautiful series of intricate convolutions of alternate bands of bright-red and steel-grey. Besides, in examining this mountain mass, we find every portion exhibiting equally fine and equally contorted series of convolutions. If these were really the result of aqueous deposition, we should expect, from analogy with other deposits of a similar character, that some of the layers would be of more considerable thickness than others; and that, supposing the contortions to have been caused by lateral pressure of the plastic mass, in some cases, at least, the foldings would exhibit a considerable radius of curvature, which is not the case here.

We know of no theory which affords so probable an explanation of this structure, as that by which the action of seggregating forces is brought into play. An analogous phenomenon may be seen both in the igneous and aqueous rocks of Keweenaw Point. Thus, (in Part I., p. 61), we have described a concretionary structure in the trappean rocks, resulting from this kind of action, by which a series of waving and differently colored bands have been formed. To a similar origin must be ascribed the parallel bands of red and white, with which the sandstone cliffs on the southern side of this point are ornamented, the direction of which is in no degree dependent on the stratification. (Part I., p. 115, and Pl. XII., Fig. 1.)

The jasper of the Porcupine mountains, in the western portion of the district, exhibits a banded structure analogous to that of the ores in question. The flexures are exceedingly intricate, and bear no marks of having been the result of original stratification. There is no actual line of separation between the lighter and darker bands, and if a specimen is struck with a hammer, it is found that it no more easily breaks in the direction of these bands than across them.

On the whole, we are disposed to regard the specular and magnetic oxide of iron as a purely igneous product, in some instances poured out, but in others sublimed, from the interior of the earth. The supposition, entertained by some, that it may be a secondary product, resulting from the decomposition of the pyritous ores, or from the metamorphism of bog-iron, is inadequate to account for the accumulation of such mountain masses, or to explain its relations to the associated rocks.

Where these ores occur in a state of almost absolute purity, in the form of vast, irregular masses, occupying preëxisting depressions; or, where the incumbent strata are metamorphosed and folded over them; or, where they are traversed by long lines of ferruginous matter in the form of dykes—there can be little doubt that these ores have risen up, in a plastic state, from below.

Where they are found impregnating metamorphic products, such as jasper, hornstone, or chert, quartz, chlorite and talcose slate, not only interposed between the laminæ, but intimately incorporated with the mass, giving it a banded structure, we are disposed to regard it as the result of sublimation from the interior.

Where they are included in metamorphic strata, in the form of beds, of variable width, with a conformable range and dip, and with minute particles of the associated rock mechanically mixed with the ore, we are disposed to regard them as the result of aqueous deposition, although the materials may have been derived from the ruins of purely igneous products.

RÉSUMÉ.

We may conceive that the various rocks of the azoic series were originally deposited in a nearly horizontal position, at a period prior to the appearance of organic life upon the earth: that these stratified deposits were composed, for the most part, of finely comminuted materials, principally silicious and argillaceous, in some cases consisting of almost pure silex, like the purest portion of the Potsdam sandstone which was afterwards deposited upon these strata.

During the deposition of these strata, at various intervals, sheets of plastic mineral matter were poured forth from below, and spread out upon the surface of the preëxisting strata. These igneous rocks are exceedingly compact and uniform in their texture, which would seem to indicate that they were under heavy pressure, probably at the bottom of a deep ocean. The same depth of water is also inferred from the comparative absence of ripple-marked surfaces throughout the whole series.

During this period, the interior of the earth was the source of constant emanations of iron, which appeared at the surface in the form of a plastic mass in combination with oxygen, or rose in metallic vapors, or as a sublimate, perhaps as a chloride; in the one case, it covered over the surface like a lava sheet; in the other, it was absorbed into the adjacent rocks, or diffused through the strata in the process of formation. Besides, a large amount of iron entered into the composition of the igneous rocks of this period, chiefly in combination with silica, as a silicate of the protoxide. Portions of the eruptive masses were occasionally subjected to denudation, and the ferruginous particles were, under the action of violent currents, spread out in thin beds, or swept into some depression of the surface, forming a lenticular mass, upon which the strata were afterwards accumulated.

When the silicious materials had become impregnated with metallic matter, which may have been scattered more or less uniformly through it, a rëarrangement of the silicious and ferruginous particles in some instances took place, under the action of segregating forces, by which the whole mass assumed a banded structure.

Subsequently, the whole series of beds, slaty, quartzose, ferruginous and trappean, were elevated, and, in all probability, folded, perhaps at the epoch of the elevation of the granite ranges on the north and south of the ferriferous belt of the azoic system.

CHAPTER V.

ECONOMIC GEOLOGY OF THE AZOIC SERIES.

Chemical Examination of the Iron Ores.— Method of Analysis adopted.— Occurrence of foreign Impurities in most Ores, and their Effect on the Quality of Iron.— Methods adopted to detect these Impurities.— Their Absence in the Lake Superior Ores.— Analysis of Ores from various Localities in this District.— Remarks on the Results.— Metallurgy of the Iron Ores.— The Catalan Forge.— The Method of working these Ores.— The Tenacity of this Iron.— Cost of Production of a Ton of Iron.— Occurrence of other Ores.— Other Economic Materials.

Before entering on the subject proper of this chapter, we shall give the results of the analytical investigation of the ores of the azoic series, since their chemical composition is the first thing required to be known, before forming an opinion of their economical value.

In the chemical examination of the ores of iron which occur within our district, we have endeavored, not simply to make our researches with sufficient minuteness to be able to give the percentage of metallic iron which they contain, but also to ascertain whether those foreign and accidental impurities, which usually accompany such ores, were present. This is an important question, since the quality of the iron manufactured from the ore depends, not only on the method employed in the fabrication, and the skill with which the metallurgic processes are performed, but also on the nature of the ore, and the kind and amount of impurities contained.

In general, the method of analysis was as follows: The specimen to be analyzed was carefully pulverized, and dried at a temperature from 110° to 120° C. In this way, all the accidental moisture contained in the substance was entirely removed, and none of the ores examined were found to lose in weight, on being subjected to ignition, after having been thus dried; they do not, therefore, contain any water, in chemical combination.

The dried substance was then transferred to a bulb-tube, and its weight being ascertained by weighing the tube before and after the introduction of the ore, it was then ignited in a stream of dry hydrogen gas. The oxygen was estimated by collecting the water formed in a chloride of calcium tube, and thus weighing it directly, or by determining the loss of weight of the tube, after the ignition. The latter was generally the method adopted, as, with all the precautions which could be taken, the collecting of the water and weighing it directly was found to give less accurate results.

The substance, after the reduction, was attacked by weak chlorohydric acid, which dissolved out the metallic iron, and left undissolved the earthy, silicious portion of the ore. This was separated by filtration, ignited and weighed, and then, either fused with carbonate of soda and analyzed as a silicate, or qualitatively determined by the aid of the blowpipe. The filtered solution was then heated, and a few drops of nitric acid added to peroxidize the iron, which was then precipitated by caustic ammonia. If the precipitate of peroxide of iron contained alumina, it was separated by treating with caustic potash. The precipitate of iron was carefully dried, ignited in a current of air, and weighed as the peroxide. The filtrate, from which the precipitate by ammonia had been separated, was evaporated to dryness, and ignited to expel the ammoniacal salts, when the nature of the remaining ingredients, which were present, if at all, only in minute quantity, could be determined. These were generally lime, magnesia, or manganese.

In this way, having ascertained with accuracy the quantity of oxygen and of metallic iron, by calculation from the peroxide obtained, it is easy to determine the state of oxidation of the iron in the ore, — that is, the relative quantities of the peroxide, $Fe_2 O_3$, and of the magnetic oxide, $Fe O Fe_2 + O_3$.

There are, however, other substances which very commonly occur in small quantities in ores of iron, and which have a great influence on the quality of the iron produced from them; but these must be sought for by a special examination, and their presence or absence thus demonstrated. The most important of these substances are phosphorus, sulphur, titanic acid and manganese; arsenic and copper are a frequent accompaniment of these ores, but generally in very minute quantity.

The influence which these foreign substances, when present in the ore, have upon the quality of the iron manufactured from it, depends principally upon their relative quantity; but, in general, it may be said, that sulphur and phosphorus have an injurious effect on the iron, if the ore contain any considerable quantity of these substances; a certain proportion of manganese, on the contrary, is generally considered to increase the value of the iron. It is generally conceded, that the best steel is not one which contains nothing but carbon and iron; but that those varieties which unite the greatest amount of hardness and tenacity, with the requisite malleability are such as contain minute portions of other substances. This is especially true of silicium and manganese; of the former, the best steel may contain as much as .02 per cent. Some metallurgists even are of opinion that silicium is an essential ingredient of good steel.

In regard to pig-iron, the qualities required in it depend on whether it is to be manufactured into bar-iron, or used for castings. In the former case, the amount of silicium or aluminium, present in the pig-iron, may easily be sufficiently reduced by puddling, while the sulphur and phosphorus are much less easily got rid of. For the manufacture of castings, it is necessary that the iron should have a sufficient degree of fluidity when melted, and that it should be of a uniform texture, and sufficiently tenacious, when cold. Phosphorus renders the pig-iron fluid, when melted, and hard, but, at the same time, brittle, when cold. Sulphur gives a porous texture to the casting, and is generally injurious.

The best methods of determining the presence of the above-mentioned impurities in an ore of iron, is as follows:

To detect *sulphur*, the ore should be pulverized, and treated on charcoal, with three times its volume of dry carbonate of soda, in the reducing flame of the blowpipe. The fused mass, after cooling, is then removed from the charcoal with the forceps, and laid on a bright, polished surface of silver, and moistened with water. If the ore is perfectly free from sulphur no discoloration of the surface of the silver will be perceived on washing off the substance, after it has been allowed to remain upon it for a few minutes. If a trace of sulphur were present in the ore, it would be indicated by a brown stain of sulphuret of silver; if the quantity of sulphur was more considerable, the stain would be more deeply and strongly colored. Of course, the absolute freedom of the carbonate of soda employed, from this impurity, must be ascertained before using it for this purpose.

The presence of *phosphorus* is best ascertained in the following manner: A small quantity of the pulverized ore is mixed with aboutfive times its volume of a mixture of four parts, by weight, of carbonate of soda, and one of pure silica, and the whole fused in the oxidating flame of the blowpipe, on charcoal. The fused bead is then pulverized, and boiled with water, which dissolves the excess of carbonate of soda, and the greater portion of the silicate of soda, as well as the phosphate of soda formed in the operation, if phosphorus was present in the substance. The alkaline solution is then supersaturated with acetic acid, and thoroughly boiled, to expel all the carbonic acid. In the solution, after filtration, a small piece of nitrate of silver is placed, when the presence of phosphorus will be indicated, by a more or less intensely colored precipitate of yellow phosphate of silver around the spot where the nitrate of silver gradually dissolves.

The presence of *titanium* may be best ascertained by the blowpipe, as follows: If the quantity of the substance is considerable, it will be made evident by heating a small portion on platina wire in the reducing flame of the blowpipe with salt of phosphorus. If titanium is present, the bead will acquire a deep brownish-red, or blood-red color. If the quantity is very minute, not over one per cent., the ore must be heated on charcoal, and after a thorough reduction, metallic tin must be added, when the presence of titanium will be indicated by the light-yellow color of the bead. If no titanium is present, the bead will have a greenish color.

Manganese is almost universally present in ores of iron. If the quantity of this metal is not almost infinitesimally small, its presence will be easily detected on fusing a portion of the pulverized ore with a mixture of two parts of carbonate of soda and one of nitrate of potash, when a peculiar blue-green color, characteristic of manganese, will be observed. Although an exceedingly minute proportion of the metal may be detected in this way, there may be so slight a trace of it present, as to require a more elaborate process to render it manifest. In this case, the substance must be dissolved in chlorohydric acid, and the solution carefully neutralized by ammonia, and the oxide of iron precipitated by succinate of ammonia; the filtrate is then to be evaporated to dryness, and ignited to expel the ammoniacal salts. If there is the minutest trace of manganese present in the ore, it will be made manifest by fusing the substance remaining after the ignition with soda and saltpetre.

Arsenic may be detected, whether it be present in large or small quantities, in the following manner:

A small quantity of the ore, fifty to seventy-five milligrammes, is to be mixed with about six times its volume of a mixture of equal parts of soda and saltpetre. The whole is then heated in a platina spoon and the fused mass treated with boiling water, until all the soluble portion is taken up. The insoluble portion having been filtered off, the liquid is evaporated to dryness, after adding a few drops of sulphuric acid. The dry residuum is then to be pulverized with about three times its volume of oxalate of potash and a little coal dust, and the mixture heated to redness in a glass tube, sealed at one end, and drawn out to a small size at the other. If the smallest trace of arsenic was present in the ore, a ring of metallic arsenic will be sublimed and deposit itself upon the inside of the tube in brilliant crystals. If the part of the tube be then cut off and heated in the blow-pipe flame, the odor of garlic peculiar to the arsenical fumes will be perceived.

ANALYSIS OF ORES.

1. *Ore from the Jackson Company's Location—Township* 47, *Range* 27, *Section* 1.— This is a massive, light-colored ore, with a highly crystalline structure, in which, under the microscope, numerous planes of the octohedron may be seen. It is a mixture of the granular peroxide and the magnetic oxide, as will be seen from the analysis which follows:

.9267 gramme gave, by reduction, .273 loss, oxygen, .0268 insoluble, and .9012 peroxide of iron = .63084 iron.

Oxygen	29.46
Iron	68.07
Insoluble	2.89
	100.42

No trace of manganese, phosphorus or sulphur was detected. The insoluble portion consisted almost entirely of pure silica.

2. *Slaty Ore from the Jackson Company's Location — Township* 47, *Range* 27, *Section* 1.— This is a very compact variety of the ore of this Company's location, and is somewhat slaty in its structure. It contains, here and there, a small amygdaloidal cavity, with a nodule of quartz. It is divided by regular joints, like the slates of the azoic system.

The analysis shows it to be a very pure ore, being mainly the peroxide, with a little quartz intermixed.

The results are: 1.0275 grammes, lost .2990 by reduction with hydrogen: gave .0169 insoluble residuum, consisting almost entirely of silica: 1.0142 peroxide of iron = .70994 metallic iron.

Oxygen	29.09
Iron	69.09
Insoluble	1.64
	99.82

No trace of sulphur, or phosphorus, was detected in the specimen examined; a slight trace of manganese was obtained.

Both the specimens from this location show a high degree of purity and freedom from injurious substances, and an abundance of the ore may be obtained of equal purity with that of the specimens analyzed.

3. *Analysis of the very compact fine-grained Ore from the Marquette Company's Ore-bed—Township* 47, *Range* 27, *Section* 10.— This is a very compact and pure variety of ore, the body of which is fine-grained peroxide, in which numerous small crystals of the magnetic oxide are disseminated

1.7450 grammes were attacked by chlorohydric acid. The solution was effected very slowly, although the substance had been finely pulverized. After an entire attack had been effected, there remained only .0032 of insoluble residuum; = 0.20 per cent.

The filtrate from the insoluble portion was supersaturated with ammonia and the precipitate of the peroxide of iron filtered off: it weighed 1.7507 = 1.2255 of metallic iron = 70.22 per cent.

1.4357 grammes reduced by hydrogen lost in weight .424 of oxygen = 29.53 per cent.

	Iron	70.22
	Oxygen	29.53
	Insoluble	.20
		99.95
Or,	Peroxide of iron	90.58
	Magnetic Oxide	9.17
	Silica	.20
		99.95

Thus it will be seen that this ore approaches very nearly to a chemically pure mixture of nine-tenths of peroxide and one-tenth of magnetic oxide. A great portion of the knob from which this specimen was taken is almost equally free from all foreign ingredients.

4. *Iron Ore from the north-west Quarter of Section* 10, *Township* 47, *Range* 27.— This is a beautiful variety of ore of great purity, consisting of a fine-grained mass, having a slaty structure, and being somewhat contorted, like many of the slates: throughout the whole mass are scattered innumerable crystals of magnetic iron, hardly more than one-fiftieth of an inch in diameter, which stand out in relief from the weathered surface of the specimens.

I. 0.8213 gramme left .0094 residuum of silicious substance, and the remaining solution gave = .8174 of peroxide of iron. In the filtrate a trace of lime and magnesia was detected.

II. .9412 gramme left .0107 residuum, which equals 1.13 per cent.: gave .9393 of peroxide of iron, which equals 99.79 per cent.

	I.	II.
Peroxide of iron	99.52	99.79
Silicious substance	1.14	1.13
	100.66	100.92

I. Gives 69.67 per cent. of metallic iron.
II. Gives 69.85 of metallic iron.

The ore is evidently a mixture of the peroxide with the magnetic oxide, as is shown by the results of the analysis, as well as by the appearance of the substance itself.

Two determinations of the oxygen were made; in one, .8213 grammes lost .2217 of oxygen = 26.99 per cent.; in the other, .9412 grammes lost .2556 of oxygen = 27.14 per cent: mean of the two 27.06. A portion of the iron is therefore in combination with the oxygen and the silica, as a silicate of iron, in such a manner as not to be reducible by hydrogen.

Ore from the Iron Cascade—Township 47, *Range* 26, *Section* 31.—This is a good specimen of the ore occurring at this locality in very large quantity. The specimen analyzed was taken from the immediate vicinity of the cascade, where the water pours over a ledge of the ore. It is a compact, fine-grained mixture of quartz and specular iron, the former making up from 30 to 40 per cent. of the whole.

1.6138 grammes of the finely pulverized substance, digested for a long time with chlorohydric acid, left .5265 of a faintly reddish residuum, = 32.63 per cent.; all the remaining portion of the substance was precipitated on the addition of ammonia, there being not a trace of residuum left, on evaporating and igniting the filtrate; the precipitate of peroxide of iron, which contained a little alumina, weighed 1.0657.

Peroxide of iron	66.03
Insoluble	32.63
Water and loss	1.34
	100.00

No trace of manganese, or sulphur was detected. The insoluble portion was analyzed by itself, as a silicate, by fusion with carbonate of soda. It contained:—

Silica	95.85
Peroxide of iron	2.88
Alumina, lime, and magnesia	1.27
	100.00

The whole quantity of peroxide of iron in the substance is 66.96 per cent., which gives 46.87 per cent. of metallic iron. The ore is mainly a mixture of silica with peroxide of iron, with a little insoluble silicate of the protoxide of iron and alumina.

Ore from the Machi-gāmig—Township 46, *Range* 29, *Section* 6.—This is a beautiful specular ore, but contains nearly half its weight of silicious matter. The remainder is nearly pure peroxide of iron.

0.5978 gramme lost by reduction with hydrogen .0894 of oxygen = 14.95 per cent.: left insoluble substance, which was silica with a little alumina and a trace of iron, .2805 = 46.92 per cent. The precipitate of peroxide of iron weighed .3222 = .2255 metallic iron = 37.73 per cent.

Iron	37.73
Oxygen	14.95
Silica	46.92
Trace of lime and magnesia	
	99.60

This ore contains a trace of manganese.

Ore from north Side of Section 4, *Township* 43, *Range* 31.—This ore was collected by Mr. John Burt. Like the other ores of this portion of the region, it contains a large amount of quartzose matter intermixed with it.

0.525 grammes gave .2208 insoluble silicious residuum, = 42.05 per cent.; the precipitate of peroxide of iron weighed .3055, = 58.09 per cent.

Insoluble silica	42.05
Peroxide of iron	58.09
	100.14

It contains about forty-two per cent. of metallic iron, with traces of lime, magnesia, and some alumina. It contains, also, a trace of manganese.

Ore from Township 42, *Range* 28, *south on line between Sections* 28 *and* 29, *thirteen Chains.*—This ore, collected by Mr. John Burt, is a quite pure and finely-granular variety, and considerably magnetic. It is a remarkably pure and valuable ore.

1.2801 grammes left .1297 insoluble silica, = 10.13 per cent. Another portion of the same specimen gave on 1.0775 grammes, a loss, by reduction, of .2844, = 26.40 per cent. of oxygen; .9750 peroxide of iron, = .6825 metallic iron, = 63.34 per cent.

Iron	63.34
Oxygen	26.40
Insoluble silica	10.13
	99.87

This would give—

Magnetic oxide	19.05
Peroxide of iron	70.69
Insoluble	10.13
	99.87

Another specimen from the same locality, also collected by Mr. Burt, was analyzed. It differs, in external appearance from the last, in being less fine-grained, and in having less of a slaty structure.

.9265 gramme gave .2573 oxygen, = 27.77 per cent., and left .0398 of silica unattached, = 4.29 per cent. The remainder was metallic iron.

Oxygen	27.77
Iron (by loss)	67.94
Silica	4.29
	100.00

This specimen contains less silica than the former, and more magnetic oxide, as is also evident by its action on the magnet. It is a very excellent ore, much superior to the larger portion of ores which occur in its neighborhood.

Analysis of the jaspery Portion of the Ore from Township 47, *Range* 27, *Section* 10.—The bands of jasper and pure ore are so finely interlaminated, and have so little continuity, that it is difficult to separate the more silicious portion from that in which the peroxide predominates. On separating the former, as perfectly as possible from the latter, and subjecting it to an analysis, it was found to contain a considerable amount of iron.

.4399 gramme was attacked by strong chlorohydric acid and repeatedly digested with it. There remained a large quantity of insoluble substance of a bright-red color, still containing a portion of iron which could not be taken up by boiling with strong acid. This residuum weighed .308 gramme. In the solution, ammonia gave a precipitate of .154 peroxide of iron.

Peroxide of iron, dissolved by the acid	33.4
Insoluble silica and iron	66.9
	100.3

The insoluble substance was fused with carbonate of soda, and was found to consist of silica, colored by about two per cent. of oxide of iron.

Silica	98.3
Peroxide of iron	1.7
	100 00

The substance is a mixture of silica colored by the peroxide of iron, and probably some silicate of the protoxide, with free or uncombined peroxide of iron.

From the above analyses, it is evident that the purest ores occur in the northern part of township 47, range 27. Here, indeed, the specimens analyzed show an almost absolute purity and freedom from foreign ingredients. The principal part of the insoluble matter left by acting on the ores with acids, is silica; none of them contain more than a very minute quantity of alumina, lime, or magnesia. In most of the ores, the larger portion, by far, of the iron exists in the state of peroxide, though nearly all contain a small per centage of the magnetic oxide. Generally, the silica seems to be mechanically mixed with the oxides of iron, since the whole of the oxygen is obtained by reduction in hydrogen. In a few instances, however, from one to two per cent. of the oxygen is in combination with the iron and silica, in the form of an irreducible silicate.

As far as the presence of injurious substances, such as sulphur, phosphorus and arsenic, is concerned, all the specimens examined are entirely, or almost entirely, free from them. A few specimens contain traces of sulphur, but not in sufficient quantity to have any perceptible effect on the quality of the iron manufactured. Manganese is present only in the most minute traces; in fact, it can only be detected in most of them, by the most delicate and careful examination.

METALLURGY OF THE IRON ORES.

The iron ores described in the foregoing pages will be found capable of producing a soft, malleable iron. With proper care in its manufacture, it may be converted into steel, adapted to the finer varieties of cutlery. The silex, so intimately incorporated with the mass, will serve as a flux, and render the reduction of the ores easy, particularly where the fusion takes place in the furnace. Ores of almost any degree of purity can be obtained, but the richest are, by no means, the most easily reduced in the blast furnace.

The specular ores of New York are found to contain more or less bisulphuret of iron (iron pyrites), which impairs their value, as it is not wholly expelled by roasting. In some instances, too, they are associated with titanium, which render them exceedingly refractory in the furnace. Neither of these substances have we been able to detect, in sufficient quantity to produce any perceptible effect, in the ores of Lake Superior.

Notwithstanding the immense amount of iron produced in Great Britain, none of it, with the exception of the Ulverstone charcoal iron, is capable of conversion into the finer varieties of steel. The Swedish hoop L, the Indian wootz and the Russia irons occupy the highest rank.

The famous Indian wootz-ore consists of magnetic oxide of iron united with a large proportion of quartz, the compound consisting of 42 silex, and 58 magnetic oxide of iron. The natives pound the ore and winnow away the earthy particles. With a clay furnace, four or five feet high — the work of a few hours — and with a blast supplied by a bellows made of a goat skin with a bamboo nozzle, plied by the hands, for three or four hours, the Hindoo brings out his bloom. A pound or two of this iron is enclosed in a clay crucible, with small fragments of dry wood, the whole being covered with a few green leaves. The orifice is then closed with clay, and the crucibles are subjected to a heat for about two hours, in a blast furnace, when the process is considered to be complete. In this rude way is produced a steel, eminently adapted to the purposes of fine cutlery.

For the reduction of these ores, the several companies have introduced the Catalan forge, so extensively employed in the Lake Champlain region of New York. This has been done for two reasons: first, it requires a small outlay of capital; and second, it avoids the uncertainty incident to working a new ore with success in a blast furnace. Besides, according to Mr. Alger, who has had a large amount of experience in the iron manufacture, these ores are better adapted to the production of malleable, than of cast iron. They do not so readily unite with carbon to produce that grey, soft condition which is found in the superior cast iron made from the hematitic and clay iron ores; and they require much greater heat for their reduction and perfect metallization. An inferior article of pig-metal will not bear transportation to a remote market, whereas a superior article of bar-iron may be profitably sent to any market in the country.

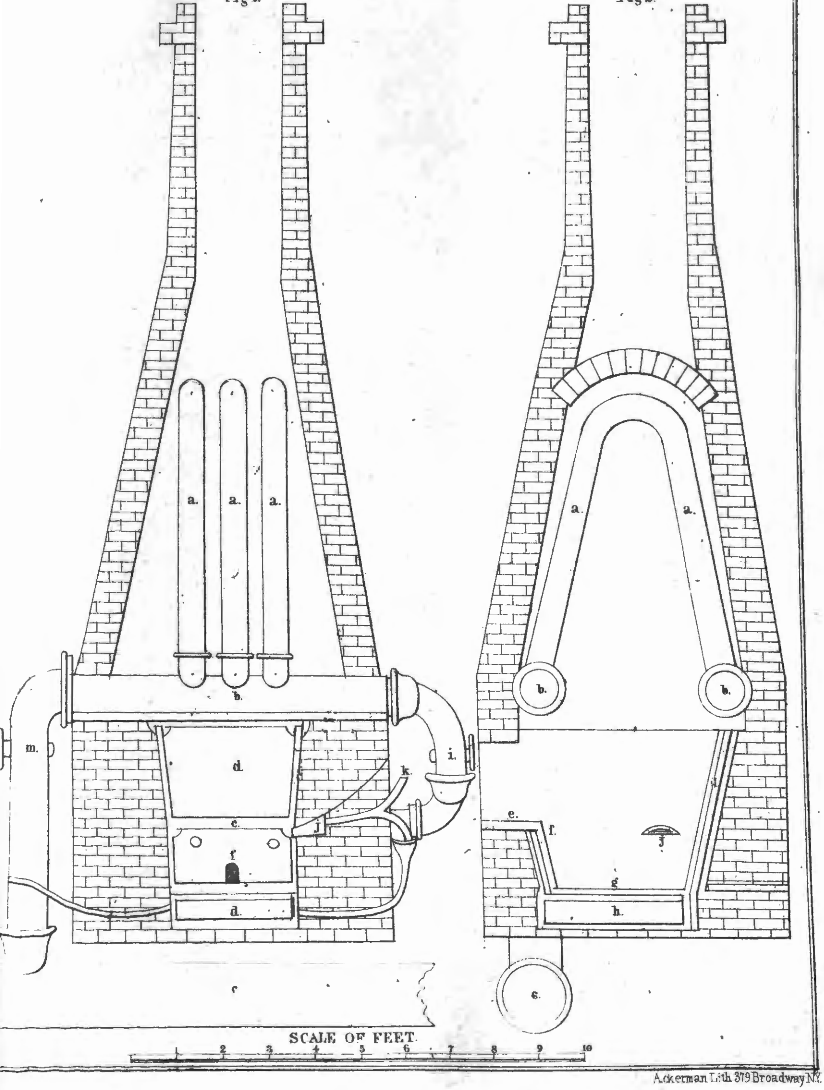
The forges are represented in plate XXII, which is copied from the American Railroad Journal, for September 1849, illustrating one of a series of valuable articles on the Iron manufactures of the United States, by Mr. James T. Hodge.

"The first four figures represent sections in different directions through the simplest form of the bloomery. Figures 5, 6, and 7, are sections illustrating a similar fire, supplied with an arrangement for heating the blooms with the gases of the escape-heat returned to the oven, and mixed with a current of atmospheric air.

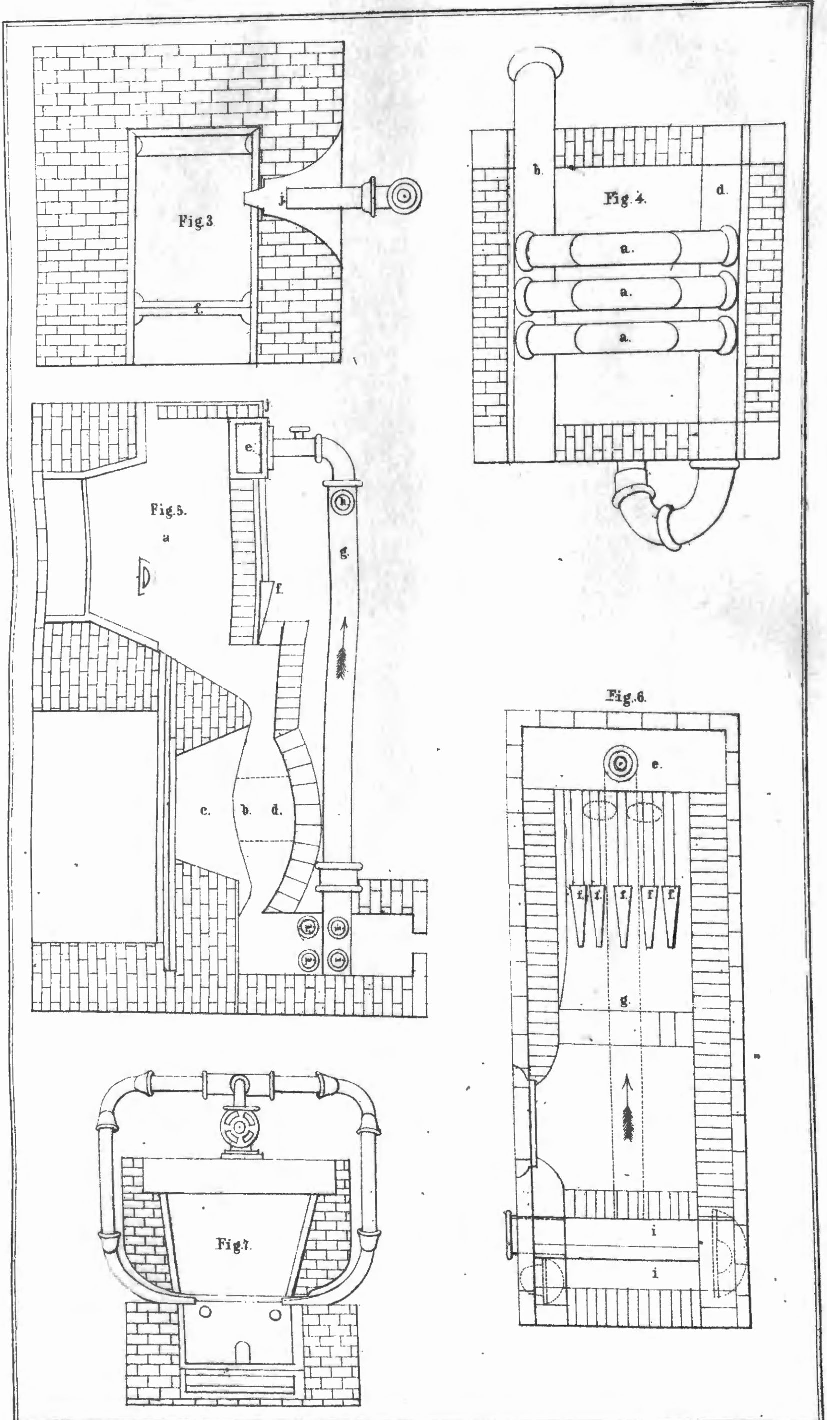
Fig. 1, is a front elevation of a common bloomery fire. The following letters designate its several parts and the apparatus connected with it, *a, a, a,*— hot air pipes; *b,*— one of two bed pipes; *c,*— main blast-pipe from the blowing cylinders; *d,*— back plate of the fire; *e,*— fire plate; *f,*— plate through which the cylinder is drained off; *g,*— bottom plate of the

SECTIONS OF AN IRON-FORGE.

Fig 1. Fig 2.



Ackerman Lith 379 Broadway N.Y.



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fire; *h*,— water-box placed under the fire; *i*,— small pipe for letting off the waste water out of the fire-box; *j*,— water tweer; *k*,— pipe for supplying cold water to the tweer; *l*,— valve for shutting off the hot air from the fire; *m*,— throttle valve for regulating the supply of cold air to the hot blast-pipes.

Fig. 2. Side elevation of the same; the letters corresponding to those of figure 1. Fig. 3. Horizontal section of the same on the level of the tweer. Fig. 4. Horizontal section on a level with the bed plates. Fig. 5. Side elevation of a bloomery fire with an oven for reheating the blooms. The following letters represent the different parts: *a*,— bloomery fire; *b*,— bottom of heating furnace, on which the cold iron is charged; *c*,— sand hearth; *d*,— charging door; *e*,— wind box; *f*,— wrought iron blow-pipe; *g*,— pipe for conveying hot air to the wind chest; *h*,— opening through which the hot air passes to feed the bloomery fire below; *i, i, i*,— hot blast pipes lying horizontally in the chimney; *j*,— cast iron door lined with fire brick, which slips up and down, closing in front, to keep out the cold air.

Fig. 6. Horizontal section of the same, on a level with the blow-pipes and heating oven. Fig. 7. Front elevation of the same, the letters 6 and 7 corresponding with those in 5."

In these bloomeries, malleable iron may be obtained from the ores by one fusion; but to accomplish this, it is necessary that they possess a great purity and melt at a low temperature. Hence only the hematites and the specular and magnetic ores are adapted to this kind of forge. Although there is but one fusion, the ores undergo two successive changes.

1st. The deoxydizement and reduction of the metal by bringing it in contact with charcoal.

2d. The melting and aggregation of the metal in a ball fit for the squeezer.

The following is the method of treatment pursued in the reduction of these ores.

The ore is introduced into the top of the forge, in alternating charges with charcoal, in a state of great mechanical subdivision, resembling coarse sand, having been previously calcined, stamped and washed, if it contain much earthy matter. The supply of fuel is maintained in the first stages of the process so as to keep the space full and prevent the ore from collecting together. Water is occasionally sprinkled over the surface, which prevents the fine siftings from being blown away, and gives increased fusibility to the scoriæ. The ore falls down and the melted iron collects in a mass at the bottom of the hearth, while the thin slags run off by an upper overflow. The mass is removed about every hour, in a pasty condition, by means of a powerful pair of tongs — working by an iron wheel on a railway suspended from the beams above — which seizes it firmly and conveys it to an anvil, where an iron lever, called a squeezer, working up and down, kneads the particles of iron together, forcing out the semi-fluid cinders and fashioning the loup for the rollers, to which it is transferred.

The substitution of drawing cylinders in the place of trip-hammers has greatly facilitated the manufacture of bar iron. It accomplishes in a few minutes, the condensation of the particles, and the distribution of the fibres, which formerly was attained only after repeated heats and hammerings.

In cylinder drawing, one workman holds the loup in a pair of tongs and passes it into the first of the grooves; another workman, on the other side, receives it and passes it back to the first, who passes it into a second and smaller set, and so on, until it is reduced to a bar, three or four inches broad and two in thickness. This is then cut by powerful shears, into short lengths called blooms, which are afterwards subjected to a refining process.

So great is the dexterity displayed in these various processes, and so admirable the adaptation of the machinery, that the rude ball as it comes from the forge, is converted into mill-bar iron, before it has had time to cool. The whole operation is accomplished in a little more than a minute.

The bars are next subjected to the refining process, which consists in heating them in the oven above described, and bringing them to a welding heat, which is accomplished in the course of one half or three quarters of an hour. Where great tenacity is required, they are re-heated and rolled. From the oven, they are passed to the extension rollers where they are fashioned into the required form, whether round, square, oval, or rectangular.

Tenacity of the Lake Superior Iron.—From the total absence of foreign ingredients, as indicated by the analysis, it would be inferred that these ores, if skilfully wrought, would produce an iron of great ductility and tenacity. In the summer of 1849, we placed two samples of this iron, selected, without any great care, from among the products of the Jackson forge, in the hands of Major Wade, of the Ordnance department—whose office it is to test the tenacity of the guns made for the government—for the purpose of experiment. The results obtained were as follows:

Sample No. 1,	7.550 density,	89582 lbs.	pressure	to the square	inch.
Sample No. 2,	7.768 "	72885 "	"	"	

In the second sample there was a slight flaw observed, after it was parted, which would account for its inferior tenacity. These results give an unparalleled tenacity, and prove the high value of this iron.

During the past season, however, we received additional samples, made from the same ore, but by a different iron-master, which were placed in the possession of Mr. J. T. Ames, for experiment. The results were as follows:

No. 1, welded three-ply,	56546 lbs.	pressure	to the square	inch.
" 2, welded	55017 "	"		"
" 3, without welding,	58583 "	"		"

The second set of experiments proves that the iron experimented on, was of a very ordinary quality; and, when we compare its tenacity with that before tried, it is very evident that it has not been properly fabricated. Nothing is more uncertain than the quality of iron, however good the ore, where it is not skilfully and systematically wrought.

To show the comparative quality of this iron, we give the results of the numerous experiments of Professor Walter R. Johnson, on the tenacity of bar-iron, from localities both at home and abroad:

			Strength in lbs. per square inch.
Iron from Salisbury, Ct., by mean of	40	trials	58009
" Sweden,	4	"	58184
" Centre county, Pa.,	15	"	58400
" Lancaster county, Pa.,	2	"	58661
" McIntyre, Essex co., N. Y.,	4	"	58912
" England, (cable bolt, E. V.,)	5	"	59105
" Russia,	5	"	76069
To which we add the tenacity of the Carp-river iron, Lake Superior, as determined by Major Wade			89582

Cost of Production.—The following estimate, showing the cost of producing a ton of iron, in the Lake Superior district, was furnished us by Mr. P. M. Everett, the former agent of the Jackson company. It will probably be found to require some modification:

Digging and transporting the ore to the forge, two tons of which are required to produce a ton of blooms		$ 3 00
Roasting the ore (2 tons) at $1 00 per ton		2 00
200 bushels of charcoal at 5c. per bushel		10 00
Incidental: 2 bloomers at $2 75 per day each, 2 firemen at 0 90 " "	6 94	
Stocking furnace at $1 15	1 15	
Costing, at that rate, per ton		6 74
Cost per ton, at the forge, of 2400 lbs. of iron in blooms		$21 74

To this estimate should be added the interest on the capital, say $20,000, wear and tear of machinery, expense of agency, and incidental expenses.

The cost of transportation to the lake shore (nine miles) is $4 00 per ton, to Cleveland $5 00, thence to Pittsburgh $2 00=$11 00.

It ought to be added, that this company have water-power sufficient to drive eight forges, whereas they now employ but two. The expenses of agency and the interest on the capital would be no greater if the whole power were employed. Besides, as the country becomes settled, there will be a reduction in wages, and the facilities for transportation will be increased. It now costs nearly as much to transport a ton of ore nine miles, by land, as it does to send it nine hundred by water.

The nearest proximity of these ores to the lake shore, as we have before stated—for example, those of the Iron cascade—is about twelve miles; those of the Jackson and Cleveland locations are a little farther removed, while those on the borders of the Machi-gămig are thirty miles—being about equidistant between the head of Keweenaw bay and the mouth of Cărp river; but the outlet at the latter point would be preferable. Those on the Menomonee are about fifty miles distant from Bay des Noquets on Lake Michigan, being as remote from that point as the beds on the Machi-gămig and the sources of the Carp. The beds of a similar character, in Dr. Owen's district, on the waters of Bad river, opposite La Pointe, explored by Mr. Whittlesey, are distant from the lake eighteen and twenty-two miles.

We have thus endeavored to give all the information in our possession, with regard to the range and extent of these ores, the relative distances of the beds from navigable water, the physical features of the country which favor or impede their exploitation, the chemical composition of the ore, the best method of working them, the tenacity of the manufactured article, and the cost of production. From these data, business men can form correct conclusions whether the time has arrived for their profitable exploitation. Nothing would give so great an impetus to this region, or tend so much to the rapid development of its resources, as the opening of a ship-canal between Lake Superior and Lake Huron. It is emphatically demanded by the mining interest; and the moment it is done, the value of the public domain is enhanced ten-fold beyond the cost of its construction.

Occurrence of other Ores.—This class of rocks, over many portions of the earth, has been found to be the repository of the rarer and more valuable metals, such as gold, silver, tin, &c. Between this district and the

Ural, there are many points of resemblance; but Sir Roderick Murchison has shown, that the impregnation of those rocks with gold took place at a comparatively recent date, as recent as the drift epoch; while, in this district, the metallic emanations ceased before the commencement of the Silurian epoch. It also presents many analogies with Cornwall; but, thus far, the results of our explorations have led us to believe, that, aside from iron, the metallic products will prove of little value. We have not seen a single regular, well-defined vein of any extent, with distinct wall-rocks and gangues differing from the enclosing mass. There are fissures and irregular rents which contain metallic products, such as copper and iron pyrites, magnetic oxide of iron, &c.; but they differ from productive lodes in their want of continuity and parallelism. At the Pemenee falls, small veins of quartz, associated with brown oxide of iron are seen in the trappean rocks, having the appearance of an auriferous gangue. We regret that the specimens procured by us in 1848, were forwarded to Washington by our predecessor, without analysis. We do not assert that the rarer metals may not be found; but, thus far, all of the explorations south of the trap range of Keweenaw Point, not only in this district, but in the Chippewa district, have not revealed their existence.

At Presqu'isle, there is a vein seen by the lake shore, bearing nearly north and south, and dipping 75° to the east. It is included in a rock which exhibits some traces of stratification, and may be likened to a volcanic sand. The New York and Lake Superior company, a few years ago, sank a shaft upon it to the depth of forty-five feet. At the surface, it yielded the sulphurets of copper and iron, galena, and black oxide of manganese, enclosed in a matrix of chlorite, calc-spar and quartz; but, a short distance below, the more valuable metals disappeared, and iron pyrites was the only metallic product.

Another vein was observed on the south-west quarter of section 27, township 48, range 26, containing copper pyrites in a gangue of quartz. It was explored to some extent, a few years since, by the New York and Michigan company, but they met with few inducements to persevere.

Narrow seams of sulphuret of copper are also seen in the quartz rocks, below Carp river.

In the banks of a small stream flowing into the Machi-gămig, about ten miles below the outlet of Machi-gummi, gălena was discovered by Mr. Crebbesă, in 1846; but we have not examined the locality, and have no information as to its economical value.

On the Menomonee river, traces of the sulphuret of copper are abundant; but the veins are not concentrated. At the upper of the Twin falls, there are seams of quartz, included in chlorite slate, which contain traces of this ore. Veins were also observed at the foot of Little Bekuenesec and Sturgeon falls.

OTHER ECONOMIC MATERIALS.

Building Materials.— The granite of the Huron islands would afford a beautiful and durable material for construction. The islands are, in every respect, accessible, and we know not why they may not soon be resorted to for the purpose of procuring blocks.

As we have described the situation of these islands and the character of the rocks, in Chapter III., a farther notice is deemed unnecessary.

Roofing Slates.—In so vast a body of slates as are here displayed, it would be surprising if numerous quarries suitable for roofing purposes were not discovered; but on the surface they have been so acted on by atmospheric agencies, that it is difficult to determine their true character. By long exposure, they lose the property of cleaving into laminæ. This is so well understood by the block-hewers in slate quarries, that they never raise more blocks than the splitters can cleave in a short period of time. A frost partially restores this property, but repeated freezings and thawings destroy it altogether. The beds at the foot of little Bekuenesec falls, and near the Twin falls, on the Menomonee river, will probably yield unlimited supplies.

Steatite and Serpentine.—From the character of the rocks, beds of these materials will undoubtedly be found in great abundance, but we are unable to indicate any localities worthy of exploration. The beds near Sturgeon falls, on the Menomonee, afford the best indications of any that have fallen under our observation.

Fire-stones.—The talcose slates, as a general thing, are little affected by fire. The divisional planes intersect them in such a manner as to produce cuboidal blocks. These have been employed in the construction of forges at the Jackson works, and answer a good purpose.

Hones.—Portions of these slates take into their composition minute particles of quartz, forming novaculite. The beds at L'Anse afford very good whetstones, but they are too coarse to produce a fine edge on razors, surgical instruments, &c.

The novaculite, however, of Carp river, is superior to any article which has fallen under our notice, not excepting the Arkansas, Turkey, or Scotch stone, for producing fineness of edge. Engravers will find these hones almost invaluable.

The coarser materials for scythe-stones are abundantly distributed.

Fire-brick.—The light-drab and plumose talc-slates, described as occurring near Chippewa island, on the Menomonee river, if ground and kneaded, would make an admirable article of fire-brick.

Lime.—The marbles described as occurring in the vicinity of Carp river and the Menomonee river, may be calcined into lime. The amount of magnesia which enters into their composition, does not seem to impair their value; but the lime will not bear the addition of as much sand as an article made from a purer limestone.

Ornamental Materials.—The limestones described as occurring near Carp river, and on the Machi-gāmig and Menomonee, afford beautiful marbles. The prevailing color is light-pink, traversed by veins or seams of deep-red. Others are blue and dove-colored, beautifully veined. They are susceptible of a fine polish, and blocks of any size may be procured. For tables, jambs, and vases, they would rival, in beauty, the most celebrated foreign products. Employed for external ornaments, the carved lines would withstand the vicissitudes of our variable climate, and remain sharp for centuries. These rocks, in place, exhibit angular surfaces, which, after all, is the best test of their durability.

Fragments of pure-white saccharoidal marble, suitable for statuary, have been found upon the surface, but the beds from which they were derived have not been discovered.

Some of the jaspers might be employed by the lapidary, for the smaller ornaments, but they have not been found in large masses, like those of the Ural.

The dark and close-grained basalts, and the porphyries, with a dark-green base of hornblende and bright-red crystals of feldspar, observed on the Menomonee, if wrought into vases and boxes, would rival those of Egypt.

Many of these materials will, sooner or later, be employed for the purposes of construction and ornament.

CHAPTER VI.

COMPOSITION OF THE TRAPPEAN ROCKS.

The Terms Trap and Trappean Rock generic.— Varieties of Rock which have been included under that Name.— Their Mineralogical Composition.— Importance of these Rocks in our District.— Trappean Rocks associated with the Potsdam Sandstone.— Analyses.— Probable Analogy with Dolerite and Anamesite.— Occurrence of them in Beds.— Trappean Rocks of the Azoic System.— Analyses.— General Remarks.

The term trap, or trappean rock, has been applied in so general a manner, and made to cover such an extensive group of mineral compounds, differing widely from each other in their external characters and mineralogical composition, that great confusion has arisen in the designation of the igneous rocks. If we examine more closely what rocks have been designated under the name of trap, and endeavor to classify them, we find great difficulty, inasmuch as our knowledge of the mineralogical composition of many of them still remains in an imperfect state; although much has been done, within the last few years, to throw light on this subject, and numerous chemists, among whom we might especially mention Delesse, Durocher, Abich, G. Rose, Cordier, and Bergemann, have devoted themselves to this long and difficult task. It is with the intention of adding our contribution to this branch of geological science, that we have, as far as our time permitted, made a chemical investigation of a few of the varieties of the igneous rocks of our district.

Not only has the term *trap* been applied to a great variety of rocks, but that of *greenstone* is hardly less extensively used, both in this country and in England, as well as on the continent. However much confusion the use of these two names may have caused, they will hardly be dropped, at least not until the nature of our igneous rocks shall have been thoroughly studied out, so that they can be arranged under systematic and fitting names. On the continent, we find that by far the larger portion of the igneous rocks embraced under the name of greenstone, are made up principally of labradorite (or oligoclase) and pyroxene, in addition to which chlorite is often present. To this variety of rock the name of diabase is given by continental geologists. The term melaphyre, which includes many of the rocks known under the name of trap, is defined to be a fine-grained compound of labradorite and titaniferous magnetic iron, and probably pyroxene, together with, in many instances, carbonate of the protoxide of iron and carbonate of lime. The absence of quartz, as an essential ingredient of these rocks, both diabase and melaphyre, is a characteristic and important point. Under the name of basalt, or basaltic trap, are included dolerite, a crystalline aggregate of labradorite, augite and titaniferous iron; and anamesite, a homogeneous and very fine-grained mixture of the same minerals, the labradorite generally predominating. This latter term includes especially the rocks of northern Europe and Iceland. Basalt proper includes the rocks which contain, in addition to labradorite augite, and magnetic iron, a small amount of a zeolitic mineral, which gelatinizes in acids, and also, in many cases olivine.

In England, we find the terms greenstone and trap used indiscriminately to indicate rocks mostly of a fine-grained and compact nature, made up chiefly of feldspar and hornblende; — no distinction being made between the different varieties of the feldspar family, or between hornblende and pyroxene, or augite. In fact, we have only two great classes of igneous rocks recognized; — granitic, or hypogene rocks as they are sometimes called, and trappean rocks; the great and essential distinction between these two classes being the presence of quartz, as a distinct ingredient in the granitic rocks; while, in the trappean, the silicious matter is all in combination with the bases alumina, lime, protoxide of iron, soda and potash, forming minerals of the feldspar and hornblende families. If the rock has a columnar structure, it is called basalt, without regard to its mineralogical composition.

In this country, the same confusion has prevailed, and all the dark-colored fine-grained igneous rocks have been called greenstone, trap, or greenstone-trap indiscriminately, without any attempt having been made to arrive at a knowledge of their composition, regard being chiefly had to their differences of external form, such as their having a columnar, or amygdaloidal structure. No attempt has been made, as far as we know, to separate, or classify, the numerous varieties included under those general and generic terms.

We find, in all the writings of American geologists, that the term "trap" is used in a generic sense, and that it is defined to be a rock composed of feldspar and hornblende and; we are not aware that any further attempts have been made, in this country, to investigate the mineralogical composition of this great and widely-extended class of rocks.

The great importance of the trappean rocks in our district, from their intimate association with the veins of copper in the lower Silurian, and their connection with the deposits of iron in the azoic system, has made it incumbent upon us to devote some attention to their mineralogical composition and, though lack of time has rendered it impossible for us to carry out our researches very fully, yet we trust that, having made a beginning, we shall ourselves, at some future time, be enabled to extend our labors still farther or that the attention of others will be called to this important subject. The mere fact that we find the veins of copper, which are productive and rich in metallic contents in one band of rock, becoming worthless when passing into another, is sufficient proof of the scientific importance and practical value of such an investigation.

TRAPPEAN ROCKS ASSOCIATED WITH THE POTSDAM SANDSTONE.

We hardly find, in any part of the world, so great a variety of mineralogical composition and external structure among the trappean rocks, as exhibited by those trappean rocks which occur in the sandstone and conglomerates between the extremity of Keweenaw Point and the Montreal river and on Isle Royale.

In Part I, of this report, we have given some account of the different varieties of trappean rocks which occur in the copper-region, particularly with reference to their external characters, and we now proceed to the discussion of their mineralogical and chemical composition.

The principal mineral ingredients, so far as we can determine, which form the different varieties of trappean rocks of this region, are labrador feldspar, (labradorite) hornblende, pyroxene, magnetic iron, chlorite, and epidote. These minerals, associated in ever-varying proportions, make up the great mass of the rocks, while the less widely diffused minerals are the zeolites, especially Laumonite, quartz, calc-spar and iron pyrites.

The prevailing characteristic of these rocks is, that the mixture of the minerals which compose them is so intimate, and the whole mass is so compact and homogeneous in its texture, that the several component parts cannot be recognized by the eye, unless in exceptional cases, and of course it is impossible to isolate and analyze each by itself. In such a case, the only way to arrive at a knowledge of the mineralogical composition of the rock is to analyze it as a whole, and endeavor to ascertain by calculation, in what manner the different substances are grouped together into mineral compounds; or if minerals which are soluble in acid, are combined with such as are insoluble, to separate them in this way, and then to analyze the soluble and insoluble portions.

We now proceed to give the results of some of our examinations of the compact homogeneous rocks, after which we will describe those in which distinct mineral compounds can be recognized by the eye, and then compare the general results with each other.

Solubility of the Rocks in Acids.—A specimen from the wall of Shaw's vein, on Isle Royale, was finely pulverized, thoroughly dried at 110° C., and ignited. It lost on 3.203 grammes .072 = 2.2 per cent.

After long digestion, at a temperature of about 80° C., with nitric acid (specific gravity 1.12), it was found that 26.95 per cent. of the whole was taken up, leaving 73.05 insoluble matter of a brick-red color.

Chlorohydric acid dissolved on 2.2993 grammes, after long digestion, at about the same temperature as before, .7803, leaving 1.519 insoluble; of the insoluble portion .5552 was silica separated in a state in which it was taken up by carbonate of soda; making for the soluble portion, including the separated silica, 58.09 per cent. The solution was tested for copper, but no trace of this metal was found; it contained a very considerable proportion of peroxide of iron.

Analysis of Greenstone from the summit of the cliff, at the Cliff Mine.—The following were the results of the examination of the greenstone from the summit of the ridge at the Cliff mine. This is a crystalline variety, very tough, and breaking with an uneven fracture. It is of a dark-greenish color, very compact and homogeneous in its structure, but, when examined with the microscope, three distinct minerals can be recognized; one is nearly colorless, or slightly tinged with green, and appears to be feldspathic; the other is of a dark-green color, and resembles chlorite, while the third is apparently pyroxene or hornblende. Occasional crystals of magnetic iron occur, and can be made evident by pulverizing the substance and applying the magnet.

The pulverized substance, dried at 100° C., lost, by ignition, on 2.114 grammes, .0374 = 1.74 per cent. of water; chlorohydric acid (1.13 specific gravity), by long digestion, at a temperature near boiling, dissolved 21.17

per cent., leaving 78.83 of silica and insoluble substance. Each portion was analyzed by itself, and the results were:

	Soluble.	Insoluble.
Silica	——	64.58 (by loss)
Alumina	30.95	11.67
Protoxide of iron	32.47	9.18
Manganese	trace	trace
Lime	9.36	4.57
Magnesia	15.98	6.86
Soda	11.26	3.14
	100.04	100.00

Analysis as a whole:

		Oxygen.
Silica	50.20	26.08
Alumina	15.43	7.22
Protoxide of iron	13.79	3.06
Lime	5.47	1.56
Magnesia	8.62	3.34
Soda	4.75	1.22
Water	1.74	1.55
	100.00	

Analysis of a Specimen from Rock Harbor.—The next rock of which an analysis will be given, is a very fine-grained and homogeneous substance, from the shaft at Rock Harbor, Isle Royale, about fifteen rods north of the house at Ransom. Like the preceding ore, it appears to be highly unfavorable to the development of the copper-bearing veins.

1.9444 grammes of the finely-pulverized and dried substance, lost by ignition .0479=2.46 per cent.

The analysis of the dried material gave:

			Oxygen.
Silica	47.97		24.93
Alumina	15.56		7.28
Protoxide of iron	12.41	2.75	9.59
Lime	7.07	2.02	
Magnesia	8.28	3.21	
Soda	6.24	1.61	
Water	2.46		2.18
	99.99		

The near agreement in the chemical composition of these two rocks will be apparent.

If we proceed to consider, from the results of the above analysis, what is the probable mineralogical composition of the rock, we are obliged to confess that the problem is not an easy one. In the first place, as to the nature of the feldspathic ingredient, which is the most important clue to this question. The feldspathic portion of the trappean rocks, though it occurs in distinct crystals, at various localities in the trappean region, both on Isle Royale and Keweenaw Point, is never found in crystals of sufficiently large size to allow them to be separated from the rock and analyzed by themselves. This is unfortunate, since, at the present time, so numerous are the different varieties of the feldspathic family, that it is impossible to recognize and distinguish them without a chemical analysis.

As far, however, as the feldspathic ingredient can be made out, from an examination of those rocks on Isle Royale and Keweenaw Point, in which there is a porphyritic structure, and separate crystals can be observed, they appear to have the crystalline character of the labradorite variety. They also fuse much more readily before the blowpipe than orthoclase, yielding a transparent, colorless and blebby glass. The results of the analyses seem also to indicate, from the nature and relative quantity of the protoxide bases, lime and soda, that the feldspathic ingredient is labradorite.

If, therefore, in the above analyses we assume that all the alumina belongs to the labradorite, and that the other ingredient is one in which alumina is not contained, we can reckon the amount of oxygen of the silica and the bases (RO) necessary to form labradorite.

In the first analysis, that of the greenstone from the Cliff-mine, the oxygen of the alumina being 7.22, if we deduct the double of that amount from the silica, and one-third from the protoxide bases, we have remaining:

Oxygen of silica	11.64
" protoxide bases	6.77
" water	1.55

And in the other rock, from Rock Harbor, we have, in the same manner, remaining:

Oxygen of silica	10.37
" protoxide bases	7.1
" water	2.18

The results of these analyses correspond pretty nearly with that of the trap of the Feroe islands, by Durocher.* In his analysis, after deducting from the oxygen of the silica and the protoxide bases an amount corresponding with that of the alumina, in the proper proportion to form labradorite, there remains:

Oxygen of silica	9.52
" protoxide bases	7.36
" water	2.66

Durocher considers that this implies the existence of a mineral analogous to diallage, or a bisilicate of bases with one atom of oxygen + hydrate of magnesia. In fact, if we deduct from the protoxide bases an amount of oxygen equal to that of the water, we have remaining a silicate, in which the oxygen of the silica is nearly the double that of the bases. The great difficulty in this case is to know what part the water plays in the constitution of the mineral. As far as our researches go, all the trappean rocks seem to contain from two to three per cent. of water. Recent investigations, however, still leave it doubtful whether this water belongs to the feldspathic mineral, or whether it may not be due to an intermixture of

* Annales des Mines, Ser. III., Vol. 19, p. 547.

chlorite in the trappean rock. The observations of Delesse seem to prove that water is constantly present in the feldspathic portion of the trappean rocks analyzed by him. This is a point on which, however, we can give no light, as we have not been able to isolate and analyze the feldspar of any of our trappean rocks. We see, however, that chlorite is abundant in them, and a portion, at least, of their water must be ascribed to its presence. In this case, if we take into consideration the variable composition of the hornblendic or pyroxenic portion of the rock, the fact that a part of the water may belong to the feldspathic portion, and that the iron is probably partially present as the magnetic oxide, we shall see that the difficulties in the way of arriving at a complete knowledge of the mineralogical composition of these rocks, by analysis of them as a whole, are nearly insuperable.

The only variety of trappean rock occurring in the Keweenaw Point range, in which the ingredients are distinctly visible, so that we have been able to make out its composition, we find to be made up of a light-red feldspathic portion, having the character of labradorite, of a dark-green foliated mineral, which is probably pyroxene, chlorite and magnetic iron. This variety occurs at Lac la Belle, and it graduates imperceptibly into the common, compact, crystalline greenstone, in which the separate minerals are no longer to be distinguished by the eye. This we consider to be the most probable composition of the dark, crystalline varieties of the trappean rocks on Keweenaw Point and Isle Royale.

We have also on Isle Royale, beds of a porphyritic rock, intercalated among the crystalline greenstones, which are composed essentially of a feldspathic ingredient, which is probably labradorite, and magnetic iron; the feldspar is of a light-greenish tinge, and occasionally exhibits metallic reflections; the crystals, are, however, very minute.

Both on Isle Royale and west of Portage lake, epidote becomes a predominant ingredient of the trappean rocks, forming beds and vein-like masses in it. In the Porcupine mountains and in the vicinity of Agogebic lake, we have this mineral forming masses of such dimensions that it must be regarded as a rock: it is often amygdaloidal, like the other varieties of the trappean rocks.

The presence of free or uncombined silica in the trappean rocks, except when it forms a part of the vein-stones, is exceedingly rare. Where, however, the trap becomes epidotic, quartz not unfrequently occurs, filling the amygdaloidal cavities. In the veins of the Ontonagon region, where epidote abounds, both as part of the rock-masses and in the veins, quartz forms the predominating gangue.

The zeolitic minerals, so common in the veins, and often filling the amygdaloidal cavities of the trap, do not appear to form an essential ingredient of the compact trappean rocks. None of them, as far as we have examined, when acted on by acids, give any gelatinous silica. Carbonate of lime, so common in the veins of the trap, seems to be rarely present in the compact trappean rocks, as few of them effervesce with acids. From the same reason, we infer the almost entire absence of carbonate of iron.

The mineral nepheline is not found in any of these rocks, unless it be in one locality on Isle Royale, near the end of Blake's Point, where the mass is made up of a fine-grained mixture of magnetic oxide of iron and a light greenish-colored material, which fuses readily before the blowpipe, and resembles nepheline in lustre and general appearance.

Olivine is entirely wanting in all these rocks, as far as we have been able to ascertain.

On the whole, these rocks may, in all probability, be classed with that member of the trap family, in which are included dolerite, anamesite and basalt. This class of igneous products is developed on a grand scale in Iceland, in the northern part of Ireland, and in Scotland. On the Faroe islands and in Iceland they have been poured out in lava-sheets of great extent and regularity, which, like those of Isle Royale, are piled upon each other in numerous strata-like masses, exhibiting almost the appearance of sedimentary deposits.

TRAPPEAN ROCKS OF THE AZOIC SYSTEM.

If the study of the mineralogical composition of the trappean rocks associated with the Potsdam sandstone is one of great perplexity and difficulty, this is still more the case in regard to the igneous rocks which occur in connection with the azoic system. So numerous are the varieties of these rocks, and so limited has been the time that we have been able to bestow on their examination, that we have accomplished but little towards arriving at a knowledge of their complex and obscure mineralogical character. The first thing which strikes the observer, in passing over the intercalations of igneous rocks among the azoic slaty and quartzose strata, is the difficulty of making a distinction between the purely igneous and metamorphic rocks. The passage of one into the other, especially in the southern portion of the district, seems, in many cases, to be so gradual, and their general appearance and structure is so much alike, that it is often difficult to say where one begins and the other ends; add to this, the very great physical difficulties in the way of a minute exploration of the almost inaccessible region in which they occur, difficulties of which those who have not themselves experienced them can form but a faint idea, and we shall not be considered as having neglected to do all in our power to throw light on this interesting subject.

The igneous products which are associated with the azoic system are, so far as we have examined them, perfectly compact and homogeneous. They are entirely destitute of the amygdaloidal structure which characterizes the traps described as occurring in connection with the sandstone and conglomerate of Keweenaw Point and Isle Royale. They are, likewise, wanting in the zeolitic minerals which are so abundant in the amygdaloidal traps, and are, in every respect, more uniform in their texture and appearance than these. In general, the mixture of the different mineral ingredients of which these rocks are made up is very intimate, and we have never seen them assume a porphyritic structure, or developed in crystals of sufficient size to be separated and analyzed. Thus we are reduced to the necessity of analyzing the rock as a whole, if we would wish to obtain any more satisfactory insight into its real composition.

If we consider, for a moment, the manner in which these igneous masses must have been formed, and the circumstances under which they were poured out from the interior of the earth, we cannot expect to find an absolute uniformity of texture or of composition, in the different sheets of plastic matter, which were spread out over the surface at different periods during the same geological epoch; but may reasonably expect that, during the continuance of the same general causes, the igneous products will be, in some degree, characterized by peculiarities of composition.

We will now proceed to the detail of the results of the examination of these rocks; and first, we will take up the trappean rock of which Presqu'isle is composed.

Analysis of the Igneous Rock of Presqu'isle.— A peculiar variety of rock occurs at Presqu'isle, and forms the principal portion of that projection of the coast. It has all the aspect of an igneous, or eruptive rock. Its color is a deep-green, almost black, and it is apparently homogeneous in its composition. It is somewhat columnar in its structure, resembling some varieties of basalt. It is all readily attracted by the magnet, when broken into small fragments, but no distinct particles of magnetic iron can be perceived in it. Before the blowpipe, it hardly undergoes any change when heated in the platina forceps; it becomes slightly rounded on the edges and remains magnetic.

It is only partially soluble in strong chlorohydric acid, after long digestion at a temperature near boiling. It contains both the protoxide and peroxide of iron. A portion of the minerali which had been previously ignited in a stream of carbonic acid gas, lost by reduction with hydrogen only 3.87 per cent., so that by far the larger portion of the iron is in a state of combination in which it cannot be reduced by ignition in a stream of hydrogen.

The analysis gave:

Silica	38.24
Magnesia	14.83
Alumina	1.48
Lime	1.42
Water	9.53
Peroxide and protoxide of iron and a little soda	34.50
	100.00

The amount of iron, as found by the analysis, and calculated as a peroxide, is 34.59 per cent.; but, on testing the solution of the mineral in chlorohydric acid, attacked in an atmosphere of carbonic acid gas, it was found that both the oxides of this metal were present in it. Want of time rendered it impossible for us to complete the analysis.

From the above results, it appears that the substance is essentially a hydrous silicate of magnesia and the protoxide and peroxide of iron.

This rock differs in its external character and chemical composition from any occurring elsewhere in our district, and it is difficult to refer it to any known class of rocks; it approaches somewhat nearly, in composition, the mineral Hisingerite.

The trappean ridges which accompany the iron of the azoic slates are interesting and important, from their connection with the valuable deposits of this metal, as those of the Silurian with the copper. An examination was made of the rock from section 10, township 47, range 27, as a good sample of the kind of trappean rock most nearly connected with the iron. It forms a high ridge, just south of the great ferriferous band extending through that section. The rock is of a light-green color, tough, made up of a finely foliated and lamellar hornblende, with a small proportion of a feldspathic ingredient, which is not distinctly to be made out, as it is not crystallized, but which appears to have the lustre and degree of fusibility of labradorite. A few specks of iron pyrites are scattered through the rock; and this mineral is common to all the trappean rocks of the azoic series. It is not easy to decide whether the main ingredient of the rock is pyroxene, or hornblende, as the crystallization is too confused to allow of the measurement of the cleavage planes; but, as far as can be judged by the eye, it seems to be hornblende rather than pyroxene.

Portions of the hornblendic element of the rock have a bright grass-green color, like coccolite, and are of a granular texture.

The following are the results of a single analysis:

		Oxygen.
Silica	46.31	24.06
Alumina	11.14	5.21
Protoxide of iron	21.69	4.82
Lime	9.68	2.76
Soda	6.91	1.78
Water	4.44	
Magnesia	trace	
	100.17	

The large quantity of water is remarkable, and we content ourselves with stating the fact, without attempting to go into the discussion of the part which it plays in the constitution of the rock.

If we neglect the water, and considering the feldspathic element as labradorite, deduct from the oxygen of the silica and the protoxide bases, a quantity corresponding with the composition of this mineral, taking all the alumina as belonging to it, we shall have remaining:

15.64 oxygen of silica.
7.63 oxygen of protoxide bases.

This would make a silicate, in which the oxygen of the silica was the double of that of the bases RO, namely, hornblende or pyroxene. Thus, the composition of the rock would be a mixture of labradorite and pyroxene, together with water.

The above analysis may be taken as a representation of the rocks accompanying the iron in the northern portion of the azoic region; in the more southerly part of the district, along the course of the Menomonee, there seem to be two classes of igneous rocks; one, a very compact, dark, hornblendic variety, with occasional crystals of a feldspathic mineral, probably labrador, interspersed; and the other, a much lighter-colored rock, and in appearance more resembling the granite family.

A specimen of the light-colored, homogeneous rock from the Menomonee, about four miles below Sturgeon falls, was particularly examined.

Before the blowpipe it fuses readily to a colorless, transparent glass; it is very incompletely dissolved in chlorohydric acid. The analysis gave:

Silica	54.54
Alumina	21.45
Peroxide of iron	5.53
Lime	8.40
Soda	7.54
Magnesia	trace
Water	2.54
	100,00

This is very nearly the composition of labradorite, so that it would seem to be a massive feldspathic rock, or a *feldstein* of the Germans, which name has been adopted into the English language by Sedgwick, and called by him *feldstone.*

The same rock occurs along the Menomonee, from Sandy portage to Big Bekuenesec falls, forming cliffs two hundred feet high; it occasionally takes into its composition a little of a light-greenish mineral, which resembles serpentine, or talc, in appearance.

There are some rocks in the same region, whether purely igneous or metamorphic, it is difficult to say, which partake somewhat of the nature of serpentine, though we have not recognized any perfectly distinctly marked specimens of this substance. A passage from rocks of this class into hornblende and chlorite slates may not unfrequently be noticed. Of this uncertain composition is the rock which is exposed in ledges on the road from the Jackson landing to the Forge, which is of a character intermediate between a trappean and serpentine rock.

In one respect, many of these igneous rocks resemble serpentine, and might, on that account, be considered as likely to contain intermixed portions of that mineral; this is the large percentage of water which they are found to contain, even when presenting a perfectly fresh and undecomposed appearance. This water may, however, with equal probability, be referred to the presence of chlorite, which is certainly an occasional ingredient of these rocks, although by no means as frequent as in the traps of the Silurian series. There is evidently a gradual passage of serpentine and steatite into hornblende rock, and they all occur so intermingled, and under such a variety of form, that no exact lines of demarcation can here be drawn between them.

On the whole, as far as our researches on the trappean rocks of the azoic series will justify us in drawing any general conclusions as to their place in the classification of these igneous products, we are inclined to refer them to the diorite family, though the feldspathic element is certainly not in all cases albite, which is generally recognized as being an essential ingredient of this class of rocks. The difficulty of determining this point, however, is very great, inasmuch as this mineral forms comparatively a small proportion of the mass, and exhibits only a granular structure.

We ought to advert to the large percentage of iron which all these rocks of the azoic series are found to contain, and which is a fact important in its connexion with the immense deposits of the oxides of this metal which are associated with them. This iron is mostly in the form of the silicate of the protoxide, in the purely igneous varieties: when, however, they pass into slates, or assume the appearance of the metamorphic rocks, the iron appears in great abundance in the form of the bisulphuret, or iron-pyrites.

CHAPTER VII.

MINERALOGY.

The following list, arranged alphabetically, comprises all the minerals which have been found in the sandstone and conglomerate, together with the associated trappean rocks of the Lake Superior copper region, as far as we have been able to determine. We have also included the few minerals which occur in the azoic slates and the associated igneous rocks.

We have added, under the head of each mineral substance, such information concerning its crystalline form, chemical composition, and peculiarities of occurrence, as may be of interest to the mineralogist and practical miner. The intimate connection between the occurrence of valuable ores and their associated gangues need not to be insisted on; and it is evident that information with regard to the veinstones and associated minerals of the copper-bearing rocks forms an important addition to the geological description of this region.

Actinolite.—See Hornblende.

Agate.—See Quartz.

Albite.—See Feldspar.

Amethyst.—See Quartz.

Analcime.—This mineral has been found in several localities, in beautifully crystallized specimens. The crystals are all trapezohedra: they are never transparent, but generally nearly opaque. They are tinged with various colors: light flesh-red, by suboxide of copper, or green, by carbonate or silicate of the same metal; the crystals which contain no copper vary from white to a light-grey or reddish-white. The largest crystals are about an inch in diameter. At the Copper Falls mine, the crystals of analcime are associated with calc-spar, and are influenced in their crystalline form by this mineral in a singular manner. A mass of calc-spar, for instance, will exhibit, on its surface, numerous crystals of analcime, of each of which, however, only from two to four of the trapezohedral faces are visible. On cleaving off the calc-spar with care, it will be seen that the analcime has been prolonged, sometimes for an inch or more, between the crystalline planes of the calc-spar, being compressed, as if by the more powerful crystalline force of the latter mineral, into four-sided prisms, on the summits of which, as they have emerged from the calc-spar, the trapezohedral faces have been formed with their usual lustre and appearance. At the old workings of the Pittsburg Company, at Copper Harbor, in the conglomerate, this mineral was found in abundance; in fact, it formed no inconsiderable portion of the gangue of the vein. The crystals were generally colored by suboxide of copper, and associated with an argillaceous substance, which was very liable to crumble, and thus destroy the value of the specimens. At Eagle Harbor, crystals of analcime occur, which are filled with a fine net-work of native copper, which has not, however, prevented the perfect development of the crystalline faces.

Other localities of this mineral are:—East bank of Eagle river; Lake Superior company's mine; Massachusetts location.

Apophyllite.—This mineral is found in considerable abundance, and in fine crystals, at several localities. At the Cliff mine, the crystallized specimens are all tabular, the faces P greatly predominating over M. The planes a^1 are developed so that M appears only as a small quadrilateral plane. The crystals are from one-eighth to one-fourth of an inch in diameter; they are, occasionally, transparent and colorless. At the North American mine, they occur in abundance, mostly in octohedra, with a square base, the face P being entirely wanting on most of the specimens, and when it occurs it is very small.

At the former locality the crystals occur in connection with native copper, in small cavities in the masses, and separated from the metal by a thin band of silicious matter.

The foliated variety (ichthyophthalmite) occurs at the Prince mine, on the north shore of the lake.

Asbestus. — See Hornblende.

Augite. — See Hornblende.

Azurite. — See Copper, carbonate of.

Baryta, Sulphate of. — This mineral occurs abundantly in the conglomerate, and occasionally forms veins of considerable magnitude. The finest crystallized specimens have been found at the works of the Mendenhall mining company, on Mineral creek. The ore obtained there consisted of calc-spar and sulphate of baryta impregnated with sulphuret of copper. The crystals are tabular in form, and colorless and transparent: they occur implanted on the gangue and are very abundant, but do not exceed a quarter of an inch in diameter. Near Agate Harbor the cock's-comb variety occurs abundantly, in a vein in the conglomerate, associated with calc-spar and sulphuret of copper. At both the above-mentioned localities the great weight of the sulphate of baryta, colored deeply by from eight to ten per cent. of black sulphuret of copper, led to the erroneous idea that the ore was very rich in this metal.

Blende.— See Zinc, sulphuret of.

Calc-spar.—This mineral constitutes an essential part of most of the veins, both in the sandstone and conglomerate, as well as in the trappean rocks; together with quartz it forms the almost invariable gangue of the copper, and it also occurs by itself in veins of great width, which are principally found in the conglomerate. Crystallized specimens occur at many localities. A few of the more interesting forms may be mentioned. At Copper Falls, Eagle Harbor, Agate Harbor, the Cliff mine, and North American mine, in the form of an obtuse rhombohedron, *cuboide* of Haüy. The crystals are often filled with bright spangles of native copper. At the old workings at Copper Harbor, highly modified scalene-triangular dodecahedra, also six-sided prisms, the latter of small size but perfectly transparent and colorless. The colorless crystals were implanted on the massive calcareous spar in the vein, and evidently formed posteriorly to the latter. At Agate Harbor, the dog-tooth variety was found in the greatest abundance, nearly the whole mass of the vein being made up of a congeries of crystals of this form and of a light-bluish color, associated with cock's-comb spar, and, generally, colored by sulphuret of copper. At the Mendenhall company's location, beautiful hemitropic crystals of the scalene-triangular dodecahedron were found.

At Presqu' isle, an abundance of finely-crystallized specimens was thrown out by the company engaged in mining at that place. The crystals are nearly all hexagonal prisms with trihedral summits, some of which are an inch in diameter, and one or two inches in length. They would be very fine cabinet specimens, had not nearly all the crystals undergone a molecular change for a depth of half a line, which has rendered them dull and rough upon the surface. The calc-spar is here associated with galena, and is posterior to this mineral. At the same locality handsome dog-tooth crystals occur.

At Copper Harbor, in the black oxide vein, numerous fine crystallizations of this mineral were obtained. They were mostly six-sided prisms, with numerous additional planes, and scalene-triangular dodecahedra.

Carnelian.—See Quartz.

Chabasie.—Doubtful if found in the Lake Superior region, which is an interesting fact, inasmuch as this mineral occurs commonly among the trappean rocks in numerous localities.

Chlorastrolite.—This mineral was first observed by Dr. Locke, on the shores of Isle Royale, and afterwards obtained by Mr. J. H. Blake. It was analyzed, and described as a new mineral by Mr. Whitney, in the fifth volume of the Boston Natural History Society's Journal. The name, chlorastrolite, was given to it by Dr. C. T. Jackson, in allusion to its greenish color and stellated structure.

It occurs in finely radiated, stellated masses, with a pearly lustre, and slightly chatoyant on the rounded sides. Hardness 5.5 to 6: specific gravity 3.180: color light bluish-green. Its behaviour before the blowpipe is as follows:

In the open tube it yields water, and becomes white.

In the platina forceps it fuses with great facility to a greyish, blebby glass, It intumesces and swells up like a zeolite.

Soda dissolves it in small quantity, and gives a bead colored by a trace of manganese: if more of the assay be added, it swells up to an infusible slag.

It is dissolved by borax readily, and in considerable quantity, and gives a transparent glass colored by iron.

Salt of phosphorus dissolves it in small quantity, and gives the reaction of iron.

With nitrate of cobalt it gives a beautiful blue.

It is readily dissolved by chlorohydric acid, the silica being entirely separated in the form of a flocky precipitate.

The analysis of two specimens gave:

	I.	II.
Silica	36.99	37.41
Alumina	25.49	24.25
Peroxide of iron	6.48	6.26
Lime	19.90	21.68
Soda	3.70	4.88
Potash	.40	
Water	7.22	5.77
	100.18	100.25

The ratio of the oxygen in these analyses is as follows:

	I. Oxygen	I. ratio.	II. Oxygen	II. ratio.
Silica	19.22	3.00	19.43	3.00
Alumina & oxide of iron	13.90	2.10	13.19	2.03
Lime, soda and potash	6.50	1.01	7.41	1.14
Water	6.40	1.00	5.13	.79

Another determination of the water was made on a third specimen, which gave 7.16 per cent., showing a near agreement with analysis No. I.

The ratio of the oxygen of the water, protoxide bases, the peroxide bases and the silica, is nearly 1 : 1 : 2 : 3; and the formula is, therefore:

$$\left.\begin{matrix} 3\,Ca\,O \\ 3\,Na\,O \end{matrix}\right\} Si\,O_3 + 2 \left.\begin{matrix} Al_2\,O_3 \\ Fe_2\,O_3 \end{matrix}\right\} Si\,O_3 + 3\,HO$$

This formula is that of meionite, with the addition of three atoms of water.

The calculated percentage of the mineral, according to the above formula, is as follows, assuming that the bases $R_2\,O_3$ are represented by six-sevenths of alumina, and one-seventh of peroxide of iron, and the bases R O by lime six-sevenths and soda one-seventh:

Silica	38.25
Alumina	24.32
Peroxide of iron	6.31
Lime	19.97
Soda	3.70
Water	7.45
	100.00

The chlorastrolite has been cut and polished for the purpose of ornamental jewelry, and makes a very pretty gem. The best specimens are found in the form of rounded masses, which have been loosened from the trap, and worn and polished by the water; they are most abundant on the small islands, near the north-eastern end of Isle Royale. This mineral is found in the rock at Chippewa harbor: the largest specimens which have been found are about an inch in diameter.

A mineral much resembling chlorastrolite occurs, on Isle Royale, in radiated epidote, in the form of small fibrous, radiated masses. The color is a light bluish-green. The quantity which could be obtained of it for analysis was so small, and it was so difficult to free it from the gangue, that the following analysis can only be regarded as an approximation.

Silica	42.6
Alumina and oxide of iron	31.2
Lime	20.6
Water	5.2
	99.6

As the ratio of the oxygen of the silica, alumina and oxide of iron, lime and water are, approximately, 3: 2: 1: 1, it is not improbable that the above may be a hydrous epidote; which supposition is rendered more probable by its mode of occurrence, in fibrous nodules enclosed in radiated and massive epidote.

Chlorite.— This mineral occurs abundantly in the trappean rocks, and is disseminated through them in fine particles, or fills the amygdaloidal cavities of the rock. It is very commonly found covering the surface of the amygdules of calcareous spar, interposed between the latter mineral and the trap. It is also a constant accompaniment of the veins, especially in the Ontonagon region, where it forms a large part of the gangue, and is associated with quartz. It occurs in large masses interposed between the sandstone and the trap, on Keweenaw Point and in the Porcupine mountains. At the mine of the Union company, a bed of chlorite, lying between the trap and sandstone, was worked for copper, which was interspersed through the mass in fine and delicate films, and which most frequently occurred lining the exterior surface of the amygdules of calc-spar; these were scattered through the chloritic mass.

Chrysocolla.— See Copper, silicate of.

Copper, Native.— This metal is in every respect the most interesting substance found in connection with the trappean rocks of the Lake Superior region. Its wide distribution, and mode of occurrence in them, have been already described in the first part of this report, and it will only be necessary to add some few particulars of mineralogical interest, to what has already been said with regard to this metal.

In addition to the enormous masses which occur in the veins of this region, sometimes attaining at the Cliff mine the weight of several hundred tons, a great variety of interesting crystalline forms are occasionally found. The most interesting localities of the crystallized copper are at the Copper Falls, the Cliff, the Phœnix (formerly Lake Superior), and the Eagle Harbor mines.

Unfortunately, but few good crystals have come into our possession, as they are highly valued by those interested in the mines, and of course difficult to be obtained, except by those residing at the localities where they occur.

The finest crystals which we have obtained were from the Cliff mine, where they are frequently thrown out with the gangue, which is generally, where the copper occurs crystallized, drusy quartz associated with calcareous spar. These crystals are generally tetrahexahedra; the largest which we have is one-fourth of an inch in diameter. The twenty-four-faced figure is formed by two replacements on each edge of the cube by the plane b^3. The crystals, however, are rarely perfect, being almost always much distorted; and, often, only one or two crystalline planes are to be recognized on the extremity of a shapeless, elongated mass. We have seen, from the Cliff and Copper Falls mines, octohedral crystals, some of which were nearly an inch in diameter; cubical crystals also occur at the last named locality.

A abundance of dendritic, or arborescent forms, have been obtained at the Eagle Harbor and Copper Falls mines, but their planes are too imperfect to allow their detailed structure to be made out.

A beautiful instance of the crystalline form of one mineral modifying the form of another, crystallizing within it, was noticed at the same locality, where the compound group of twin crystals lay within a crystal of transparent calc-spar, and the individuals of which had assumed, in reference to the main stem, the angle of the rhombohedral crystal in which they were enclosed.

No doubt, as these mines are farther opened, an abundance of interesting forms will be developed. Crystals of analcime occur at Copper Falls, which are completely filled, throughout their whole interior, with delicate ramifications of metallic copper, so that, if the silicious material were dissolved out, the form of the crystal would still be recognized by the mass of metallic matter remaining.

Copper, black oxide of.—This substance was found in large quantities, forming a vein in the conglomerate at Copper Harbor. Its geological position has been described in a previous report. This, so far as known, is the only instance of the occurrence of this substance in a state of purity, and forming the principal mass of a vein. It is not to be confounded with the substance known to mineralogists as "copper-black," which is a product of the decomposition of other ores, and a mechanical mixture of various hydrated oxides, especially of iron, manganese and copper. The name of Tenorite has been given to the oxide of copper found in minute hexagonal scales on the lava of Vesuvius.

As we were present at Copper Harbor during a portion of the time while this vein was being worked (in 1845), we had a good opportunity of seeing the real nature of the ores. We searched all the masses thrown out, at that time, for crystallized specimens of this substance, but without succeeding in finding any. Mr. J. E. Teschemacher has, however, discovered in the masses, mined after that time, and sent down to Boston, a number of crystals, which are cubes with their solid angles replaced. The question therefore arises, whether this is really a dimorphous substance. Mr. Teschemacher has suggested that these crystals may originally have been crystals of red oxide of copper, and that they have been converted into the black oxide by the agency of heat.

In regard to this, it may be said, that crystallized red oxide of copper occurs abundantly in the same vein, but that the crystals are all *octohedral;* moreover, the crystals of $Cu^2 O$ occur implanted on metallic copper, when, according to Mr. Hayes's views, they ought to have undergone the greatest amount of heat, and, therefore, to have been converted into black oxide.

We are inclined, in every point of view, to regard the whole formation of the black oxide vein as one which occurred in the *humid,* rather than in the dry way, and see no sufficient reason to suppose the cubic crystals of CuO pseudomorphs.

Portions of the black oxide of copper are mingled with silicates of the oxide, more or less hydrous, but large masses were obtained of almost pure CuO. Severa l analyses of the black oxide have been made by us, which show the presence of from one to two per cent. of impurities, mostly silex, lime, and iron, in the massive varieties.

The following is a mineralogical description of this remarkable mineral:

Substance tesseral; crystallized in cubes with their solid angles replaced; generally found massive; no distinct cleavage; hardness, about 3; specific gravity, 6.25; color, steel-gray to black; lustre, sub-metallic; the earthy varieties acquire a metallic lustre on being scratched with the knife; opaque; chemical composition.

Copper	79.86
Oxygen	20.14
	100.00

Copper, red oxide of.—This substance is found in numerous localities, but rarely in very fine specimens. The best were obtained from the black oxide vein at Copper Harbor, where they occurred crystallized in octohedra, and implanted on masses of native copper. A few very fine specimens were obtained here, the crystals being about one-eighth of an inch in diameter, and very perfect.

The capillary variety, of a beautiful cochineal-red, was observed near the surface of the vein of the Cliff mine, when first opened, evidently a secondary product. Numerous minerals throughout the copper region are colored of a beautiful red tint by the presence of this substance.

Copper, carbonate of.—The green carbonate occurs in numerous localities, but only in very small and unconspicuous masses, resulting from the action of meteoric agencies on the metallic copper. The blue carbonate is much rarer; and we have, in fact, only noticed it in minute quantities in two or three localities. The green carbonate occurs in slender fasiculated fibres, in the cavities of the amygdaloid, at Copper falls; azurite, or the blue carbonate, is found in small quantities at the Algonquin location.

Copper, phosphate of.—Occurs at Copper Harbor, forming a delicate incrustation over some of the masses of the black oxide.

Copper, silicate of.—*Chrysocolla*, or the hydrated silicate of copper, was obtained in considerable quantity from the so called "black oxide vein," at Fort Wilkins. In the outer belt of conglomerate at Copper Harbor, the same vein was made up principally of calcareous spar mixed with, and stained by, silicate of copper. This vein, projecting into the lake, was long known to the voyagers as "the green rock." The silicate was occasionally quite pure, and of a fine bluish-green color, but more frequently mixed with ferruginous and argillaceous matter, or, sometimes, with the black oxide.

Dioptase, also a hydrated silicate of copper, but containing only one-half the quantity of water of the chrysocolla, is said to have been found in minute crystals at the same locality.

Copper, sulphuret of, and Copper Pyrites.—Copper pyrites, or sulphuret of iron and copper, $Cu_2 S + Fe_2 S_3$, occurs in minute particles, occasionally, in the native copper mines. In the southern trap range on Keweenaw Point, the sulphurets of copper are the prevailing ores, and are found in considerable quantity. Copper pyrites occurs at Lac la Belle, in the vein, and scattered in particles through the rock adjoining; but the greater portion of the metalliferous contents of the lode at this mine are the vitreous and variegated ores ($Cu_2 S$ and $FeS + 2\ Cu_2 S$). They are not crystallized, as far as we have observed. The sulphurets of copper have been mined also at the locations of the Suffolk and Mendenhall companies. In the latter case, the ore was mainly sulphate of baryta, colored by sulphuret of copper. The same was the case at the workings of the New York and Michigan company, the vein, in both these cases, being in the conglomerate. In the azoic system, copper pyrites is found in small quantities in a gangue of quartz, which forms veins traversing the slates. On the north shore of the lake, the sulphurets, especially pyritous copper, have been extensively worked at the Bruce mine, and the Prince vein.

Arsenical copper pyrites occurs at the Medora mine on Keweenaw Point.

Copper, vanadate of.—The vanadate of copper is said, by Mr. Teschemacher, to have been found at the Cliff mine; we have been unable to detect the presence of vanadium in any of the specimens which we have found there, and Mr. Schlieper, to whom Mr. Teschemacher referred his specimens for examination, was not able to satisfy himself of the existence of vanadium in them.

Datholite.—No mineral occurring in this region affords more beautiful and abundant specimens than this. The principal localities are on Isle Royale, where it forms, in some cases, nearly the whole gangue of the copper-bearing vein. By far the finest locality of crystallized specimens is in township 65, range 34, section 10, where beautiful groups of crystals, some of which were half an inch in diameter, were obtained. The crystals are implanted on massive datholite, which is translucent, and has a lustre inclining to resinous. The massive variety forms nearly the whole width of the vein, being enclosed between selvages of radiated epidote. Most of the copper in the vein is associated with the epidote near the walls. The cavities in the massive datholite are filled with crystallizations of the same mineral. On these crystals are occasionally implanted delicate honey-yellow scalenohedra of calcareous spar. The datholite is colorless, except in the proximity of the copper, when it is occasionally tinged of a pale-red by the suboxide of that metal.

We have thought it worth while to make an analysis of the massive variety of this mineral, the results of which show that it is equally as pure as the crystallized, and agree well with those required by the formula.

Silica	37.64
Lime	34.68
Boracic acid	21.88 by loss.
Manganese, oxide of	trace
Water	5.80
	100.00

Dioptase. — See Copper, silicate of.

Dolomite — Forms immense beds in the Niagara limestone, on the shores of Lake Michigan, and in the St. Mary's river. The interior of the casts of the fossils contained in it are lined with crystals of the same mineral.

Epidote. — This mineral is most abundantly distributed through the whole trappean range of Keweenaw Point. It sometimes even forms, of itself, mountain masses. It rarely, however, occurs in distinct crystals, so as to form good cabinet specimens. Some of the radiated specimens, from the Ontonagon region, where it occurs in quartz, and associated with copper, are very pretty. Epidote sometimes colors the crystals of quartz, with which it is associated, and forms very pretty specimens. It is one of the most common attendants of the native copper.

Feldspar. — The only variety of feldspar which occurs in distinct crystals, is a peculiar reddish variety of orthoclase, which is found in some of the veins, implanted on quartz or copper. It occurs, also, in fine acicular crystallizations, which have a striking resemblance to stilbite, at the Copper Falls mine, where it is associated, in the vein, with calcareous spar and native copper. At the Douglass Houghton mine, the same variety occurs in the vein, in crystals implanted on quartz. An analysis of the indistinctly crystallized mineral from Copper Falls, gave the following result:

Silica	65.88
Alumina	17.35
Oxide of iron	.57
Potash and soda	16.20 by loss.
	100.00

A sufficient quantity of the substance could not be obtained for a direct determination of the alkalies, but the above results agree so nearly with the composition of orthoclase, that its identity with that mineral cannot be doubted. This is an anomalous occurrence of this mineral, and one which it is difficult to explain. The feldspar is evidently posterior, in its formation, both to the copper and the calcareous spar, and must be considered here as an undoubted aqueous product.

Labradorite is the prevailing variety of the feldspar family in the trappean rocks of Keweenaw Point and Isle Royale: it is generally so intermixed with the other ingredients of the rock as not to be distinguished by the eye; but, in the porphyritic belts of Isle Royale, it occurs in distinct crystals of a green color.

For an analysis of the orthoclase of the granite of the azoic region, see the chapter on the igneous rocks. In the same chapter will be found an analysis of the massive labradorite, or feldstone, of the azoic series.

Orthoclase forms almost the entire mass of extensive ridges in the granite, south of the azoic slates, through the whole extent of our district.

Fluor-spar.—The only localities in which this mineral has been found in our district, as far as we know, are at Copper Falls, where small cubic crystals were obtained, which hardly exceeded an eighth of an inch in diameter; and about a mile above Eagle Harbor, in the conglomerate. On the north side of the lake, fine specimens have been obtained at Prince's bay, where it occurs in cubical crystals of a green color. It also occurs on Fluor island.

Galena.—At Presqu'isle, this mineral occurs in a variety of crystalline forms; namely, the cube, the octahedron, the octahedron with its solid angles replaced, and the dodecahedron. Some of the crystals show a very beautiful, secondary crystalline action induced upon the faces of the original crystal. Thus, the sides of the cubic crystal have become, apparently, roughened on the surface, as if a coarse file had been drawn across them; but, on examination with the microscope, it will be seen that this appearance is due to the projection from the surface of numerous minute facets of the octohedron, of which the solid angles project beyond the surface. In other instances, the whole crystal is made up of very thin plates, laid one upon the other, retreating by steps. In other crystals, the whole side of the cubic crystal is made up of the minute plates of which the edges are indented with triangular notches, showing a tendency of the surface of the original crystal to develope into octohedral forms. Similar phenomena of crystallization have been noticed in other minerals, especially fluor-spar and salt. The variety of quartz, called Babel quartz, presents a structure similar to that displayed by some of the crystals of galena at this locality.

Garnet.—In the mica slates of the southern portion of the district, this mineral occurs, not unfrequently, but the specimens are of little interest.

Gypsum—Occurs in small quantity in the Niagara limestone of the shore of Lake Michigan, but no good crystallizations have been found. We have seen specimens said to be from St. Martin's island, but were unable to discover it there; at the time of our visit, the deposit was, probably, under water. Beds of plaster are marked on the map as occurring on the east shore of Green bay, but we traversed a large portion of that coast, without succeeding in discovering this valuable mineral.

Harmotome.—A single specimen of this mineral is said by Mr. Teschemacher to have been found on Isle Royale by Mr. J. H. Blake. The most careful examination has failed to reveal the presence of this mineral to us in our explorations on that island, or on Keweenaw Point.

Heulandite.—This mineral is said to have been found on the north shore of the lake, but we are not aware of its occurrence in our district.

Hornblende.—This mineral occurs in abundance in the slates and trappean rocks of the azoic system, but nowhere developed in very distinct crystals. It is generally of a deep-green color, almost black, sometimes thinly foliated, and sometimes asbestiform.

Iron, magnetic oxide of, and peroxide of.— The nature of the occurrence of these ores has already been discussed at length in the geological portion of this report, so that it will not be necessary to enter into any farther particulars respecting them. The specular oxide which occurs in the quartz veins cutting the massive beds of iron, is in large and brilliant plates, and affords very pretty specimens.

Crystals of magnetic oxide occur in abundance in the chloritic slates, associated with the azoic rocks, and in the proximity of the massive ores.

Magnetic iron forms one of the most common and almost unfailing minerals of the trappean rocks of the Silurian age. Associated with labradorite, it forms beds of porphyry, intercalated among the compact and crystalline traps of Isle Royale.

Iron Pyrites.— One of the most common minerals; it occurs in great abundance in fine particles, scattered through the hornblende rocks of the azoic series. It is found in cubic crystals at Presqu'isle, associated with calcareous spar.

Iron-sand — Occurs on the shores of the lake in great abundance, and is probably derived from the disintegration of the slaty rocks of the azoic series.

Jasper.— See Quartz.

Labradorite.— See Feldspar.

Laumonite.— This is one of the most abundant of all the trappean minerals in the Lake Superior region. It occurs in the bedded trap of Keweenaw Point, filling the amygdules, especially near the contact of the conglomerate and sandstone. It forms a considerable part of the gangue of some of the metalliferous veins, and is especially frequent in the selvages of the veins. On Isle Royale it frequently occurs in thin bands, between the different belts of trappean rock. Near Eagle harbor it forms a wide vein, filled with irregular strings and bunches of copper.

Near the location of the Atlas company, in the Porcupine mountains, it forms a considerable portion of the trappean rock, over a great extent of surface. The rapid change which this mineral undergoes, when exposed to the air, by losing a portion of its water, causes the rock containing this mineral to crumble and disintegrate rapidly. The Leonhardite, on the contrary, appears to remain unaltered by exposure.

Leonhardite.— This mineral has a most remarkable resemblance to Laumonite in its general habitus, but appears to have, unquestionably, a different composition, and must, therefore, be classed as a distinct species.

The following analyses of this mineral were made by Mr. G. O. Barnes, under Mr. Whitney's direction:

	I.	II.
Silica	55.96	55.04
Alumina	21.04	22.34
Lime	10.49	10.64
Water	11.93	11.93
	99.42	99.95

The formula $3CaOSiO_3 + 4Al_2O_3Si_2O_3 + 15HO$ requires—

Silica	56.57
Alumina	21.99
Lime	9.40
Water	12.02
	99.98

This formula differs from that of Laumonite principally in its containing a one-third, (instead of a bi-) silicate in the first term; and fifteen atoms of water instead of eighteen.

This mineral occurs at Copper Falls. It seems to remain unaltered by exposure to the atmosphere, containing less water than Laumonite, and therefore not parting with it so readily as that mineral does.

Malachite.— See Copper, carbonates of.

Magnetic Iron Ore.— See Iron, oxide of.

Manganese, oxide of— Occurs at Manganese lake, near Copper Harbor, and, also, at Presqu'isle, but the specimens are of no mineralogical interest.

Mesotype.— Fine slender prisms of this mineral occur at Copper Falls, associated with analcime, on which mineral they are implanted: it is also implanted directly on the copper, at the same locality.

Mesole.— A mineral resembling mesole, in external character, is found in the amygdaloidal trap of Keweenaw Point.

Mica— Occurs sparingly diffused through the granitic rocks. The great predominance of the feldspathic and quartzose ingredients of the granites, and the comparatively small quantity of mica, is an interesting fact, and especially so, when taken into consideration in connection with the great scarcity of simple minerals in the same rocks. Over the whole region covered by granite, we have hardly found a single mineral of interest, the only foreign substance present, as far as we have observed, besides specks of hornblende and chlorite, being occasional strings of magnetic iron.

Pectolite.— This mineral occurs on Isle Royale, in spheroidal masses, consisting of delicate, silky fibres radiating from a centre, and which closely resemble the foreign specimens of this mineral from Monte Baldo.

This mineral fuses readily before the blowpipe in the platinum forceps, with but little intumescence, and gives a colorless, blebby glass. Chlorohydric acid dissolves it readily; the silica separating as a flocky precipitate.

The following are the results of the analyses of two specimens from Isle Royale:

	I.	II.
Silica	53.45	55.66
Lime	31.21	32.86
Soda	7.37	7.31
Potash	trace	——
Alumina	4.94	1.45
Water	2.72	2.72
	99.69	100.00

No. I. contains considerable alumina, which, however, does not form an essential part of the mineral; as is evident from the analysis of No. II., in which only 1.45 per cent. was found. It is difficult to obtain a radiated, or fibrous mineral in a state of perfect purity from the gangue; there being in each case, a small quantity of quartz in the silica separated by digestion with acid. The results, however, show conclusively that this mineral agrees in constitution with the formula proposed by Von Kobell.

Pitchblende.— A mineral containing uranium, from Maimanse, on the north side of Lake Superior, was analyzed and described by Dr. J. L. Le Conte, under the name of *coracite.* For analysis and description of this mineral, by Mr. Whitney, also, see Boston Journal of Natural History, Vol. VI., p. 37. This mineral is particularly distinguished from pitchblende by its ready solubility in acids, and hence was supposed by Mr. Whitney, who analyzed it, to contain the oxide of uranium $U_2 O_3$, and not $U_3 O_4$, which is generally considered the state of oxidation of the metal in pitchblende. To this view it has been objected that the solubility of the mineral might be owing to the presence of the carbonate of lime contained in it. This view is, however, hardly sustained by facts, since it is often the case that the common pitchblende contains a considerable amount of impurities, and especially carbonate of lime, without becoming soluble. A portion of the lime, and the whole of the lead, which the mineral contains, must remain uncombined, unless we suppose it to play the part of a base in combination with the uranic acid.

Pitchstone.— This mineral occurs in a large mass, in the trap of Isle Royale.

An analysis furnished us the following results:

Before the blowpipe, in the forceps, it swells up considerably and becomes nearly white; it then fuses without much difficulty to a greyish glass.

The fluxes give with it a strong reaction of iron.

If finely pulverized, and digested with chlorohydric acid, it is only imperfectly decomposed, considerable iron being taken up by the acid.

An attack by carbonate of soda gave:

Silica	62.51
Alumina	11.47
Peroxide of iron	11.05
Lime	2.67
Magnesia	2.11
Soda and trace potash	3.03 by loss.
Water	7.14
	100.00

Pitchstone is generally supposed to be a natural, vitreous product, and, as such, of course no formula can be given for it. The analyses of this substance show considerable uniformity of composition, and all exhibit from five to nine per cent. of water. The part which this large amount of water plays in a vitreous product associated with trappean rocks is not easy to explain.

Prehnite.— Hardly any one of the zeolitic minerals is so widely and universally disseminated through the trappean rocks of the Silurian series as Prehnite. It forms one of the predominating minerals in the vein-stone of the copper-bearing veins. Loose, rounded masses of this mineral are common on the beaches of Isle Royale, and often contain fine scales of metallic copper and native silver distributed through them. Other pebbles of this mineral are colored of a faint flesh-red by suboxide of copper, no metallic copper being present in particles perceptible to the eye. Some of these pebbles have a fibrous structure.

The following is an analysis of one of those fibrous, rounded masses, in which no metallic copper could be seen, on examination with the microscope:

Silica	44.80
Alumina and trace of iron	25.34
Lime	24.75
Soda	trace
Suboxide of copper	1.04
Water	4.01
	99.94

The finest specimens of Prehnite, which we have seen from this region, were obtained at the location of the Atlas mining company, near the Porcupine mountains; at which locality the zeolitic minerals form large, flat sheets in the trap.

Pyroxene.—This mineral occurs abundantly as one of the constituents of the trappean rocks, but no where in well-defined crystals.

Quartz.—The specimens of crystallized quartz (rock crystal), which occur in this district, are rarely worthy of notice. The druses of this mineral which occur in the vein, at the Cliff mine, when associated with crystallized copper, or Prehnite, sometimes form very elegant specimens. The smoky variety occurs at Rock Harbor, Isle Royale. Amethystine quartz, nearly transparent and of a purplish-violet color, is found in the vein of the Prince mine, on the north side of the lake, and this locality furnishes magnificent specimens of deep-colored groups of crystals, associated with calcspar. It also occurs in the geodes of the trap, near Copper Harbor.

Of the varieties of quartz which occur in the south side of the lake, *agate* is by far the most abundant. It occurs in the cellular cavities of the amygdaloid, and especially in the outer band on the north side of Keweenaw Point, and along the shores of Isle Royale. As this is gradually broken up and disintegrated by the action of the waves, the agates contained in it are accumulated on the beach. In general, the specimens found along the shore of the lake possess little value, except as souvenirs to those who have collected them, though occasionally an agate of considerable size and beauty is found. The finest of which we have any knowledge were found by Professor Mather, on one of the outer reefs of Michipicoten island; some of the specimens were two feet in diameter. The agates occasionally pass into cacholong and carnelian.

Jasper—Is very abundant, forming mountain-masses in the Porcupine mountains, and at Mount Houghton. Some of that occurring in the Porcupine is of a brilliant, deep-red color, and beautifully banded. That of Mount Houghton assumes, at times, a ribboned structure, but is so fusile, that it is difficult to procure good specimens. (Vide Part I, p. 65, 70.)

It also occurs abundantly in the azoic series, forming alternating bands with the iron ores. It is of a deep-red color and susceptible of a high polish. (Vide Part II, ch. IV.)

Scapolite.— This mineral was fouud in prismatic crystals at Twin falls, Menomonee river.

Serpentine.— An occasional ingredient of the trappean and metamorphic rocks in the southern portion of the azoic region.

Silver, native.— This metal occurs diffused through the trap, at various localities on Keweenaw Point and Isle Royale: in fact, its distribution is cöextensive with that of native copper; but the principal portion of that which has been obtained thus far, was from the old Lake Superior (now Phœnix), the Cliff, the Copper Falls, and the Minnesota mines. The silver occurs in connection with the metallic copper, both metals being united together at their edges, and yet each being almost entirely pure, and free from alloy with the other. The silver is almost invariably accompanied by a greenish, hydrous silicate of alumina and iron. The most curious specimens are those in which the silver occurs in patches, like the crystals of feldspar in a porphyry. There is nothing of particular interest to add with regard to crystallization, since, so far as we have observed, no crystals of this metal have been found in this region.

The largest mass of silver obtained, up to this time, weighed more than six pounds. This was found at the Phœnix mine. Beautiful specimens of native silver, in Prehnite, have also been picked up on the beaches of Washington Harbor, Isle Royale. No ores of silver have been noticed in the trappean rocks. (Vide Part I, pp. 139, 173 and 178.)

Silver, Sulphuret of.— This mineral occurs at the Prince mine, on the north shore of the lake; we are not aware, however, that any *ore* of silver has been observed on the south side.

Stilbite.— This mineral is found very sparingly, if at all, in the trappean rocks of Keweenaw Point.

Sphærosiderite—Is found in amorphous masses, occupying the cavities of the greenstone of Keweenaw Point, resembling that from Hanau.

Tabular-spar.— See Wollastonite.

Talc.— Although this mineral constitutes a portion of the slaty rocks of the azoic series, it is rare to find any good specimens, or masses of any considerable size.

Titanic iron sand.— Some of the sand, which occurs so abundantly along the shores of the lake, is titaniferous; but, in general, the iron ores of this region are remarkably free from this metal.

Uranium.— See Pitchblende.

Wollastonite.— This mineral, or table-spar, as it is often called, occurs at the Cliff mine, and on Isle Royale, near Scovill's Point. Specimens from both those localities are identical in external characters, but differ much from the same mineral, as it occurs elsewhere; so much so, indeed, that their real nature could only be learned by chemical analysis.

The mineral, as it here occurs, is compact, of a light, flesh-red color, and remarkable for its exceeding toughness, surpassing in that quality anv mineral, or rock known.

Two analyses of this mineral, from the Cliff mine, gave as follows:

	I.	II.
Silica	49.09	49.06
Lime	46.38	44.87
Protoxide of manganese	.48	.93
Alumina	.23	1.28
Magnesia	.14	—
Water	2.96	2.96
Carbonic acid and loss	.72	.90
	100.00	100.00

This mineral is therefore a bi-silicate of lime, colored by a little manganese.

It receives a beautiful polish, and might be wrought for ornamental purposes, if it occurred in sufficient quantity.

Zinc.—Carbonate of zinc has been supposed to occur on Keweenaw Point, but this is an error. Blende, or sulphuret of zinc, occurs abundantly on the north shore, at the Prince mine, associated with calc-spar, sulphuret of silver, and sulphuret of copper.

A small quantity of zinc has been observed at Presqu'isle.

CHAPTER VIII.

LOWER SILURIAN SYSTEM—POTSDAM AND CALCIFEROUS SANDSTONES.

General Characters of the Members of this System.— First Traces of Organic Life.— Ancient Limits of the Oceanic Basin.— General Remarks on the Identity of the Groups.— Potsdam Sandstone.— Organic Remains.— Range and Extent.— Lithological Changes.— Attempts to identify it with the New-Red.— Its Development on the Northern Shore of Lake Superior.— Evidences of Volcanic Action during this Epoch. — Its Developement on Isle Royale, in Connection with Volcanic Products.— Fiords.— Monument Rocks.— Its Development on the Southern Shore.— Keweenaw Point and the Ontonagon Region.— Examples of Diagonal Stratification.— Its Character and Relations to the preëxisting Rocks at Granite Point, Carp River, and Presqu'isle.— Fissures.— Grand Island.— The Pictured Rocks.— Miners' Castle.— The Amphitheatre.— Sail Rock.— The Grand Portal.—The Chapel.— Examples of Diagonal Stratification.— The Grand Sable.— The Extension of the Sandstone eastward to the North Shore of Lake Huron, and westward to the Menomonee.—.Occurrence of Trilobites.— Its Developement in Wisconsin.— Sandstone of the Mississippi and St. Croix Rivers, identical with the Potsdam of New York.— Repetition of the Causes which produced it during the Deposition of the Calciferous.— Calciferous Sandstone.— Range, Extent, and Mineral Characters.— The Want of Horizontality in the Detrital Deposits not necessarily Evidence of Disturbance.— Chemical Composition of the Sandstone.— Review of the Various Opinions as to its Age.

We now proceed to a description of the palæozoic series of this region. Unlike the rocks which we have hitherto described, they exhibit few traces of igneous outburst, and few displacements of the strata; but, on the other hand, they repose nearly horizontally on the basset edges of the slates, or occupy the depressions in the granite.

This general remark, however, must be received with some qualification, for we find that there existed, during a part of the Silurian epoch, at least two lines of volcanic foci, from which flowed numerous streams of lava. These, mingling with the detrital deposits, then in the progress of accumulation, formed a mass, whose united thickness far surpasses the height of the loftiest summits in this region. We refer to the trap ranges of Keweenaw Point and Isle Royale, described in a previous report.

The materials forming these rocks appear to have been deposited as sediments in the bottom of the ocean, enveloping the various types of animal and vegetable life, which, by successive creations, started into being. From the commencement of this period, so far as we yet know, may be dated the dawn of animal life. At the base of the Potsdam sandstone, we reach the verge which separates the organic from the inorganic world. "Here," in the language of another, "our voyage, like that of the old, fabulous navigators of five centuries ago, terminates on the sea, in a thick darkness, beyond which there lies no shore, and there dawns no light."* Starting then, from this point, we find but a few forms of organized existence represented. As we ascend in the series, we meet with new tribes, new genera, and new species. Generation succeeds generation. Old forms disappear and are replaced by new, which, in their turn, become obsolete. The duration of a single species comprehends an immense period of years; and, when we consider the numerous changes which have taken place in the different types, since first the Lingula and the Trilobite appeared in the Potsdam sandstone, our thoughts are carried back to a period so remote that all ordinary modes of expression fail to convey an adequate idea of the lapse of time. The geologist represents periods of duration by millions of years, as the astronomer represents the distance of the fixed stars from the earth, by millions of miles.

The limits of this oceanic basin are but imperfectly defined. It stretched east and west, from the shores of the Atlantic to the flanks of the Rocky mountains; to the south, it extended beyond the Rio Grande, and north, to the Arctic ocean.

Within this basin, the granite axes between Lake Superior and Lake Michigan, and between Lake Superior and Hudson's bay, rose above the waters of the Silurian sea.

A large portion of North America is embraced within this oceanic bed, constituting its fairest and most productive tracts. The uplifting force, by which this sea-bottom was converted into land, must have been gradually applied; since the strata, for the most part, repose in a nearly horizontal position, and exhibit few marks of derangement. We meet with no mountain chains, and no transverse valleys, except such as have been excavated by running water. The whole region is spread out in gently undulating plains; or, if ridges exist, they are due to accumulations of drift, or to the greater coherence between the particles in certain groups, which enabled them to resist the general denudation, which has everywhere left such incontestible evidence of its action.

From the MS. of Mr. Hall, we append some general remarks on the identity of the members of the Silurian groups, as developed in different parts of this basin:

"The observations of the past season have served to show that nearly all the more important groups of the Silurian system extend uninterruptedly from the more easterly points, where they have been investigated, through the northern peninsula of Michigan, as far west as the Mississippi, and even beyond. These observations form a connecting link between those heretofore made in New York and Canada, and those made in the southern peninsula of Michigan, Wisconsin, Iowa, Minnesota, and other portions of the West, and enable the geologist to form a correct idea of the range, extent, and fossil contents of these groups, as developed in the northern portion of the United States. We believe that these results will render some points of resemblance, heretofore obscure, clear and distinct; and remove any doubts that may have been entertained, as to the identity of certain members of the Silurian system, in their eastern and western prolongation. If

* Hugh Miller

these results are attained, we shall be satisfied that we have not labored in vain.

These strata, originally deposited in a wide ocean, every where present evidences of organic existence. It is not to be supposed that in tracing deposits of this kind over such wide areas, the conditions of the ocean-shores would have been uniform in their physical character, and we cannot, therefore, expect uniformity in the character of the deposits themselves. The very circumstances under which the sediment was thrown down and the causes which gave origin to it, are of themselves evidence, *a priori*, that absolute uniformity could not prevail over so wide an area. We are to look, in like manner, for corresponding changes in organic remains. It cannot be supposed that animals, possessing certain characters and habits of life, would continue to live for any length of time, when the physical conditions were unfavorable to their existence. When we consider, also, the extent over which these deposits have been traced, the difference in longitude alone would lead us to expect some differences in the fauna of this ancient period. We have only to compare this great linear development of the palæozoic strata with an equal extent of modern coast, to form some idea of the changes that might be expected to occur under similar circumstances. In making such a comparison, however, we shall find that the actual condition of these ancient deposits is far more uniform than that of the sea-shore, or sea-bottom, at the present day.

By making the preliminary examination of recent shores, or of recent geological deposits, we are far better prepared to appreciate and understand the changes which will be observed in the rocks themselves. These changes, though gradual, and readily understood, when studied continuously, are, nevertheless, difficult of explanation, when seen at wide intervals, or examined at distant localities.

The general results of these examinations, as will be seen by the local details, have shown an increasing thickness in the Potsdam sandstone, in its western extension, though, at some of the intermediate points, it is much thinner than in New York. It should be recollected, however, that these beds were deposited upon the uneven surface of preëxisting rocks, and their entire thickness may, therefore, be exposed only at some of the points where the originally unequal floor presents some of its elevations, and thus give an erroneous idea of its actual, entire thickness. The calciferous sandstone, in like manner, appears to increase as traced from the eastern limits of the district westward, and on the Mississippi, attains a thickness equal to that which it has in New York.

From all of the evidence, it would appear that these two groups, which are very intimately related to each other, have their most extreme tenuity somewhere near the northern extremity of the great arch, formed by the circuits of the older formations around the northern shores of lakes Huron and Michigan. From this point, they increase in thickness as traced to the east and to the west. On the other hand, the lower limestones — the Chazy, Birds-eye, Black river, and Trenton groups — appear to decrease gradually in thickness, as traced westwardly from the Mohawk valley, and the outlet of Lake Ontario, where they exist in great force. This fact is made very conspicuous, when their entire thickness, as developed in New York, is compared with that of the same groups on the northern side of lakes Huron and Michigan, where they contract to within a hundred feet and in some places even less. We have also evidence that they do not, like the preceding groups, increase in thickness, when traced into Wisconsin and across the Mississippi; for there, they hardly attain a vertical range of fifty feet. Although over the entire area the identity of character and the continuity of the beds are maintained, it is clear that the materials have continually undergone diminution, and that the formation, unless it has been supplied from other sources, will be found to die out.

In the upper member of the Lower Silurian system, the Hudson-river group of New York, we have also a striking example of the marked change which a deposit is found to have undergone when traced over a considerable area. In the district under consideration, it is clearly recognized throughout its whole extent, from Drummond's island to Green Bay, except where it has been denuded, and the space occupied by lakes, or bays. This group, like the other members of the limestone series before alluded to, exhibits a diminution in its thickness, as traced westwardly, and disappears, a short distance beyond the limits of the district.

If we next consider the upper groups of the Silurian system, as displayed in this district, we find that, to a great extent, the reverse is true. Leaving out of view the Medina sandstone and the arenaceous portions of the Clinton group, which are scarcely recognizable here, we find the succeeding limestones much increased in thickness, and exhibiting no diminution, but rather an augmentation, as traced to the westward.

From these general remarks, the reader will be prepared to understand the details given under each division of the series. It should be observed, however, in the outset, that the width of surface occupied on the map, by a particular group, is not always to be regarded as an indication of its thickness; for this, in most cases, is dependent upon the amount of dip in the beds, which, in this case, nearly corresponds with the slope of the country; so that it often happens that a group, less than a hundred feet in thickness, forms a belt several miles in width.

The bearing and inclination of these successive groups indicate that they formed the outer margin of a great geological basin, whose greatest depression is in the lower peninsula of Michigan, where the surface is occupied by rocks of the carboniferous epoch. It is only in a northern and northwestern direction, however, that we are enabled to trace the strata in a descending order quite to the lowest members of the series, and even to the non-fossiliferous series beneath them. In other directions, we find the most elevated portions of the border exposing only members of the upper, or at most, of the middle, portion of the Silurian system."

POTSDAM SANDSTONE.

This was the first formed deposit in the Silurian basin, and attained, in its greatest development, a thickness of about two hundred and fifty feet, if we exclude the conglomerate-bands associated with the trap of Keweenaw Point and Isle Royale.

Range and Extent.—The bed of Lake Superior, embracing an area of about 32,000 square miles, is occupied almost exclusively by this rock, if we may judge from the islands which dot its surface, and the isolated patches which occur along its shores. On the north, the granite ranges approach near the coast and confine the sandstone within narrow limits; on the south, it occupies a broader area, and has been traced continuously around the axis, which divides the waters respectively flowing into Lake Superior, Lake Michigan, and the Mississippi. While the granite ranges attain in places an elevation of 1200 feet above the lake, the sandstones, except in the vicinity of the trap, do not reach higher than 350 feet, and rest in a position nearly horizontal. Consequently, the granites and slates rise up like islands through this great waste of sandstone.

This sandstone does not exhibit, at remote points, a homogeneity of character, or uniformity in thickness; but appears to have been modified, to a great extent, by local causes. Thus, in the vicinity of the trappean rocks, which afford ample evidence of intense and long-continued volcanic agency, the beds attain the enormous thickness of 5000 feet, and often consist of conglomerates, composed of trappean pebbles, cemented by a volcanic sand. Away from these lines of disturbance, and where it abuts against the azoic rocks, the mass consists of nearly pure silicious sand, enveloping pebbles of quartz and patches of slate. Where granite forms the adjoining rock, an equally marked change is observed in the character of the pebbles.

Since, therefore, the nature of the purely detrital rocks is influenced by the surrounding masses which formed the ancient land, it follows that lithological characters afford an uncertain criterion in determining their age, at points widely separated. Yet, we have seen distinguished geologists undertake to identify these rocks, simply from lithological characters, with the *bunter sandstein** of Germany, with the new-red of England, and the trias of the Connecticut valley. Such a doctrine presupposes a universality of formations,—as though the same accumulations of silt and sand were taking place at the same time in opposite parts of the earth,—as though the volcanoes of different hemispheres were at the same time actively excited and poured forth the same igneous products. Such a doctrine is repugnant to all of our preconceived notions. It finds no confirmation in the history of the past, and no agreement with the existing order of things.

The doctrine of the universality of formations receives less conformation the more the structure of the earth is investigated. The sandstone which rests at the base of the Silurian system in the Baltic and Russian provinces, according to Murchison and de Verneuil, is slightly coherent and in a nearly horizontal position. In the vicinity of St. Petersburgh, the oldest beds of this system consist of blue clay, the several members differing but little in external aspect from the tertiary and cretaceous rocks which are spread out around the estuaries of many parts of Europe. The old-red sandstone, in many places, is colorless, and presents great diversity in mineral composition.

The Potsdam sandstone of New York is a quartzose rock, whose particles are firmly aggregated, while the same rock, on the northern slope of Lake Michigan, is so slightly coherent, that it may be crushed in the hand. The calciferous sandstone of New York, when traced west, passes into a magnesian limestone. Even in that state, according to Hall, groups which, at one extremity, are of great importance, and well characterized by fossils, cannot be identified at the other.

The great mass of the materials which form the sandstones of this region appears to have been derived from the north-west, since the beds there attain a much greater thickness, and are composed of coarser sediments. They thin out as we trace them south and east, and are charged with fewer

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* Dr. Owen's Report, 1847-48, p. 57. Dr. Jackson's Report, 1849-50, p. 399.

pebbles. On the Atlantic slope, according to the Messieurs Rogers, the sandstones expand in their south-easterly prolongation, while the limestones decrease. Hence, the ancient land was to the south-east and north-west, while the intervening space which formed the ocean bed, is occupied by the palæozoic series.

SANDSTONES OF THE NORTHERN SHORE.

On the northern shore of the lake, as before remarked, the sandstone occurs in insulated patches. According to Mr. Logan, to whom we are largely indebted for our knowledge of the geology of this portion of the region, on the isthmus between Thunder and Black Bays, sandstone occurs composed of white, silicious particles, but occasionally calcareous grains are intermingled. These beds attain a thickness of at least two hundred feet, and are succeeded by beds of red and white, in alternating layers. Conglomerates, containing pebbles of coarse red jasper, held in a reddish-white, or greenish sand, are also interstratified. The upper portion of the beds contains more calcareous matter, and some of the conglomerates envelope patches of limestone and chert. Mr. Logan estimates their entire thickness at five hundred feet. They are succeeded by limestones of a reddish-white color and very compact, interstratified with calcareo-argillaceous shales and reddish-white sandstones, — the whole attaining a thickness of eighty feet, with an addition of fifty feet of reddish, indurated marl. Succeeding these calcareous strata, after an interval, the amount of which is uncertain, red and white sandstones occur, with conglomerate layers, which become interstratified with trap layers, and an enormous amount of a volcanic overflow crowns the formation.

The extremity of Thunder cape is occupied by the older slates and the associated igneous rocks; but Mr. Logan observed, about six miles to the eastward, a transverse dislocation, which lets down the sandstone at least 1300 feet, bringing it suddenly to occupy the coast in the strike of the slates. On the north side of the bay, the conglomerate is seen to rest in a nearly horizontal position upon the highly tilted chloritic slates, and in one spot, it evenly covers over, without any disturbance, a step in the slates produced by an ancient transverse fault. The sandstones rise in vertical cliffs to the height of two hundred feet, and occupy the coast for the distance of seven miles. The limestones and marls start from a point about a mile and a half east of the down-throw, and run parallel with the sandstones, dipping south-east at an angle of about 3°. At Granite islet, a conglomerate, composed of granitic ruins, is seen occupying the inequalities and worn fissures of the supporting rock, and displaying a southern dip of about 10°.

The more volcanic portion, consisting of grits and conglomerates, interstratified with trap layers, commences at Point Porphyry; and, forming a belt from seven to ten miles wide, stretches in a N.N.E. direcction, embracing not only a portion of the main-land, but St. Ignace and Simpson's islands.*

We examined this volcanic formation, as displayed along the western shore of Neepigon bay and on the island of St. Ignace, and found its geo-

* Canada Report, 1846-7.

logical structure identical with that of Isle Royale and Keweenaw Point. The pebbles consist almost entirely of trappean rocks, and the interstratified igneous beds are aften highly amygdaloidal and contain traces of native copper, which is one of the characteristics of this formation.

On the eastern side of the lake, (again quoting the authority of Mr. Logan,) insular patches of sandstone, and also of volcanic products, rëappear. About two miles north of Cape Choyyê, a coarse-grained bed abuts against a precipitous cliff of the older formations, and dips to the south of west at an angle of 10°. At Gargantua, and on some of the adjacent islands, amygdaloidal trap is observed, in beds dipping 40° to the south of west. Caribou, Leach, Lizard and Montreal islands, consist of sandstone, the beds of which are but slightly inclined. The amygdaloidal trap and sandstone occupy the lower side of the cove above Pointe aux Mines, and the promontory of Mamainse is composed of amygdaloidal trap and coarse conglomerates, made up of the ruins of the subjacent granite, syenite and slate—the whole dipping to the south of west, at an angle of 20° or 25°.

Sandstones compose the promontory between L'Anse aux Crêpes and Batcheewauaung bay, and the coast around Goulais bay, with the exception of a limited space occupied by the amygdaloidal trap, and thence extend in a narrow strip for seven miles, as we advance towards Gros Cap, dipping gently to the north-west.

Isle Royale was formed during this epoch, and owes its origin to submarine, volcanic agency. The main mass is traversed by numerous ridges of bedded trap, of unequal hardness, while the coast is intersected by deep passages, or *fiords*, like those of Iceland and Norway.* They undoubtedly originated during the drift epoch, for we know that the waves of the sea, as manifested along the coast at this day, are incapable of such excavating power. Over the whole surface of the island, we meet with numerous evidences of powerful denudation. The rocks have been ground down, polished, and striated, and nearly all of the superficial materials removed.

* Mr. Dana has called attention to the important fact of the frequent existence of these fiords in the higher latitudes, and their almost total absence from coasts in the lower temperate and torrid zones. "Along the west coast of America, they abound, to the north above 48°; and to the south, in Lower Patagonia and Tierra del Fuego, south of 48°, there are similar passages intersecting the land, and often cutting it into islands; but between these limits the coast has few bays, and fewer still of these channel-like indentations. On the eastern coast of the continent, we observe the same general fact. To the north of the equator, the coast is singularly even in its outline, until we reach Maine, north of latitude 48°, where, as may be seen on a good map, the fiords become very numerous, and deep and complex in their long windings and ramifications. The same remarks will apply to the eastern continent. The fiords of Norway are well known, and this coast is a singular contrast to that of France, Spain and Africa."—[Geology of the Exploring Expedition, p. 675.] They appear to be intimately connected with the drift phenomena, being the most abundant where the drift action is most conspicuously displayed, and ceasing altogether before arriving at the extreme limits of the boulders. The rocks bordering these fiords are ground down, polished, and scratched, and, in many cases, covered with rudely stratified beds of sand, pebbles, &c., which must have been accumulated when the land was submerged. The fiords are probably due to causes which have ceased to operate, since the present action of the sea is to fill up the sheltered bays, and wear away the projecting capes.

Their existence, too, results, in a great measure, from the geological structure of the region where they occur, as we have shown in Part I. of our report. Where the rocks are of uniform hardness, we meet with gently-curving shores and wide-mouthed bays: but, where there are alternating bands of unequal hardness, we meet with numerous projecting head-lands and deeply-indented coves. Rocks of this character prevail, north and south, between the equator and latitude 48°; but the causes by which their denudation was effected, do not appear to have operated within these limits. We must, therefore, look to other sources than the action of the sea as manifested at this day.

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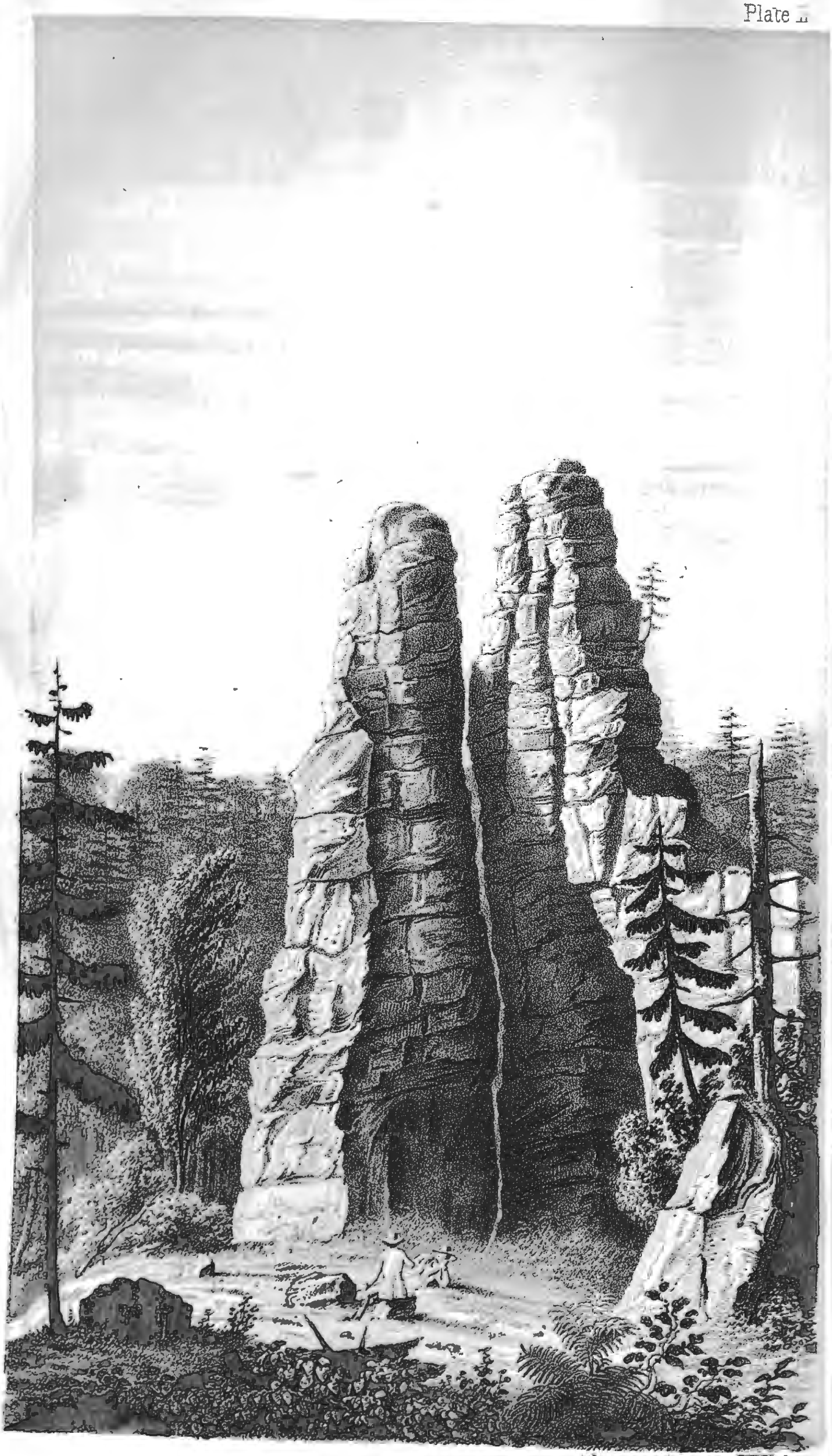
Ackerman Lith 379 Broadway

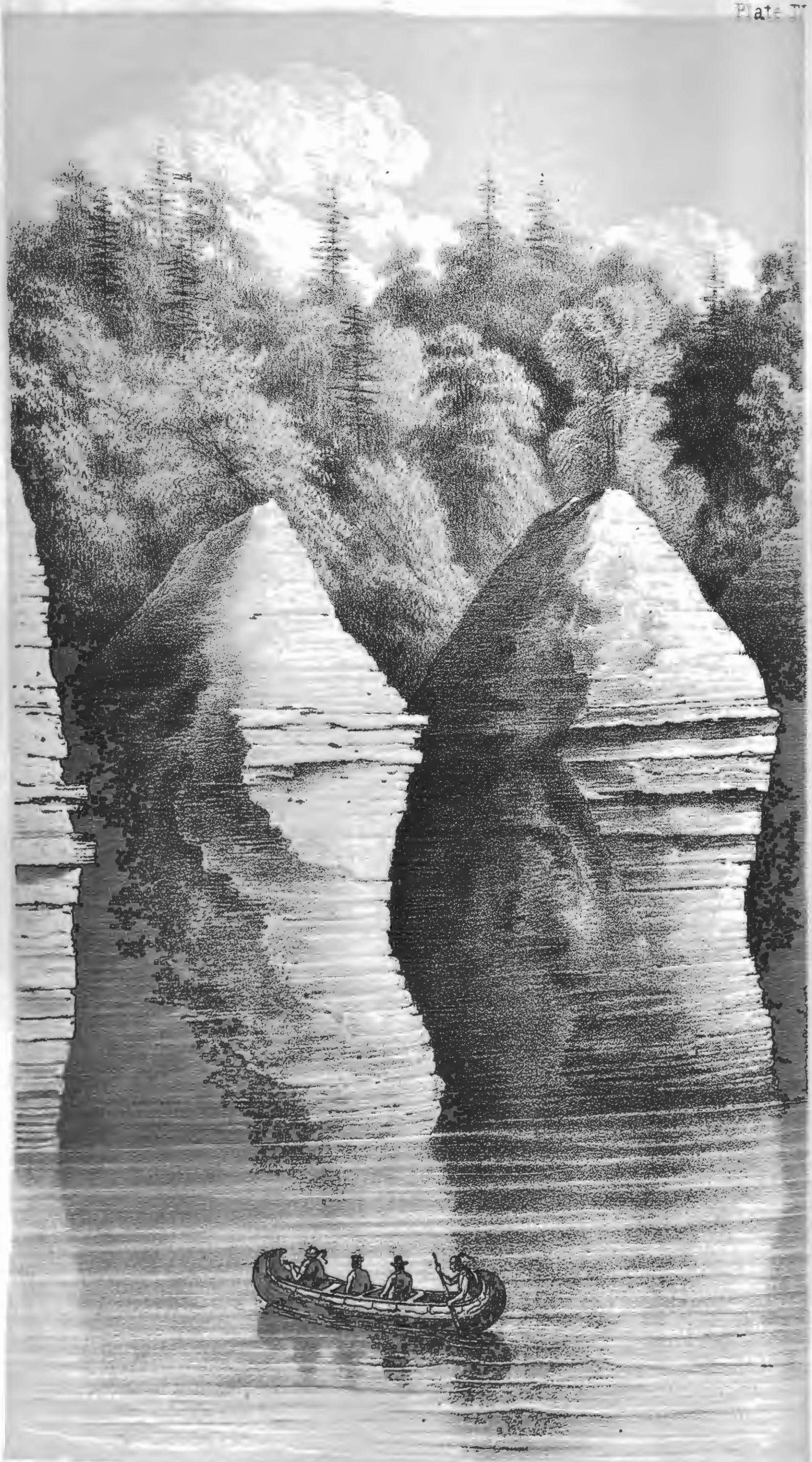
[illegible]MENT ROCK NORTH EAST VIEW ISLE ROYALE

Plate II



Ackerman Lith 379 Broadway N.Y.

MONUMENT ROCK FRONT VIEW, ISLE ROYALE.



Ackerman Lith. 379. Broadway N.Y.

"THE CASTLES."

In some instances, isolated blocks remain as obelisks to remind us of the extent of the desolation.

The sketches, marked Plate II., III., represent the "Monument Rocks," which occur on a bold headland known as Blake's Point, near the eastern extremity of the island. The ridge here is, perhaps, two hundred and fifty feet above the lake, and the rocks shoot up nearly seventy feet. Their symmetrical and tower-like forms, aided by the different systems of joints, which intersect the trappean mass at nearly right angles, cutting it into rectangular blocks, render it one of the most interesting objects on the lake coast. The summit of these rocks, as seen from below, seems entirely inaccessible, and yet we believe that it has once been attained by a daring, and, we might almost add, fool-hardy, climber.

From the ridge a short distance to the north, which overlooks Duncan's bay, and is about three hundred feet above Lake Superior, the eye sweeps over the whole region. Rock Harbor, sheltered by a narrow chain of islands, is seen below, beyond which the lake spreads out in a broad sheet, without an object to obstruct the gaze. To the north and west, Thunder cape, McKay's mountain, and Pie island, stand out in bold relief, and the outline of the Canada shore can be traced for more than a hundred miles, while to the south, in clear weather, the forms of the hills on Keweenaw Point are indistinctly seen.

Along the southern border of the island, we meet with narrow bands of conglomerate interposed between the igneous masses, succeeded by layers of red sandstone, somewhat fissile, the whole dipping to the S.S.E. at an angle, in some cases, of 30°.

SANDSTONE OF THE SOUTHERN SHORE.

Between Keweenaw Point and Isle Royale, there is, as we have before remarked, an immense curvature of the strata, probably reaching five hundred feet below the ocean level. A narrow belt of conglomerate and sandstone lines nearly the whole southern coast, from the head of Keweenaw Point to the Montreal river, beyond which, the latter, no longer associated with coarser bands, rapidly expands in width, and continues to Fond du Lac. For the most part, it appears in low ledges, or reefs, along the lake shore, but, at a few points, it rises in vertical cliffs, which afford many scenes of great beauty. The sketch (Plate IV), entitled "The Castles," represents the sandstone as it appears a few miles above the portage—a locality which we have particularly described in a former report.

The bedded trap and conglomerate are admirably exhibited on Keweenaw Point, and in many places in the Ontonagon district; but as we have minutely described the geographical distribution of all the trappean rocks of this era with the associated conglomerate and sandstone, in a former report, a further description is deemed unnecessary.

Where the Bohemian range breaks through the sandstone, the strata on the north side of the axis are observed to dip at an angle of 45°, while on the south the dip is 70°. A few miles removed, southerly, they settle down nearly horizontally, or present a series of long and gentle flexures. From a highly broken region — the hills rising abruptly to an altitude of nine hundred feet — the country at once sinks down into comparatively level plains. The sketch of Mt. Houghton from the Bohemian range may serve to illustrate the topography of this portion of the region. (Plate V.)

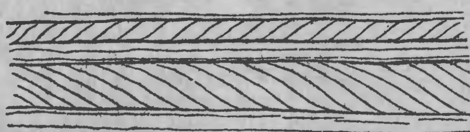
Between the trap range, and the granite and slate region, there is a valley eighty miles in length and twenty in breadth, mainly occupied by sandstone; but a few isolated patches of the lower limestones remain as monuments to determine the age of their deposition and remind the geologist of the extent of the subsequent denudation. These were fully described in our former report, as well as the organic remains entombed in them. Extensive deposits of clay prevail throughout this valley, so that the subjacent rock is rarely exposed. One of the best exposures, however, of the junction of the trap and sandstone, along the southern slope of the axis, occurs in the gorge of Trap-rock river. The trap here rises in a mural cliff, eighty feet in height, intersected by different planes of cleavage, which give to it a stratiform appearance. Over this, the stream is precipitated by a succession of leaps into a rocky basin below, and thence flows through a gorge lined on either side by walls of sandstone. (Plate VI.) At the point of junction the trap assumes an amygdaloidal appearance and a brick-red color, and some portions possess a slaty cleavage. Higher up, however, it becomes more compact, resembling greenstone. The sandstone differs from that which occurs on the northern slope, being granular and almost wholly composed of silicious particles, intermingled with pebbles of pure-white quartz and patches of dove-colored slate or clay.

Over most of this district, the sandstone rests in a nearly horizontal position; but we have shown that it has been subject to disturbances over limited areas. Along the shores of Keweenaw Bay, it rises in cliffs of considerable height, and the strata present a succession of gentle undulations. As we approach L'Anse, the dip to the north-west becomes apparent. Near the head of the bay, the sandstone is seen reposing unconformably on the slates of the azoic system, leaving no doubt that both groups belong to distinct geological epochs, and were produced under conditions widely different. (Vide plate XXI., figure 1.) Its external characters and its relations to the slates have been described in the chapter relating to the azoic system.

The projecting spit forming Point Abbaye, on the eastern side of Keweenaw Bay, is of this rock, and cliffs from twenty to thirty feet in height skirt the shore, while low reefs are seen near the water's edge.

The sandstone, in numerous places, exhibits a stratification like that represented in the annexed figure. (Fig. 11.)

Fig. 11.



Example of Diagonal Stratification.

This stratification, having first been observed in the bed of the Rhone, was called *stratification torrentielle;* but is now known as diagonal, or cross stratification. It is found to pervade the detrital rocks, from the recent alluvial deposits to the sandstones of the Silurian system. From the numerous examples of diagonal and horizontal stratification afforded by the

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MOUNT HOUGHTON, LAC LA BELLE.

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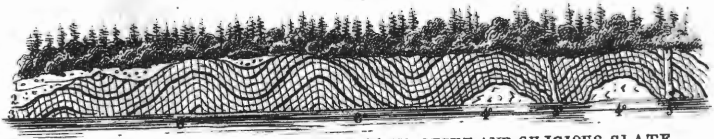
TRAP ROCK RIVER.

7 N

SECTION
of
Folded Strata at L'Anse.

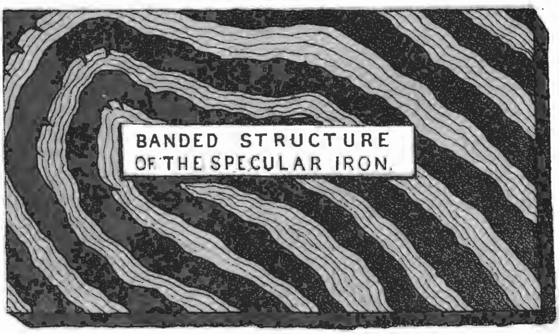
Fig.1.



1° 2° CONGLOMERATE AND SANDSTONE. 3° CHLORITE AND SILICIOUS SLATE. 4° 4° TRAPPEAN ROCKS. 5° 5° TRAP DYKES. 6° 6° LINES OF DIVISION.

Fig 2. ½ Natural Size.

Fig 3.



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Potsdam sandstone, it would appear that its deposition resulted both from mechanical suspension, and the pushing of the materials along the sea-bottom by tidal or oceanic currents. Thus, in the above section, taken at Point Abbaye, the beds 1, 3 and 5, appear to have been deposited from materials mechanically suspended; while the materials composing the beds 2 and 4, were drifted by oceanic or tidal currents. Again, it would appear that the current, which drifted the materials of bed 2, set in a different direction from that which formed the bed 4.

To account for these phenomena it is not necessary to suppose that there were sudden oscillations of the land; they are such as might result from the shifting of tidal currents, or even of the surface winds. The importance of these facts, as indicating a shoal bottom, will be commented upon, under another head.

In some instances where the observer saw only a diagonally stratified bed, he might mistake for local disturbance, what, in fact was the result of tranquil deposition.

East of Huron bay, the sandstone forms a narrow belt, rarely exceeding three miles in width, along the lake shore, and abuts against the slates and granites on the south.

Numerous small veins, or rather joints, containing green carbonate and grey sulphuret of copper have been observed in ranges 29 and 30, by the lake shore, some of which, in the early days of copper mining, were explored, but proved of no economical value. They bear N.N.E., coinciding with one of the systems of joints which here prevail.

Occasionally, as for example, near the head of Huron bay, a knob of hornblende is seen rising above the surrounding country, with the sandstone abutting against its base, in nearly horizontal strata.

At Garlic river, and probably at the Huron river, the continuity of the sandstone is interrupted — the older rocks forming for some distance the coast line.

Granite Point affords one of the most interesting and instructive sections to be found along the whole coast of Lake Superior. A dome-shaped

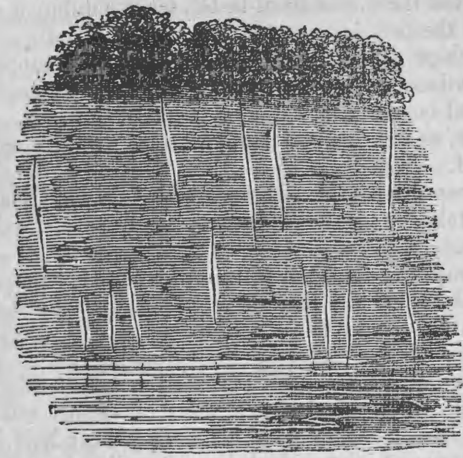
Fig. 12.

Section at Granite Point:— Distance, three miles.

1. Granite.
2. Sandstone with occasional bands of conglomerate.
3. Greenstone dykes, terminating in the granite.
4. Fissures extending from the granite through the sandstone.

nucleus of granite (quartz and feldspar) (1) rises to the height of seventy or eighty feet, exhibiting, where the overlying sandstone (2) has been denuded, a polished and rounded outline, like a reef by the sea-side, over which the surf has rolled for centuries. Upon this ancient surface, the sandstone has been deposited in nearly horizontal layers, although many of the beds exhibit in a very striking manner, a diagonal stratification. Dykes of greenstone (3) traverse the nucleus, but in no case penetrate the overlying rock. Fissures (4) however, are observed to extend uninterruptedly from the granite into the sandstone, and the latter rock is deprived of its coloring matter for the distance of three or four inches, on either side, so that, at first glance, the sandstone appears to be traversed by regular and well-defined veins of calc-spar, as represented in the following diagram. (Fig. 13.)* This appearance is undoubtedly due to the agency of subter-

Fig. 13.



Fissures in the Sandstone at Granite Point.

ranean gases which, escaping through the fissures, discharged the coloring matter, by reducing the peroxide of iron to the protoxide.

The sandstone here is dark-red and divided into numerous layers, through which are distributed numerous white, circular blotches,—a peculiarity which has been noticed, at intervals, from the head of Keweenaw Point to Saut Ste. Marie. They vary from half an inch to an inch in diameter, and often enclose a dark speck in the centre. They are found to be spheres, instead of superficial films, and differ in no respect in structure from the enclosing mass, except that the coloring matter, which consists of peroxide of iron, is driven off. The dark spot in the centre may be the remains of some organic substance, which, in the process of decomposition, has discharged the coloring matter in the immediate vicinity.

Mr. Miller has described similar blotches as occurring in the old red-sandstone of Scotland. "In a print-work, the whole web is frequently thrown into a vat and dyed one color; but there afterwards comes a discharging process. Some chemical mixture is dropped on the fabric; the dye disappears wherever the mixture touches; and in leaves and sprigs and patches, according to the printer's pattern, the cloth assumes its original white. Now, the colored deposits of the old red sandstone have, in like manner, been subjected to a discharging process. The dye has disappeared in oblong or circular patches of various sizes from the eighth of an inch to a foot in

* The tufas of St. Calogero, situated in the largest of the Lipari islands, according to Hoffmann, extend for four miles along the coast, forming cliffs more than two hundred feet high. The strata have, in many places, been discolored and strangely altered by the penetrating vapors. Dark clays have become yellow, or often snow-white; or have assumed a chequered or brecciated appearance, being crossed by ferruginous red stripes,

diameter, the original white has taken its place, and so thick are some of these speckles grouped in some of the darker tinted beds, that the surfaces, where washed by the sea, present the appearance of sheets of calico. The discharging agent was organic matter; the uncolored patches are no mere surface films, for, when cut at right angles, their depth is found to correspond with their breadth; the circle is a sphere, the ellipsis forms the section of an egg-shaped body, and in the centre of each we generally find traces of the organism, in whose decay it originated. I have repeatedly found single scales in the ichthyolite beds, surrounded by uncolored spheres about the size of musket-bullets."*

Thin bands of conglomerate, charged with pebbles of white and yellow quartz, occur at frequent intervals, and occasionally angular fragments of granite, derived from the immediate neighborhood, are observed. On the main shore, the granite rises in an abrupt hill, two or three hundred feet in height, and stretches away inland, while the sandstone is folded around its base in nearly horizontal strata; so that there is no doubt that the latter formation was deposited in an erosion of the former. Under such circumstances, we might expect that there would be waves and shifting currents and eddies, which, acting upon the incoherent mass of sand, would cause the subordinate layers to be deposited unconformably with the main ones.

From all of the facts, we infer that the following was the order in the succession of events:

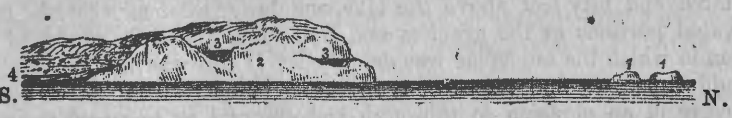
1. That the granite was raised, and its ancient surface water-worn, before the deposition of the sandstone.

2. That the dykes of greenstone were protruded before the deposition of the sandstone.

3. That the sandstone was deposited over an unequal surface, amid shifting currents and eddies, giving rise to cross-stratification.

4. That one system of fissures communicating with the interior, was formed more recently than the sandstone, and that, through them, the gases escaped, bleaching the overlying rocks.

Fig. 14.



Section at Presqu'isle.

1. Granite, composed of feldspar and quartz.
2. Dark-green, magnesian rock (trappean).
3. Volcanic ash.
4. Sandstone.

Presqu'isle affords a section equally instructive. (Fig. 14.) A short distance from the shore, two granite islets (1) are observed rising a few feet above the surface of the lake. A bold promontory (2) juts into the water, consisting of a dark-colored ferruginous and magnesian rock, evidently trappean in its origin, although it contains nearly ten per cent. of water. (For an analysis of this rock, see chapter on the chemical composition of the igneous rocks). It rises in overhanging cliffs, which occasionally assume a columnar structure. The outline of this mass is very irregular, and

* Old Red Sandstone, p. 234, American Edition. Also, Professor Flemming in Cheek's Edinburgh Journal, 1881.

resembles an immense consolidated lava-stream, except that the vesicular structure is wanting. To the north, the surface of the igneous rock is bare; but, on the eastern side, it is covered in places with a rudely stratified mass, which appears to have been deposited in the inequalities of the preëxisting surface. It resembles a volcanic sand, or ash, portions of it being composed of a scoriaceous mass of a light-brown color, and reticulated with numerous veins of a white mineral, portions of which are calcareous, and others silicious. In some instances, these reticulations penetrate to a limited extent the underlying rock; but, for the most part are restricted to the ash. This attains, in places, a thickness of seventy or eighty feet, but is very unequally distributed.

On the west side of Presqu'isle, at the point of contact between the igneous and sedimentary (pluto-neptunian) rocks, their character is completely changed, and they have become impregnated with metallic emanations from below. The sulphurets of lead, copper, and iron, occur here in small quantities in a pseudo-vein, while the containing rock exhibits a strong tendency towards a concretionary structure.

Above the last described deposit, we meet with the sandstone in nearly horizontal layers. From its base upward, for six feet, it contains rounded fragments of quartz and granite, with angular fragments of agate and jasper. The prevailing tint of the rock is dark-red; and, intermingled with the silicious particles, are to be seen minute spangles of specular oxide of iron. Higher up, the layers exhibit a yellow tint. Traces of green carbonate of copper are abundant; in fact, they pervade this rock from the Huron mountains to the Grand Sable.

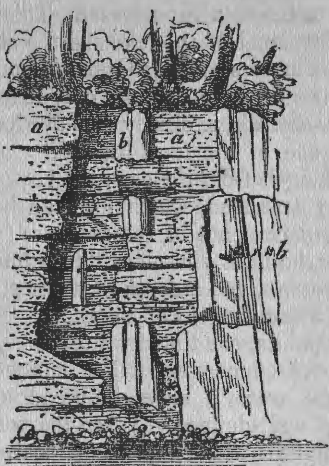
At Middle island, the sandstone is seen reposing on the granite with an inclination of 7° to the S.E. Below Little Presqu'isle, it is occasionally detected forming reefs by the lake shore, abutting against the older rocks. A patch, less than a half mile in width, extends from the shore up the valley of Carp river for two miles, enclosed between high walls of quartzose rocks. It was observed by Mr. Hill in the bed of the stream and in the adjoining banks to the height of seventy feet.

Insulated patches are never met with at a greater elevation than three hundred and fifty feet above the lake, and hence we infer that the more elevated portions of the granites and slates rose above the surface of the ocean in which the sandstone was deposited. If this was not the case, we should expect to find traces of it in the sheltered valleys; for we cannot conceive of an abrasion so thorough and effectual as to sweep away the overlying strata, without leaving behind even a block or pebble. The barometrical observations extended over this region by the two corps, when collated, will enable us to determine the contours of this ancient island which rose above the surface, when a wide waste of waters covered nearly all of the habitable portions of the United States.

A short distance below Carp river, the sandstone is again exposed by the lake shore, in contact with quartz. The latter rock exhibits ripple-marked surfaces and distinct lines of bedding which bear east and west and dip south at an angle of 86°.

The surface of the quartz, where the sandstone is removed, is rounded and polished like that of the granite before described, and it is only where the lake surge has undermined the cliff that the true character of the mass is revealed. While the more ancient beds are thus displayed in a nearly vertical position, the more recent are seen deposited around them nearly horizontally. Their relations to each other are exhibited in the accompanying diagram.

Fig. 15.



Section near Carp river.

a. a. Sandstone horizontally stratified. b. b. Beds of quartz nearly vertical.

In one place, the sandstone has been deposited in a wide fissure in the quartz, resembling the matrix of a vein. Upon the surfaces of the quartz are seen wave-lines, as though made by water at the period of its deposition. This vicinity affords conclusive evidence that the sandstone has been subjected to repeated oscillatory movements since its consolidation; for, where it comes in contact with the prëexisting rocks, the ends of the strata are ground off and polished, like the walls of a vein. Dislocations in the strata ten feet in a vertical direction were observed, and also, instances where they were bent up and broken off; but at what period these took place, we have no means of determining. Beyond Chocolate river, the coast is lined for some distance with sand dunes; but the sandstone is occasionally seen at the water's edge, in low ledges, or reefs, and is undoubtedly the underlying rock as far as Saut Ste. Marie, occupying a zone from six to twenty miles in width. Another portion of it starts from Chocolate river, and, sweeping round the granitic and metamorphic rocks, but conforming to their outlines, crosses the Escanāba and Menomonee rivers, and is thence prolonged into Wisconsin. Here, its trend for some distance is parallel with the western coast of lake Michigan, when, curving rapidly, it bears north and connects with the Lake Superior sandstone near the head of the lake.

We resume our description of the character of the sandstone, as displayed along the south-eastern shore of Lake Superior. From the head of Grand island, and thence easterly for ten miles, it rises from the immediate coast in bold, mural cliffs, extending not in a direct line, but *en echelon*—certain portions of the wall being in advance of the others. The forest trees, which consist of birch, maple, cedar, and spruce, cover the summits to the very verge, and, occasionally, a stream of water is seen to issue from the leafy canopy, and precipitate itself, with an unbroken leap, into the lake.

The lower portion of the cliffs consists of a brick-red, iron sand, while the upper is grey, or yellow, and contains sufficient carbonate of lime to cause a feeble effervescence with acids. The whole mass is distinctly stratified, and dips slightly to the south-south-east. This is not so apparent on the main shore, where the trend of the lake and the strike of the strata are nearly conformable; but, in approaching Grand island from the north-east, where the strata are for miles exposed, not only longitudinally, but transversely, this south-south-east dip is clearly displayed.

Grand island affords one of the most beautiful and sheltered harbors in the world. In approaching it from the east, the voyageur passes along the base of the cliffs before described, which form an immense sea-wall, and oppose the further encroachments of the water. (Plate VII.) Having passed a projecting hook, he finds himself within a harbor completely land-locked, with secure anchorage, and a depth of water sufficient to enable him to moor his craft within a few lengths of the shore.

These rocks, at many points, are tinted white, red, yellow, and green, by oxide of iron, carbonate of copper, and saline incrustations, and the tints extend upward, from the water's edge, in broad stripes, not dull and blended, but brilliant and well-defined. When the whole face of a cliff is lighted up by a clear sunlight, the effect is magical. The water flowing from above, down the transverse fissures, has furrowed the escarpments of the cliff into deep channels; while the heavy surf of the lake has excavated numerous caverns in its base. Thus, by the combined action of the elements, these rocks have been wrought into forms resembling towers, battlements, domes, and gateways.

PICTURED ROCKS.

The range of cliffs, to which the name of the Pictured Rocks has been given, may be regarded as among the most striking and beautiful features of the scenery of the north-west, and are well worthy of the attention of the artist, of the lover of the grand and beautiful, and of the observer of geological phenomena.

Although occasionally visited by travellers, a full and accurate description of this extraordinary locality has not as yet been communicated to the public.*

This deficiency we shall attempt to supply, partly by written descriptions, and partly by a series of illustrations, which, however deficient in artistic effect, have, we believe, the merit of being careful copies from

* Schoolcraft has undertaken to describe this range of cliffs, and illustrate the scenery. The sketches do not appear to have been made on the spot, or finished by one who was acquainted with the scenery, as they bear no resemblance, so far as we observed, to any of the prominent features of the Pictured Rocks. On the title-page of his narrative, he has figured the "Doric Rock," but it is impossible for us to make out what particular point it was intended to represent.

It is a matter of surprise that, so far as we know, none of our artists have visited this region, and given to the world representations of scenery so striking, and so different from any which can be found elsewhere. We can hardly conceive of anything more worthy of the artist's pencil; and, if the tide of pleasure-travel should once be turned in this direction, it seems not unreasonable to suppose that a fashionable hotel may yet be built under the shade of the pine groves, near the Chapel, and a trip thither become as common as one to Niagara now is.

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ENTRANCE TO GRAND ISLAND HARBOR.

nature. Though necessarily on a small scale, they convey a correct general idea of the most striking and characteristic features of the scenery.

The Pictured Rocks may be described, in general terms, as a series of sandstone bluffs extending along the shore of Lake Superior for about five miles, and rising, in most places, vertically from the water, without any beach at the base, to a height varying from fifty to nearly two hundred feet. Were they simply a line of cliffs, they might not, so far as relates to height or extent, be worthy of a rank among great natural curiosities, although such an assemblage of rocky strata, washed by the waves of the great lake, would not, under any circumstances, be destitute of grandeur. To the voyager, coasting along their base in his frail canoe, they would, at all times, be an object of dread; the recoil of the surf, the rock-bound coast, affording, for miles, no place of refuge,—the lowering sky, the rising wind; all these would excite his apprehension, and induce him to ply a vigorous oar until the dreaded wall was passed. But, in the Pictured Rocks, there are two features which communicate to the scenery a wonderful and almost unique character. These are, first, the curious manner in which the cliffs have been excavated, and worn away by the action of the lake, which, for centuries, has dashed an ocean-like surf against their base; and, second, the equally curious manner in which large portions of the surface have been colored by bands of brilliant hues.

It is from the latter circumstance that the name, by which these cliffs are known to the American traveller, is derived; while that applied to them by the French voyageurs ("Les Portails"*) is derived from the former, and by far the most striking peculiarity.

The term Pictured Rocks, has been in use for a great length of time; but when it was first applied, we have been unable to discover. It would seem that the first travellers were more impressed with the novel and striking distribution of colors on the surface, than with the astonishing variety of form into which the cliffs themselves have been worn.

The Indian name applied to these cliffs, according to our voyageurs, is *Schkuee-archibi-kung*, or "*The end of the rocks,*" which seems to refer to the fact that, in descending the lake, after having passed them, no more rocks are seen along the shore. Our voyageurs had many legends to relate of the pranks of the *Menni-bojou* in these caverns, and, in answer to our inquiries, seemed disposed to fabricate stories, without end, of the achievements of this Indian deity.

We will describe the most interesting points in the series, proceeding from west to east. On leaving Grand island harbor,† high cliffs are seen to the

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* Le Portail is a French term, signifying the principal entrance of a church, or a portal, and this name was given to the Pictured Rocks by the voyageurs, evidently in allusion to the arched entrances which constitute the most characteristic feature. Le Grand Portail is the great archway, or grand portal.

† The traveller, desirous of visiting this scene, should take advantage of one of the propellers which navigate the lake, and land at Grand island, from which he can proceed to make the tour of the interesting points, in a small boat. The large vessels on the lake do not approach sufficiently near the cliffs to allow the traveller to gather more than a general idea of their position and outlines. To be able to appreciate and understand their extraordinary character, it is indispensable to coast along in close proximity to the cliffs, and pass beneath the Grand Portal, which is only accessible from the lake, and to land and enter within the precincts of the Chapel. At Grand island, boats, men, and provisions may be procured. The traveller should lay in a good supply, if it is intended to be absent long enough to make a thorough examination of the whole series. In fact, an old voyager will not readily trust himself to the mercy of the winds and waves of the lake without them, as he

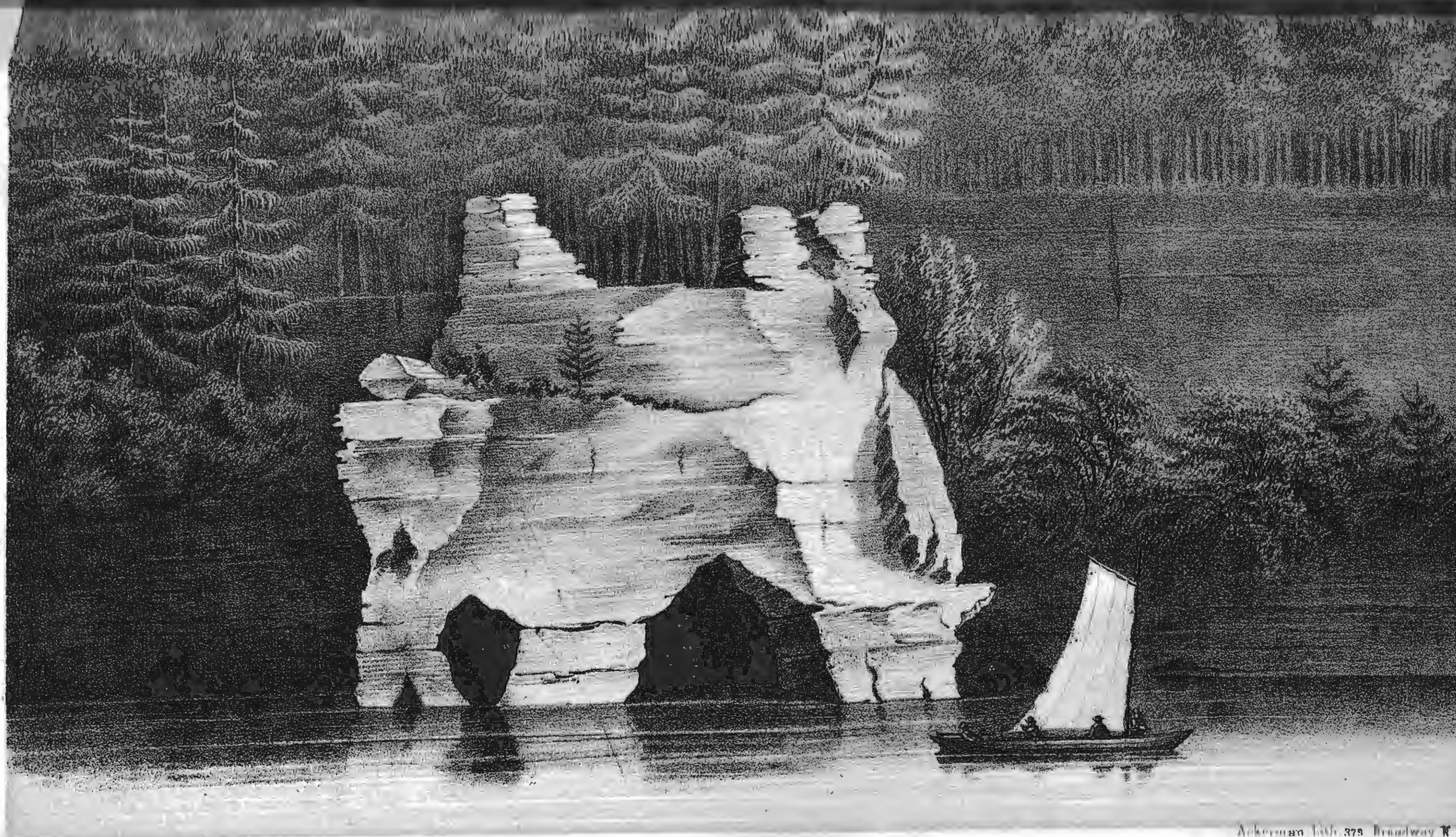
east, which form the commencement of the series of rocky promontories, represented in Plate VII., before referred to, which rise vertically from the water to the height of from one hundred to one hundred and twenty-five feet, covered with a dense canopy of foliage. Occasionally, a small cascade may be seen falling from the verge to the base in an unbroken curve, or gliding down the inclined face of the cliff in a sheet of white foam. The rocks at this point begin to assume fantastic shapes; but it is not, until having reached Miners' river, that their striking peculiarities are observed. Here, the coast makes an abrupt turn to the eastward, and just at the point where the rocks break off and the friendly sand-beach begins, is seen one of the grandest works of nature in her rock-built architecture. This is represented in Plate VIII., and, as we could not learn that it had received a distinctive appellation, we gave to it the name of "Miners' Castle," from its singular resemblance to the turreted entrance and arched portal of some old castle — for instance, that of Dumbarton. An inspection of the plate will exhibit the principal features more correctly than an elaborate written description. The height of the advancing mass, in which the form of the Gothic gateway may be recognized, is about seventy feet, while that of the main wall forming the background is about one hundred and forty. The appearance of the openings at the base changes rapidly with each change in the position of the spectator. On taking a position a little farther to the right of that occupied by the sketcher, the central opening appears more distinctly flanked on either side by two lateral passages, making the resemblance to an artificial work still more striking.

A little farther east, Miners' river enters the lake, close under the brow of the cliff, which here sinks down and gives place to a sand-bank nearly a third of a mile in extent. The river is so narrow, that it requires no small skill on the part of the voyager to enter its mouth when a heavy sea is rolling in from the north. On the right bank, a sandy drift plain, covered with Norway and Banksian pine, spreads out, affording good camping-ground — the only place of refuge to the voyager until he reaches Chapel river, five miles distant, if we except a small sand beach about midway between the two points, where, in case of necessity, a boat may be beached.

Beyond the sand beach at Miners' river, the cliffs attain an altitude of one hundred and seventy-three feet, and maintain a nearly uniform height for a considerable distance. Here, one of those cascades of which we have before spoken, is seen foaming down the rock. The cliffs do not form straight lines, but rather arcs of circles, the space between the projecting points having been worn out in symmetrical curves, some of which are of large dimensions. To one of the grandest and most regularly formed, we gave the name of "The Amphitheatre;" this is represented in Plate IX. Looking to the west, another projecting point — its base worn into cave-like forms — and a portion of the concave surface of the intervening space are seen.

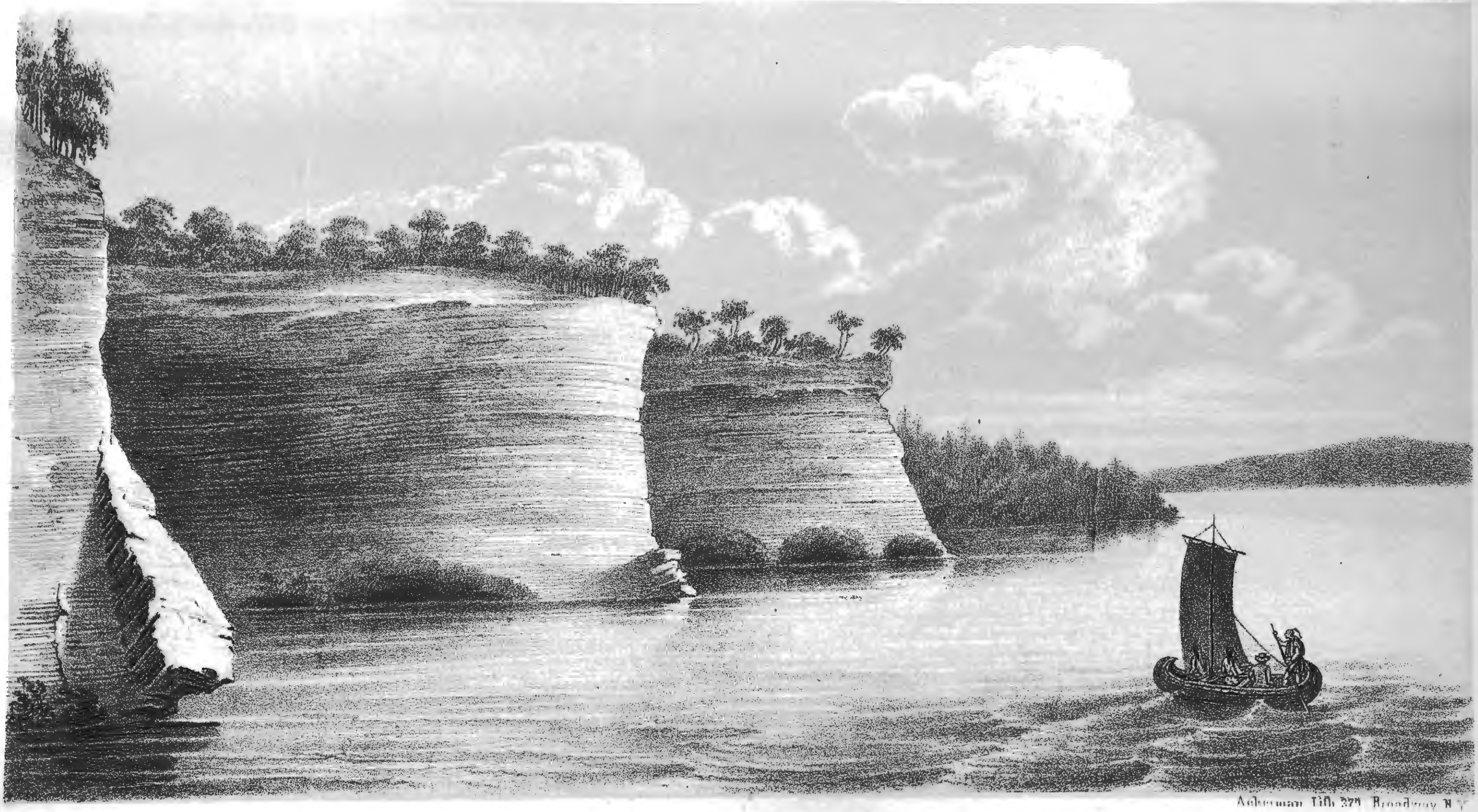
It is in this portion of the series, that the phenomena of colors are most beautifully and conspicuously displayed. These cannot be illustrated by a mere crayon sketch, but would require, to reproduce the natural effect, an elaborate drawing on a large scale, in which the various combinations of

may not unfrequently, however auspicious the weather when starting, find himself weather-bound for days together. It is possible, however, in one day, to start from Grand island, see the most interesting points, and return. The distance from Williams's to the Chapel — the farthest point of interest — is about fifteen miles.



MINERS' CASTLE . PICTURED ROCKS.

Plate I



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THE AMPHITHEATRE PICTURED ROCKS

color should be carefully represented. These colors, do not, by any means, cover the whole surface of the cliff even where they are most conspicuously displayed, but are confined to certain portions of the cliffs in the vicinity of the Amphitheatre; — the great mass of the surface presenting the natural, light-yellow, or raw-sienna, color of the rock. The colors are also limited in their vertical range, rarely extending more than thirty or forty feet above the water, or a quarter, or a third, of the vertical height of the cliff. The prevailing tints consist of deep-brown, yellow and grey — burnt-sienna and French-grey predominating. There are also, bright blues and greens, though less frequent. All of the tints are fresh, brilliant and distinct, and harmonize admirably with one another, which, taken in connection with the grandeur of the arched and caverned surfaces on which they are laid, and the deep and pure green of the water which heaves and swells at the base, and the rich foliage which waves above, produce an effect truly wonderful.

They are not scattered indiscriminately over the surface of the rock, but are arranged in vertical and parallel bands, extending to the water's edge. The mode of their production is undoubtedly as follows: Between the bands, or strata, of thick-bedded sandstone, there are thin seams of shaly materials which are more or less charged with the metallic oxides, iron largely predominating, with here and there a trace of copper. As the surface-water permeates through the porous strata, it comes in contact with these shaly bands, and, oozing out from the exposed edges, trickles down the face of the cliffs and leaves behind a sediment, colored according to the oxide which is contained in the band in which it originated. It cannot, however, be denied that there are some peculiarities which it is difficult to explain by any hypothesis.

On first examining the Pictured Rocks, we were forcibly struck with the brilliancy and beauty of the colors, and wondered why some of our predecessors, in their descriptions, had hardly adverted to what we regarded as their most characteristic feature. At a subsequent visit, we were surprised to find that the effect of the colors was much less striking than before; they seemed faded out, leaving only traces of their former brilliancy, so that the traveller might regard this as an unimportant feature in the scenery. It is difficult to account for this change, but it may be due to the dryness or humidity of the season. If the colors are produced by the percolation of the water through the strata, taking up and depositing the colored sediments, as before suggested, it is evident that a long period of drought would cut off the supply of moisture, and the colors, being no longer renewed, would fade and finally disappear. This explanation seems reasonable, for at the time of our second visit, the beds of the streams on the summit of the table-land were dry.

It is a curious fact, that the colors are so firmly attached to the surface that they are very little affected by rains, or the dashing of the surf, since they were, in numerous instances, observed extending in all their freshness, to the very water's edge.

Proceeding to the eastward of the Amphitheatre, we find the cliffs scooped out into caverns, and grotesque openings, of the most striking and beautiful variety of forms. In some places, huge blocks of sandstone have become dislodged, and accumulated at the base of the cliff, where they are ground up, and the fragments borne away, by the ceaseless action of the surge.

A striking group of detached blocks is represented in Plate X. To this, the name of "Sail Rock" has been given from its striking resemblance to the jib and mainsail of a sloop when spread — so much so, that, when viewed from a distance, with a full glare of light upon it, while the cliff in the rear is left in the shade, the illusion is perfect. This is represented in Plate XI. but, unfortunately, the lithographer has thrown a shade over both cliff and sail. The height of the block is about forty feet.

Masses of rock are frequently dislodged from the cliff, if we may judge from the freshness of the fracture, and the appearance of the trees involved in the descent. The rapidity with which this undermining process is carried on, at many points, will be readily appreciated, when we consider that the cliffs do not form a single, unbroken line of wall; but, on the contrary, they present numerous salient angles to the full force of the waves. A projecting corner is undermined until the superincumbent weight becomes too great, the overhanging mass cracks, and, aided perhaps by the power of frost, gradually becomes loosened, and finally topples, with a crash, into the lake.

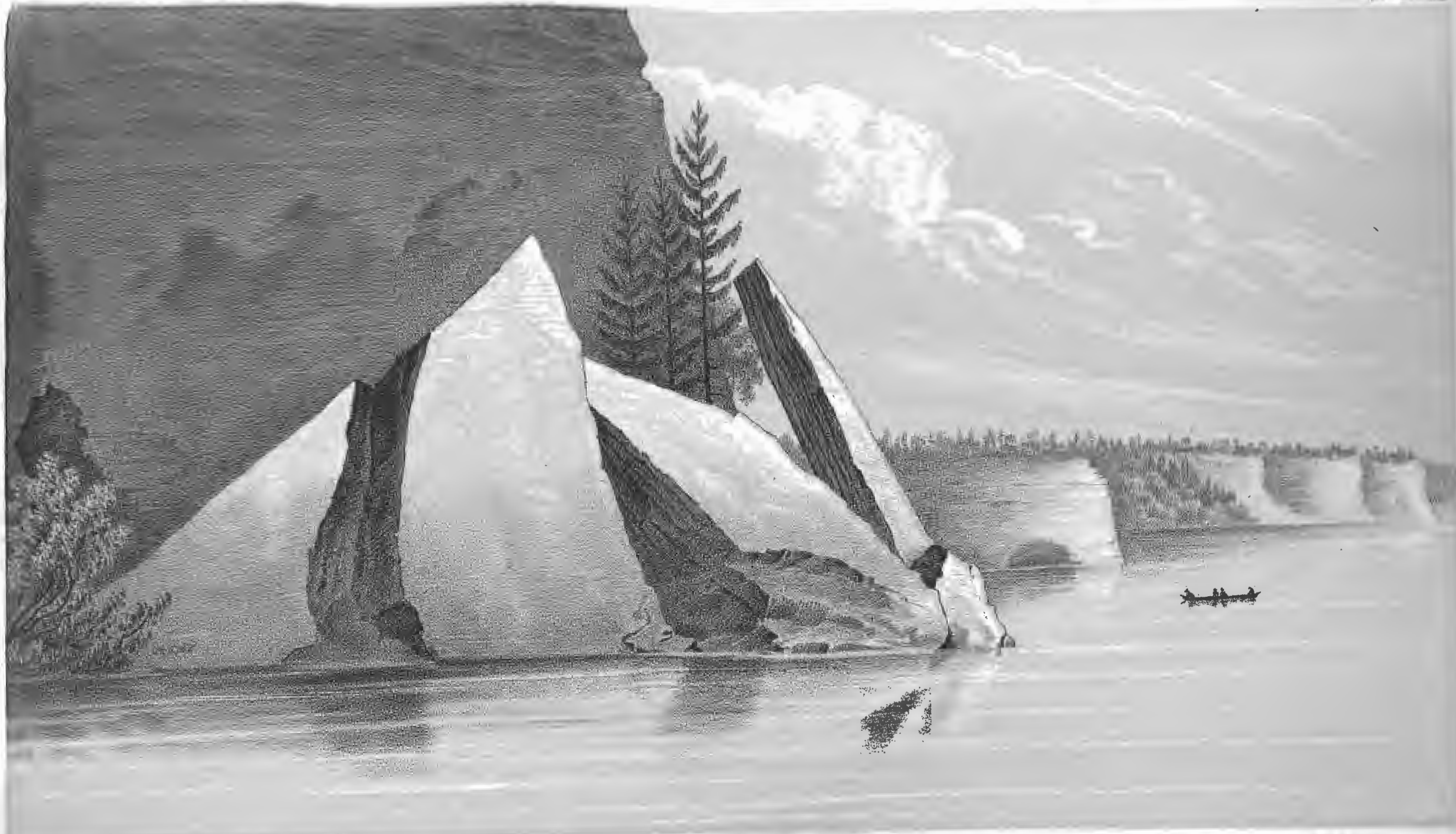
The same general arched and broken line of cliffs borders the coast for a mile to the eastward of Sail Rock, where the most imposing feature in the series is reached. This is the Grand Portal — *Le Grand Portail* of the voyageurs. The annexed Plate, No. XII., is a representation of this arch, though it conveys but an imperfect idea of its vastness and grandeur. The general disposition of the arched openings, which traverse this great quadrilateral mass, may, perhaps, be made intelligible without the aid of a ground-plan. The main body of the structure consists of a vast mass of a rectilinear shape, projecting out into the lake about six hundred feet, and presenting a front of three hundred or four hundred feet, and rising to a height of about two hundred feet. An entrance has been excavated from one side to the other, opening out into large vaulted passages which communicate with the great dome, some three hundred feet from the front of the cliff. The Grand Portal, which opens out on the lake, is of magnificent dimensions, being about one hundred feet in height, and one hundred and sixty-eight feet broad at the water level. The distance from the verge of the cliff, over the arch, to the water, is one hundred and thirty-three feet, leaving thirty-three feet for the thickness of the rock above the arch itself. The extreme height of the cliff is about fifty feet more, making, in all, one hundred and eighty-three feet. In addition to these main passages, there are numerous other openings, smaller and intricately formed, some of which are seen in the foregoing sketch, at the water's edge.

It is impossible, by any arrangement of words, or by any combination of colors, to convey an adequate idea of this wonderful scene. The vast dimensions of the cavern, the vaulted passages, the varied effects of the light as it streams through the great arch and falls on the different objects, the deep emerald-green of the water, the unvarying swell of the lake, keeping up a succession of musical echoes, the reverberations of one's own voice coming back with startling effect, — all these must be seen, and heard, and felt, to be fully appreciated.

Beyond the grand portal, the cliffs gradually diminish in height, and the general trend of the coast is more to the south-east; hence, the rock being less exposed to the force of the waves, bears fewer marks of their destructive action. The entrance to Chapel river is at the most easterly extremity of a sandy beach, which extends for a quarter of a mile, and affords a con-

Ackerman, Lith. 379 Broadway, NY.

SAIL—ROCK—DISTANT VIEW.



Ackerman Lith! 379 Broadway N.Y.

SAIL ROCK NEAR VIEW—PICTURED ROCKS.

Ackerman Lith 379 Broadway. N.Y.

THE GRAND PORTAL, PICTURED ROCKS.

Ackerman Lith. 379 Broadway. N.Y.

CHAPEL — PICTURED ROCKS — VIEW FROM THE WEST.

VIEW OF THE CHAPEL FROM THE EAST.

Ackerman Lith 378, Broadway N. Y.

INTERIOR VIEW OF THE CHAPEL _ PICTURED ROCKS.

venient landing-place, while the drift-terrace, elevated about thirty feet above the lake-level, being an open pine plain, affords excellent camping-ground, and is the most central and convenient spot for the traveller to pitch his tent, while he examines the most interesting localities in the series which occur in this vicinity: to wit, the Grand Portal and the Chapel.

The Chapel—*la Chapelle* of the voyageurs—if not the grandest, is among the most grotesque of nature's architecture here displayed. The three views (Plates XIII., XIV., XV.,) convey a faithful idea of its appearance as seen from the east and the west, as well as its interior. Unlike the excavations before described, which occur at the water's edge, this has been made in the rock at a height of thirty or forty feet above the lake. The interior consists of a vaulted apartment, which has not inaptly received the name it bears. An arched roof of sandstone, from ten to twenty feet in thickness, rests on four gigantic columns of rock, so as to leave a vaulted apartment of irregular shape, about forty feet in diameter, and about the same in height. The columns consist of finely stratified rock, and have been worn into curious shapes. At the base of one of them, an arched cavity, or niche, has been cut, to which access is had by a flight of steps, formed by the projecting strata. The disposition of the whole is such as to resemble, very much, the pulpit of a church; since there is, overhead, an arched canopy, and in front, an opening out towards the vaulted interior of the chapel, with a flat tabular mass in front, rising to a convenient height for a desk, while on the right is an isolated block, which not inaptly represents an altar; so that, if the whole had been adapted expressly for a place of worship, and fashioned by the hand of man, it could hardly have been arranged more appropriately. It is hardly possible to describe the singular and unique effect of this extraordinary structure; it is truly a temple of nature—"an house not made with hands."

On the west side, and in close proximity, Chapel river enters the lake, precipitating itself over a rocky ledge ten or fifteen feet in height.*

It is surprising to see how little the action of the stream has worn away the rocks which form its bed. There appears to have been hardly any recession of the cascade, and the rocky bed has been excavated only a foot or two, since the stream assumed its present direction.

It seems, therefore, impossible that the river could have had any influence in excavating the Chapel itself, but its excavation must be referred to a period when the waters of the lake stood at a higher level.

Near the Grand Portal, the cliffs are covered, in places, with an efflorescence of sulphate of lime, in delicate crystallizations; this substance not only encrusts the walls, but is found deposited on the moss which lines them, forming singular and interesting specimens, which, however, cannot be transported without losing their beauty.

At the same plaee, we found numerous traces of organic life, in the form of obscure fucoidal markings which seem to be the impressions of plants, similar to those described by Hall, as occurring in the Potsdam sandstone of New York. These were first noticed at this place by Dr. Locke, in 1847.

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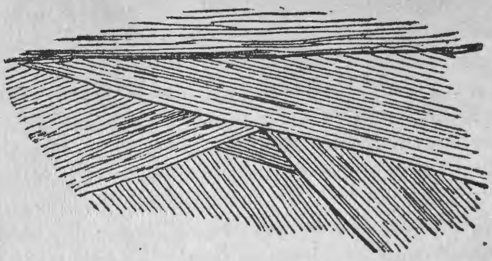
* At this fall, according to immemorial usage among the voyageurs in ascending the lake, the mangeurs de lard, who make their first trip, receive baptism; which consists in giving them a severe ducking—a ceremony somewhat similar to that practised on green-horns, when "crossing the line."

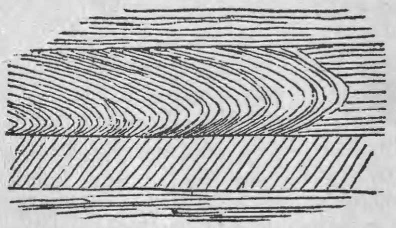
The phenomena of cross stratification are beautifully shown in the columns of the Chapel, and at numerous points along the whole line of the Pictured Rocks. Figure 16 represents a section near Miners' river.

Fig. 16.



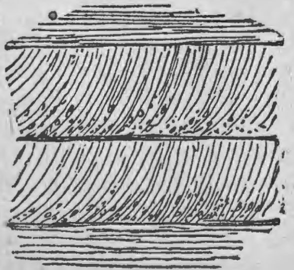
In some cases the individual lines are curved as represented in the following figure.

Fig. 17.

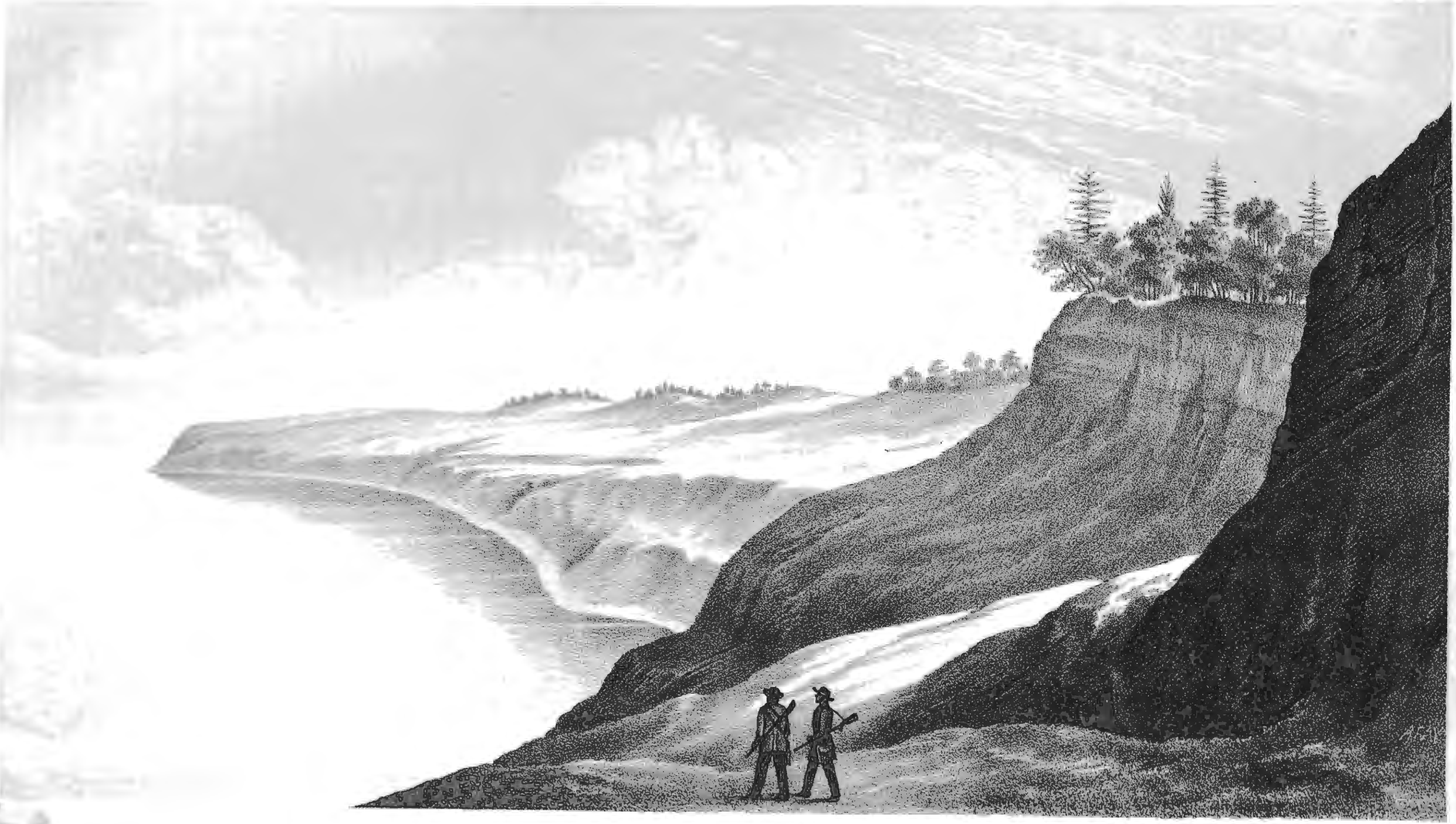


The following is an illustration of the same thing, in which the pebbles and coarser materials are seen to be principally confined to the lower portion of each stratum. These two last figures represent sections exhibited near the chapel.

Fig. 18.



These examples show, as before remarked, that the materials composing the rock were drifted along the sea-bottom by strong currents, and deposited in shifting eddies. Numerous undulations were also observed which might in the first instance be mistaken for bent and contorted strata, but were the



Ackerman Lith

GRAND SABLE.

result of the distribution of color along certain curved lines without regard to stratification, like those before described as occurring at Tobacco river.

The Grand Sable, represented in Plate XVI., possesses a scenic interest little inferior to that of the Pictured Rocks. The explorer passes abruptly from a coast of consolidated sand to one of loose materials; and although in the one case the cliffs are less precipitous, yet in the other, they attain a higher altitude. He sees before him a long reach of coast, resembling a vast sand-bank, more than three hundred and fifty feet in height, without a trace of vegetation. Ascending to the top, rounded hillocks of blown sand are observed with occasional clumps of trees, standing out like öases in the desert. This has been described, by former travellers, as a gigantic dune, but we have shown* that it is composed of stratified materials accumulated during the drift epoch, and that the dune-like appearance is due to the trickling down of the loose and highly comminuted sands.

At the base of these cliffs, the sandstone is occasionally seen by the water margin in low ledges; but after leaving them, it does not reäppear until we reach the mouth of Tequamenen river, seventy miles eastward. Ascending into township 48, range 8, the river, according to Dr. Houghton, is precipitated over two ledges of this rock, the one forty and the other forty-five feet in height. Along the southern coast of this bay, it is occasionally seen in reefs, and at the base of the islets. From one of these, Mr. Forrest Shepherd, several years ago, procured two or three specimens of Lingula.

At Saut Ste. Marie, the river falls twenty-one feet, in the distance of a mile, over this rock, which is exposed at the head of the rapids, on the islands and in its bed. It is very fissile, of a brick-red color, and interspersed with the spherical blotches before described. It here dips, as observed in other parts of the region, at a gentle angle *away* from the azoic series which occur on the opposite, or Canadian side of the river.

The junction of the Potsdam and calciferous sandstone is supposed to occur near the southern portion of Sugar island; but the accumulations of drift have buried up the subjacent rocks.

Mr. Murray of the Canada survey has traced it along the northern shore of Lake Huron, where it is seen, as in our district, in a nearly horizontal position, filling up the hollows in the quartz rock; but, in many places, he remarks, the irregularities in this ancient bottom are so great, that different members of the fossiliferous groups come in contact with it. Captain Bayfield describes it as occupying low levels and forming nearly horizontal strata at the bottom of Lake George, whilst the horizontal fossiliferous limestone of St. Joseph's and Sugar island rise into higher ridges.†

The ancient land, as we before remarked, from which these arenaceous beds were derived, lay to the north-west; since there, they acquire their greatest expansion, and thin out, as traced to the south-east. It is probable that along the St. Mary's river, the vertical range both of the Potsdam and calciferous sandstone is less than a hundred feet. Mr. Murray estimates the thickness of the former at forty feet; but does not appear to have recognized the latter, in any place.

The south-westerly prolongation of this sandstone, which, starting from Chocolate river, sweeps around the granite, and flanks the southern slope

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* Part I. p. 210.

† Lond. Qr. Journ. Geol. Soc., April, 1845.

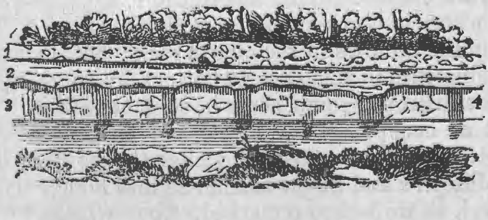
of the axis, is obscurely traced, in consequence of the depth of the superficial materials. Mr. Burt describes it as a coarse, quartzose rock, generally red, but in some places mottled, and in others of a yellowish white. Mr. Hall failed to detect it in the bed of the Escanāba river, which, after leaving the granite, winds its way for some distance through drifted materials.

On section 33, township 40, range 30, Messrs. Whittlesey and Desor discovered this sandstone, with the calciferous superimposed, in a nearly horizontal position; and, further to the south-east, it rëappears in isolated patches. The mineral characters of this deposit and its relation to the older rocks, are fully described by Mr. Whittlesey, in the section included in the chapter on the azoic system. Where it crosses the Menomonee, the belt is about fourteen miles in width; the strata dip very gently, corresponding with the slope of the country, since the subjacent slates and igneous rocks are exposed in the bed of the river for ten miles, after the sandstone is intersected.

In descending the river, it is first observed near the foot of Chippewa island. The subjacent rocks in this vicinity consist of talcose slates, in nearly vertical beds, intermingled with dark, compact, igneous rocks and crystalline greenstone. Their contour is very irregular, as though they had been abraded before the deposition of the arenaceous beds which occupy the inequalities in the surface of the more ancient rocks, in horizontal layers. The greatest inclination observed in the superior rock was 3° to the south-east. The sandstone consists of alternating bands of red and white, and is so friable, when first removed, that it may be crushed in the hand. The grains are coarse and silicious, adhering together without any visible cement. After having parted with the water disseminated through the pores, it acquires a considerable degree of consistency, and is little acted on by the weather.

The following section (Fig. 19) occurs on the left bank of the river, near the foot of Chippewa island.

(Fig. 19.)



Section on the Menomonee river.

1. Drift, composed of coarse rubble and sand, enveloping angular fragments of Trenton limestone.
2. Alternating layers of white and red sandstone.
3. Talcose slates, of the azoic series.
4. Compact serpentine rocks.

At the White Rapids, the sandstone is again exposed, presenting very nearly the same external characters, except that it is less discolored, and reposing on the uptilted edges of the quartz. It may be seen in some of the rapids below, and rëappears, for the last time, in the river banks, forming ledges six or eight feet high, about three miles above the Big Bend in township 35, range 29.

"* In this vicinity, Mr. Desor discovered, in some of the loose masses of this rock, other fossils than the *Lingulæ*, which are so characteristic of this group further to the east. These fossils consist of the fragments of one or more species of trilobites, resembling *Asaphus*. From the characters preserved in a single caudal extremity, one species is identical with that which occurs in the same rock on the Mississippi and St. Croix rivers.

From the Menomonee river, the Potsdam sandstone approaches within fifteen or twenty miles of the shore of Green bay, being distinctly exposed on all the streams flowing into it. Continuing in the same direction, its easterly limit passes near the Great Bend in the Wolf river, northwest from the outlet of Lake Winnebago. From thence, meandering westerly, it follows nearly the course of Wolf river, crossing it in the neighborhood of Lake Pauwaiceen, and is thence prolonged southwesterly towards Green and Puckaway lakes. In the neighborhood of Pleasant Valley, about twelve miles west of Strong's Landing, on the Fox river, it is exposed in several low escarpments, succeeded by the calciferous sandstone, which here presents its usual characters. From this region, its southern limit stretches to the west and north-west. The country here presents a feature which continues to the Mississippi river. The hills appear to be outliers, capped by the calciferous sandstone, or succeeding limestones, while the valleys and the lower part of the escarpments are composed of the Potsdam.

The rock is fine-grained, of a light-yellow color and very friable. Some of the superior beds, which are thin, have been wrought for grindstones. The friable character of this sandstone is one of its most prominent features, and, owing to this circumstance, the escarpments are not usually high, or abrupt, unless it has been protected by the overlying rock. In its want of cohesion, it differs, in a very marked degree, from the prevailing character of this rock, as developed in New York and Canada, where it is usually, though not always, compact. It is not, however, unlike the sandstone of the Pictured Rocks, and is less friable than that of the Mississippi and St. Croix region.

The almost uninterrupted continuity with which this rock can be traced, even from its eastern extension through Canada and along the northern shore of Lake Huron to the St. Mary's river, and thence westerly, leaves no doubt as to its true position and identity in age with the Potsdam sandstone of New York. If we were at a loss in thus tracing it continuously, we have still the evidence of the succeeding fossiliferous strata, which show, conclusively, the same relations to this sandstone as they do to its equivalent in New York. With both these evidences combined, we cannot hesitate for a moment in our conclusion regarding its age and place in the series.

From the points just noticed, where this sandstone appears in eastern Wisconsin, it can be traced uninterruptedly across the entire breadth of the state to the Mississippi and St. Croix rivers. It is true, at the last named localities, we have the evidence of fossils which are not known to occur in its easterly extension; but we have already noticed the occurrence of the Trilobite on the Menomonee, while we have the Lingula everywhere, though in far greater profusion in the St. Croix region than elsewhere. In draw-

* The description of the westerly prolongation of this sandstone is from the MS. of Mr. Hall.

ing inferences as to the age of the rock, from the occurrence of these fossils, it should be remembered that it is by no means improbable that similar ones may yet be found in more easterly localities. They seem to be cöexistent with calcareous bands, or the more calcareous portions of the group, and it is to this modification that we should look for the development of the fauna of this ancient period.

From all this evidence, we regard the question of the age of this rock as settled — that the Potsdam sandstone of New York is identical with that of the Mississippi and the St. Croix. One great source of doubt and perplexity in its determination, heretofore, was the recurrence of a sandstone identical in character with the lower, but superior in position to the calciferous sandstone, or lower magnesian limestone. It is a thin mass, evidently due to a recurrence of the same causes which produced the inferior deposit. This has been well elucidated by Dr. Owen in his reports on the upper Mississippi, in which he has shown that, near the junction of the lower sandstone with the calciferous, there are several alternations of calcareous and silicious bands, the latter having the character of the sandstones below, and the former of the calcareous deposits above. These occur in several places on the upper Mississippi river, and give the geologist an introduction to that condition of things which subsequently produced the upper sandstone, which is distributed over a large part of Wisconsin, so often mistaken for the lower member of the series; but which, in fact, is separated from it by two or three hundred feet of calcareous rocks.

This upper sandstone can be regarded in no other light than as the result of the same causes which produced the Potsdam, and were suspended during the period of the deposition of the calciferous sandstone, or lower magnesian limestone, to be renewed, for a short period, in the deposition of a mass of sandstone, varying from fifty to eighty feet in thickness, upon the surface of the calcareous deposit. This fact shows the more intimate connection between these two lower groups than has heretofore been suspected. It is, nevertheless, shown in many places within the Lake Superior district, that the true sandstone, as it is traced upward, becomes gradually calcareous, and "finally passes into well-characterized, compact, magnesian limestone."* The same is true, also, of this rock, in Canada and New York; while, however, there is rarely any evidence of increase in the silicious materials towards the termination, as we observe in the west. In some localities, there are thin but distinct bands, near the upper portion, having an öolitic structure, which, as we go westward, appear to be replaced by beds of a granular texture and of a silicious character.

CALCIFEROUS SANDSTONE.

In the eastern part of this district, this rock is but imperfectly defined. The north shore of Drummond's island does not extend sufficiently far to reach it, and it is but obscurely seen on the shores of the St. Mary's river. In tracing the strata westward, this rock is distinctly defined in the banks of the Escanaba river, and can be traced from above the forks for several miles below. It preserves its characters in a remarkable degree, although it does not expand to a greater thickness than fifty feet. The upper por-

* Part I., p. 117.

tions are highly calcareous, having, on fresh fracture, the peculiar granular structure so characteristic of this rock. It is thin-bedded, and contains small cavities lined with crystals of calc-spar, or quartz, and sometimes simply with hornstone. The surfaces of the layers are often impressed with the forms of marine plants, identical in character with those associated with the calciferous of New York.

The lower part of this rock, as seen on the Escanāba, is thin-bedded, the layers not more than from three to six inches thick, often variegated and highly silicious. This, though not one of the characteristic features in its eastern extension, was again observed in Wisconsin, along the valley of the Fox river. The lowest layers were of an olive, or dark-slate color, having the same character in texture and color as the beds on the St. Croix river, above Stillwater. These beds may, perhaps, with equal propriety, be referred to the lower sandstone, and regarded as exhibiting a transition from one rock to another. On the Escanāba, the only fossil observed was a species of *Lingula*.

This rock, according to the observations of Messrs. Foster and Whitney, is distinctly exhibited on the Menomonee. "In descending the river, it is first seen at the head of the Grand Rapids, and continues thence to the first saw-mill, sixteen miles from its mouth, occupying a belt nearly eight miles in width. The lower layers are of a buff color, sub-crystalline in their texture, and contain numerous geodes, lined with crystals of rhomb and dog-tooth spar, quartz, &c. On chemical analysis, it is found to contain a large percentage of magnesia. Interstratified with it, are to be seen thin bands of sandstone, tinged red by the peroxide of iron, which contain sufficient carbonate of lime to cause a brisk effervescence with acids. The rapids, more than a mile in extent, are over this rock; but the adjoining banks are so low, that it is difficult to obtain good exposures.

The upper layers, however, as displayed at the saw-mill, are frequently made up of rounded grains of quartz, united by a calcareous cement, which communicate to the mass the appearance of an öolitic structure, though none, in fact, exists."

Tracing this rock westerly from the St. Mary's river, there appears to be a gradual augmentation in thickness. This is apparent, when we compare its development on the Escanāba, and on the Wisconsin and Mississippi rivers. In its easterly extension, its increase is equally great, attaining, on the St. Lawrence, a thickness equal to that exposed on the Mississippi.

Little can be said, in detail, of this rock, since nearly the entire extent of country occupied by it, in this district, is covered by forests; and it is only in the river banks that good exposures exist. From all that can be observed, it maintains the same character here as in other localities, both to the east and west; and, from what we know of it elsewhere, and from its tenuity and unaltered condition in this district, we cannot expect the occurrence of any minerals of economic value. Except that this rock is so important a member of the series, both in its eastern and western extension, it might be regarded as a subordinate member of the lower Silurian limestones."

THEORETICAL CONSIDERATIONS.

We have thus endeavored to define the boundaries and describe the principal peculiarities of the Potsdam and calciferous sandstones which play so conspicuous a part in the geology of the north-west.

From the details, incorporated into this chapter, it will be seen that, wherever the Potsdam sandstone comes in contact with the granite, or prior-formed schists, it is observed to have a slight inclination *away* from the older rocks, rarely exceeding 8° or 10°. It is not necessary to suppose that this inclination has been occasioned by a subsequent bodily upheaval of the granite, but that it was, in the first instance, deposited at this angle. From the topography of this region, it is evident that the sandstone was deposited in a basin-shaped depression, having an irregular bottom. Granite for the most part constitutes the rim of Lake Superior, and we have seen that it rose above the surface of the ocean in which the Silurian strata were accumulated.

Where the materials forming strata are for a while mechanically suspended, or held in chemical solution, they will, when thrown down, accommodate themselves in a measure to the prëexisting inequalities: — so, too, where they have been distributed along a shelving shore, they partake in some degree, of the prevailing slope. Hence, a hasty observer might infer that there had been a slight uptilting of the land, when in fact it had remained undisturbed. It will be seen, from the investigations of Dana, that the detrital accumulations around the islands of the Pacific have almost invariably an inclination sea-ward, where there is no evidence of upheaval; and Mr. Jukes, another explorer in the same field, mentions a similar mode of occurrence at Heron island, where not only the sand and intermingled fragments of coral exhibit this tendency, but the solid coral, also, is traversed by lines of cleavage conformable to those of the stratified deposits, the whole dipping sea-ward at an angle of from 8° to 10°.

From the experiments of M. de Wegmann, it would appear that sedimentary strata may be deposited on slopes not exceeding 40°, and that it is not safe to assume an upheaval, simply from the unconformability of the strata, where there is no evidence of dislocation, or protrusion. Thus, sandstones, or other sedimentary strata, folded over a granite nucleus, at moderate angles, do not necessarily indicate that the nucleus is posterior to the sandstones, since the latter might have been deposited over and around it. The bed of the Gulf of Mexico, near Galveston, has such a constant and regular slope that sailors can calculate the distance from shore by the depth of water. By sounding at two points, the distance between which is known, the difference in depth will represent the tangent of the angle with the coast; and this angle being known, the distance is easily ascertained by means of a second rectangle triangle.*

The want of horizontality in the stratification, therefore, is not of itself, proof of upheaval.

* Bulletin of the Geol. Soc. of France, April, 1850.

REMARKS.

Great diversity of opinion has been entertained with regard to the age of this sandstone. Dr. Jackson, in his report communicated to the Land Office, in 1849, describes it as the *new-red,* and seems to think that he has clearly demonstrated that it cannot belong to the Potsdam. He founds his belief on the fact, that a patch of Silurian limestone has been discovered, with a high inclination, in the midst of the sandstone, and hence infers that the latter is the superior rock. He also states that a fragment of *Pentamerus oblongus* was obtained from this locality, which would identify it with the Niagara limestone; and that, therefore, this sandstone must belong, either to the *old-red,* or the *new-red.* From the absence of fossils, and from mineralogical resemblance and mineral contents, he thinks it must be referred to the latter.

This reasoning would be conclusive, if the facts were admitted. We have shown, in our former report, that the region where the limestone is exposed, exhibits many evidences of local disturbance; that in some places the sandstone rises in hills, having a quâquâversal dip, and that a few miles farther west, the igneous rocks break through, and form a mountain a thousand feet in height. The highly inclined position of these beds, therefore, proves nothing. Admitting that the limestone is the inferior rock, is it not singular that it should nowhere be found interposed between the slates and the sandstone, along a line two hundred and fifty miles in length? Mr. Whitney's notes, which furnished him with all the information he possessed—he never having seen the locality—will not authorize the inferences which have been drawn from them. On page 625, (Documents accompanying President's message, 1850, Vol. III.,) he speaks of the sandstone in his district as resting *directly* on the granite rocks, and describes this limestone as belonging to the *lower* portion of the Silurian system. On p. 711, he remarks that, "if no other data can be collected than those which I have already, I should hardly feel willing to pronounce which is the oldest formation."

All of the fossils were collected by Mr. Whitney. They were subsequently submitted to Mr. Hall, whose authority in these matters cannot be questioned; and from his report, contained in Part I., it will be seen that he failed to recognize among them, the *Pentamerus oblongus*, or any other form, characteristic of the Niagara limestone; but, on the other hand, he pronounces them all as belonging to the lower Silurian types. We have, however, in other parts of the district, as shown by the detailed examinations, the most conclusive evidence as to the age of this sandstone; not only the evidence of superposition, but of fossil contents. The occurrence of the Lingula and the Trilobite in this group, must be regarded as conclusively settling its age, and outweighing mere theoretical considerations founded on lithological characters, which are a very uncertain guide.

It is but justice to those who have examined this group, that we should refer to their conclusions.

Dr. Owen, in his report on the Chippewa district for 1848, pp. 57 and 58, remarks that, in the absence of all conclusive evidence derived from organic remains, there is certainly strong, presumptive evidence, that the red sandstone and marls were deposited subsequently to the *carboniferous era*.

Dr. Locke, in his report for 1847, describes this sandstone as the *old-red*, but it is evident, we think, that by this remark he did not regard it as part of the Devonian series, since he was of the opinion that it must pass beneath the Silurian limestones.

On the plats of surveys of township lines, made by Mr. William A. Burt in 1845, under the direction of Dr. Houghton, the sandstone of the southern slope is designated as the Potsdam, thus leaving no doubt that Dr. Houghton had, at that time, satisfied himself as to its true position in that portion of the district.

Captain Bayfield was the first to explore this sandstone with care, while conducting the trigonometrical survey of Lake Superior. In the Quarterly Journal of the London Geological Society, for November, 1845, there is a communication by him, "On the junction of the Transition and Primary Rocks of Canada and Labrador." In reference to the sandstone of Lake Superior, he remarks:—"No organic remains having as yet been found in this sandstone, and its junction with the Lake Huron limestone in the St. Mary's, below the rapids, being hidden by drift, water, and an impervious forest, so as hitherto to have escaped notice, it is difficult to determine, with any confidence, its place or age. There seems no reason to think that it can be more recent than the old-red sandstone; and when it is considered that it appears in the St. Mary's at low levels, forming nearly horizontal strata at the bottom of Lake George, whilst the horizontal fossiliferous limestone of Sugar island and St. Joseph's rises into higher ridges, so as to make it appear highly probable that the sandstone occupies the inferior position, and that, moreover, a sandstone is known very generally to underlie transition limestone in Canada and the United States; when all this is taken into account, it is not perhaps unlikely that the sandstone in question may belong to the Silurian rather than the Devonian period. On the other hand, its appearance in unworn slabs, that must be near the parent rock, in the neighborhood of Michilimackinac, where great beds of gypsum occur, would seem unfavorable to this conclusion; as may also, perhaps, the red marly beds of the Twelve Apostles."

Mr. Foster, in his synopsis of observations between Lake Superior and Green Bay, dated September, 1848, and published in the report of the Commissioner of the General Land Office, for 1848-9, describes the sandstone of the northern and southern slope as belonging to the same age, and as resting at the base of the palæozoic series.

That same year, Mr. Murray, of the Canada survey, examined the St. Mary's river and the northern shore of Lake Huron, and satisfied himself that this sandstone passed beneath the Trenton limestone, and was the equivalent of the Potsdam. In reference to his explorations, Mr. Logan remarks:—"The evidence afforded by the facts is clear, satisfactory, and indisputably conclusive."

From the concurrent testimony of those whose opportunities for observation have been the most extensive, there can be but one opinion as to the age of this sandstone. It has ceased to be a mooted point.

CHAPTER IX.

LOWER SILURIAN SYSTEM.—CONTINUED.

BY JAMES HALL.

Chazy, Birds-eye, Black River, and Trenton Limestones.— Their intimate Association in this District.— Their Range and Extent.— Organic Remains.— On the St. Mary's River.— On the Escanāba, Rapid, and White-fish Rivers.— At Little Bay des Noquets.— Along Ford and Cedar Rivers, and the Shores of Green Bay.— In Wisconsin.— Along the Fox River, and the Shores of Lake Winnebago.— At Plattsville, Galena, and Dubuque.— The Galena or Lead-bearing Limestone, a distinct Member of the Lower Silurian Series, not recognized in New York.— Not a portion of the Cliff Limestone.— Hudson-river Group.— Its Development on Drummond's Island.— At Pointe aux Baies.— Organic Remains.— Its Identity with the Blue Limestone and Marls of Ohio and Indiana.— Lithological Characters.—This Group the true Termination of the Lower Silurian Series.

CHAZY, BIRDS-EYE, BLACK RIVER, AND TRENTON LIMESTONES

These limestones are so intimately connected, one with another, in the Lake Superior district, and each is so thin, that no advantage can be derived from treating them separately. It is true, however, that each can be recognized as a distinct member of the lower Silurian series, and is characterized by fossils peculiar to itself, as has been shown in New York. Reduced as these formations are in thickness, it will, nevertheless, be necessary to study them separately, and for the geologist, or collector, to preserve the fossils distinct.

Commencing at the eastern limits of the district, these limestones are first seen upon the St. Mary's river; but they are better exposed upon the eastern side of St. Joseph's island, than upon the main land of the Michigan side. The sandstone, which is seen on Sugar island, plunges to the south, and passes beneath all these limestones, leaving, as far as observed, no trace of the calciferous; but an interval, covered by drift, occurs, where no rock is visible. In examining the shore of the island, the first rock seen, after the disappearance of the sandstone, is the Birds-eye limestone; but, further to the eastward, near a projecting point, some layers of the Chazy make their appearance, having, towards the bottom, an arenaceous character; while higher up, they assume an argillo-calcareous composition, and contain fossils characteristic of this member of the New York series. This limestone is also seen to pass directly beneath other beds, which, by their peculiar character, may be recognized as the Birds-eye. The fossils of the Chazy do not pass above the limits of the Birds-eye; but the respective limits of the two members are as well defined here as in any of their eastern localities.

The Birds-eye limestone is, for the most part, thin-bedded, the layers being separated by shaly matter, which rapidly wear away under the influence of the atmosphere and the water, while the harder parts are brittle and easily fractured. This limestone appears to be more fossiliferous here than in New York, and, in the upper layers particularly, we found a great number of Orthoceratites.

The Black-river limestone, or beds which may be regarded as the equivalent, seems to be intimately incorporated with the Birds-eye; so much so, that no line of demarcation could be detected.

Further to the south, the Trenton limestone was observed extending in a low cliff, for some distance along the river, maintaining, to a great extent, the characters by which it is distinguished in more eastern localities. Its higher portions are made up, in a great degree, of crinoidal remains, and it preserves the same character as this portion of the series in the Mohawk and Black-river valleys. The whole mass is evidently much thinner than at any locality east of Lake Huron, and there is, also, a larger proportion of shaly matter, not only between the layers, but incorporated in them.

In addition to the evidence derived from lithological characters, the fossil contents are of such a character, and so abundant, as to leave no doubt in this respect. The aspect not only of this member, but of the others, was such as to impress one with the belief that, though identical in age and in composition, and a continuation of their eastern equivalents, they were deposited under circumstances less favorable to organic life, resulting from the nature of the materials deposited, or from varying conditions in the ocean. The quantity of shaly materials mingled with this limestone, and distributed in layers between the beds, would seem to indicate that a shallow and turbid state of the water prevailed during its deposition.

The observations made by Messrs. Whittlesey and Desor, on the Manistee river, tend to confirm these views.

On the Escanaba river, for more than seventy miles along its meanders, above its mouth, these limestones are almost constantly exposed, and present these features. The river, for the distance of a mile before it enters the lake, flows over limestone strata, which are nearly horizontal, or dip very slightly in the direction of the current, but more gently than the descent of the water; consequently, the strata are cut through and their edges exposed, to the thickness of only a few feet. The first rock met with, in ascending the stream, is a tough limestone, in thin layers, separated by bands of shale. It has the lithological characters of the Birds-eye, and contains Orthoceratites and other fossils, characteristic of that member of the series, as well as of the Black-river limestone. The succeeding layers, which are well-exposed about a mile above this point, consist of thin, irregular, or wedge-shaped, layers of light ash-colored limestone, verging to a dark-blue color, and contain many species of fossils, characteristic of the Trenton series; leaving no doubt of their identity. Many of the thin layers are composed of crinoidal remains, and the weathered surfaces are often completely studded with the detached joints or fragments of columns, standing in relief. This character of the weathered surfaces is unlike that exhibited in any part of this limestone noticed within the limits of New York; but an examination of these crinoidal fragments shows that they belong to genera, and, perhaps, species known in this series elsewhere.

The thin and even-bedded layers at the mouth of the river, may be quaried to a considerable extent, whenever there shall exist a demand for them, and will form a durable building material. The succeeding layers are too irregular to be of any value, except for burning into lime.

At the lower mill-dam, a mile above the first exposure, the banks of the stream, as well as the base of a small island, consist of beds of limestone, which form an escarpment fifteen feet thick. These also belong to the Trenton group, as indicated by the following fossils, which were collected at this point: *Isotelus gigas, Calymene Blumenbachii*, var. *senaria, Orthis testudinaria, Leptæna sericea*, and *L. alternata*.

In ascending the river, this limestone, and even the identical beds, continue as far as the Lower falls, distant two miles from the upper mill-dam. The stream for the most part is very rapid, and the dip of the strata very nearly corresponds with the descent.

At the Lower falls, the thin and irregularly stratified portions are succeeded by regularly-bedded strata of limestone, attaining a thickness of fifteen or twenty feet. It is impure from an admixture of arenaceous and argillaceous matter, while layers of these materials occur beneath. A few fossils were found at this place, among which were Brachiopods of the Trenton and Hudson-river groups, with *Chætetes lycoperdon*.

After passing the falls, these last described beds very soon disappear, and there occurs an interval of several miles, where few traces of rock are observed; but, at several points, the limestone is seen by the margin of the river,—the descent of which is here very gentle—in no instance exposed to a greater thickness than two feet. The layers are thin, of a light-grey color, of a granular structure, and contain numerous cavities, some of which are partially lined with crystals. Although these few beds of themselves are of little importance; yet, when studied in connection with the range of the series, they present a feature of considerable interest, noticed here for the first time. These compact, grey beds lie above the limestone seen at the Lower falls, since they clearly pass beneath the channel of the river, before the others emerge. Between the Lower falls and the Meadow,* distant nine miles from the lake, the surface is mainly covered by an accumulation of boulders, apparently derived from the drift, which forms a steep escarpment on the eastern side of the river. Below this place, the river curves to the eastward, cutting deeply into an accumulation of this character; but, above, it again bends to the westward, and lays bare, on the east side, a ledge, some twelve feet thick, of grey limestone, thin-bedded, and containing small cavities, sometimes lined with crystals of magnesian carbonate of lime, and at others empty. These

* This is a somewhat remarkable feature in a river of this character, where the general descent is very rapid, being some seven or eight hundred feet in the distance of thirty miles. The principal meadow is found at a bend in the river, the ordinary channel just above it turning abruptly to the east, and making a broad curve, where it has cut through the drift; while to the west is another channel, through which a part of the water is discharged during freshets, uniting with the main channel half a mile below; thus leaving on the west side a large tract of bottom-land, the upper extremity of which consists of a wooded island. In looking from the eastern bank, a broad meadow bounds this temporary channel, flanked on the right by the wooded island, and on the left by the unbroken forest. In this meadow are several elms of magnificent size, the nearest ones standing out in bold relief, while the farthest blend with the forest growth of maples, beaches, &c. Their mode of growth shows that, from their commencement, which is very ancient—since two or three were observed which had fallen from age—they had stood in the open areas which they now occupy. In such wooded bottom-lands, in this latitude, we often find plants and trees flourishing luxuriantly, which, under ordinary circumstances, are only found in more southern situations.

layers are a continuation of those before described as occurring at the water's edge, several miles below.

From this point, onward, for a considerable distance, the dip of the strata is more rapid than the descent of the stream, though the latter is quite rapid; consequently, there is a succession of the lower strata presented to view in its banks. I had, therefore, an opportunity of verifying my first observations, that the grey, granular, limestone rested upon some shaly and arenaceous beds with thicker calcareous strata, like those seen at the Lower falls, succeeded by the irregularly stratified beds observed at the upper mill-dam. We had an opportunity of tracing these two last divisions for several miles along the river, where these escarpments were exposed from twenty-five to thirty feet in thickness, disclosing, in the ascending order, the Birds-eye limestone, succeeded by the Trenton, with scarcely a trace of the Black river limestone; for, while the *Ormoceras*, characteristic of the latter rock, occurs at the junction of the other two, in the same connection is found the *Orthoceras multicameratum*. Notwithstanding, therefore, the extreme tenuity of these different members, and the great admixture of arenaceous and shaly matter, there is no difficulty in recognizing, at this remote point, the important subdivisions which have been made in New York, and of determining them by their characteristic fossils.

From the first exposure of the rocks above the meadow, they are almost constantly in view to the Upper falls, and from thence, onward to the forks of the river. About two miles from the upper end of the meadow, the Birds-eye limestone is seen at the level of the river and continues, with some slight undulations, to occupy the surface, as far as the first rapids below the Upper falls. At Indian creek, a short distance below the foot of the rapids, the Birds-eye limestone is very distinctly defined, and rests upon some heavy beds, which clearly represent the Chazy limestone. One of these beds is remarkable for weathering in a peculiar manner, and an examination shows that it is filled with a kind of tough, silicious and irregularly-shaped concretions, or segregations, which stand out in relief, while the calcareous part wastes away.

At the Upper falls, the strata rise more rapidly to the northward, and though the ascent of the stream is considerable, yet, on arriving at the foot, the calciferous sandstone is exposed, forming the base of the escarpment over which the water is precipitated; while, above it, there are two layers which represent the Chazy and Birds-eye limestones and the lower part of the Trenton group.

Here, the following section is exposed in an ascending order.

1. Birds-eye limestone, fine-grained and compact, of a bluish-drab color.
2. Calcareous layers, of a grey color, with crinoidal joints and other fossils,—4 feet.
3. A heavy-bedded, variegated limestone, with much silicious matter, the surface weathering very unevenly,—2 feet.
4. A thick, silico-calcareous bed, with fossils in the upper part,—2 feet.
5. Silico-calcareous layers at the foot of the falls, thin and even-bedded,—1 foot.

The whole exposure at the falls is about fifteen feet, and in the bank above, about ten feet more. The beds forming the top of the falls disappear below the river, near the point where Indian creek comes in from the east. The layers having the character of the Birds-eye limestone disappear a short distance below, and are succeeded by thin beds containing an abundance of *Orthis testudinaria*, *Leptæna sericea*, and *L. alternata*, with other fossils of the Trenton limestone, and have the same character as some of the layers about midway in this group, as developed in the Mohawk and Black-river valleys, in New York. Above the falls, the low cliff of fossiliferous limestone continues for some distance, gradually declining to two or three feet in height above the river. The same changes take place, with the recurrence of the same layers, in ascending the stream, the strata rising more rapidly than the ascent of its bed. From this cause, we find the calciferous sandstone coming out from beneath the fossiliferous limestones, at a point some three miles above the falls, and continuing thence up the stream for the distance of two miles above its forks.

These limestones, which have a combined thickness of less than seventy-five feet, are exposed almost continuously in the bed and banks of the stream, for the distance of more than thirty miles, following its meanders, and a distance of about twenty miles in a direct line. The difference between the dip of the rock and the descent of the river, is less than sixty feet. There is, however, very little parallelism between the two; for, within the first eight miles after leaving the lake, we meet with the highest beds of limestone in the series which occur on this river. Although its descent is rapid, yet it is unequal in its rate, and these inequalities appear to be due to undulations in the strata, which can be detected at several points. For the most part, the stream is very shallow, and its bed rocky.*

Along the whole extent of this exposure of the rocks, whether examined continuously, or at intervals, there is no difficulty in identifying different portions with their New York equivalents. When taken as a whole, and all of the beds examined in connection, the principal subdivisions, such as the Chazy, Birds-eye, and Trenton limestones, are readily identified, not only by their lithological characters, but by their organic remains. Even in the arenaceous layers, which form some twenty feet of the whole thickness, we not only detect numerous species of fossils peculiar to the Trenton limestone, but many peculiarities of bedding, and other characteristics, which, though not easily described, are readily understood and comprehended by the geologist.

It is deemed unnecessary to give farther details of the variable features of these limestones along the Escanāba river; in all the localities examined, they offer little of economical value, aside from their application to building purposes.

At the mouth of Rapid river and along its borders, and also at the mouth of the White-fish and at the head of Little Bay des Noquets, the Trenton limestone is exposed, exhibiting the same lithological characters as at the upper dam on the Escanāba.

Farther explorations, made by Mr. Whitney, along the White-fish river, in crossing from Little Bay des Noquets to Lake Superior, proved the occurrence of the Trenton group, for the distance of fifteen miles, or more, from the head of the bay. The specimens procured are filled with fossils principally *Leptæna sericea*, and occasionally with *L. alternata* and *Orthis testudinaria*, while, in lithological characters, they agree with those observed on

* The name Escanāba signifies *Smooth Rock*, given for the reason that the stream often flows for considerable distances, over the smooth surfaces of the slightly-inclined rocks. The inequalities caused by the offset of particular beds, give rise to numerous rapids, and render the navigation so difficult that even a small skiff cannot be impelled against the stream, when the water is low, except by using setting-poles armed with steel points.

the Escanāba and Manistee. The country along the White-fish river is low, rising little above the river margin; consequently, there are no cliffs, or escarpments, where the strata are exposed to any extent, and specimens can be procured only at the water's edge. This river then, like the Manistee, affords evidence of the existence of certain groups, but does not admit of continuous observation as to their succession, thickness, and importance.

In the present state of the northern peninsula, being almost an unbroken wilderness, and the elevation of the country occupied by the Silurian series but a few hundred feet above the lake, with no abrupt curves in the strata, by which they are brought to the surface, it is impossible to determine anything more than the limits of the more important groups; for all practical purposes, however, the determinations already made are sufficient; and it was only with the hope of acquiring more detailed information, that we desired more time and better opportunities of investigation.

Leaving the Escanāba, and following along the coast of the bay in a south-easterly direction, we soon find the limestones, just described, coming out to the surface at the lake-level and scarcely rising above it, the character of the beds being the same as those seen within a mile of the mouth of the river.

At the mouth of Ford river, the country is low and there are no rocks visible. The banks consist of alluvial, or drift materials, for four miles, when there occurs a long rapid over the thin-bedded limestone, the same in character as that at the upper mill-dam on the Escanāba. Proceeding towards Cedar river, we passed several reefs of rock and observed large slabs of limestone in the shallow water, which appeared identical with those at the mouth of the Escanāba, and lower than the thin-bedded portion of the Trenton group. Upon Cedar river, there are no rocks visible for two miles after leaving its mouth; but here, at the end of a mill-dam, the arenaceous and shaly bands, which occur at the Lower falls of the Escanāba and opposite "Wood's Camp," are visible. These occupy a higher position in the series than those seen at Ford river. Few fossils were here observed, crinoidal joints being the most numerous.

From the mouth of Cedar river to the mouth of the Menomonee, the more thickly-bedded portions of the Trenton, with layers of Birds-eye, occur along the margin of the bay. Although nearly in situ, the beds have been raised and broken by the water, and, in some places, piled up in walls, or barriers, which have a very artificial appearance.

At the lower dam, on the Menomonee, a little above the water, limestone is observed, in places, on the right bank, its surface being ground down, and grooved with drift-scratches. Its character is very similar to that of the Birds-eye, and the only fossils observed were crinoidal joints.

The west side of Green bay, from the mouth of the Menomonee to its head, was explored by Messrs. Whittlesey and Desor. The specimens collected showed a continuation of the same limestones which had been observed from Little Bay des Noquets to the Menomonee. The fossils collected were two species of *Murchisonia*, *Pleurotomaria lenticularis*, and several *Brachiopoda*.

After examining the eastern shore of Green Bay, I took up my observations upon the same limestones at Depere, tracing them along the Fox river to the outlet of Lake Winnebago. Subsequently, in order to connect the geology of the Lake Superior district with that of the Chippewa district, I continued my examinations across the state of Wisconsin to the Mississippi river, and thence, at intervals, along that river to the falls of St. Anthony. At Mineral Point, the lower members of the series have become very argillaceous, weathering into a light drab color, and are characterized by numerous fossils. At Plattsville, the Birds-eye layers are pretty well defined, though associated with much shaly matter and some layers of dark shale. The rock, on being freshly fractured, is very dark-colored, but weathers to an ashen hue. The Trenton limestone, which succeeds, is thin-bedded and light-colored, and all that remains is scarcely more than twenty-five feet in thickness. The same features are observed at Galena, and again at Dubuque. At the latter place, the connection of this group with the succeeding limestone is very obvious. In all these localities, the entire thickness of these lower limestones, which can clearly be identified with the Trenton and associated limestones of the east, is less than fifty feet; but it is possible that some better exposures would give a greater thickness.

I conceive that there can be no longer a doubt in reference to the age of the limestones under consideration. Their identity with those of New York and of Canada has been established, not only by a comparison of the fossils, but also by tracing almost continuously their range from the Mohawk, Champlain, and Black-river valleys, through Canada, to the eastern limits of this district, and thence westward, continuously, to the Mississippi river.

These remarks also apply to other groups, concerning which some difference of opinion has heretofore pervailed. Feeling the necessity of adopting some recognized standard, we have referred these subdivisions, so well marked, to those which have already been made by the New York geologists.

Before leaving the subject of these limestones, it will be necessary to recall to mind some observations made on the Escanāba river, above the Lower falls, and at the bend above the Meadow. The upper layers of grey limestone, at the last named point, have a thickness of some fifteen feet, are meagre in fossils, and do not appear to be identical with any portion of the series, which I have observed farther east. In going westward, I had not an opportunity of observing the overlying deposits of the Trenton limestone until I arrived in Wisconsin. Here, in numerous localities, as well as in Illinois and Iowa, the deposit above that which is marked by an abundance of fossils characteristic of the Trenton, is a grey, or drab-colored limestone, and very friable, forming a part of the "cliff limestone" of the Ohio and Indiana reports, and is called by Dr. Owen, in his report on the Lead region, the "upper magnesian limestone." From its position, as well as its lithological characters, it appears that this limestone, which is the principal lead-bearing rock in these states, is a continuation of that noticed on the Escanāba, lying above the fossiliferous beds of the Trenton limestone; but that it has increased in thickness, as traced westwardly, and becomes an important member of the series; and hence, we have designated it in the classification of the rocks, as the "Galena limestone."

In the neighborhood of Galena, Dubuque, Mineral Point and other places, there are numerous localities where a direct succession in the beds may be traced. It is very evident that this limestone diminishes in thickness eastwardly from these points, and becomes a very subordinate member of the series, losing, at the same time, its metalliferous character. From the general absence of fossils, and from its resemblance to the next succeeding limestone in lithological character, no distinction has usually been made between them. In the localities cited, particularly in the neighborhood of Dubuque, the higher grounds are occupied by a limestone containing an abundance of *Catenipora*, *Heliolites*, and other corals marking it as of the age of the Niagara. From the relative position of these coral-bearing rocks to the lead-bearing strata, it has been inferred that they were but parts of the same group, and they have heretofore been described as such.

This was the state of our knowledge, when I examined this series in 1841, and having satisfied myself that the coral-bearing limestone of Wisconsin and Iowa could be clearly identified with the Niagara group of New York, I expressed the opinion that the lower part of the cliff limestone was of the same age. Up to the present time (1850) I am not aware of any published evidence from an examination of the rock in place, to prove that the lead-bearing rock is of lower Silurian age.* The principal fossil resembles a *Coscinopora*, but is probably a *Receptaculites*. I have found, however, in the same rock, the head of an *Illænus*, a *Leptæna*, not unlike *L. alternata*, *Spirifer lynx*, and *Atrypa increbescens*. The still higher, thin-bedded, argillaceous limestone contains a species of *Lingula*, undistinguishable from *L. subquadrata*, *Spirifer lynx*, *Pleurotomaria lenticularis*, *Murchisonia bellicincta*, and another species with angular volutions, a large *Orthoceras*, and fragments of *Illænus*. Up to this point, I found no corals of the Niagara period, and, though the fossils are not numerous, they are all of lower Silurian forms, and furnish the best evidence we have of the age of this limestone.

This lead-bearing rock, as before observed, rests upon fossiliferous strata of the Trenton age, which can be recognized as the identical group traced over several hundred miles. The galena sometimes penetrates the Trenton series, in films or sheets, but does not form veins, as in the grey, heavy-bedded limestone above.

From all the evidence, therefore, the lead-bearing, or Galena limestone, must be regarded as a distinct member of the lower Silurian system, which is not recognized at the east. From its gradual diminution in thickness, its source appears to have been towards the west. The conditions of the ocean, though favorable to the deposition of this immense mass of calcareous materials, were unfavorable to the development of organic life; for, although there remain a few species which continue through the period of its deposition, the greater number known in the group below did not survive beyond the commencement of this. The occurrence of more highly fossiliferous strata above, still of lower Silurian age, would show that the Galena limestone does not form a series of transition beds between the upper and lower Silurian.

To the south and south-west, this rock is of limited extent, probably nearly coincident with the lead region; the universal testimony showing that no productive lead mines exist in the western states, out of the range of this rock.

* Mr. Conrad, in the proceedings of the Academy of Natural Sciences of Philadelphia, 1843, expressed his opinion that the lead-bearing limestone was of the age of the Trenton, from certain fossils obtained at Mineral Point. These fossils are from the Trenton limestone proper, but no productive veins are known to occur in that rock so far as I can learn. Dr. Owen in his report upon that region has remarked that the veins die out on reaching the "blue limestone." This blue limestone, in Wisconsin, is no other than the Trenton limestone containing large numbers of the fossils peculiar to that rock, and underlying the blue marl and limestone of Cincinnati and other western localities, and which are not recognized in central and western Wisconsin.

This fact sets at rest all speculations as to the probable metalliferous character of certain rocks which have been supposed to be identical with the Galena limestone. The lead-bearing rock is a peculiar one, holding a certain place in the series, and of limited geographical extent. It is metalliferous throughout the greater part of its known limits, where it has considerable thickness. The lead veins are almost wholly confined to it, and evidently have their source in it. The small quantities sometimes found below its base are in seams that die out, as they penetrate the inferior rock, and it often takes the form of interlaminations among the strata, having little connection with the lower masses.

Regarding the higher beds before alluded to as identical with the Galena limestone, it is not probable that the rock contains any valuable deposits of ore within the Lake Superior district; but, on the other hand, the small thickness of the mass would preclude the possibility of the occurrence of valuable veins. The fact of the existence of this rock, as a distinct member of the series, is interesting in a geological point of view, and opens the question as to the completeness of the series, which has been studied in New York, Canada, Pennsylvania and Virginia.

There is another question which may arise, and that is, as to the relations of the lead-bearing rock to the Hudson-river group; for there appears to be little probability of identifying this group, at any of the localities west of Lake Michigan. If the upper, ash-colored beds on the Escanāba are identical with the Galena limestone, there is then no difficulty in determining the question; for the Hudson-river group is superior to this limestone. Although I am not aware that the shales of this group have been recognized in Wisconsin, or Iowa, I am disposed to believe that the numerous fossils found in the drift,—among which are a small *Nucula, Cleidophorus, Pleurotomaria*, and others,—are derived from the destruction of beds of that age, which lie above the Galena limestone. This opinion is further strengthened from having found on Little Bay des Noquets some beds filled with small fossils similar to those noticed; and I have received a specimen of similar character, said to have been procured, in place, near Galena

HUDSON-RIVER GROUP.

The first appearance of this group, in this district, is upon the northern side of Drummond's island, where it lines the shore for the distance of several miles, forming, in fact, that portion of the island lying north of the deep bays which indent its eastern and western extremities. The thickness exposed is not more than thirty or forty feet of the upper part of the group, consisting of some calcareous beds, with *Favistella stellata* in great abundance. Below these are alternations of shaly and calcareous layers with *Streptelasma, Chætetes, Spirifer lynx, Atrypa increbescens, Orthis occidentalis, Modiolopsis modiolaris, Ambonychia radiata*, and other forms, characteristic of this period.

As the strata appear here, they are far more calcareous than in New York, and approach in character the same beds in Ohio and Indiana; while the prevailing fossils are those which predominate in the western localities. From the evidence here observed, this group of strata has undergone great changes between this point and the northern shore of Lake Ontario; the changes being in the accession of calcareous and the diminution of arenaceous matter. In the state of New York, the prevailing characters of the strata are shaly and arenaceous, calcareous matter being subordinate to the other two.

After leaving Drummond's island, we had no good opportunity of seeing the strata of this group, before arriving at Pointe aux Baies, between Great and Little Bays des Noquets. Here, the calcareous shales, with thin bands of limestone, indicate the higher portions of the group, and are charged with fossils, principally those before noticed. The highest layer visible contains large numbers of *Ambonychia radiata,* with a few specimens of *Modiolopsis modiolaris.* The surface of the country on the east side slopes gradually down to the level of the water, and offers no opportunity for determining the nature of the beds upon that side. On the western side, however, there is a low escarpment, interrupted at intervals, but nearly continuous, to a point opposite the mouth of the Escanāba river. The strata exposed along this coast consist of alternations of calcareous and argillaceous beds, above which is a considerable thickness of arenaceous and calcareous strata, readily crumbling on exposure to the weather. The highest portions seen are compact strata of impure limestone, containing both arenaceous and argillaceous matter incorporated with the mass and intercalated in thin layers. In the lower beds, the fossils are principally *Brachiopoda; Orthis testudinaria, Leptæna sericia,* and *L. alternata* being the prevailing forms. A single thin stratum is charged with small *Nucula, Cleidophorus* and minute *Gasteropoda.* Another calcareous layer is partially filled, and the upper surface covered, with fragments of *Isotelus.* This stratum can be traced continuously for more than a mile along the coast, and is everywhere charged with these fragments. A single articulation from the shaly mass, just above this layer, measured ten inches in length, which represents the transverse diameter of the animal, the length having been twice as great. Many of the layers are completely covered with fragments of branching forms of *Chætetes lycoperdon,* and considerable variety of surface is presented among them.

In the succeeding beds there are some thin, calcareous layers, with *Orthis testudinaria* and *Spirifer lynx* in the softer and lower shale, while in the higher portions occur the *Modiolopsis* and *Ambonychia,* with a few *Orthoceratites.* The heavy, calcareous beds above have still the same fossils as those next below, which we have just enumerated.

Except in lithological characters, arising from the accession of calcareous matter, and the almost entire absence of arenaceous strata, the similarity between these beds and the upper beds of the Hudson-river group, as developed in north-western New York, is complete.

Although their actual contact with the Trenton limestone was not observed, there can remain no question as to their relative position. The limestones, as already described, exist upon the west side of the bay, with a uniform dip south-easterly in a direction at right angles to the curve of their outcrop. The beds of the Hudson-river group show an escarpment on the east side, dipping conformably with those on the west, and consequently lying above them. This fact is important to be established here; for, there can be no doubt of the positive identity, in composition and fossil contents, of the shales and calcareous beds of Pointe aux Baies and Little Bay des Noquets with the "blue limestone and marls" of Cincinnati, Ohio, of Madison, Indiana, and other places.

For these beds, then, on the northern shore of Lake Michigan, we establish a distinct geological horizon, and in tracing westward the Trenton limestone, we prove that they are not contemporaneous with, or a continuation of, that group. If, therefore, this is the case in the north, it is a legitimate inference that those further south hold the same relation (although we are not able there to see the base of the Hudson-river group); and the further inference may be drawn, that the blue limestone and marls of Cincinnati and other localities do not include the Trenton, or any of the lower limestones, but are strictly the equivalent of the Hudson-river group, being, in fact, everywhere but a continuation of it, changing, as we go westward, its lithological characters, and including other fossils.

It has been deemed necessary to go somewhat into these details, for the reason that it has been made a question whether the groups of New York were continuous and could be recognized in the west; and, particularly, whether the blue limestone and associated marls could be identified with the Hudson-river group of New York.

The conditions of the Hudson-river group, in the west and south-west, are such as we might expect, when we consider the source from whence the materials have been derived,—that is, from the east and the north-east. The coarser materials were first deposited, while the finer portions were carried farther into the ocean, and thrown down as the current diminished in velocity; consequently, we should expect just what we find, an impalpable mud, which, mingling with calcareous matter derived from organic or other sources, has produced such a deposit as we see distributed over so wide an area. It is not to be expected that a sedimentary deposit, made under such circumstances, should present a homogeneity of aspect over the whole area. Greater depth of ocean, distance from land and from the source of supply, as well as conflicting currents, would unite in producing the changes which we observe; and this, so far from creating surprise, is what we might reasonably expect.

In tracing the boundaries of the Hudson-river group on the map, it will be seen that, from Pointe aux Baies, its trend is in the direction of Green Bay, and there is no doubt that this arm of Lake Michigan has resulted from its excavation and removal, affording a striking example of the dependence of the topographical features of a country upon its geological structure. It is not until arriving near the head of the bay, on the eastern shore, that we again meet with the shales and calcareous beds of this group, forming an escarpment which, with some interruptions, continues to the "Red banks," where it is concealed by alluvium; but beyond this, it can be traced along the base of an escarpment, as far as Lake Winnebago. Its development along the eastern margin of this lake has been examined by Mr. Whittlesey. From this point, I have been able to learn little of its occurrence in a southerly direction, in Wisconsin and Illinois. In a south-westerly direction, in passing through these states, I saw nothing of it, beyond what has already been noted in the remarks on the Trenton limestone. It is not impossible that this group may be found to exist in the north-west; if so, it must lie above the Galena limestone, which does not enter into our estimates, in speaking of the Trenton and Hudson-river groups in eastern localities.

From the observations made upon the shores of Little Bay des Noquets and of Green Bay, it is evident that this group has greatly diminished from its amplitude in New York, or in the vicinity of Cincinnati. The aggregate of all the beds seen would not give over one hundred or one hundred and fifty feet, though it is by no means certain that we have been able to see the entire thickness. In localities at a distance from the lake-shore, the junction of this group with that above and below is concealed by drift and alluvium, while no absolute point of contact could be observed along the shores of the bays and rivers.

From what has been stated, we believe it will be admitted that this group does undergo the lithological changes which we have pointed out, and that to these changes are due the peculiar characters of the blue limestone and marls of Cincinnati.

We shall attempt to show in the succeeding pages that with this group terminates the true fauna of the lower Silurian period.

CHAPTER X.

UPPER SILURIAN AND DEVONIAN SERIES.

BY JAMES HALL.

Clinton Group.— Its Development on Drummond's Island.— On Big Bay des Noquets.— On the Eastern Shore of Green Bay.— Fucoidal Markings.— Tracks and Trails of Animals.— Its Prolongation into Wisconsin. — At Hartford.— Conditions of the Ocean at this Period.— Niagara Group.— Range of some of the Fossils.— Its Development on Drummond's Island.— Fossil Contents.— Character at Point Patterson and Pointe Detour.— Summer Islands.— Peninsula of Green Bay.— Lithological Characters.— Section at Big Bay des Noquets.— Ancient Coral Reefs.— Probable Condition of their Growth.— Thickness of the Niagara and Clinton Groups.— Onondaga Salt Group.— Its External Characters.— Range in this District.— Organic Remains.— Missing Groups which occur in New York. — Evidences of Ancient Denudation.— Source of various Economic Materials.— Devonian System.— Upper Helderberg Series.— Mackinac Limestone.— Gros Cap.— Island of Mackinac.— Arched Rock.— Sugar Loaf.— Fossil Contents.

View near Gros Cap, Lake Michigan.

CLINTON GROUP.

We now commence our description of the groups which compose, in this district, the upper portion of the Silurian system, to wit: the Clinton group, the Niagara group, and the Onondaga salt group. The Medina sandstone, which occurs below the Clinton group, in New York, has not been recognized in this district sufficiently developed to require a separate notice, while higher up in the series, there occur several well-marked groups in New York, which are entirely wanting here. These will be adverted to in the succeeding pages of this report.

Resting at the base of the upper Silurian, we find the Cinton and Niagara groups, which are here so intimately associated with each other, that the line of demarcation between them cannot readily be drawn.

It has been shown in the reports on the geology of New York, that the strata composing the Clinton group contain a larger proportion of calcareous matter as they are traced to the westward; while, in the same direction, the shaly and argillaceous beds gradually diminish in thickness and importance.

So great is this change, that this group, which, in the central part of the state, consists mainly of shaly and arenaceous beds with very subordinate layers of calcareous matter, is, at the Niagara river, made up of two members of limestone and one of shale. Although, in some Canadian localities, the shaly and arenaceous beds acquire a temporary importance, yet the calcareous matter, on the whole, greatly predominates.

The first point in the district, where the strata of the Clinton group were observed, is at the eastern extremity of Drummond's island. Here, in some thin, calcareous beds, at the level of the water, we recognized several fossils of this group. The strata are thin-bedded, of an argillo-calcareous character, and of an ashen or drab color. Only a few feet in thickness are exposed, and, alone, they would hardly have been regarded as of any importance. These beds, however, are below others which are well-characterized by an abundance of Niagara fossils, and overlie other strata belonging to the Hudson-river group, though the actual junction of the two has not been observed. In going westward, along the northern shores of the Lakes Huron and Michigan, I was unable to observe any beds so low as those on this part of Drummond's island, until after having passed the entrance to Little Bay des Noquets. About three miles above this point, and along the base of a high bluff, I found, at the water-level, layers of precisely the same character and characterized by the same fossils. The fossils consisted of a species of *Cytherina*, an *Avicula*, and *Murchisonia subulata*. At this locality, they lie at the base of a cliff about two hundred and fifty feet in height. These thin beds, as traced upwards, gradually pass into thicker beds which belong to the Niagara group. We must regard these thin, calcareous strata as intermediate between the two groups, containing, however, no fossils characteristic of the Niagara period.

In examining the eastern shore of Green Bay, we find thin-bedded calcareous strata extending from near Washington Harbor to Sturgeon Bay, identical in general character with those at the eastern extremity of Drummond's island and Big Bay des Noquets. Some beds were observed to be more silicious and very compact; and, in many instances, separated by thin layers of green shale. They maintain this uniform character nearly the entire distance indicated. The line of the coast is nearly cöincident with the bearing of the strata, so that we have no opportunity of seeing beds through a greater vertical range than fifty feet. On both shores of Sturgeon Bay, we find beds somewhat higher in the series, and more calcareous in composition, the highest of which are charged with casts of *Pentamerus oblongus*. On the north-eastern side of the bay, we noticed a single bed with strong, rigid, fucoidal markings which are characteristic of some portions of the Clinton group in New York.

On the south-western side, and on the next point of land in the same direction, the following section in an ascending order may be seen.

5. Light-grey, or drab-colored limestone, friable, with *Pentamerus oblongus*, corals, &c. Some of the layers are two, or three feet thick. One layer marked with a net-work of fucoids, the stems one-half or three-fourths of an inch in diameter.—Thickness, 10 feet.*
4. Thin, calcareous, with silico-calcareous layers, the same as were noticed at Windy Encampment, on the east side of Green Bay, opposite the mouth of the Menomonee river, graduating into the mass below, but still showing a line of separation.—Thickness from 6 to 10 feet.
3. Shaly beds alternating with silicious, silico-argillaceous and silico-calcareous layers of variable thickness.—Upper part more calcareous, the layers in many places having a concretionary structure, and containing *Cytherina;* a continuation of the beds seen at the lake-level, on Drummond's island, and at the cliffs of Big Bay des Noquets.—Thickness, 15 feet.
2. A heavy-bedded, silico-argillaceous limestone of a greenish color, with nodules of hornstone.—Thickness, 6 feet.
1. A soft, brittle, greenish colored mass, apparently calcareo-argillaceous, extending 4 or 5 feet above the water-level.

A few miles farther to the south-west, the successive layers present the following section. (A mile farther on, about fifty feet of the same section can be seen at a single exposure in the cliff.)

5. Friable limestone with *Pentamerus oblongus.*—10 feet.
4. Hard, thin-bedded limestone, more or less silicious, with thin bands of greenish shale.—10 feet.
3. A mass, the upper layers of which are calcareous, containing *Cytherina*, succeeded by shaly layers of a greenish, or chocolate color, with intercalated, silicious layers. Ripple and fucoidal markings, and tracks and trails, possessing all the characters of those of the Clinton group in New York. The upper layers are less calcareous than the corresponding ones farther east.—20 to 25 feet.
1. Compact, tough, argillo-silicious rock, with interspersed nodules of silicious matter, sometimes in layers more or less continuous.—6 feet.
1. Green, shaly rock, crumbling rapidly on exposure and showing a concretionary structure, and occasionally with small cavities.—20 feet.

In the preceding section, the lower part, as well as the six feet mass above, is entirely destitute of fossils. The succeeding beds are everywhere characterized by fucoidal markings, by tracks and trails of some animals, by ripple-marks and by smooth, even, beach-like surfaces, on some of which there are irregular depressions like those worn by water under the influence of wind and tidal currents.

The peculiar features of this group resemble so much those of the same group in central New York, that their identity is unmistakable. The layers of the six feet mass, next below this, resemble very closely the grey band, or upper member of the Medina sandstone, while the next below has the color and texture of this sandstone; and, although there is no other evidence than position in relation to the positively identified lower part of the Clinton group, it cannot be reasonably doubted that we have, at this remote point, the representative of this sandstone, which in New York and Canada forms an important member of the series. From the difficulty of obtaining a view of the whole series, arising either from denudation, as on the northern side of Drummond's island, or from their obscuration by drift accumulations, as at other places, we are not able to say

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* This band is at the level of the lake, on the N.W. side of Sturgeon Bay. At this point, a bluff of limestone rises to the height of one hundred to one hundred and fifty feet, visible at intervals, though mainly covered with forests. This cliff was not examined in detail.

with certainty whether these peculiar beds exist at other points in the district. However, the alternating, shaly and arenaceous beds, marked by tracks and trails, so characteristic of this group in central New York, have now been found here. They do not exist in Canada for a long distance west of the Niagara river, and at what point they come in, we are at present unable to say, having observed them only on the peninsula of Green Bay. These evidences, then, of shallow water, of beaches, marked by the trails of shells and other animals, which have been observed in New York, cease for a long interval, thus authorizing the inference that the intervening portion of the ocean was deeper and the shores more remote. The strata of limestone and shale which occupy the intervening space are charged with *Brachiopoda* (and for the first time the genus *Pentamerus*), a few *Acephala, Gasteropoda* and corals. It is unquestionably true, therefore, that the conditions of the ocean, where one class of these deposits occur, must have been very different from those under which the others were thrown down. After leaving the locality cited in the preceding section, an interval of two miles occurs, where no rocks are visible, when a greyish-green shale, with harder calcareous layers, appears on the shore of the bay. These beds contain fossils of the Hudson-river group, or lower Silurian series. The strata rise to the south-west, but so gradually that it was hardly possible to have passed over an interval of fifty feet of rocks not observed; and this interval with the non-fossiliferous beds at the base of the last section, constitutes the beds of passage from the lower to the upper Silurian rocks. Although the lower fossiliferous beds are filled with organic remains, among which occur abundantly the *Spirifer lynx, Orthis testudinaria, Orthis occidentalis, Leptæna alternata,* and others; yet, I was never able to detect one of them, either in the beds of passage or in the fossiliferous beds, recognized as belonging to the Clinton group.

It will be observed that, in our examination along the coast of the lake from the St. Mary's river to the Detour, the exposures were all upon the upper or inclined surface, dipping lake-ward. The exceptions were of minor importance. From the Big Bay des Noquets, where we have exposed a complete section of the strata, our observations of the upper Silurian and the upper part of the lower Silurian are on the line of strike and upon the exposed cliffs of the northern outcrop. In the first instance, the slight undulations gave us no opportunity of penetrating beneath the limestones of one group, which, from their uniform character, could not always be distinguished from one another. In the latter, or on the outcrop, every undulation presented us with an opportunity of examining beds not before seen, or of recognizing the same beds, with some slightly varying characters.

Although no good opportunity offered for tracing these beds to the southward beyond the present locality—which extends along the shore of Green Bay for a few miles south-west of Sturgeon Bay—yet, it would appear that a part of the shales in the escarpment from the head of Green Bay to Lake Winnebago, and along the eastern shore of that lake, are of the Clinton group. Pursuing the same course a little farther to the south-west, we have additional evidence of the occurrence of this group; for, on the western side of a low escarpment of limestone, near the eastern line of the town of Hartford, we meet with a greyish crystalline mass, similar to that seen on the shores of Green Bay. Here occurs a band of iron ore, öolitic in its structure, and containing more or less shaly matter. This iron ore is undistinguishable from that associated with the Clinton group in New York, Although, at this locality, the ore-bed cannot be traced to a direct connection with this limestone, it evidently passes below it. At Sterling's, the ore is four or five feet thick, presenting the appearance of a regular, continuous bed, surrounded by a mass of pebbles and fragmentary rocks, accumulated during the drift epoch. It would appear that the outcropping edges of this bed had resisted the denuding action which has removed the shale above and below; while the ore is simply broken up, without having been removed or transported.

At a point some twenty feet higher, the limestone crops out; while the top of the terrace is about thirty feet above the iron ore, the bottom of the valley is about the same distance below.

In tracing this escarpment further to the north-east, the thickness visible is from twenty to twenty-five feet. At another point, the superincumbent limestone recedes to the eastward, and in a bend thus formed, an extensive ore-bed has been opened, by simply removing the surface soil. It is in a loose and incoherent condition, like some of the beds in this association, in Oneida county, New York. I was unable to detect any rock in connection with the ore, the under surface of the bed not being visible. Along the base of this escarpment, rise numerous springs which, uniting, form a permanent stream, indicating the existence of impervious strata beneath the limestone and iron ore. The surface of the country affords no deep ravines, and it is with difficulty that the line of the outcrop of the rocks can be followed for any great distance, in a connected manner. These localities of iron ore, taken in connection with the succeeding limestones, leave no doubt of the occurrence of this portion of the Clinton group in Wisconsin; but beyond this point, I have no evidence of its existence. It is probable, however, that traces of it will be found, on more careful examination, in following the out-cropping edges of the limestones in a more southerly direction. To the west of the low axis, which brings up the lower limestones and sandstones and extends to the southern line of the state, I have no evidence of the occurrence of any members of the Clinton group.

It is interesting, however, to have traced over so great an area, a subordinate group of the systems which have been recognized in New York and Pennsylvania; and, although having in some places the appearance of local deposits, it is proved to have a wide distribution. The ocean in which these deposits were made, however different they may be at distant points, was wide-spread, with occasional shoals and insular coasts, as evidenced by the marine vegetation and the tracks and trails of animals.

The iron-ore beds, forming in New York so important an economical feature in the Clinton group, do not probably occur within the limits of the Lake Superior district, though they do in Wisconsin. We are led to this conclusion from the fact, that they disappear in the region of the Genessee river, and have not been observed to the westward of that point, except in Wisconsin. Neither along the shores of Green Bay, where they could not have escaped observation had they existed, nor at localities further east did we detect a trace of them.

NIAGARA GROUP.

It is scarcely possible, as before remarked, to describe the limestones of the Clinton group, observed in this district, as distinct from those of the Niagara group. The thin-bedded, ash-colored and sometimes concretionary limestones which we have described as occurring at the eastern extremity of Drummond's island, on Bay des Noquets, and again on the eastern shore of Green Bay, pass imperceptibly into limestones, thicker bedded, more crystalline and often porous in their structure. Along the eastern shore of Green Bay the *Pentamerus* bed limits very nearly, the more compact and thin-bedded portions, and here this fossil forms a reliable guide; but the *P. oblongus*, which in New York is never known above the Clinton group proper, does enter, as we have been able to discover, in many western localities, into the Niagara group. It may, therefore, be doubted whether, in the west, the calcareous beds of this period can be distinctly separated into groups; but at present, I am not able to determine this question, which, for its perfect solution, would require many months of exploration with a careful examination of the succession of beds and their fossil contents. One fact of interest will strike the observer, who is familiar with the members of this group in New York, and that is: from the commencement of the calcareous deposits, through the whole period, there is no interruption of the materials, except by thin, shaly intercalations of a dark-green color, which, although indicating that this material still remained suspended in the waters of this ancient sea, was not sufficient to form beds of importance, as observed farther to the east. While there, the calcareous deposits have been interrupted at intervals, and form beds containing, to a considerable extent, fossils of different species, and distinct from those of the intercalated shales; in this region, there are no strongly-marked changes in lithological or fossil characters.

It must be remembered, however, that, for the most part, the species of fossils characteristic of the Clinton group, are wanting in all the localities examined. Less than one-tenth of those known in this group in New York, have been recognized on the shores of Lakes Huron and Michigan; but, at the same time, we have not met with three well-marked new species,—a less number probably than would be found, with equal examination, in the same beds in New York. Therefore, no new conditions of life have supervened to change the fauna of this period, though a general paucity of organic life is observed in the lower calcareous beds.

Above the thin-bedded layers already noticed as containing some fossils of the Clinton group, the beds gradually assume the semi-crystalline and somewhat cellular texture which is so characteristic of the limestones of this period. The *Pentamerus* beds often contain corals; and, in a higher position, where this limestone has assumed the characters of the Niagara group, with its characteristic fossils, this shell is still found.

The southern portion of Drummond's island is occupied by the Niagara group: the beds are exposed along its eastern, western and southern sides, dipping southerly or south-westerly; and, at several places along the southern shore, the gently-sloping surfaces of the rock afford an abundance of fossils. In a single locality, we were enabled to see strata exposed to the thickness of twenty-five feet, charged with fossils, consisting chiefly of corals, among which are *Catenipora escharoides*, *C. agglomerata*, *Syringopora?* two species, and *Heliolites spinipora*. *Favosites favosa*, and *F niagarensis*, *Astrocerium venustum*, *Stromatopora concentrica*, *Caninia*, *Diplophyllum*, and several others, characteristic of the Niagara period. Among all these, the broken and separated valves of the *Pentamerus oblongus* were very abundant. We were also enabled to trace the same group from the eastern end of Drummond's island across the southern extremity of St. Joseph's, and thence along the coast and islands, from the mouth of the St. Mary's westward. In several of the localities, the rock has a lighter color than usually belongs to the Niagara group, and contains casts of a species of *Pentamerus* similar to one known at Galt, in Canada West.

The rocks at Pointe St. Vital, and at other places in this neighborhood, have the aspect of the higher beds of the Niagara group, which evidently pass northward of Mackinac and Pointe St. Ignace.

My observation upon beds of this period was again taken up along the coast in the neighborhood of Point Patterson, where I found similar rocks. Between this place and Pointe Seul Choix, strata of a similar character are again visible beneath the deposits of sand, which form the lake shore. At the latter place, the strata were examined by Messrs. Whittlesey and Desor, who found them to possess the same characteristic features and the same organic remains, among which the *Pentamerus* was the most conspicuous.

Along the whole coast, from Point Patterson, the rocks at intervals only appear above the level of the lake, the water near the shore being shallow, and the bottom strewn over with numerous boulders of northern origin and fragments of limestone, little worn, indicating that the latter were derived from the immediate vicinity. In many places, the rock may be seen beneath the water, with a very gradual slope towards the lake, and presenting, for a long distance, a gently-sloping shore.*

From Pointe aux Barques to Pointe Detour, the rock is more frequently seen above the lake-level, though rarely rising higher than five or six feet. It is extremely hard, resembling externally a highly silicious limestone; but, on analysis, it is found to contain only a small percentage of silica. The hardness, or rather toughness, may then arise from the magnesia which is shown to be present everywhere in considerable proportions

With the escarpments of the eastern shore of Big Bay des Noquets and Pointe Detour, the limestones of the Clinton and Niagara groups terminate upon the northern shore of Lake Michigan, and no traces of them are seen on the north or west shore of Green Bay. Their prolongation is in the direction of a group of small islands south-west from Pointe Detour, known as the Summer islands, St. Martin's, Rock, and Potawatomee islands, together with several small islets which have no distinctive name.

The more elevated portions of many of these islands contain fossils of the Niagara group, consisting chiefly of corals, among which are two species of *Favosites*, *Catenipora* and *Heliolites*. These corals are chiefly above the great *Pentamerus* bed, in the lower part of the group; but are, nevertheless, occasionally intermingled with that fossil, which even ranges into the higher portions of the Niagara group.

The limestones belonging strictly to the Clinton group, and which have already been mentioned in that connection, exist along the west side of the peninsula of Green Bay, forming the shore as far as Sturgeon Bay, and even for a short distance beyond. At Potawatomee island, and along the

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* The bold, rocky shores, represented on the geographical maps as extending along the whole northern coast of Lake Michigan, are all imaginary. It is scarcely possible to find so great an extent of coast, with so few bold points and so little deep water, and equally rare to find one so dangerous of approach, even for coasting boats, during high winds.

The gradual dip of the rocks lake-ward, broken occasionally in step-like forms, produces shoal water, with irregular reefs. Upon these are accumulated the coarser drift materials, which often rise to within a few inches, or even quite to the surface of the water. The action of the winds and the ice changes the distribution of these materials every year, and even adds to them by dislodging fragments of limestone from the solid strata beneath.

west side of the peninsula as far as Horse-shoe island, we find a considerable thickness of limestone belonging to the Niagara group. Beyond this point, however, we scarcely find it on the immediate shore, which, breaking off above or below the Pentamerus bed, recedes for some distance, when it rises with an abrupt slope, and even an escarpment, formed by the out-cropping edges of the Niagara beds. The whole of the interior, therefore, as well as the eastern side of the peninsula, is composed of strata of the Niagara group.

As might be expected, this assemblage of strata (Niagara group) here assumes a very different external aspect from its equivalent in the New York series: and, although there is no difficulty in identifying the whole as a continuation; yet, it is difficult to recognize subordinate members and individual beds. As an example of the variation in character, I will here give a section, in the ascending order, of the cliff of Big Bay des Noquets, where a thickness of about one hundred feet of the rock is exposed

1. Compact, hard, and apparently silicious limestone, forming the summit of the cliff—5 feet.
2. Friable and porous limestone, resulting apparently, in part, from the solution and removal of some mineral matter—10 feet.
3. Thin, silico-argillaceous layers—10 feet.
4. Porous, friable, and calcareous strata, charged with corals and imperfect remains of other fossils, often cavernous—10 feet.
5. Thin-bedded, shaly limestone of a drab-color, with few fossils—25 feet.
6. A more porous and friable limestone, sub-crystalline, and containing corals—15 feet.
7. Shaly, thin-bedded limestone, with few fossils—thickness not ascertained.

The manner of deposition is here made quite evident, in the character of the successive beds. The more purely calcareous ones, or those with no appreciable admixture of argillaceous matter, abound in corals, and appear to have been coral-reefs, scarcely disturbed in their natural position, but covered by sedimentary deposits, composed, in a great degree, of finely comminuted matter, probably derived from the remains of corals and other marine animals, intermingled with an argillaceous mud. In this deposit, or over the ocean bed, while it was being formed, no corals lived; nor are there other fossils seen in this portion of the rock. Again, the condition is changed, and corals reäppear and continue to flourish through a longer, or shorter period, until another change takes place, when they cease to exist; and thus we meet with several repetitions of bands, charged with these remains, in this group.

It is not probable that these reefs extended uninterruptedly over very wide areas, and we may expect to find them in one direction entirely replaced by shaly limestone, the materials composing it having been furnished in sufficient quantity to keep up a continued deposition, in some parts; while, in others, these shaly materials, having been transported at intervals, may have allowed the uninterrupted growth of corals, and the formation of continuous reefs. Between these extremes, the two kinds of deposits may have been mingled in all degrees of proportion, and charged with a greater or less amount of corals, dependent on the quantity of intermingled shaly matter.

To such conditions, we owe the production of different and successive beds in the same group, and the different aspects which the strata assume at remote points. Thus, the features of a group, which, in one place, are subordinate in importance, become, at another point, predominant. The shale which, in New York, forms more than one-third, and in places, more than one-half, of the thickness of the entire Niagara group, is not recognized in this district; unless it be in the thin-bedded, shaly limestone, which alternates with the coralline beds, or, in some places, forms a mass of considerable thickness by itself, being destitute of all the larger corals, and furnishing only some of the characteristic shells.

Notwithstanding all the changes which have taken place in the Niagara group, as developed at different points, and its intimate blending, as in this district, with the limestone of the Clinton group below and the Onondaga salt group above, we find no serious difficulty in recognizing it as a whole, both by lithological characters and fossil remains. We have been able, by these characters combined, to trace its continuation throughout the entire district from east to west. We have seen it, in this extent, assuming different aspects, dependent on causes before adverted to; but we have never failed to find a greater or less number of known-characteristic fossils, even where the strata were explored only to a limited extent. Their occurrence, under such circumstances, and their persistence over so great an area, where physical characters have in a great degree failed, only serve to demonstrate the value of these means of studying and identifying the stratified deposits.

I have, also, had an opportunity of tracing this group, at intervals, across the country between Lake Michigan and the Mississippi river, and of recognizing it by its fossils, particularly its corals, even beyond that point, to the south-west. It exists in Ohio, Indiana, Kentucky, and Tennessee, and may be recognized, not only by its lithological characters, but by its numerous fossils, identical with those first described in the New York Geological Reports, as occurring in this group. Among these, we have, in addition to the corals, which are the more common fossils, several species of crinoids, the *Caryocrinus*, *Eucalyptocrinus*, *Ichthyocrinus*, and others which are identical with species known to occur in New York.

In a south-westerly direction, and without the limits of this district, this group has been examined by Mr. I. A. Lapham, of Milwaukee, who has had no difficulty in recognizing it by its characteristic fossils. His observations will be found incorporated in the subsequent pages of this report.

Thickness of the Niagara and Clinton Groups.—As already remarked in the commencement of this chapter, the lowest beds are seen at the lake-level on the eastern side of Drummond's island; while, on the northern side, we find the higher beds of the Hudson-river group. Again, on the St. Mary's river, the lowest beds of the Clinton group come to the water-level just above Lime island. Passing westward, along the northern shore of Lake Michigan, although numerous undulations are visible, often enabling the observer to see a considerable thickness of strata, yet the lower beds are nowhere exposed, until we arrive at the bluffs on Big Bay des Noquets. I have already mentioned the exposure of the same beds here which we had seen on Drummond's island. The entire height of the cliffs does not exceed two hundred and fifty feet, and we have nowhere evidence of the existence of superior beds of more than one hundred feet in thickness belonging to these groups. The entire thickness, therefore, of the calcareous beds of the Niagara and Clinton groups does not exceed three hundred and fifty feet. This is, I am aware, somewhat less than the estimate of Mr. Murray, in his section across the Grand Manitoulin islands, which, including both groups, amounts to five hundred and sixty feet.* Although there are, at intervals, exposures which appear along the coast, where the rate of dip is such as to give a greater estimated thickness than three hundred and fifty feet, yet we have no positive proof of a greater observed thickness.

In this estimate, it must be understood that the elevated portions of the island and peninsula of Mackinac are not included, for they are occupied only to a small extent, if at all, by strata of this age.

ONONDAGA SALT GROUP.

It has already been stated in the preceding pages that, with the exception of Mackinac and St. Ignace, the northern shores of Huron and Michigan, within this district, are low, and void of scenic interest. The whole extent, with the exception noticed, presents a single geological plateau from Drummond's island to Pointe Detour, the Niagara limestone everywhere forming a barrier to the encroachments of the lake; and, though often covered by superficial accumulations upon the shore, it manifests itself in broken ledges beneath the water, or gives evidence of its presence in the accumulation of loose blocks, forming shallow water and dangerous reefs. With the exception of the points noticed, the superincumbent strata have been entirely removed from the surface of the Niagara limestone, along the entire distance, and even beyond this point nearly to Milwaukee.

The succeeding strata in New York and Canada West belong to the Onondaga salt group, and consist of shales and marls, with some beds of more or less impure magnesian limestones. The shores of the island of Mackinac, and of some of the small islands to the east, present an abundance of pebbles of light-drab or chocolate color, with the vesicular structure so characteristic of the Onondaga salt group. The lower beds of limestone, at Mackinac, have also this character; while others have their surfaces marked by straight, gash-like lines, which have been described as appearing like shallow cuts made with an axe on a yielding surface. This feature, like the vesicular structure, is characteristic of this group.

The north and west sides of the island present a good exposure of the lower beds, while the shore is strewed with fragments of this and the superincumbent group. The general ashen color of the whole renders the distinction obscure; and the succeeding strata being for the most part destitute of fossils, or presenting them usually in an obscure condition, the observer fails at first to recognize the distinction.

In the islands of St. Martin, a few miles to the north of Mackinac, it is reported that gypsum has been found in considerable quantities along the shore. At the time we visited the island, we did not succeed in discovering it, which may have been in consequence of a high stage of water.

To the north of St. Ignace, Mr. Whittlesey found a marly bed about fifty feet in thickness, containing gypsum in isolated masses, occurring under the same forms as in New York and Canada West. This marly bed, with some higher and more calcareous ones, undoubtedly represents the Onondaga salt group; holding, in all respects, the same geological position and possessing the same lithological characters and the same association of minerals. The group has greatly diminished in thickness, and with its

* Geological Survey of Canada, Report of Progress, 1847-48.

small proportional importance, it is remarkable that it should retain, in so great a degree, its distinctive characters. We have not the means of making a comparison of its gradual changes as prolonged to the westward, this being the only place along the whole line of coast where we had an opportunity of seeing it. It is a single outlier, giving us the only facts by which to infer the character and persistency of the group, not only within the limits of this district, but farther to the south-west, along the peninsula of Green Bay, as far as Milwaukee, where we have some evidence to show that it has entirely thinned out.

Returning, for a moment, to the island of Mackinac and the more elevated positions of Pointe St. Ignace and Gros Cap, we find the marly beds succeeded by a brecciated limestone, composed of what appears to be thin argillo-calcareous beds, or laminæ, which often partially, or entirely, indurated, have been broken up and mingled with a softer argillo-calcareous mud. It may be very appropriately termed a brecciated limestone.* This brecciated mass, in its lower parts, is composed of broken, thin-bedded limestone, like the higher layers of the Onondaga salt group, or the thinly laminated beds connected with the gypsum deposits of New York and Canada West, which have been recemented by a calcareous mud. The fragments are presented in every possible attitude, as if broken up by the action of conflicting currents, though I was unable to detect the effects of anything like wearing action upon their edges.

In the brecciated beds, I have been unable to find any traces of fossils; but, in the succeeding strata, there occur numerous traces.

I cannot but regard the brecciated mass as terminating the Onondaga salt group, or perhaps more properly, as marking the era of the commencement of the succeeding group, which, as will be shown, corresponds with the upper Helderberg limestones of New York. Coming here directly upon the former group, they show the absence of several important members which are well developed in the east. These consist of the *Tentaculite*, or *Water limestone*, the *Pentamerus limestone*, the *Delthyris*, or *Shaly limestone*, the *Encrinal limestone*, and the *upper Pentamerus limestone*, (constituting altogether the lower Helderberg series,) together with the *Oriskany sandstone* and the *Cauda-galli grit*. All of these form well-marked features in the geology of eastern New York, but are not recognized in the western portion of that state. These gaps in the succession also occur at Mackinac, so that the upper Helderberg series rests directly on the Onondaga salt group. A long interval has, therefore, intervened between the termination of one group and the commencement of another, during which these absent members were deposited at a point farther east; and two distinct faunas lived and died, without having left a trace of their existence in the region under consideration.

It is greatly to be regretted that we have not an extended line of this brecciated limestone exposed, by which we might be able to form some conjecture as to the conditions of the ocean-bed during this interval. In western New York, the lower beds appear to have been undisturbed; the upper member exhibiting an apparently water-worn surface, while the succeeding

* The aspect of this rock is very similar to what may be seen, on a small scale, in countries where calcareous springs are abundant. The thinly-laminated and shaly limestone mingled with others of a more massive character, being broken up, becomes cemented together by the calcareous deposit from the springs, and forms a mass not unlike some portions of this limestone.

beds have been deposited conformably upon it. There appears, then, to be some evidence of ancient denudation, though there has been no opportunity of making connected observations.

From the examinations of Mr. Lapham, already referred to, it appears that the Onondaga salt group, as a distinct member of the series, is not recognized at Milwaukee; and from its greatly diminished thickness at Mackinac, we are warranted in concluding that it does not occur farther west; nor has it been recognized to the south or south-west of this point. Our present knowledge, therefore, of this group, shows that it is represented in its more easterly prolongation, by a thin band along the base of the Helderberg mountains and along the borders of the Hudson river. It is here the source of the immense supply of the hydraulic cement, conjointly, perhaps, with some of the thin beds below. Tracing it westwardly, we find it gradually expanding, until, in central New York, its vertical range is a thousand feet in thickness, where it becomes the repository of the gypsum beds and the brine springs. From that point, westwardly, it can be traced, with a slightly diminished thickness, to the Niagara river, and throughout all of this range, it forms the strongly marked plateau, intermediate between that formed by the Niagara group, and that by the upper Helderberg series. In the western part of that state, it is characterized by the presence of beds of gypsum and of brine springs, though of little economical value, and of springs of sulphuric acid. In Canada West, the prolongation of this group has been traced from the Niagara river to the shores of Lake Huron. It is there characterized, also, by the presence of gypsum and brine springs, and presents similar lithological characters, though greatly attenuated in thickness. We have been unable, for reasons before assigned, to trace it uninterruptedly from the last named point into the limits of our district, having detected its presence only on the island of Mackinac and on Pointe St. Ignace.

We shall indulge, at this time, in no speculations on the origin and influence of this immense deposit, which occurs in the midst of the upper Silurian series, superimposed upon the Niagara and Clinton groups; characterized, on the one hand, by at least three hundred species of fossils, peculiar to the upper Silurian, and, on the other, by a series of calcareous deposits marked by an equal number of distinct species of the same age. In the absence of the latter deposits, in this district, it marks a line of separation between the Niagara group and the upper Helderberg series, which at present is regarded as of Devonian age. In the succeeding pages, we intend to consider the value and importance of these subdivisions, as they are presented to us in the United States.

DEVONIAN SYSTEM — UPPER HELDERBERG SERIES.

The Schoharie grit, the Onondaga and corniferous limestones form a well-marked series known as the upper Helderberg limestones, and, according to the prevailing belief, as before remarked, are to be ranked as members of the Devonian system.

Although not entirely cöextensive with each other, they constitute a group which, perhaps, is more persistent and uniform in character than any in the United States. The lower member, where possessing its normal character, is a silicious limestone, becoming, in places, entirely calcareous; and where it does not exist as a distinct member, some of its characteristic fossils may be found in the beds at the base of the next succeeding group. As a whole, it partakes of the character of the others in the increase of calcareous matter, as traced to the westward. The subdivisions, which are clearly defined in New York, cannot always be recognized farther west, and it therefore becomes desirable to speak of the whole collectively.

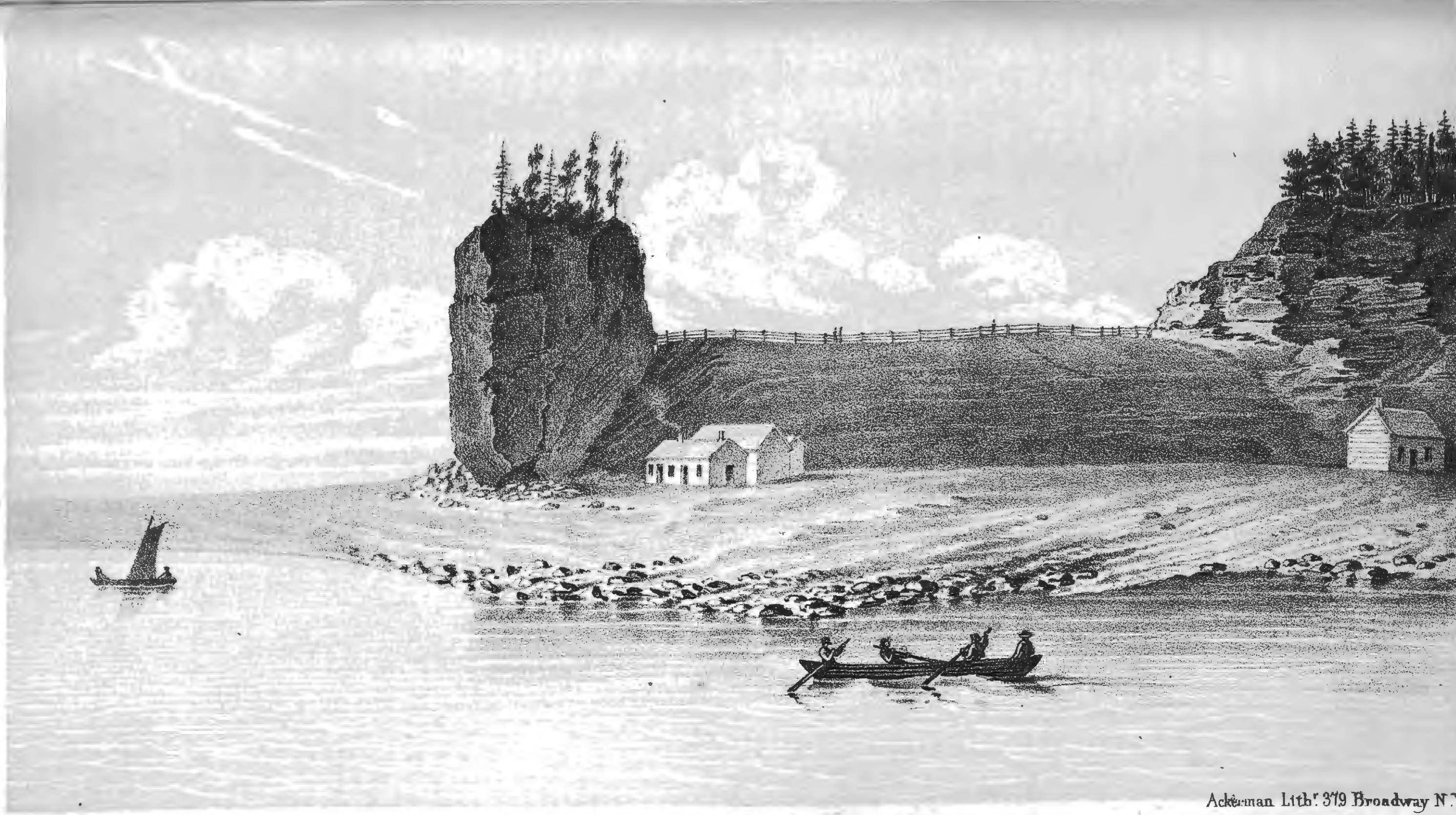
In the district under consideration, the only points where these limestones have escaped the general denuding action are the island and the peninsula of Mackinac, where they form outliers of remarkable features. Resting on the marly beds of the Onondaga salt group, the brecciated limestone supports isolated, tower, or dome-shaped masses belonging to this group. The rapidity with which the underlying rock is decomposed and removed has a tendency to keep the base of the overlying rock smaller than the body of the mass. The effects of this decomposition and denudation are well illustrated at Gros Cap, on the west side of the peninsula of Mackinac. (Vide Plate XVII.) The tower-like mass near the extremity of the point is only an outlier of the main body which skirts the shore, represented on the right side of the sketch. The wearing action of the water upon the base of this cliff is clearly indicated by its form; and though, for the present, partly protected by the talus of fallen fragments, it is ultimately destined to be undermined and destroyed.

The whole island of Mackinac is another example of this kind of denudation, but on a more extended scale. The limestones of this group are in thin, irregular layers, such as would apparently result from deposition in a chopped sea. The lower beds are somewhat argillaceous, but, in ascending in the series, they become almost purely calcareous. The analyses show a very small percentage of magnesia, and, in this respect, it differs in a very remarkable degree from all the lower limestones, and particularly from those of the Niagara group. In its thin, cuniform laminæ, with shaly matter interposed between, it does not essentially differ from the limestone of the same age in the Helderberg range of New York.

As particular examples of denuding action on the island, we would mention "The Arched Rock" and "The Sugar Loaf." The former, situated on the eastern shore, is a feature of great interest. The cliffs here attain a of nearly one hundred feet, while at the base are strown numerous height fragments which have fallen from above. The Arched Rock (Plate XVIII,) has been excavated in a projecting angle of the limestone cliff, and the top of the span is about ninety feet above the lake-level, surmounted by about ten feet of rock. At the base of a projecting angle, which rises up like a buttress, there is a small opening, through which an explorer may pass to the main arch, where, after clambering over the steep slope of debris and the projecting edges of the strata, he reaches the brow of the cliff.

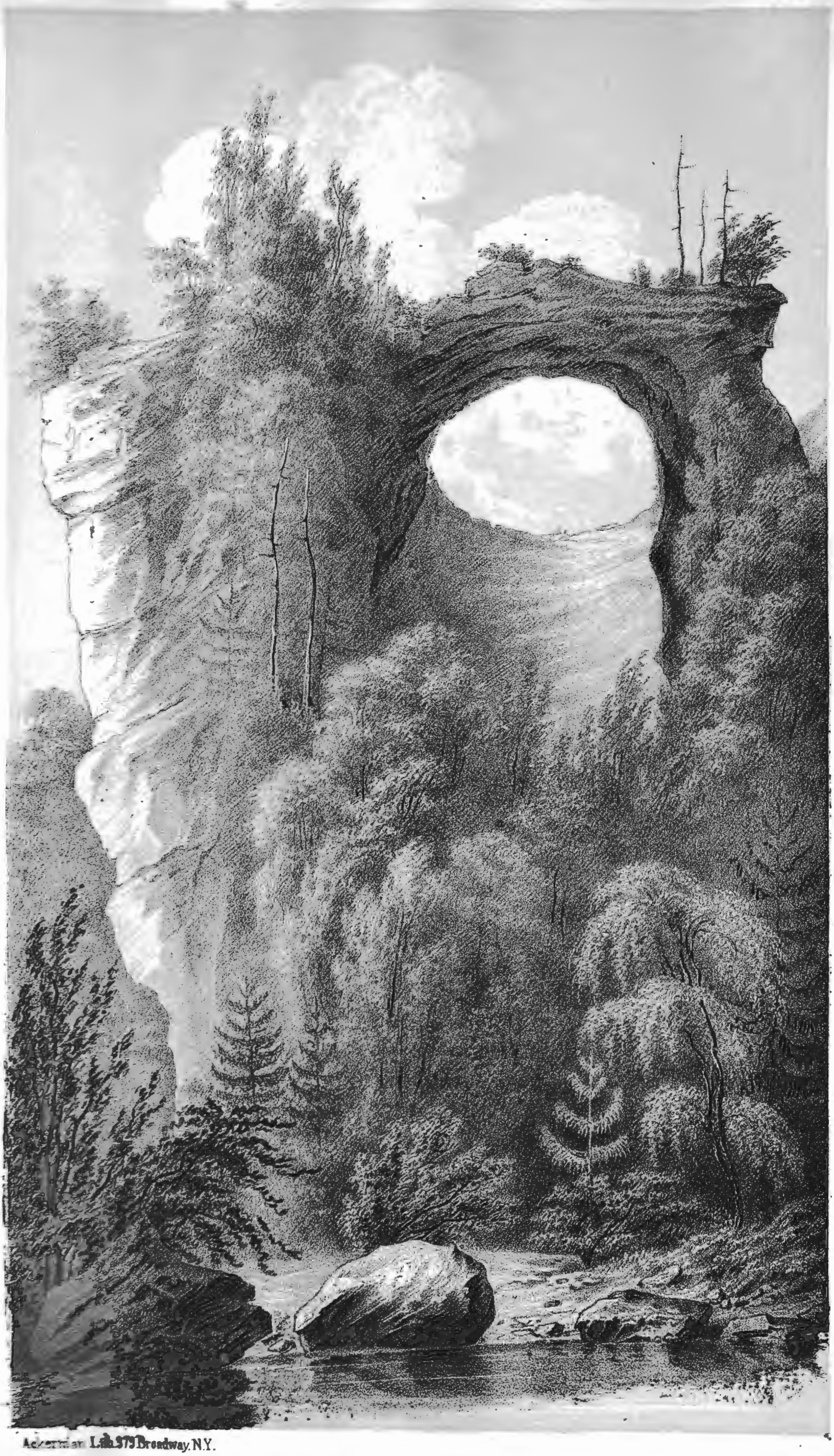
The beds forming the summit of the arch are cut off from direct connection with the main rock by a narrow gorge of no great depth. The portion supporting the arch on the north side, and the curve of the arch itself, are comparatively fragile, and cannot, for a long period, resist the action of rains and frosts which, in this latitude, and on a rock thus constituted, produce great ravages every season. The arch, which on one side now connects this abutment with the main cliff, will soon be destroyed, as well as the abutment itself, and the whole be precipitated into the lake.

It is evident that the denuding action, producing such an opening, with other attendant phenomena, could only have operated while near the level



Ackerman Lith. 379 Broadway N.Y.

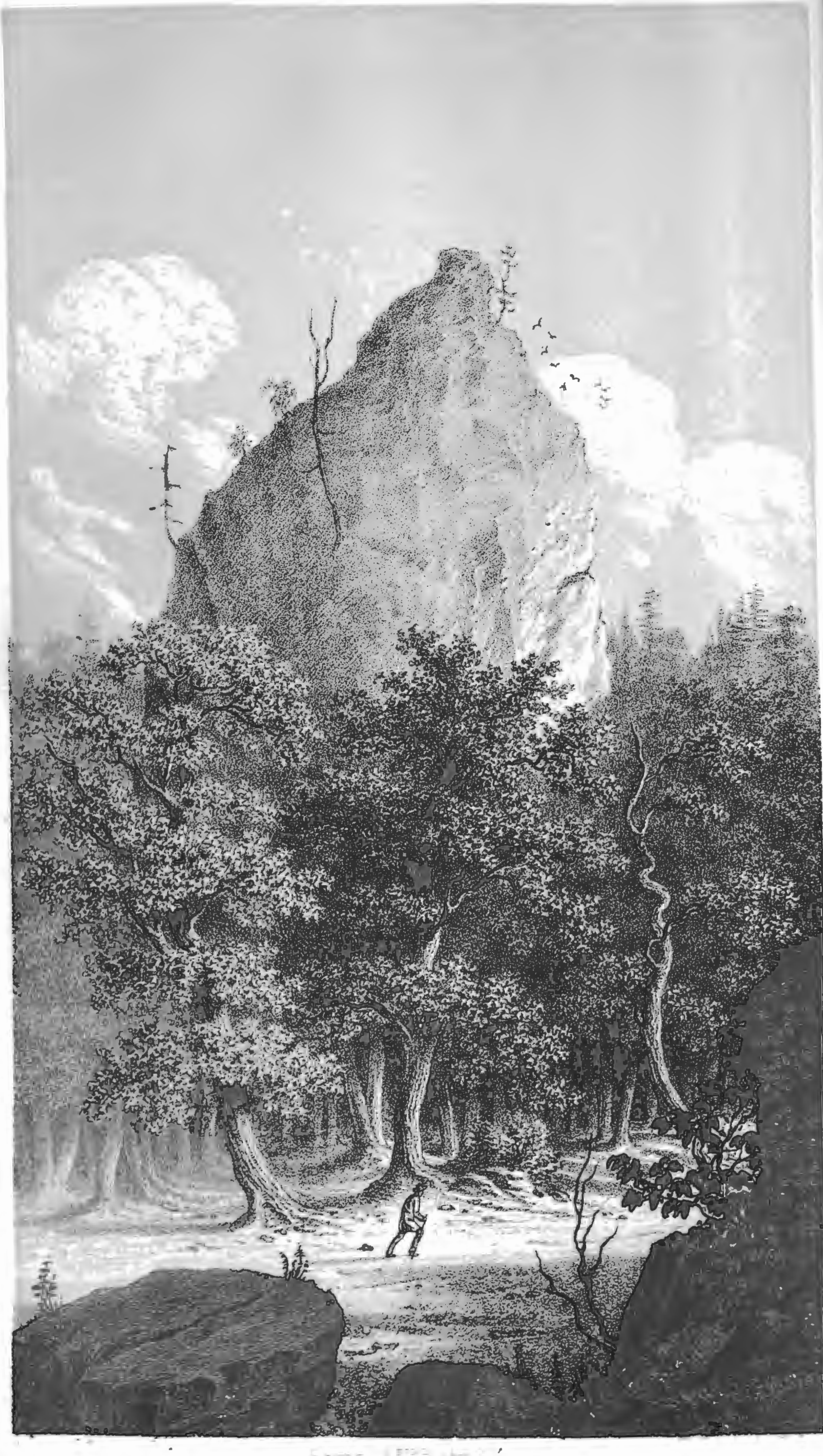
GROS CAP OF LAKE MICHIGAN.



Ackerman Lith. 379 Broadway, N.Y.

ARCHED ROCK _ MACKINAC.

Plate. XIX.



of a large body of water, like the great lake itself; and we find a striking similarity between the denuding action of the water here in times past, and the same action as now manifested in the range of the Pictured Rocks on the shores of Lake Superior. As an interesting point in the scenery of this island, the Arched Rock attracts much attention, and, in every respect, is worthy of examination.

Evidences of erosive and undermining action are everywhere visible along the cliffs of the island. On the south and south-east side, the formation of beaches and the accumulation of talus at their bases, have prevented the encroachments of the lake, and protected the cliffs; but, on the north-west side, where the winds have full sweep, the waves have undermined the strata, leaving overhanging cliffs above.

On the plateau of the island, which may be one hundred and fifty or two hundred feet above the lake, there are other evidences of this character, in the occurrence of caverns and isolated columnar masses of limestone. The latter are, for the most part, of small magnitude, but there is one which is very conspicuous, and has received the name of "Sugar-Loaf." (Plate XIX.) It is entirely isolated, and towers above the surrounding forest. In its rough and weathered contour, the lines of stratification are not so distinctly preserved in the sketch as they appear on close examination. It appears, at one time, to have formed a part of a continuous mass occupying the summit of the island; if so, it gives a thickness of about three hundred feet to the limestones above the Onondaga salt group, which is greater than at any other point where I have examined them. It is scarcely to be conceived, however, that such a mass as the Sugar-Loaf could have been transported to its present position by those agencies which have dispersed the boulders; nor is it necessary to resort to such a supposition; for, immediately west, the ground attains a higher elevation than its summit; and, although the underlying rock is concealed by drift, it undoubtedly is of the same character.

This assemblage of strata which was termed by Dr. Houghton, in his survey of Michigan, the "Mackinac limestone," although separated from all of the limestones of the northern peninsula, except that of Pointe St. Ignace and Gros Cap, can, nevertheless, be identified with that of the southern peninsula of Canada West, and of New York, as well as with that of the states to the west and south-west. From its known thickness, in all these places, its apparently increased thickness on the island of Mackinac is the more surprising. Our knowledge of this group, at the present time, enables us to conclude, with great certainty, that the whole formed, at one time, an immense coral reef; and, at intervals, it is abundantly charged with their remains. It is occasionally intermixed with silicious layers, or nodules, in the form of chert, and also with argillaceous mud, which apparently proved unfavorable to the growth of the larger corals; but the smaller ones, with numerous Bryozoa and shells, appear to have flourished.

So far as I observed, the island of Mackinac and the adjoining coast, furnish few of the larger corals, though Favosites and many species of Cyathophyllideæ are common. Farther south, however, in the neighborhood of Presqu'isle, on the western shore of Lake Huron, where the upper beds of this group come to the level of the water, the corals largely predominate, and the conditions of the ocean appear to have been highly favorable to their growth and development.

In collecting fossils about this island, one is liable to be deceived in regard to the character of the rocks, since it often happens that those of the Niagara group have found their way among the loose materials which have been transported from the northern shore. Thus, the *Catenipora*, *Heliolites*, and other corals of the Niagara group may be picked up at the base of these cliffs, associated with those which have fallen from the cliffs above. As a general remark, however, it may be stated that the fossils of the Niagara are much oftener silicified than those of the group under consideration. Owing to this fact, it might readily be inferred, without careful comparison, that the Niagara group existed on the island of Mackinac and on the peninsula to the north-west. Notwithstanding, however, the great similarity in aspect and color, they are very different in their chemical composition and their associated organic remains.

Most of the fossils collected at Mackinac prove to be undescribed, but are identical, however, with species which occur in the same rocks in New York. Some of the smaller bryozöoid corals belong to the genus *Trematopora* and *Cladopora*, while two or more species of *Favosites* were observed. A few shells only were collected, and these, with a single exception, belong to the *Brachiopoda*. Among the trilobites was a *Phacops*, resembling *P. bufo* and a species of *Proetus*, both apparently identical with species which occur in the upper Helderberg range. One of the most characteristic species, however, is the *Phacops anchiops*, characteristic of the Schoharie grit. The specimens of the latter fossil, though consisting only of portions of two bucklers, are so peculiarly characteristic, that I cannot doubt the identity in age of these widely-separated localities. Although it would have been desirable to identify a larger number of fossils with those occurring in the corresponding series elsewhere, yet the evidence is sufficient to remove this group from any below the Oriskany sandstone.

CHAPTER XI.

MISCELLANEOUS OBSERVATIONS ON THE PALÆOZOIC SERIES.

Extension of this Series into Wisconsin.— Section by Mr. Lapham.— Mr. Hall's Remarks.— Section by Mr. Whittlesey.— On the Origin of the Basins of Lake Michigan and Lake Huron.— Mr. Hall's Remarks. — Mr. Whittlesey's Observations on the Thickness, Bearing and Inclination of these Groups.— Evidences of Denudation and Subsidence, during the Deposition of these Groups.— Effects of Oscillations on Animal Life.

Having given a descriptive account, in the last three chapters, of the range and extent of the several groups of the palæozoic series which occur in our district, and described their mineral characters and organic remains, group by group, we next propose to offer some general remarks upon the assemblage of groups, their thickness, bearing, and inclination, the varying conditions of the ocean in which they were deposited, and the extensive denudation to which they have, in comparatively recent times, been subjected. These remarks, from the variety of topics embraced in this chapter, must necessarily be somewhat discursive in their character; but, at the same time, they may serve to illustrate some of the most interesting features in the geology of our district.

CONTINUATION OF THE PALÆOZOIC SERIES IN WISCONSIN.

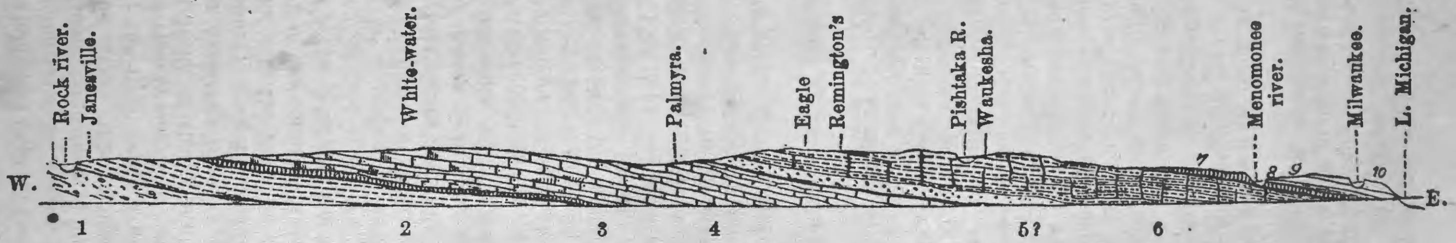
To illustrate, still further, the succession of the palæozoic groups, as developed in the north-west, we introduce the subjoined section and description by Mr. I. A. Lapham, of Milwaukee, a gentleman who has made numerous and extended observations on the geology of this portion of the Silurian basin. This contribution of Mr. Lapham is the more valuable, since it serves to fill up a blank between the Lake Superior and Chippewa districts. Although his nomenclature of the groups is somewhat different from that adopted by us, there is little difficulty in identifying them with their equivalents in our district.

"*On the Geology of the south-eastern portion of the State of Wisconsin; being the part not surveyed by the United States Geologists, in a letter to J. W. Foster, by I. A. Lapham of Milwaukee.*

In answer to the several inquiries in your letter, relating to the rocky strata in the south-eastern portion of the State of Wisconsin, I cannot, per-

Section from Milwaukee to Janesville, Wisconsin—By I. A. Lapham.

Fig. 20.



Scale, 10 miles to an inch. Dip, about 17 feet per mile, due east.

1. Inferior, or Potsdam Sandstone. 2. Calciferous Rock. 3. Blue, or Trenton Limestone. 4. Galena Limestone. 5. Sandstone.? 6. Waukesha Limestone. 7. Soft, yellow Limestone. 8. Geodiferous Limestone. 9. Shaly Limestone. 10. Corniferous Limestone.

haps, do better than to exhibit and explain the accompanying section (Fig. 20) from near Milwaukee, on Lake Michigan, to Janesville on Rock river.

I. *The Inferior, or Potsdam Sandstone,* is found at Janesville and above, occupying the bed of the river. The grains are rounded, smooth, and without apparent cement; the rock easily crumbles upon exposure; color white or red. The white variety might be used for the manufacture of glass. The discovery, in 1849, of that singular and characteristic fossil described by Mr. Hall as *Scolithus linearis* (New York Pal. Vol. I. p. 2), in this rock, in Sauk county, may be considered as settling the question of the identity of this rock with the Potsdam sandstone of the New York reports. It occupies much of the counties Marquette and Columbia, enters Dane county, and is seen in the banks of Rock river from Lake Koshkonong to Janesville. The "granite quarries," so called at Portland, in Dodge county, prove to be a metamorphic sandstone, and not a true granite. It consists almost wholly of quartz; and for building purposes, it ranks with the granites, and passes generally by that name.

II. *Calciferous Rock of Eaton.*—Resting immediately upon the sandstone, at Janesville, is a limestone with grains of the same sand intermixed, giving it the form and appearance of an öolite limestone; the amount of sand diminishing as you rise from the surface of the sandstone. It accords exactly with the description given of a portion of the calciferous sandstone of New York, and contains the same fucoid, (*Palæophycus tubularis,*) as well as other characteristic fossils. Its character and relative position also clearly show that it is the same rock that, further west and north, is called the *lower magnesian* limestone, by Drs. Owen and Locke.

III. *The Blue, or Trenton limestone,* is here, as in the more western districts, a very thin layer, often penetrated in digging wells, &c. It presents everywhere its characteristic fossils, and is too well known to need further notice.

The upper sandstone, noticed by Dr. Owen, does not appear on the east side of Rock river.

IV. *The Galena limestone.* At Diamond Grove, and also at Fort Atkinson and White-water, is found the true lead-bearing rock, with fossils of the same kind as those brought out with the rubbish at the lead-mines. It is a soft, yellowish, magnesian limestone, very fully described in the report of the United States Geologists for 1839, as well as by Mr. Hodge and others, at an earlier day. It is usually identified, in distant localities, by the occurrence of a peculiar fossil coral, resembling the *Coscinopora sulcata* of Goldfuss, the tubes of which are sometimes filled with lead. The connection of this rock with the superior strata is unfortunately obscured by large deposits of drift, so that its exact geological age cannot be clearly made out. Judging, however, from the fossils, we may assign to it a place coeval with, or immediately succeeding, the blue limestone. It may, perhaps, be regarded as a portion of the same formation; at any rate, it is much more ancient than the true geodiferous, or cliff limestone, to which it has usually been referred. In this part of the state, it does not contain lead, or other ores, except in limited quantities.

V. *Sandstone?*—Before we reach the rock next to be described, we find, at various places, a narrow strip of sandy land, with occasional fragments of hard, red, slaty sandstone; thus indicating that there may be a layer of sandstone here, concealed beneath the drift. Such places have been observed from Kenosha to La Belle lake in the north-western corner of

Waukesha county; but, as no sandstone has been seen in place, its existence may be considered doubtful.

VI. *Waukesha Limestone.*—Throughout the county of Waukesha, is found a hard, white, or bluish-white limestone, which, as it appears to be new, I propose to call the *Waukesha limestone.* It forms an excellent and beautiful building material, being disposed in regular layers from a few inches to a foot or more in thickness. It does not, however, receive a good polish, being in many places filled with small, irregular cavities, occasioned probably by the decay of some mineral substance. It contains but few fossils: the most remarkable are two large species of Orthocera. These, with a spiral-chambered shell and a Trilobite, are all that have been discovered. The Waukesha limestone extends eastward along the Menomonee* river of lower Wisconsin, to within three miles of Milwaukee, where it is extensively quarried for building purposes in the city. At this point it is only thirty-three feet above the level of Lake Michigan, while at the village of Waukesha, twelve miles west, it has an elevation of about two hundred and fifty feet.

VII. *A Soft, yellow limestone* is found on the Menomonee river of southern Wisconsin, resting immediately upon the Waukesha limestone. The same rock occurs near Racine, and at other points on Root river; also at the Menomonee falls and at the falls of the Milwaukee river in Washington county. It may be considered as only the lower portion of the next rock.

VIII. *The geodiferous limestone of Eaton, or Niagara limestone of the New York reports.*—This rock is very well characterized, and exhibits many of the fossils of the geodiferous rock of Lockport and the Niagara falls. Its hardness, numerous cavities, or geodes, its want of regular stratification, as well as its palæontological character, all go to show its identity with that rock. It extends, with some interruptions, along the whole length of Lake Michigan from Chicago to Porte des Morts, the entrance of Green Bay. In the vicinity of Milwaukee, it is well developed, and affords an excellent material for the manufacture of lime. Both the Niagara and Clinton groups of New York appear to be represented in Wisconsin by this one limestone. The extensive beds of öolitic iron ore, found in Dodge and the western part of Washington counties, are connected with a limestone supposed to be the same as that now under consideration.

IX. *A shaly limestone* is found at one locality, representing some of the formations that, in New York, are interposed between the geodiferous and the corniferous limestones.

X. *Corniferous Limestone of Eaton.*—The most recent of the rock formations, properly so called, found any where in Wisconsin, is the limestone that, at Louisville, Columbus, and Sandusky, lies immediately below the black shale; being the upper part of the cliff, and corresponding with the corniferous limestone of Eaton, as found in the state of New York. This is known by its position, as well as its lithological and fossil characters. It occupies the shore of Lake Michigan and the bed of the Milwaukee river, for several miles above its mouth, but does not extend far towards the interior. Hydraulic limestone is found associated with it at Louisville and other places. This and the last preceding rocks occupy but a small extent of surface in this state.

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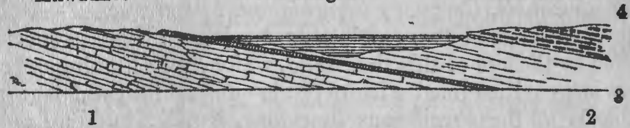
* This is not to be confounded with the Menomonee of Green Bay.

The black, bituminous shale (Marcellus shale of the New York reports) is found in numerous fragments in the drift near Milwaukee; thus indicating that it formerly existed at no great distance; but it has nowhere been found in place.

Connecting these observations with those of Drs. Owen and Locke on the west, it will be seen that there is an anticlinal axis extending along the valley of Rock river, from which the strata are inclined eastwardly towards Lake Michigan, and westwardly towards the Mississippi. Rock river, therefore, has a geological position quite analogous to that of Cincinnati; the only difference being, that there, the blue limestone is the lowest rock, while in Wisconsin there are two or three groups below it.

It will be seen, also, that Lake Michigan occupies (like Lake Superior) an ancient basin, of which the hard geodiferous limestone forms the edge or rim. The soft, shaly strata that, in Indiana, Ohio, and New York, occupy the next succeeding geological periods, appear to have been swept away to make room for the waters of the present lake. This is more fully illustrated in the accompanying diagram (Fig. 21.)"

Fig. 21.



Section across the Basin of Lake Michigan.

1. Waukesha limestone.
2. Hard, geodiferous limestone.
3. A soft, shaly limestone.
4. Shales.

It will thus be perceived that the observations of Mr. Lapham verify, in almost every particular, those which have been incorporated in the preceding pages. They show the necessity of recognizing, throughout the whole northern range of the palæozoic groups, from New York to the Mississippi, essentially the same subdivisions.

Since the foregoing communication was received, Mr. Lapham has sent us some additional facts which serve to illustrate his general views. He states that, on penetrating the limestone on the top of the ridge above the iron ore, fossils of the Niagara age have been obtained, and, also, that below the iron ore at Hartford and at the Iron ridge, as well as at the northeast corner of Lake Winnebago, a soft, blue shale has been found; thus corroborating the view taken by Mr. Hall, as to the age and position of this ore, though he was unable to trace its connection with the rocks, above and below.

With reference to Mr. Lapham's section, Mr. Hall remarks: "The sandstone, No. V., conjecturally marked, holds the place of the Hudson-river group, Medina sandstone, and the lower, or arenaceous part of the Clinton group. It is not improbable that a meagre representation of these may occur in the line of the section, since our observations on the shore of Green Bay would prepare us to expect such a condition here; besides, the iron ore and shale of the Clinton group have been traced to within a short distance of the line of the section.

I am inclined to regard the Waukesha limestone, No. VI., the soft, yellow limestone, No. VII., and the geodiferous limestone, No. VIII., as constituting the Niagara, and the calcareous portion of the Clinton group.

The Waukesha limestone, as I saw it near Milwaukee, is a thin-bedded, argillaceous deposit containing few fossils; I collected from it, however, *Orthoceras undulatum*, and *O. virgatum*. I saw the same in Mr. Lapham's cabinet, with another species from this member of the series; also, a species of *Gomphoceras*, like that occurring in the Niagara shale at Rochester and in the limestone at Niagara falls (Pal. N. Y. II., p. 290); also, *Spirifer lineata*, and a flattened Trochus-like shell, similar to a species occurring in a limestone of this age on Lake Michigan; and a species of *Cyrtoceras*, and *Calymene Blumenbachii*, var. *niagarensis*. Among the fossils from the lower geodiferous limestone, in Mr. Lapham's cabinet, I saw *Favosites niagarensis*, *F. favosa*, or *striata*, *Diplophyllum*, crinoidal joints, *Caryocrinus ornatus*, *Eucalyptocrinus decorus?* and *Orthoceras undulatum*.

From the upper geodiferous limestone, there were the two species of the *Favosites* just mentioned, with a third one; two species of *Heliolites*, *Catenipora escharoides* and *C. agglomerata*, *Sarcinula? Diplophyllum*, *Cystiphyllum*, *Stromatopora concentrica*, *Pentamerus oblongus*, *Pentamerus*, n. sp., *Spirifer niagarensis*, *Atrypa reticularis*, *A. obtusiplicata*, *Orthis hybrida*, *Orthoceras undulatum*, *Calymene Blumenbachii*, var. *niagarensis*, *Bumastis barriensis*, *Ceraurus insignis and Sphærexochus —?*

All these, with one or two exceptions, are known Niagara species, leaving no doubt as to the age of this limestone, which, in its lithological characters, —also having cavities lined with crystals—resembles the Niagara.

The fossils of the corniferous limestone, No. X., in Mr. Lapham's collection, are mostly undescribed species. Among them, however, I recognized *Phacops bufo*, an *Avicula*, like one in the Scoharie beds, and an acephalous bivalve shell, similar to, if not identical with, one in the Scoharie grit. In their general characters, the fossils from this group resemble those of the upper Helderberg series of New York; and, though I had no opportunity of making a direct comparison of specimens to prove their identity, it is, nevertheless, certain that they are unlike any of the known species of the Niagara group.

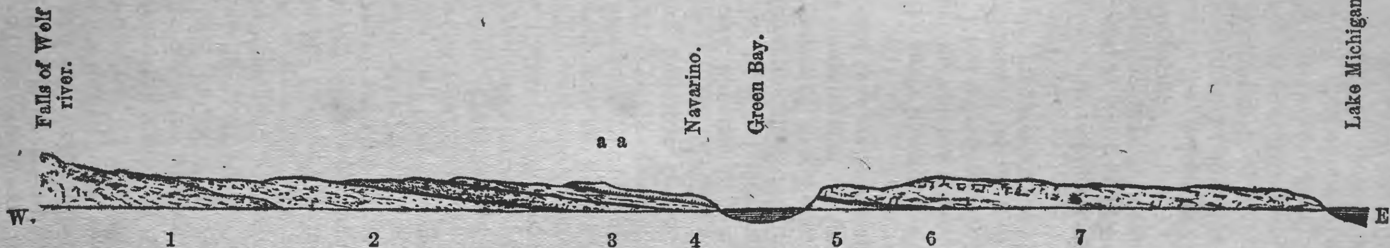
Admitting this to be true, the shaly limestone of Mr. Lapham's section represents the Onondaga salt group, which, however, has so far thinned out as to be of little importance. I had no opportunity of seeing the two last members in place; but the specimens of the shaly limestone are very similar to the thin layers of hydraulic limestone in the upper part of the Onondaga salt group of western New York.

The higher limestone, a few feet only in thickness, as seen at Milwaukee, when compared with its thickness, as developed along the northern extremity of Lake Michigan, shows either a rapid diminution, or an enormous denudation; the latter is probably true."

In order still farther to illustrate the geology of this part of Wisconsin, we append a section across the formations, from the granite to the summit of the upper Silurian, by Mr. Whittlesey.

Section from Wolf River, Wisconsin, to Lake Michigan.—By Charles Whittlesey.

Fig. 22.



Course S. 55° E.; distance, 66 miles; dip S. 76° E. = 14 feet per mile.

1. Granite and Syenite. 2. Potsdam Sandstone. 3. Calciferous Sandstone. 4. Trenton Limestone. 5. Hudson-river Group. 6. Clinton Group. 7. Niagara Limestone. a a. Red Clay and Drift.

Remarks upon the Section from the Falls of Wolf River, through Navarino to Lake Michigan.

By Charles Whittlesey.

Formation 1. *Igneous Rocks.*—In 1849, while connected with the survey of the Chippewa land district, in Wisconsin, I penetrated from Green Bay, across the sedimentary beds, to the borders of the igneous rocks, ascending the Oconto river, and crossing westward to the falls of the Wolf river. Previous to that time, Messrs. Ellis and Conkey, of Green Bay, United States deputy surveyors, had subdivided a tract west of the Menomonee river, as far as range 20 east, and north to township 38, at the Big Bekuenesec falls, and had collected specimens of the rocks for the Land Office. The surveyed district extends no farther into the interior than the sources of the Oconto, and the falls of Wolf river; so that that part of Wisconsin beyond these points is, as yet, unexplored. The falls, which consist of a series of chutes, descend twenty-one feet, besides intermediate rapids, in the distance of one and a half miles. At these falls there is an abundance of excellent, red, coarse-grained syenite, which passes, in some places, into granite. This rock rises above the banks of the stream, attaining, in some places, an elevation of fifty feet, and is covered by heavy deposits of drift. This is in township 28 north, range 15 east.

On the Oconto, in township 31 north, ranges 16 and 17 east, the same red syenite and syenitic granite are seen, and are there overlaid by the Potsdam sandstone; they extend westward and northward for a distance of ten or twenty miles. For the detailed description of these rocks, the reader is referred to my report to Dr. D. D. Owen.

Between the Oconto and the Menomonee, according to Messrs. Ellis and Conkey, the country is occupied by syenite, granite, hornblende-rock, greenstone, and trappean rocks.

No. 2. *Potsdam Sandstone.*—The junction of this rock with the underlying igneous masses, is nowhere visible. The sandstone is here exceedingly friable, so that it may generally be easily crushed between the fingers, there being no cement between the silicious grains. For this reason it has been extensively denuded, so that, here and there only, a trace of its former existence is still left remaining. The exact line of junction between the sandstone and the granite, is covered by drift, both on the Menomonee, the Oconto, and the Wolf rivers. The sandstone is visible in township 28 north, range 18 east, on the Oconto; in township 22 north, ranges 15 and 16 east, near the Wolf river; and in township 16 north, range 12 east, between the Fox river and Green lake.

No. 3. *Calciferous Sandstone.*—The junction of this rock with the Potsdam sandstone was seen and examined by Mr. Hall, at Pleasant Valley, Wisconsin, township 16 north, range 12 east; and also by myself in township 22 north, ranges 15 and 16 east; but its upper limit was nowhere clearly recognized. The exposure at the falls of the Oconto in the southeast part of township 28 north, range 19 east, is probably near the junction of this rock with the Chazy and Birds-eye limestones; no fossils were observed here.

No. 4. *Chazy, Birds-eye and Trenton Limestones.*—Whether a division can properly be made between these three groups, as recognized in New York, is not yet determined, and I have, therefore, included them under one number. There is no distinction recognizable in them from their lithological characters, and too few fossils have been, as yet, discovered to allow of their being classed according to the palæontological evidence.

There is no difficulty in fixing the upper limit of the Trenton limestone, either by its fossils or from its lithological characters. The soft, marly beds of the Hudson-river group, or "blue limestone," rest directly upon the Trenton limestone, and their lithological character has had a marked influence on the topographical features of the country west of Green Bay. The bay itself, as well as the low, flat country which gently declines towards it, from the west, have resulted from the denudation of this group by drift-agencies; the hard Trenton limestone, which now occupies the surface, did not yield to the denuding effect, while the blue, soft marls were easily excavated and removed.

No. 5. *Hudson-river Group, Blue Limestone and Marls, of the Ohio Reports.*—This group, which is seen at Bay des Noquets, on the west side of Green Bay, passes obliquely along its bed and appears on the eastern shore, and at its southern extremity.

No. 6. *Clinton Group.*—This group is well-defined and easily traced, from Big Bay des Noquets, along the small islands, between Chambers's island and the eastern shore of Green Bay; thence, as seen by Mr. Hall, on the eastern shore, near Sturgeon Bay; again, in the bluffs west of "Des Peres" (Depere or Depeer), and farther south-west, on the bluffs which overhang Lake Winnebago, on the east. It is nowhere a thick, or heavy bed, but is well known for the beautiful white lime which it furnishes.

No. 7. *Niagara Group.*—It is not yet determined whether there should be a higher formation, or formations, represented on the line of this section; but what is included here under the head of the Niagara group, probably embraces two of the next superior beds of the New York system. By reference to Mr. Lapham's section, it will be seen what are his views and observations respecting this division. My section strikes Lake Michigan in township 22 north, range 24 east, about twelve miles north of Twin rivers, and near where Mr. Lapham places the lower face of the "geodiferous lime-rock." This group presents another instance of the intimate connection between the geological structure and the topographical features of a country. The Niagara limestone, consisting of a close, compact and durable mass, overlies the marly beds of No. 6, and the yielding strata of No. 7, protecting them from erosion. It presents a series of mural fronts along the bay, facing the north-west, while its surface declines gently with the dip towards Lake Michigan, exactly in the same manner as the Trenton does towards the bay. For the particulars of the dip and thickness of these formations, the reader is referred to another portion of this chapter, where I have discussed this subject, embracing all the rocks of the north and west shore of Lake Michigan.

a. a. *Red Clay and Drift.*—As above remarked, there are, on the line of the section between the Wolf river and Green Bay, extensive deposits of northern drift. The drift hills about the head of the Oconto and around Shawanse lake, are discussed in the report on Wisconsin.

From the falls of Wolf river, southerly, beds of red clay occur, interstratified with the coarse drift: they become more heavy and numerous, as we proceed towards Green Bay, until, at Appleton, the red clay constitutes the mass of the superficial deposits. It is there about one hundred feet thick, and rests on the Trenton limestone (No. 4), as at Navarino. At this place, it passes beneath the surface of the waters of Green Bay; and here are sunk the wells, of which the details of the borings will be found in the Appendix.

Passing over the crest formed by the Niagara limestone at Lake Winnebago, the same clay and drift beds continue most of the way to Sheboygan. Their thickness is very considerable, but their extent on the line of this section is not known. At Green Bay, as at Lake Winnebago, it occurs in patches, filling the depressions in the stratified rocks, at various elevations from the level of the water to the top of the bluff. From Sheboygan, I have traced it to the southward, and found it gradually changing to a purple, and finally becoming a blue clay like that of Lake Erie; I am, therefore, satisfied that all these varieties of clay belong to one formation.

ORIGIN OF THE BASINS OF LAKES MICHIGAN AND HURON.

It has been generally supposed that the immense depressions which constitute the basins of Lakes Michigan and Huron, and which reach below the ocean level, had their origin in great, transverse fissures, or dislocations of the strata. The evidence, collected during the progress of this survey, shows conclusively that this has not been the case, but that, on the contrary, they must be regarded rather as the result of an extensive denudation and excavation of the more yielding strata, and that there is no evidence of any system of faults or dislocations in the region occupied by them.

Mr. Hall has summed up the evidence with regard to this point, in the following remarks:

"From the examination of this region, it appears that Lake Michigan has been, to a great extent, excavated from the Onondaga salt group and the upper Helderberg series, while the Niagara limestone, being harder and more indestructible, forms its western border, from one extremity to the other. From the breadth of country over which we find vestiges of the Onondaga salt group and the upper Helderberg series, in the northern parts of Lakes Huron and Michigan, we are warranted in the conclusion that at least two-thirds of the latter lake, in a direction conforming to its trend, has been excavated from these limestones. The eastern portion of Michigan is in the shaly sandstones, which are superior to the upper Helderberg series, corresponding to the beds No. 4, in Mr. Lapham's diagram (Fig. 21).

These observations, to a great extent, are applicable to Lake Huron. The Niagara limestone there forms a barrier, occasionally broken through, extending along its northern shore, embracing Cabot's Head and the Grand Manitoulin islands. It dips southerly, so as to leave the Onondaga salt group and the upper Helderberg series to the south; and the area once occupied by them is now covered by the waters of this lake.

Thus, the beds of these two great lakes occupy precisely the same position with regard to the geological series, having been excavated in the same beds, and occupying opposite sides of a low, synclinal axis. The basins of these lakes have not been caused by any upheaval of the strata, except so far as the whole country has been raised, by which these strata were brought within the operation of denuding forces.

Whatever of evidence there may be elsewhere of the effects of a denuding force operating in an eastern and western direction, it appears to me, in these examples, we have the most conclusive proof of a force having acted from north to south. In this direction, the lakes have been excavated in the trend of the strata; while the same groups, equally exposed, and as easily destroyed, are left as outliers, almost continuous, in the neighborhood of Mackinac.

We can only account for this fact, on the supposition that the shales and the shaly sandstones of the southern peninsula afforded a more resisting barrier to the denuding forces, which were turned to the right and the left. The water, the chief agent of excavation, found here a more ready outlet, and swept before it, in its resistless force, the excavated materials from these basins, while the northern point of this peninsula is left covered with the finer sediments derived from the destruction of the sandstones.

To form a correct idea of the force of this argument, the observer should place before him a map of the United States, and upon it indicate, by a colored band, the range of the Niagara group, from the peninsula of Green Bay, southward along the western border of Lake Michigan, and extending inland to a width twenty-five or thirty miles, and he will have a pretty correct idea of the geological position of the lake. Let him represent, by a parallel band, differently colored, the Onondaga salt group and upper Helderberg series, and he will observe that the lake now covers very nearly their ancient limits. Again, on the east, protract the Niagara limestone, from Drummond's island along the southern part of the Manitoulin group, and thence, by Cabot's Head, towards Lake Erie, and we will find that the same observations are true with regard to Lake Huron.

The continuation of the Onondaga salt group and upper Helderberg limestones, from the peninsula of Canada West, in the direction of Mackinac, is interrupted by the lake basin.

At Thunder Bay, on the western shore of Lake Huron, we have the occurrence of the upper Helderberg limestones, while Cabot's Head, on the opposite coast, is occupied by the Niagara group, giving the intermediate space as the width once occupied by the superior groups, but which have been removed by denudation.

The direction and contour of these lakes, then, have resulted from the bearing and the yielding character of the beds which once occupied the watery surface; but, towards the north, their irregular and broken outline has resulted from the destruction, in places, of the shaly beds below the Niagara group.

These general observations apply with equal force to the lower lakes—Erie and Ontario."

We here offer the results of Mr. Whittlesey's observations on the thickness, area, dip, &c., of the palæozoic groups described in the foregoing chapters. They may be regarded as approximations; but entire accuracy, where the whole thickness of the groups is nowhere exposed, is unattainable.

The Dip, Bearing, and Thickness of the Silurian Groups.

By Mr. Whittlesey.

"The inclination of the sedimentary rocks of the peninsula between lakes Huron and Michigan on the south, and Lake Superior on the north is very slight, but regular, In groups like these, possessing similar external characters, it is difficult to identify beds and lines of stratification at remote points, and therefore not easy to determine their exact dip; but, where this can be done with accuracy, over large areas, it is a plain mathematical problem to determine their precise thickness. On no part of the north shore of Lake Michigan did we discover lines of strata in the limestones which could be safely said to be continuous for many miles together. From the superior face of the lower, or Potsdam sandstone, to the top of the Mackinac limestone — a vertical thickness of at least one thousand feet — the beds are entirely calcareous; and although these beds may be separated, without great difficulty, into *geological groups*, the lines of separation can only be fixed approximatively. For the purposes of measurement, something more precise is desirable.

Along the western shore of the St. Mary's river, the Potsdam, or lower sedimentary rock, is seen, with the Birds-eye and Trenton limestones superimposed, succeeded by the Clinton and Niagara groups; but dividing lines have not been discovered and probably do not exist. These groups, with the exception of the sandstone, graduate into each other, and are recognizable, not so much by lithological characters as by their included fossils.

All observations agree in showing that the outcrop, or edges of these groups are curved, and that the convexity is towards the north. Between Lakes Superior and Michigan the lines which indicate the boundaries of the rocks will be seen on the map, where the breadth of each subdivision is indicated by an appropriate color. These bands are concentric, their outlines being rudely parallel, and the curves approaching in form an ellipse, of which the greater axis is east and west.

In theory, the general direction of the dip is known at once, when the line of outcrop is determined; for if, as in the present case, the rocks are not disturbed by upheavals and the country is comparatively level, the dip is at right angles to the line of bearing — the one being a radius and the other a tangent to the curve of outcrop. The radius of curvature in the strata which encircle the northern shores of Huron and Michigan proceeds from a point at, or near, the centre of the lower peninsula of Michigan, where the greatest depression of these beds will be found; consequently, as might have been predicted, it is at that point that the most recent groups are seen, such as the coal-seams, shales and sandstones of the carboniferous era, occupying the deepest depression in the great geological basin of Lakes Huron and Michigan.

The observations of this season complete the circuit of the Silurian groups of the northern part of the United States, connecting, through the upper peninsula of Michigan, those of New York and Canada on the east, with those of Wisconsin and Minnesota on the west.

These groups, in the northern peninsula, known as the Lake Superior district, are rarely exposed, being covered by thick deposits of drift, sustaining a heavy growth of timber; but, along the coast, where it is intersected by inlets and bays, the rocks are sufficiently exposed to enable us to determine their outlines with sufficient exactness for general purposes. Since they are the repositories of none of the valuable metals, minute accuracy in this respect is of no practical importance.

Taking Mackinac as a starting point, where the inclination of the strata is south and the bearing east and west, and proceeding thence westwardly, we should expect to see a change in the direction of the line of dip, and our local observations confirmed this expectation; for their dip was found to vary regularly towards the eastward, until, on reaching Point Detour, at Great Bay des Noquets, it was found to be nearly south-east. Following the coast past Death's door, or *Porte des Morts*, to Sheboygan and Milwaukee, where the Niagara limestone forms a sea-wall, the dip is observed to become more easterly, until, at the latter place, according to the observations of Mr. Lapham, it becomes due east.

As regards the amount of dip, I have already adverted to the difficulty of making a correct estimate. We have had, however, some good opportunities of calculating the amount over large areas, where the observations were worthy of credit. The surface of the Potsdam sandstone is well-defined, being overlaid by a rock—the calciferous sandstone—widely different in external characters; but it has not been practicable, with the means at our command, to take accurate levels of all the points where it would be desirable.

We have the means of making tolerable estimates of its elevation at several points, connecting it, by short levels, with lakes and rivers whose altitude is pretty correctly determined. For the other elements of the calculation, viz: courses and distances, nothing is wanting, for we have the aid of the linear surveyors, who have subdivided a large portion of the territory into tracts of a mile square.

Before entering upon the general dip of the several groups, we will proceed to notice some minor deviations and irregularities.

Local Dips.—From Saut Ste. Marie, along the western bank of the St. Mary's river and the straits of Mackinac, as far as St. Martin's Bay, no good opportunity occurs of estimating the dip of the strata. Wherever they are exposed, the lines of bedding are indistinct and by no means continuous. There is, however, evidently a slight inclination to the south. On the east side of St. Martin's Bay, there is a local dip to the S.S.W. of thirty or fifty feet to the mile, but, at the mouth of Pine river, it changes to the south or south-east. At the mouth of Carp river, on the west side of the bay, another irregularity is observed. At the first rapid, one-fourth of a mile from its mouth, it is from 1° to 2° N.E. by N. Ascending the stream, the strata become horizontal, but, farther up, a mile from its mouth, the dip becomes reversed, being S.W. by W., but is very slight. The bold, rocky cliffs of St. Ignace show a perceptible inclination to the south, but no well-defined lines, capable of being measured, are observed. The same may be said of the coast line, as far as Seul Choix. Here, the upper face of the Pentamerus member of the Niagara group has a marked undulation, the axis of which is nearly north-west and south-east.

From Pointe aux Chênes to the last mentioned place, the rock is seldom observed to rise above the surface, and the inference is, that, within this distance, there is no irregularity in the inclination, for the irregular outline of the coast seems to be due, in the main, to this cause.

At the extremity of the Pointe Seul Choix, the dip is 2° south-east, the strata gradually bending around to the southward; but, about a mile farther west, they are observed to plunge, at first, S. 60°E. 6°, and still farther west, S.E. 7°; thence S.E. 5°; and at the harbor, S. 25°W. 7°; and one mile west of the harbor, S.W. 3°. Eight miles west of Seul Choix, I had the first opportunity of measuring the dip on a smooth flat surface of the limestone, and found it to be S. 30° E. ½°. Thence, to the

Manistee river, a slight, but regular dip was observed to the south-east. At the mouth of this river, and at Indian lake, on the west fork, as well as the rapids between the two points, there was a very perceptible and uniform dip to the south-east, varying from ¼° and ½° to 1° Up the main stream, as far as the north boundary of township 44, range 13, the rocks are too indistinctly exposed to determine their inclination. Four miles westwardly of the Manistee, the southerly dip is very slight; at Orthoceras Point, twenty miles S. W., it is a few degrees to the east of south, and at Pointe Detour, it is still more easterly, but subject to a local undulation — probably a repetition of that at Seul Choix. On the east side of the point, the plunge is S. E. 2°, at the extremity S. 1°, but, on the west side, it is from ¼° to ½° to the S. W. by S.

The first lines of stratification, which could be considered as of much value in determining the inclination of the beds, were observed on the eastern side of Great Bay des Noquets. Here, in the high bluffs, occur alternating bands of coarse and fine-grained materials, which are visible for long reaches. A particular stratum, which is here two hundred feet above the lake-level was identified near the surface, opposite the most westerly of the Summer islands, — a distance of six miles. This would give an inclination of S. E. by S. of thirty-three and a half feet per mile.

Another coarse-grained stratum, which occurs in these bluffs, was observed to sink at the rate of thirty feet in the distance of one and a half miles on a meridian line; another sank thirty-five feet, in 1¼ miles, on a course S. 20° E. Passing among the Summer isles, the dip was everywhere observed to be to the S. E. and S. E. by E., at the rate of forty to forty-five feet per mile. On the west side of the main island, it was greater, being one foot in one hundred, or fifty to sixty feet per mile; but, crossing to the next island, one mile west, it was very slight. Although the local deviations are here numerous, yet the general direction is to the south-east. Between this island and St. Martin's, there are three smaller ones, about two miles distant, on the northernmost of which there is little inclination in the beds; but, at St. Martin's, it is very perceptible and regular to the south-east, at an angle of forty to fifty feet in a mile.

On Light-House island it is the same in direction, but irregular in amount. On Potawotomee island, in the high cliffs north-west of Washington harbor, there is a well-defined stratum of coarse-grained rock, which, at the point, is twelve feet above the water-level; one-third of a mile south, it is eight feet, and one-third of a mile east, it is three feet. This gives a dip of about thirty feet to a mile, in a south-east direction. Thus, all the observations in the vicinity of Green Bay coincide in the direction of the line of greatest dip, and show no undulations in the strata; a fact to be remembered when we consider the question of the total thickness of these beds.

We now proceed to the discussion of the more extended lines of dip, so far as they have been determined.

Extended Lines of Dip.— The elevation of the upper surface of the Potsdam sandstone has been determined by Mr. Lapham, at Janesville, Wisconsin, (in township 3 N., range 12 E.,) to be one hundred and sixty feet above Lake Michigan; and by myself, in 1849, while engaged in the survey of Wisconsin under Dr. Owen, near the Wolf river, (township 22 N., range 16 E.,) to be one hundred and ten feet above Lake Winnebago, which is stated, by Captain Cram, to be one hundred and sixty, and by Mr. Alston, to be one hundred and sixty-five feet above Lake Michigan, making, say two hundred and seventy feet. The upper surface of this belt, where intersected by the Menomonee river, is between fifty and sixty feet above Lake Michigan. At the centre of township 39, range 28, of the Michigan meridian, I estimate its height at three hundred feet. At the Pictured Rocks, Lake Superior, it is at about the same elevation above the surface of that lake, which is supposed to be about forty-six feet above Lake Michigan. Where the St. Mary's river crosses this band, on Sugar island, the elevation is but a few feet above the surface. The bearing and distance of these several points have been determined by the public surveys.

Line No. 1. From Janesville to Township 22 N., Range 16 E.—Wisconsin meridian—course N. 11° E.; distance one hundred and twenty-six miles; rise one hundred and ten feet.

2. From Township 22, Range 16 E.—Wisconsin meridian—near Wolf river, to the Menomonee river in Township 34, Range 28 W.—Michigan meridian—course N. 27° E.; distance sixty-two miles; descent two hundred and twenty feet.

3. From the Menomonee river, west side of Township 34 N., Range 28 W.—Michigan meridian—to the centre of Township 39 N., Range 28 W.; course N. 6° E. twenty-eight miles; rise estimated at three hundred feet.

4. From the crossing of the Menomonee to the Pictured Rocks; course N. 35° E,. eighty-four miles; rise estimated at three hundred feet.

5. From the first-mentioned point to the crossing of the St. Mary's river, at Sugar island, N. 68° E.; one hundred and ninety-two miles, descent estimated at forty feet.

6. From the Pictured Rocks to the last-mentioned point; east one hundred and twenty-three miles; descent estimated at two hundred and ninety feet.

By combining any two of these lines so as to form a plane, it will represent the inclination of the surface of the sandstone (disregarding the sphericity of the earth), and by a simple geometrical construction, the bearing and quantity of the dip, or line of greatest descent, are easily obtained. Lines Nos. 1 and 2, combined in this manner, give for the dip of the lower sandstone in Wisconsin, 14.3 feet per mile in the direction S. 76° E. Nos. 2 and 3, at the crossing of the Menomonee give for dip thirty-nine feet per mile, course S. 68° E. Nos. 3 and 4, at the centre of Township 39 N., Range 28 W., 11.2, along a course S. 30° E. Nos. 4 and 5, course S. 23° E., give a dip of seven feet per mile.

The disadvantage in rising lines like these, along the line of outcrop, is, that they do not make the best angles with each other; but, in a level country, no others can be obtained. They do not in general represent the dip as great as it really is, or would appear to be, if they were protracted to the centre of the basin. Those above given are nearly coincident with the lines of bearing along the northern and western margin of the Silurian groups.

The Hudson-river group, or that portion known as the Cincinnati blue limestone of the Ohio reports, is so marked in its external characters and zöological contents, that it is easily recognizable. By the aid of Mr. Lapham, I have been able to obtain two lines along its outcrop, which may be regarded as approximately correct.

No. 1. From Stockbridge, Calumet county, Wisconsin, to the north line of township 26 N., range 23 E., on Green bay. Course N. 32° E., fifty-eight miles; descent two hundred and sixty feet.

No. 2. From the first-mentioned point, S. 30° W. 56 miles, to the north-west corner of township 10 N., range 14 E.; rise twenty feet.

This would give the line of dip S. 75° E., at 13.8 feet per mile, which corresponds very well with the results before given.

By my measurements and estimates in the bays and among the islands near the entrance to Green Bay, the dip of the superior members of the Silurian system was determined to be S. E. and S. E. by E., at the rate of thirty or forty feet to the mile.

Mr. Lapham, who has carefully examined the various groups in the vicinity of Milwaukee, estimates their dip at from fifteen to seventeen feet per mile, due east. The best estimate which I have been able to make from observation between Fond du Lac of Lake Winnebago and Sheboygan gives about seventeen feet per mile in a direction S. 65° E.

Between the Manistee river and Point Detour, the inclination is S. E. by S., forty feet per mile; and in the vicinity of Mackinac, S. at the rate of thirty or forty feet.

Thickness of the several Groups.— The Mackinac limestone, which is the equivalent, in part, of the Onondaga salt group—the superior member of the Silurian series — and the upper Helderberg limestone, is, by my measurement, three hundred and fifty feet in thickness. Below this, is a thin, marly bed, containing gypsum, which probably does not exceed fifty feet.

Classifying the beds without reference to organic remains, the next member, in the descending order, may attain a thickness of one hundred and fifty or two hundred feet, although its exact measurement is impracticable. It is characterized by numerous corals, and hence may be designated as the coralline bed.

Next succeeds the Pentamerus limestone, cropping out north of Mackinac, where it appears thinner than farther west; but it is difficult to estimate its thickness, so slightly is it exposed. It appears on the coast at Seul Choix and continues thence beyond Porte des Morts, having, at the entrance to Green Bay, a thickness of four hundred and eighty or five hundred feet. The groups from Mackinac to Seul Choix curve gradually to the south and pass into the lake. The upper portion of the Pentamerus bed is seen on Drummond's island and on the St. Mary's river — the dividing line between it and the coralline bed passing in a curvilinear form from Seul Choix to the northward of St. Martins' Bay, and thence to the St. Mary's river, a few miles above the Detour light.

It is difficult to obtain the thickness of the subordinate groups, consisting of the Hudson-river, Trenton, Birds-eye and Chazy limestones, and the calciferous sandstone, superior to the Potsdam. If we knew their precise dip and area, the calculation would be comparatively easy. For the dip, we should take a medium between the upper and the lower groups, since the inclination of the superior strata is greater than the inferior; but, in the interior, where the intermediate groups exist, their presence is almost entirely concealed by drift, and they cannot, by direct observation, be separated. They occupy a belt of country about forty miles in width, on the waters of Green Bay; their easterly boundary passing from Sturgeon Bay through the middle of Great Bay des Noquets, while their westerly boundary crosses the Wolf, Menomonee, Oconto and Escanaba rivers, on a line nearly parallel with one through Green Bay, and about forty-five miles distant to the north-west. If the average dip of these intermediate beds be assumed at twenty-five feet per mile, on a line of forty miles across the basset edges of the strata, the rise would be one thousand feet; but the surface of the country has also risen from three to four hundred feet, which should be deducted from the thickness of the mass, leaving it at six or seven hundred feet; and, allowing for irregularities in the strata, a further deduction of one hundred feet should also be made.

Without attempting to separate the several members between the Pentamerus limestone and the Potsdam sandstone, I put their entire thickness at five hundred feet, as displayed on the waters of Green Bay, thinning out, however, as traced towards the St. Mary's.

There is also a difficulty in estimating the thickness of the Potsdam sandstone, since its base is seldom visible. On the upper Menomonee, I saw one exposure of one hundred and fifty feet; and I should estimate its entire thickness at two hundred feet.

The results, then, of all my observations are as follows:

1. Potsdam sandstone, on the Menomonee,		200 feet.
2. Calciferous sandstone, Birds-eye, Chazy, Trenton, Hudson-river and Clinton groups, as developed in the vicinity of Green Bay,		500 "
3. Coralline and marly beds, near Mackinac,	200 to	250 "
4. Mackinac limestone,		350 "

Making the aggregate thickness 1200 or 1400 feet."

EVIDENCES OF DENUDATION AND SUBSIDENCE.

In describing the detailed geology of this region, we have had occasion to speak of extensive tracts which were denuded at a remote geological epoch, of numerous examples of diagonal stratification, of ripple-marked surfaces, of clay cracks, of the trails of vertebrated animals, of shelving shores, of beach accumulations, and of stratified deposits of sand and clay, high above the present surface of the lake:—all of which indicate that the sea-bottom in which the various groups were deposited, was subject to repeated oscillations.

As this is a subject of much geological interest, we deem it proper to recapitulate this evidence, in a connected form, even if we lay ourselves open to the charge of repetition.

It has been shown that the surface of the ocean in which the Potsdam sandstone, or lowest member of the Silurian system, was deposited, did not reach within eight hundred feet of the culminating points of the granite and schists composing the azoic system; that, all along the line of contact between the two series, there is a marked unconformability, the strata of the one being highly inclined, and of the other nearly horizontal; that, in numerous instances along this line, particularly at Middle island, Presqu'isle, Granite Point, Carp river, on the northern coast of Lake Huron and in the valley of the Menomonee, the harder and firmer rocks of the azoic series were denuded, their angularities worn down and their surfaces smoothed, before the deposition of the sandstone,—resembling, in this respect, the rocks exposed, at this day, to the breaker action of the ocean.

We have further shown that the detritus composing this sandstone was arranged in layers, dipping slightly *away* from the prior-formed land,— an arrangement which is observed at this day in the accumulations around the islands of the sea, and along shelving shores; that, at numerous points—for example—at L'Anse, Granite Point and Dead river, are found intermingled with the finer detritus, angular and slightly rounded fragments of the prëexistng rocks, derived from the immediate vicinity, partaking, in this respect, of the character of beach accumulations; that the frequently recurring instances of diagonal stratification, particularly observable in the series composing the Pictured Rocks, in the detrital accumulations at Granite Point, at Point Abbaye, and on the western coast of Keweenaw Bay, indicate that the materials were not, in all instances, mechanically suspended, but were drifted along the bottom by tidal, or oceanic currents; and that the frequent occurrence of ripple-marked surfaces, in the series, is strong if not conclusive proof of the subsidence of the sea-bottom.

We have, also, as shown in Part I. of our report, similar evidences of oscillation and of tidal deposits along the volcanic fissures in the copper region. These have been particularly observed on the northern flank of the Porcupine mountains, on the west coast of Keweenaw Point (at a locality known as the Hitz location), and on the southern coast of Isle Royale. It frequently happens that we meet with slight alternations of arenaceous and aluminous particles, the one in the nature of a red sand and the other of a red mud,— such as are respectively deposited by an advancing and retreating tide. This mud, now consolidated into marl, is covered over with fissures, or cracks, such as result at this day from the drying of similar deposits along the margins of rivers, or over low tracts adjoining the sea, indicating an exposure of the ancient surface to atmospheric influences.

Passing over several intermediate groups and ascending in the series of formations, we meet with evidences of a different character, but illustrating the same point, in the ripple-marked surfaces of the Clinton group, indented with the trails and tracks of animals. These layers were accumulated, if not upon ancient sea-margins, at least, upon the bottom of shoal and tranquil waters.

We have seen, that, between the termination of the Onondaga salt group and the commencement of the upper Helderberg series, there occurs, in our district, an immense hiatus, during which, according to Mr. Hall, two distinct faunas lived and died, without having left a trace of their existence here; but we are uncertain whether the intervening deposits, which are clearly recognized in New York, thinned out before reaching this portion of the oceanic bed, or whether they may not have once extended over it, though diminished in thickness, and been removed by an ancient denudation.

There are some facts which seem to warrant the latter conclusion, that is, of a denudation of the strata, not local, but extending over a wide area, which took place at about the close of the period of the Onondaga salt group. Thus, in New York, Mr. Hall states that the upper member of this group exhibits an apparently water-worn surface, upon which the succeeding beds have been conformably deposited. Thus, too, near the upper portion of the cliff limestone, at Columbus,* Ohio, whose deposition must

*This interesting phenomenon was pointed out to us, in company with M. Agassiz, by Mr. Joseph Sullivant. After having pointed out the line through one quarry, he took us to another, a mile or more distant, where he showed us the same thing, thus leaving no doubt that it was not a mere local phenomenon.

be referred to about this period, the ancient surface appears to have been planed down and smoothed in a most wonderful manner, differing altogether from the effects of breaker action. Were it not for the absence of striæ, it might be likened to the effects of drift agency. The fossils, principally *Cyathophylla*, are silicified, and, being harder than the matrix in which they are enclosed, project a few lines above the polished surface; but show that they, too, were planed down by this agency, whatever it was. Upon this polished surface, the succeeding layers were conformably deposited, so that, in a vertical section, this line of demarcation appears no wider and no more distinct, than one of lamination, or stratification. We may further add that each division is characterized by a distinct fauna.

Between the commencement of the Devonian and the dawn of the drift epoch, there is an immense gap in the series of formations in this district, and we search in vain for any evidences of the condition of the ancient surface. In a former report, we have shown that stratified deposits of drift clay and sand occur in some cases at an altitude of nearly one thousand feet above the present level of the lake, and that, therefore, the waters in which these deposits were made, reached four hundred or five hundred feet higher than the surface of the ocean at the dawn of the Silurian epoch. We have, also, shown that the lake margin is lined in many places with stair-like ridges of loose materials, known as terraces, arranged one above the other, from which we infer that within comparatively recent geological times, the surface of the water has occupied different levels; or, in other words, that the land has been subject to repeated elevations.*

We have thus, then, abundant evidence of the oscillations of the surface, during the accumulation of the detrital deposits of this district, embracing a period of inconceivable duration, from the dawn of the Silurian epoch, when the Lingula and the Trilobite first appeared, to the close of the drift, when the gigantic pachyderms—the Mastodon and the Elephant—became extinct. These oscillations, with a few exceptions, to be adverted to hereafter, appear to have been attended with no corrugations, or displacements, of the strata, although they may have prescribed the limits of certain groups and modified their vertical range. They indicate nothing like catastrophes, nothing which would produce an instantaneous destruction of organic life; and yet perhaps, they were less gradual than those elevations and depressions which are now taking place in different parts of the earth's surface, the effects of which are rendered apparent by the lapse of centuries rather than of years. The coast of California exhibits fossil shells a hundred or more feet above the water,† identical with those which flourish along the shore: the same is true with regard to the St. Lawrence, Sweden, and other parts of the earth. The inference, therefore, is that in these instances, the rising of the land has been sufficiently gradual to enable the species to migrate and accommodate themselves to new conditions; but these ancient oscillations appear to have been attended with far different results.

In this connection, it may be proper to enquire into

The Effects of these Oscillations on Organic Life.—To account for the repeated destruction of the varied forms of animal and vegetable life, which is attested by all geological researches, it is not necessary to suppose that these results have, in all instances, been brought about by violent perturbations, at variance with that calm operation of nature which we now see going on

* Part I., pp. 188–194. † On the authority of Col. Jewett.

around us. The sea, like the land, has its mountains and valleys and its far-stretching plains, tenanted by a fauna more circumscribed in its range, and as susceptible to great changes as that which inhabits the land. An elevation of its bed to the height of a thousand feet, would convert many a chain of islands into mountain ranges, with intervening valleys, and many banks into plains, like the prairies of the West, the deserts of Africa, or the llanos of South America. It will at once appear obvious to the geologist that an elevation or depression of the bed of the ocean to such an extent, would be attended with a marked modification of both animal and vegetable life, over the entire area thus disturbed. New conditions would arise which would be fatal to their existence. These conditions have been ably discussed by De la Beche,* and consist of a change in temperature, pressure, light, and in the amount of air mingled with the water. In the depths of the ocean, according to the researches of Sir James Ross, and other navigators, the water is supposed to possess a uniform temperature of 39.5°. At the poles this line approaches the surface, while at the equator it sinks far below it. By a subsidence of the land, many species in the equatorial regions, which are surrounded by a medium possessing a temperature of 78°, might be brought within the range of a temperature of 39.5°—a change which would be fatal to their existence. The investigations of Dana have shown that many of the corals, for instance the *Astræacea*, *Madreporacea*, and *Gemmiporidæ* range within latitude 28° north and south of the equator, and that they are confined to a depth within one hundred and twenty feet of the surface. Darwin had before pointed out the depths at which other forms occur.

The researches of Professor E. Forbes have shown that the eastern Mediterranean may be divided into eight zöological zones, each characterized by a peculiar fauna. Similar results were contemporaneously arrived at by Professor Löven from his investigations of marine life along the coast of Norway. The same observations are true with regard to the marine flora, although it ceases far above the deepest regions of animal life. It would seem improbable that a coral which lives at an inconsiderable depth, in an equatorial sea, where the temperature rises to 78°, could continue to flourish, when transported near the poles, where the line of 39.5° approaches the surface, or the colder water forms a stratum above it. As well might we expect to find an arctic vegetation, at the sea-level, beneath the tropics.

But let us recur to the conditions of organic life on our own coasts. According to Dr. Gould,† of the one hundred and ninety-seven marine species found in Massachusetts, eighty-three do not pass to the south shore of Cape Cod, and fifty are not found on the north shore. The remaining sixty-four take a wider range, and are found on both sides. These results have been somewhat modified by subsequent investigations, but the great fact, as to their limited distribution, remains unimpaired.

The same law, according to the same authority, is true with regard to Cape Hatteras — that cape forming a natural boundary between many of the forms of animal life inhabiting the sea, north and south.

As marine life, then, like terrestrial vegetation, is adjusted to certain

* Geological Observer, pages 162 to 190. We shall quote many of the prominent facts adduced by him, which bear upon this point.
† Report on the Invertebrata of Massachusetts, page 316

zones, the geologist, in investigating an anciently raised sea-bottom and the variously distributed organic remains, should be on his guard, lest he assign to different epochs animals which were really contemporaneous; nor should he neglect to distinguish between littoral and deep sea deposits, which, although simultaneously formed, would differ both in lithological characters and in organic remains. Without observing the gradations between the two extremes, he might rashly infer, from their relative level, that the one was imposed upon the other.

Aside from the differences of temperature, we are, also, to consider the modifications arising from pressure. The law relating to this subject is well understood, and need not here be recapitulated.* When we know the depth to which a certain animal penetrates, we can calculate the pressure which it is adapted to sustain. While some forms of marine life, like the nautilus, have a wide, vertical range; others, like the oyster, are extremely restricted; but to all there are fixed limits, beyond which they cannot penetrate.

In investigating, therefore, the palæontology of past epochs, we ought, *a priori*, to expect to find certain forms ranging through a series of groups, while others would be restricted to a single one.

"We cannot suppose an animal so constructed," remarks De la Beche, "as to sustain a pressure of more than two hundred atmospheres at one time, and two or three atmospheres at another. A creature inhabiting a depth of one hnndred feet would sustain a pressure, including that of the atmosphere, of about sixty pounds to the square inch, while one at four hundred feet, no very important depth, would have to support a pressure of 1,830 pounds to the square inch.

"Animals, among other conditions for their existence, are adapted to a given pressure, or certain ranges of pressure, so adjusted that they can move freely in the medium, either gaseous or aqueous, in which they live. All their delicate vessels and the power of their muscles are adjusted to it. When the pressure becomes either too little or too great, the creature perishes; and, therefore, when acting freely in such a medium as the sea, an animal will not readily quit the depths in which it experiences ease. All are aware of the adjustment of an abundance of fish to the depths, to or from which they may frequently descend, by means of the apparatus of swimming-bladders. This arrangement, however, only changes their specific gravities as a whole, the relative volume occupied by the air, or gases in the swimming-bladders, being the chief cause of difference; though, no doubt, also the squeezing process at great depths would diminish the volume of such other parts of their bodies as were in any manner compressible, the reverse happening with a rise from deep waters to near the surface. So adjusted to given depths do these swimming-bladders appear for each kind of fish, that it has been observed that the gas, or air, in the swimming-bladders of fish brought up from a depth of about 3300 feet (under a pressure of about one hundred atmospheres), increased so considerably in volume, as to force the swimming-bladder, stomach and other adjoining parts, outside of the throat, in a balloon-formed mass."* The modifications, therefore, of animal life resulting from pressure would be quite as great as those resulting from temperature.

Light, also, exercises a powerful influence upon marine, as well as ter-

* Pouillet, Elemens de Physique Experimentale. Geol. Obs. 164.

restrial life; and we should expect that the fishes, crustaceans and molluscs, which possessed eyes, should occupy such levels as were adapted to their range of vision.

Thus the *Pomatomus telescopium*, which, according to Professor Forbes, inhabits considerable depths in the Mediterranean, possesses remarkably large eyes, apparently constructed so as to concentrate all of the rays which penetrate to that level. The Trilobite of the ancient world, as demonstrated by Buckland, possesses a set of lenses similarly adapted to enable it to see at great depths. Professor E. Forbes has also adverted to the influence of light upon marine animals, and shown that those inhabiting different zones are differently colored. Perhaps, however, the mere deprivation of light would not in all cases be attended with the extinction of marine animals, possessing visual organs; since the eyeless fishes of the Mammoth Cave, as shown by Wyman, have, in those respects, a rudimentary organization.

Marine animals, also, require for their existence a supply of oxygen, and at the junction of the sea and the atmosphere the absorption is the greatest. The observations of M. Biot render it probable that the contents of the swimming bladders of fishes vary according to the depths at which they live. He found the contents to consist of pure nitrogen in those inhabiting shoal waters, while the contents of the bladders of those living at great depths consisted of oxygen and nitrogen, in the proportion of nine-tenths of the former to one-tenth of the latter.

Again, as suggested by De la Beche, in tidal seas we find certain molluscs, adjusted to live alternately exposed to the atmosphere and the sea. Some species are confined to the shores, while others are only found at great depths, and hence there can be no doubt that some require for their sustenance a greater supply of oxygen than others.

There are other effects resulting from the oscillations of the land, which might produce modifications in marine life. A greater amount of elevation in one part of the area than in another, might cause a change in the direction of the streams, and produce an influx of fresh water, which would be attended with the destruction of such testacea as were exclusively marine. In fact, this accords with the observations of Professor E. Forbes, in the Ægean Sea, where certain species are wanting, which occur abundantly in the western Mediterranean. This result he attributes to the composition of the sea-water, rather than to climatic influences. Again, his observations have led him to believe that the distribution of marine life is effected by the nature of the sedimentary deposits distributed over the bottom. Thus, those animals whose habits adapt them to a muddy bottom, would not flourish upon a sandy one, and vice versa. Thus, too, the researches of Mr. Hall, in our own district, have shown that during the period of the deposition of the Niagara limestone, the character of the sediment was a variable. Under certain conditions, corals flourished in great abundance: change ensued, and they disappeared; and this occurred not in one instance only, but was frequently repeated. Their extinction appears not to have been due to catastrophes, for we find no evidences of them, but to a change in the sediment. In the purely calcareous, or calcareo-magnesian beds, they appear to have flourished, forming reefs of considerable extent; but where there was an influx of argillaceous mud, they died out altogether.

A change in the relative level of the land might produce a change in the character of the detrital deposits and of the marine animals dwelling upon them

On the other hand, the submergence of the land would be attended with changes equally marked. The length of the streams would be shortened, and their power to transport detritus diminished, and the character even of that detritus might be modified. "When the shores ceased to present themselves, the littoral marine animals, previously inhabiting them, and moving to the coasts as these retreated upon the descent of the main mass of land, would be expected also to have disappeared, unless able wholly or in part to have adjusted themselves to the new conditions. When, however, zone after zone of the marine vegetation disappeared as the circumstances fitted for its growth ceased, the animals which fed upon the plants would perish, and with them those which lived upon the vegetable eaters, unless they could escape to other localities where food of the same kind, or of others which they could substitute for it, was to be found, and was sufficient for them."* In a region, for instance, like that under consideration, encircled in the main, with vast fresh-water lakes, as the sea invaded the land, the waters would first become brackish and then saline; and thus we might have three distinct sets of formations, each characterized by a peculiar fauna.

We thus see that the elevation or depression of extensive tracts of land at this day, would be attended with the extinction of many forms of animal and vegetable life; and, reasoning from analogy, we have a right to infer that the mutations in the surface of the earth, in times past, which as the researches of geologists have shown were of frequent occurrence and of vast extent, were attended with similar results.

* Geological Observer, p. 625.

CHAPTER XII.

CHEMISTRY AND ECONOMIC GEOLOGY OF THE PALÆOZOIC SERIES.

Prospects of the Mining Interest in the Copper Region.— Sandstones and Conglomerates. — Their Chemical Composition. — Their Economical Application.— Chemical Examination of the Limestones.— Method of Analysis.— Lower Silurian Limestones.— Remarks on the Composition of the Lower Silurian Limestones.— Upper Silurian Limestones.— Marble of the Azoic Series.— General Remarks on the Analyses.— Theory of Dolomitization.— Occurrence of Soda, Chlorine and Sulphuric Acid.— Probable Origin of these Substances.— Economic Application of the Limestones.— For Calcination.— Building Materials.— Occurrence of Metallic Ores in the Limestones.— Gypsum.

In Part I. of this report, we have described, somewhat in detail, the extent, mode of occurrence and economic value of the metallic deposits, which occur in the lower portion of the palæozoic series. In regard to the value and extent of the mineral deposits of the copper region, we have no additional remarks to offer, except that the productiveness of the veins has fully equalled, if not exceeded, the estimate given by us in our report; and that the prospects of companies engaged in mining, at various points along the cupriferous belt, are better, at this time, than at any period since the first exploration and settlement of that country.

We shall now proceed to give some account of the rocks and minerals of the above-named series, especially of those occurring in other portions of the district, remote from the trappean ranges, with especial reference to their economic value; and in order to arrive at a more accurate knowledge on this point, we shall give the results obtained by us in our chemical examination of some of the more important of these materials. Where these investigations seem to throw light on any points of scientific interest, we shall briefly discuss them in their theoretical bearing and general application.

SANDSTONES AND CONGLOMERATES.

Chemical and Mineralogical Composition. — At a distance from all igneous action, where the sandstone has been regularly deposited and not subjected to any disturbing influences, it appears to be made up almost entirely of angular fragments of nearly pure quartz, which are hardly held together by any visible cement. The grains are generally of the size of a pin's head, and often present crystalline facets.

The sandstone, on the southern slope of the axis, is generally of this character, and its composition will be seen from the following analysis, which shows it to be almost pure silica, or quartz.

The specimen analyzed was from the White Rapids of the Menomonee river; it is white, granular, and very friable — so much so, that it is difficult to preserve a specimen, since it crumbles so easily when handled.

It was fused with carbonate of soda, after ignition, in which process it lost two-tenths of a per cent. of water, and retained its original pure-white color perfectly.

1.3880 grammes gave 1.3835 of silica, which was perfectly soluble in carbonate of soda. The residuum consisted mostly of alumina, with only a trace of iron and lime.

Silica	99.67
Alumina, trace of iron and lime	.33
	100.00

The Potsdam sandstone, at numerous other points, will probably be found of equal purity, though in general it is somewhat colored by a trace of iron. In the vicinity of the trappean rocks, it becomes highly charged with iron and calcareous matter, the latter being so generally and intimately associated with all of these sandstones, that they effervesce strongly with acid, even when no perceptible particles of lime can be seen. A specimen from the first bed at Copper Falls, of a deep brownish-red color, lost 2.7 per cent. on ignition at a low red heat; it effervesced strongly with acid, and 38.8 per cent of the pulverized substance was dissolved by digestion with chlorohydric acid. The soluble portion contained a trace of copper, and a large amount of peroxide of iron, a little alumina and lime, and a trace of magnesia. The insoluble part consisted mainly of quartzose grains, of a light reddish-grey color.

Economical Application of the Sandstones.—The above analysis of the sandstone shows conclusively that it would furnish an excellent material for making glass, as it possesses a remarkable degree of purity. There are many localities where an abundant supply of an equally pure material might be obtained, both near the shores of Lake Superior and Lake Michigan. The grains of silicious substance, in the purer sandstones, not being held together by any calcareous, or ferruginous cement, the stone can be pulverized with the greatest facility. In fact, there is so little coherence between the particles, that it crumbles readily between the fingers, so that we have found it difficult to preserve specimens of these sandstones, except in the form of sand.

The sandstones of the Silurian system, in our district, rarely furnish good building materials, except in the vicinity of the trappean belts. Here, they are cemented firmly by ferruginous matter, and appear to contain few impurities of a nature to cause them to crumble, and become discolored by the action of the weather. From the total absence of organic remains in them, they seem to be free from many substances which result from the decay of organic matter. Some of these sandstones are in beds of two or three feet in thickness, and are traversed by joints, which would afford essential aid to the quarry-man in getting out blocks of a convenient size for building. At other localities, for instance above the portage of Keeweenaw Point, the more thinly-bedded varieties would furnish tolerable stones for flagging. Some of these sandstones would undoubtedly be found to make excellent hearths for furnaces; and could be used for other purposes, where a very refractory material is required.

CHEMICAL ANALYSIS OF VARIOUS LIMESTONES.

Method of Analysis.— The analyses of the various limestones occurring within our district were made as follows:

The pulverized substance, of which a quantity equal to from 1 to 1.5 grammes was taken for analysis, was carefully dried at a temperature a little above 100° C. A portion was then introduced into a weighed apparatus, in which the carbonic acid was set free by the action of chlorohydric acid, and dried in its escape by a tube containing chloride of calcium. The loss of weight was estimated as carbonic acid. The insoluble portion was filtered off, ignited and weighed; and, when it was considered necessary, analyzed as a silicate, after fusion with carbonate of soda. In the filtrate, the iron and alumina were then precipitated by ammonia, together with a small portion of the magnesia and manganese, which were separated from each other in the usual way. The lime was precipitated in the ammoniacal solution by oxalic acid, and ignited and weighed as a carbonate. In the filtrate, if the soda was not to be determined, the magnesia was precipitated by phosphate of soda, and weighed as phosphate of magnesia. If the soda was estimated, it was done by several of the processes described for separating it from magnesia. The method, however, which seems to furnish the most accurate results, and by which we are satisfied that these two substances can be separated most perfectly and with the least trouble, at least when the quantity of soda is small in comparison with that of the magnesia, is as follows: The filtrate, after separating the lime, is evaporated to dryness over the water-bath, and ignited in the platina capsule to expel the ammoniacal salts; the remaining substance is then transferred to a thin, but tolerably large-sized, platina crucible, and strongly ignited for a considerable time, the cover of the crucible remaining on. The ignition must be repeated till there is no longer any loss of weight; and, at short intervals, the crucible must be allowed to cool and its contents must then be moistened with a drop or two of water, and a small fragment of carbonate of ammonia laid upon the bottom. In this way, all the chloride of magnesium will be decomposed, and pure magnesia be left behind, which, being almost entirely insoluble, can easily be separated from the chloride of sodium. If the operation is properly conducted, no trace of magnesia will be found in the solution containing the soda. The chlorine was estimated on a separate portion, by dissolving in pure nitric acid, and precipitating by a salt of silver.

ANALYSES OF LOWER SILURIAN LIMESTONES.

Analysis of Limestone from near Miners' River, Township 46, *Range* 18, *Section* 12—(*Calciferous Sandstone.*)—This is a light, yellowish-grey variety, and represents very well the lowest limestone in the series, being found near the Potsdam sandstone,—the two appearing to pass into each other.

1.502 grammes left .2155 insoluble substance, mostly quartzose matter in angular grains = 14.34 per cent.: .0487 peroxide of iron, with a little alumina: 1.1410 carbonate of lime: .0995 phosphate of magnesia.

Silicious matter	14.34
Carbonate of iron	4.74
Carbonate of lime	76.36
Carbonate of magnesia	5.02
	100.46

Traces of soda and chlorine were contained in it, but were not estimated

Brownish, sub-crystalline Limestone of the lower Silurian Series, near L'Anse, Keweenaw Point, Section 13, *Township* 51, *Range* 35.—This limestone is probably a little higher in the geological series than that last mentioned. It is, from its isolated position and relation to the surrounding country, likely, at some future time, to be of economical value. It is highly magnesian; but, on the other hand, contains very little silicious matter.

1.9563 grammes gave .104 insoluble silicious matter; .0357 alumina, with a trace of iron; 1.0165 carbonate of lime; .9555 phospate of magnesia.

In another analysis of a specimen from the same locality, 1.2370 grammes lost .5495 carbonic acid; left .0670 insoluble substance; gave .0115 precipitate, by ammonia, mostly peroxide of iron; .6400 carbonate of lime; .6727 phosphate of magnesia.

	I.	II.
Silicious matter	5.32	5.41
Protoxide of iron	1.64	.83
Alumina	1.82	
Lime	28.58	28.97
Magnesia	17.89	19.92
Carbonic acid		44.34
Water and loss		.53
		100.00

Limestone from Township 43, *Range* 25, *section ?, below the Forks of the Escanāba River.*—This is a light-colored, compact stone, from the calciferous sandstone formation; probably from nearly the same geological position as the two preceding, but from the southern slope of the axis. It is by no means so pure a limestone as either of the two of which the analyses are given above, since it contains almost forty per cent. of sand, or silicious matter. It also contains a considerable amount of water.

1.6934 grammes lost .4777 carbonic acid; left .6361 insoluble substance; gave .0085 peroxide of iron; .0020 alumina; .4361 carbonate of lime; .7335 phosphate of magnesia.

2.0993 grammes gave .0011 chloride of silver.

Silicious substance	37.62
Protoxide of iron	.45
Alumina	.15
Lime	14.16
Magnesia	15.51
Carbonic acid	28.21
Chlorine	.05
Sulphuric acid	trace
Soda	trace
Water (by loss)	3.85
	100.00

Shale of the Hudson-river Group from Little Bay des Noquets.—This specimen was a fair sample of the shaly portion of the Hudson-river group, as it occurs on the east side of little Bay des Noquets, where it is filled with organic remains. Like the preceding it contains considerable water. It is a mixture of argillaceous and calcareous matter, the former being mostly insoluble in acids.

2.461 grammes lost .7603 carbonic acid : left .7067 insoluble silicate of alumina, with a little silicate of iron and manganese : gave .0623 peroxide of iron : .0162 alumina : 1.0135 carbonate of lime : .3006 magnesia : .0112 chloride of sodium and traces of chlorine and sulphuric acid.

A separate estimation of the water on 2.9170 grammes gave .0852 water = 2.9 per cent.

Insoluble silicate of alumina	28.71
Protoxide of iron	2.28
Alumina	.65
Lime	22.65
Magnesia	12.21
Soda	.24
Carbonic acid	30.89
Chlorine and sulphuric acid	traces
Water (by loss)	2.37
	100.00

The amount of soda, as seen in the above analysis, is very considerable; but the chlorine was hardly present in sufficient quantity to be weighed.

Remarks on the above analyses of lower Silurian limestones;

By Mr. Hall.

The analyses of several specimens of these limestones show them to be highly magnesian. A single exception occurs in the limestone from the vicinity of Miners' river, in which only five per cent. of magnesia was found. In the other examples of limestone from the same geological position, the per centage amount of magnesia is equal to two-thirds that of the lime in two of them, and more than equals the lime in the other example.

The specimen from the Escanaba river, of which the analysis is given, was from the lower part of the calciferous sandstone and near its junction with the Potsdam sandstone; this accounts for the large proportion of silicious matter. The calciferous sandstone is everywhere magnesian, from the Hudson to the Mississippi river, the character of the rock changing mainly from the varying proportion of silicious matter which it contains at different points.

Other specimens, taken from widely separated localities, show that the inferior members of the lower Silurian limestones are everywhere magnesian.

A specimen of the calcareous shale of the Hudson-river group shows a proportion of 12.21 per cent. of magnesia and 22.13 of lime, which, deducting the silicate of alumina 28.71 per cent., would form a dolomitic compound.

In its eastern extension, where the proportion of calcareous matter is far less, the shales are highly magnesian. This is still farther shown where the same strata, in a metamorphic condition, form the talcose slates of New York and the western part of New England. The occurrence of magnesia in these rocks in their unaltered and undisturbed position, over so wide an area, is a sufficient explanation of the character of the same rocks when metamorphosed, without supposing that the magnesian character was the result of this process. Since the age of these slates has been well determined, the chemical examination of their unaltered equivalents becomes a matter of much interest, and chemistry can hardly render a greater service to geology than by furnishing the results of accurate analyses of these metamorphosed rocks and of the same rocks where they have not undergone this change.

UPPER SILURIAN LIMESTONES.

Greenish Limestone of the Clinton group, from east side of Green Bay. — This is an argillaceous, compact limestone, and may be taken as a fair representation of the greenish limestone of the Clinton group. It contains considerable water, like all the argillaceous limestones.

1.5584 grammes of the substance, which had been carefully ignited and afterwards treated with carbonate of ammonia, and heated gently, in order to restore any carbonic acid which might have been lost in the ignition, lost .4651 carbonic acid; left .4380 insoluble silicate of alumina and iron; gave .0267 peroxide of iron; .033 alumina; .6106 carbonate of lime; .6750 sulphate of magnesia, and .0159 magnesia separated afterwards from the chloride of sodium; .0159 chloride of sodium; and traces of chlorine, manganese and sulphuric acid, not determined.

Ignited Substance.

Insoluble	28.10
Protoxide of iron	1.54
Alumina	2.12
Lime	21.55
Magnesia	15.49
Soda	1.02
Carbonic acid	29.84
Chlorine and sulphuric acid	traces
	99.66

A separate determination gave 4.3 per cent. of water, on the substance dried at 110° C.

The insoluble portion consists principally of silica and alumina.

Limestone of the Niagara group from the bluffs on east side of Big Bay des Noquets. — This is a compact variety, in which the fossils appear to have been obliterated, as only occasional, faint traces of organic remains are seen in it; it breaks with a conchoidal fracture, and is of a light-greyish color.

1.4145 grammes lost .6245 carbonic acid; left undissolved .0607 of silicious and argillaceous residuum; gave .7313 carbonate of lime.

Another specimen gave on 1.543 grammes, .6762 carbonic acid; .0603 insoluble silicate; .0038 peroxide of iron and alumina; .8132 carbonate of lime; .0065 chloride of sodium; and trace of sulphuric acid.

1.6984 grammes gave .0070 of chloride of silver, and left .0667 of insoluble silicates.

	I.	II.	III.
Insoluble	3.93	3.92	4.28
Protoxide of iron and alumina	.24	—	—
Lime	29.16	—	28.43
Magnesia	20.66	—	—
Soda	.23	—	—
Chlorine	—	.12	—
Sulphuric acid	trace	—	—
Carbonic acid	44.11	—	44.15
Water (by loss)	1.67	—	—
	100.00		

Limestone of the Pentamerus beds of the Niagara group—from south side of Sturgeon Bay.—This is a highly crystalline rock, filled with casts of a species of Pentamerus. The interior of the casts is lined with crystals of brown-spar, while the rock itself, as the analysis shows, is a pure dolomite.

1.1964 grammes, dissolved in hydrochloric acid, left .0068 residuum; gave no precipitate by ammonia, or, at most, barely a trace of iron: gave .6481 of carbonate of lime, = 54.17 per cent.: gave .7080 phosphate of magnesia, = .5311 carbonate of magnesia, = 44.39 per cent.

Carbonate of lime	54.17
Carbonate of magnesia	44.39
Silicious residuum	.57
Water, soda, chlorine and loss	.87
	100.00

This is nearly a pure dolomite, as will be seen on comparing it with the theoretical composition of that substance, which is:

Carbonate of lime	54.3
Carbonate of magnesia	45.7
	100.00

Limestone of the Onondaga salt group, from the island of Mackinac.—The specimen of this limestone, which was analyzed, was of light-brownish color, quite compact in its texture, with but a very slight trace of a crystalline structure. It consists principally of carbonate of lime, with a small amount of silica, and less than half a per cent. of iron and alumina.

1.038 grammes dried at 100° C, lost .430 carbonic acid; left .0587 insoluble, chiefly silica; gave .0032 of alumina and peroxide of iron; .9063 carbonate of lime; and .0857 phosphate of magnesia.

Silicious substance	5.65
Alumina and iron	.31
Lime	48.88
Magnesia	3.03
Carbonic acid	41.42
Chloride of sodium and sulphuric acid	traces
Water and loss	.71
	100.00

This rock is burned into lime on the island, and furnishes a very good article. It contains much less magnesia than any of the other Silurian limestones, affording, in that respect, a marked contrast to the Niagara group, which it overlies, and which is so abundantly displayed on the main land and the adjacent islands. The quantity of silicious matter in the rock is not by any means large, though more considerable than is usual in the Niagara limestones.

CRYSTALLINE LIMESTONE OF THE AZOIC SERIES.

Flesh-colored Marble from the Vicinity of Carp River, Township 48, *Range* 26, *Section* 35.—In this connection we introduce an analysis of a limestone from the azoic series, to afford an opportunity of making a comparison between the composition of the marbles of this series and the limestones of the Silurian period.

This is a compact, highly crystalline marble, and, from its position with regard to the deposits of iron, and the settlements in its vicinity, is of considerable importance. It is a highly magnesian limestone, containing almost forty per cent. of carbonate of magnesia.

2.0675 grammes gave .3005 insoluble silicious substance; .007 peroxide of iron, = .0063 protoxide; .954 carbonate of lime; .1665 phosphate or magnesia, and a trace of manganese.

Silicious substance	14.53
Carbonate of iron and manganese	.49
Carbonate of lime	46.14
Carbonate of magnesia	38.01
Water and trace of chlorine and sulphuric acid	.83
	100.00

All the saccharoidal marbles accompanying the rocks of the azoic series resemble each other in external characters, and, probably, have a chemical composition similar to that given above. They are, when polished, highly ornamental, being variegated with flesh and buff-colored bands and patches.

General Remarks — Theory of Dolomitization. — From the above series of analyses, it will be seen that nearly all the Silurian limestones contain considerable magnesia. The limestone of the Pentamerus beds of the Niagara group is almost a pure dolomite. This is an interesting fact, as it shows the existence of heavy, stratified deposits of this substance, in a position where there is no reason to suppose that any change could have taken place in them, after their deposition, from the action of *igneous* causes, since they are far removed from any rocks of any other than a sedimentary character. They extend, with great similarity of external characters, through the whole of our district, from the St. Mary's to Green Bay, and are developed to a very great thickness. They are white, and highly crystalline, and abound in casts of the Pentamerus, the interior of the casts being generally lined with crystals of dolomite. There are only two theories which can be admitted with regard to the formation of these beds; either, that they were deposited originally in their present form; or, that they were originally deposited in the same manner, and with a similar composition to the beds above and below, and have since been metamorphosed and converted into dolomite, by *hydro-chemical* agencies; in other words, the metamorphic action must have been of an aqueous, and not of an igneous, character. Although the possibility of the original deposition of dolomite from an aqueous solution has been denied, and is still, by some geologists, the large majority are disposed to admit the Neptunian origin of dolomite strata, at least in some instances.

Numerous are the theories which have been put forth as furnishing a probable idea of the chemical action, by which the originally deposited carbonate of lime might have been converted into dolomite. That of Haidinger, which has excited considerable attention, and which has been insisted on by Morlot, takes for its starting point the frequent occurrence together of gypsum and dolomite, and maintains that the change was brought about by the agency of a solution of sulphate of magnesia, at a great depth and under pressure. According to this theory, one atom of carbonate of magnesia was formed, by the mutual action of the solution of sulphate of magnesia and the carbonate of lime, which united with another atom of the latter, forming dolomite; while the sulphate of lime, formed at the same time, was removed. This reaction, though exactly the reverse of what actually takes place, under common circumstances of pressure and temperature, has been supposed to be upheld by some experiments of Morlot, at a high temperature and under a pressure of fifteen atmospheres, though the result was only partially favorable; for, although by the double action, sulphate of lime and carbonate of magnesia were formed, yet it remained uncertain whether any combination took place between the latter and the carbonate of lime, so as really to form dolomite.

If this theory be the correct solution of the formation of dolomite, we should expect to find some traces remaining in these dolomitic beds of the sulphate of lime, which must have been formed at the same time with the dolomite. We were unable, however, to find any deposits of gypsum in the Pentamerus beds, and are disposed to regard this as a difficulty in the way of adopting this theory, which would require the formation and subsequent removal of such an enormous amount of sulphate of lime.

If we consider the very large amount of magnesia present in some of the shales, which have evidently undergone no change since their deposition, since the fossils entombed in them remain in a perfect state, and do not exhibit any marks of metamorphic action, we must allow the possibility of the original formation, under circumstances not hostile to animal life, of a highly magnesian deposit. The shales of the Hudson-river group, which are filled to repletion with organic remains, in perfect preservation, contain, after subtracting the silicious and aluminous portion, almost a sufficient per centage of carbonate of magnesia to form a dolomite; the same is true of the shaly beds of the Clinton group; but these strata are highly impure, since they contain from thirty to forty per cent. of insoluble residuum, and are, of course, destitute of a crystalline structure.

We may conceive that the production of these marly beds involved a two-fold action in their deposition. In the first place, a mechanical action was introducing into the great basin, in which the deposition was going on, a supply of finely-comminuted, argillaceous materials, or mud, which was gradually sinking to the bottom; while, on the other hand, a chemical action was separating from the solution a mixture of the carbonates of lime and magnesia. If the quantity of the carbonates was in the proper relative proportion, a true dolomite would be formed, if not a dolomitic limestone. In the process of formation of the Pentamerus beds of the Niagara group, the action was almost purely a chemical one, since the quantity of matter introduced by mechanical causes, is hardly more than a half of one per cent. Hence, we can easily conceive of the exertion of a force by which the whole mass was made to acquire a crystalline structure—an arrangement of the particles of the rock which may have been contemporaneous with its deposition, or posterior, and dependent on some change in the causes acting externally at the time.

We see from the above analyses that all the Silurian limestones of our district contain a small amount of soda, chlorine, and sulphuric acid. The quantity of soda is generally sufficient to be weighed, amounting, sometimes, to one or two-tenths of a per cent. This soda is probably present mostly as a carbonate, since the quantity of chlorine is too small to take it all up, in forming chloride of sodium. The sulphuric acid may, probably, be combined with the magnesia. Distinct traces of these salts may be obtained by digesting these limestones, after they have been pulverized, with pure, distilled water.

In regard to the occurrence of these substances in the limestones and shales of our district, Mr. Hall's manuscript furnishes the following remarks:

"It is an important geological fact, that all of these limestones contain a small proportion of soda, chlorine, and sulphuric acid. The source of these substances was undoubtedly the water of the ocean, from which the rocky strata were originally thrown down; and we are enabled to trace throughout the strata of this long period, from the earliest Silurian, to the dawn of the Devonian series, the existence of these substances; and, notwithstanding the influence of the weather to which the edges of the strata have been exposed, an appreciable quantity yet remains undissolved.

We are aware of the production of sulphate of magnesia, by the slow decomposition of many of the shaly rocks, in situations sheltered from the weather; and, also, in a few instances, of the production of carbonate of soda. Salt springs, or licks, occur abundantly in many geological groups, and their origin is, doubtless, to be sought in the decomposition of the rocky strata. In certain situations, or from other causes than the chemical composition of the deposited mass, a larger portion of the saline matter has been included in the rock, whose dissolution gives rise to salines, or brine springs, of great economical value. The earliest group in which, at this time, they are known to occur, is that known as the Medina sandstone, while in the Onondaga salt group, we have them in greater purity and far more copious, thus indicating a larger proportion of saline ingredients in the strata.

In attempting to account for the presence of sulphuric acid in the strata, we may reasonably suppose that, in some instances, the decomposition of animal remains has given rise to the sulphur, while its existence in the waters of the ancient ocean, even before the advent of animal life, may, also, have been one of the sources from which it was derived."

ECONOMICAL APPLICATION OF THE LIMESTONES.

For Calcination into Lime.—That portion of the district which was especially the subject of Part I. of this report, is, for the most part, destitute of the materials for making quick-lime. The only locality which may be said to be at all near to the copper region, is that described by us in Part I., page 117. This limestone is highly magnesian, but quite free from silicious matter, and would furnish good lime. It will, however, for a long time, at least, be more convenient to bring lime from the islands and vicinity of the St. Mary's river, where the limestones are directly on the waters' edge, than to construct a road of ten or twelve miles in length, to the deposit west of L'Anse. For want of a better material, the mining companies on Keweenaw Point have occasionally resorted to the somewhat expensive method of mining the veins of calc-spar in the conglomerate, for the purpose of getting a material to calcine into lime. One or two instances have come to our knowledge, where they have even had recourse to picking up the limestone pebbles on the lake-beaches, for this purpose. It is evident that, when once a canal has been built around the falls at the Saut, it will be much less expensive than it now is to procure lime from the kilns of the St. Mary's river.

Throughout the whole of the district which borders on the St. Mary's river and Lakes Huron and Michigan, there is an abundance of limestone suitable for calcination. The Niagara limestone is that which is most commonly exposed on the lake-shore, and which has hitherto furnished the principal part of the lime used in that region. Kilns exist on Lime island, at the Detour, and at other places. The above analyses of the limestone of the Pentamerus beds of this group, show that they consist of an almost chemically pure dolomite, well adapted to burning into lime. The magnesia is not detrimental to the mortar, but displaces a portion of the sand which would be required, were the material used a chemically pure carbonate of lime. The coralline beds of this group, when not silicious — and this is the case with the upper part of the group—furnish lime of an excellent quality. Large quantities might be furnished, at numerous points, along the lake-shore.

Hydraulic Cement.— Many of the lower, thin-bedded portions of the Clinton group are well adapted to making hydraulic cement; and, whenever there shall exist a demand for this substance in this region, it may be procured here in unlimited quantity.

Building Materials.— The value of the limestones of the Niagara group for the purposes of construction, has been tested throughout western New York and Canada West. The locks and other structures on the western part of the Erie and Welland canals are good examples of the durability of this limestone, and its adaptation to such works.

It has been determined by careful experiments, made in England, especially with a view to the selection of the material for the new houses of Parliament, that those limestones are most durable, and best in every respect, in which the lime and magnesia exist in the proportion required to form a proper dolomite. This is the case with a large part of the beds of the Niagara group in this district, and, hence, we should conclude that they would furnish a durable building stone. They also contain but a very minute portion of soluble salts, or of protoxide of iron, which are generally allowed to be detrimental to the durability and beauty of a material intended for architectural purposes.

A large portion of the lower limestones, especially of the Trenton group, will also be found available for the same purposes. The limestone of this group, at the mouth of the Escanaba, may be instanced as a good locality for a durable building material.

ORES AND OTHER SUBSTANCES OF ECONOMICAL VALUE.

Traces of copper are not unfrequent in the sandstone, even at a distance from the trappean belts; but there is no reason to suppose that there are any metallic veins of any value, either in the sandstones or limestones of the palæozoic series in our district.

With regard to the occurrence of ores of lead and other metals, in the southern portion of the district, Mr. Whittlesey makes the following remarks:

"From the general belief which prevails among those residing on the shores of Green Bay, and the numerous rumors afloat respecting the existence of lead, copper and silver, an explorer in that quarter would be led to indulge in high hopes of success.

Many of the supposed metals, on inquiry, are found to exist only in the stories of Indians, who are fond of telling marvellous things, and ever ready to feed the credulity of the whites. There are, however, well-authenticated cases of the occurrence of lead, copper, and silver; but these have, for the most part, been traced directly to the drift. As it is now settled that the force, whatever it was, which denuded the country and transported the blocks of rocks and the beds of sand and clay, acted from the north towards the south, it follows, that the ores which exist at the north would be found in the detritus at the south. Blocks of native copper, according to Mr. Lapham, have been found in Wisconsin as far south as Milwaukee and Racine; and, according to Mr. Bela Hubbard, as far south as the county of Berrien, in the state of Michigan. We saw almost every mile along the northern shore of Lake Michigan, fine illustrations of this transporting power, in the rolled pieces of magnetic and specular iron ore scattered along the beach, from Drummond's island to Green Bay. They varied in weight from a few grains to two or three hundred pounds.

The Galena limestone in Wisconsin and Iowa is richly impregnated with lead. The reported occurrence of this metal in the sandstone of the Oconto and Peshetego rivers is undoubtedly true, as it occurs, under similar conditions, farther west; but not in such quantities as to give encouragement to mining enterprise. It exists, also, in some of the Silurian groups which form the coast of Lake Michigan, from Great Bay des Noquets to Seul Choix. The same rocks appear on the west shore of the lake, and on the east coast of Green Bay; and, according to Mr. Lapham, in their south-westerly extension, connect in the valley of Rock river with the true lead-bearing rocks of Wisconsin and Iowa. East of Rock river, they have not as yet been found to contain any productive veins. They lack that frequency, openness and regularity of fissure which seem essential to valuable deposits.

Fragments of lead may also have been distributed over portions of the north-west by means of the Indians; for, it is well known that they were in the habit of resorting to the mines and procuring specimens for traffic, long before the whites took possession of the country. I have seen specimens a few inches in diameter, perfectly angular, three hundred miles from the parent source, which were thus distributed by the agency of the red man. Float mineral, or that dispersed by the drift, is invariably rolled and water-worn. Its presence is to be regarded merely as an inducement to search, and not as conclusive evidence that the parent bed exists in the vicinity."

Gypsum.—Below the limestone of Mackinac, as observed by Mr. Whittlesey, there is a marly bed about fifty feet in thickness which contains gypsum. It is generally of a brown cast, with spots of white; and, no doubt, exists in large quantities. The northern out-crop of this bed is not very broad, and would be represented on the map by a curved line from St. Martin's island, extending back from St. Ignace and Gros Cap and intersecting the lake at Pointe aux Chênes. It does not everywhere contain gypsum, but incloses this mineral in the form of nests, or irregular patches.

It has been quarried at Pointe aux Chênes. In the shoal water around St. Martin's island, when the lake is low and tranquil, it may be picked up in blocks of fifty or sixty pounds weight. Much of it is impure, being more or less mixed with carbonate of lime.

If a search were to be made for workable beds, the best mode would be to find the marly stratum, where it emerges from the lower surface of the brecciated limestone, and there bore through it, examining the borings with care for gypsum. As this substance may not be readily recognized in a pulverized state, by the ordinary observer, we give the most obvious tests: On the application of sulphuric, or nitric acid, no effervescence takes place; whereas, with carbonate of lime, it does. When exposed on red-hot coals, it decrepitates, becomes white and splits into brittle plates. At a temperature of about 400° F., the water of combination escapes, attended with ebullition.

The presence of ten or twelve per cent. of carbonate of lime improves its quality. Used as a mortar, it becomes more adhesive, and stucco work, executed in this manner becomes firmer and more durable.

Geologically, the position of this gypsum corresponds with that of Sandusky Bay, Ohio, and that of Grand river, Canada.

CHAPTER XIII.

DESCRIPTION OF NEW, OR RARE SPECIES OF FOSSILS, FROM THE PALÆOZOIC SERIES.

BY JAMES HALL.

Marine Fossils from the Potsdam and Calciferous Sandstone.—From the Chazy, Birds-eye, and Black-river Limestones, and the Hudson-river Group.—From the Clinton Group.—From the Niagara Group.—From the Upper Helderberg Series.—List of Organic Remains.—General Remarks.

POTSDAM AND CALCIFEROUS SANDSTONES.

This sandstone on Lake Superior, so far as we have been able to observe, is generally destitute of fossils. It is true, the incoherent character of much of this rock, along the southern shore, would, in some degree, prevent the recognition of the small shells of the Lingula, which is the prevailing fossil of the same formation in other regions.

In 1845, Mr. Forrest Shepherd brought from Tequamenon Bay, two specimens of sandstone containing Lingulæ. The rock was composed of rounded grains of quartz, cemented by calcareous matter, having the appearance of öolite, and corresponding, in general appearance, with the upper part of the Potsdam, in other localities. In a small fragment were parts of five separate valves of Lingula, two of them nearly entire. The form of the entire shell is round-obovate, and more elongated in proportion to its breadth than the ordinary specimens of *L. prima* from the same sandstone in New York. Nevertheless, I am not prepared to describe it as a distinct species. A careful comparison of specimens shows that the shell is very variable in the proportions of length and breadth.

A comparison of these specimens from Tequamenon Bay, with the round forms from the St. Croix, shows such a close similarity, that I have little hesitation in regarding it as the same species. A careful measurement of a number of forms shows that the proportion between length and breadth is very varying; in some cases the length is equal to the breadth; in others one-fourth to one-third greater. Externally, the shell shows distinct, concentric striæ, and, sometimes, faint, longitudinal striæ; the latter becoming more distinct in the cast, or where the external shell has exfoliated; and, in some instances, they are very prominent. This is decidedly a variable character, both as shown on the casts, and upon the interior of the shell; the former often appearing quite smooth, perhaps from accidental causes.

Specimens from the Escanaba river, in the lower part of the calciferous sandstone, resemble, in all of their important characters, those from Tequamenon Bay. From the comparison of specimens, I am inclined to unite all these in one species, which, in its wide distribution, and in more or less favorable situations, has undergone considerable changes; but showing its most perfect development in the calcareous beds on the St. Croix river, which are crowded with the valves of this species, and another so closely resembling the *L. antiqua*, that I have not found characters to warrant the separation.

From the number of individuals occurring in the small fragment, from Tequamenon Bay, it is evident that, at that point, the rock was highly charged with these forms of organic life. These were not generally distributed, but restricted to particular layers of greater or less vertical range.

In the almost purely quartzose beds, as for instance, in New York, it is difficult to ascertain their true form, or proportions; but, as the beds become more calcareous, the shells acquire greater dimensions, and are far better preserved, both in their outlines and their external markings.

Lingula prima.

Plate XXIII., figure 1, *a, b, c, d, e, f, g*.

Lingula prima Conrad, Palæont. N. Y. Vol. I. p. 3, Plate I., figure 2.

Shell round, or roundish, obovate; beak obtuse; umbo elevated; base rounded, or sub-truncate; surface marked by close concentric striæ, and, at wider intervals, with more prominent lines of growth; longitudinal striæ more or less distinct, often scarcely visible on the exterior of the shell; muscular impression.

The form of the shell is often altered by the sides being more or less rounded, and sometimes nearly straight, from the broad base to the obtuse beak. In many instances in the New York specimens, the longitudinal striæ are more prominent than the concentric ones; but, in a larger number of specimens, procured since my description of the New York specimens was written, I find this character extremely variable, and, in some of them, scarcely visible.

Some of the illustrations in Plate XXIII. are drawn from specimens collected by myself on the St. Croix river. These, together with those previously given, will enable the collector to form a correct opinion of the characters of this widely-distributed species in the oldest fossiliferous rock.

Fig. 1. *a*, **Specimen from Tequamenon Bay, form, obovate.**

Fig. 1. *b*, **Specimen from the Escanāba river, having a form similar to that from Tequamenen Bay.**

Fig. 1. *c, d*, **Similar forms from the St. Croix river.**

Fig. 1. *e*, **Ather form of this species.**

Fig. 1. *f, g*, **Muscular impressions on two valves.**

Lingula antiqua.

Plate XXIII., figure 2, *a, b, c*.

Lingula antiqua Hall, Palæont. N. Y. Vol. I. p. 3, Plate I., figure 3, *a, c*.

The specimens from the Potsdam sandstone in the North-west, when compared with those from New York, prove so similar to this species, that I can only regard it as the same, but developed under more favorable cir-

Plate XXIII

POTSDAM SANDSTONE

Ackerman Lith.379 Broadway NY

cumstances. The great number of well-preserved specimens enables us to indicate its character and form, more fully than the imperfect specimens described in the New York Palæontology. The absence of longitudinal striæ, in the specimens described, is owing to the imperfection of the specimens; but there are other specimens from New York which exhibit this character in as marked a degree as those from the North-west. In many of the latter, the width, at the base, is proportionally greater than in those of New York, and, in the same individuals, the beak is proportionally more extended. We have, thus far, comparatively few specimens from New York, and, until we possess more extensive collections, the proper comparisons for determining the question can scarcely be made.

Fig. 2. *a*, *b*, *c*, Different individuals, showing a variety of forms.

In connection with the Lingulæ on the Escanaba river, I collected a number of obscurely pointed, triangular bodies, like those described in the Palæontology of New York as *Thecæ?* They are, however, too indefinite to be described with any advantage at the present time.

TRILOBITES OF THE POTSDAM SANDSTONE.

In the Lake Superior district, the only fossils seen in the Potsdam sandstone, in addition to those just described, are the fragments of one or more species of Trilobites, which were found on the Menomonee river. These have the characters of the *Ogygia*, or *Brontes*; but those in the possession of the survey, are too imperfect to admit of a satisfactory determination. A farther examination of the prolongation of this sandstone across the interval between Lake Michigan and the Mississippi and St. Croix rivers, has resulted in satisfying us that the sandstones of the two termini are identical in age, and the Trilobites specifically the same.

These facts increase the interest of these specimens, and suggest the hope that we may yet find Crustaceans in more eastern localities.*

With the above suggestions, as to the relations of the genus figured, I adopt the name proposed by Dr. Owen, presuming that the specimens collected by him warrant the establishment of a new genus.

DIKELLACEPHALUS, D. D. Owen.

Plate XXIII., fig. 3, *a*, *b*, *c*, *d*, *e*, and fig. 4.

The fragments in our possession do not admit of a complete description

* I have recently received from Professor Adams, of Amherst, specimens of partially metamorphosed sandstone from Salisbury, Vt., which he regards as the equivalent of the Potsdam. The specimens have all of the characters of the purely quartzose variety of this rock, and contain fragments of crinoidal columns, and casts of an acephalous bivalve, similar to Modiolopsis.

Such facts are highly interesting, and promise important results for the future. Since, however, no known fossils of the Potsdam sandstone occur with those just mentioned, it requires a careful scrutiny to determine the age of the rock *in situ*.

of this fossil. The cheeks are projected posteriorly into long spines. In one fragment, a line, which may have been the facial suture, reaches to the margin just within the angle. The spines are long, gradually curving and becoming round towards the extremity. The surface is marked by strong elevated striæ; caudal shield semicircular, the axis prominent and obtusely conical, extending about two-thirds the length, marked by five distinct rings: in the cast, there may have been six or seven in the outer-crust; lateral lobe, with seven ridges, four of which may be called bifurcations of the second and third, which are simple in their origin; margin flat, or depressed just within the margin.

The margin is broken off, and its original extent not precisely defined: some faint remains of striæ are preserved; but, from the friable nature of the rock, it is impossible to determine the character.

It is very apparent that there is a degree of similarity between the tail of this species and the *Ogygia Portlockii;* but the difference is quite specific, and the cheek-shields present few points of resemblance.

The glabella figured on the same plate, fig. 4, is from the Mississippi; and though the identity cannot be positively determined from this fragment, yet the fragments of cheek-shields found with it are undistinguishable from our specimens. From an examination of these and other similar fragments, I have been inclined to refer the species to *Ogygia.*

Fig. 3, *a*, *b*, *c*, Fragments of the cheek and the prolonged spine.
Fig. 3, *d*, A fragment of one of the pleura, showing a groove nearly the entire length.
Fig. 3, *e*, The tail of this species.
Fig. 4. A glabella, probably of the same species, from the Mississippi river.

Locality.— On the Menomonee river, above the Grand Rapids, in the Potsdam sandstone.

Fossils from the Chazy, Birds-eye, Black River, and Trenton Limestones and Hudson-river Group.

The following are among the undescribed and little-known species, collected from these groups; but principally from the two latter.

Phenopora multipora.

Plate XXIV., figure 1, *a*, *b*.

Frond broad, irregularly ramose; branches not numerous, broad, flat and thin; surface marked by numerous parallel or slightly diverging rows of minute, roundish oval pores; each row of pores separated by a distinct, elevated line, in a direction parallel to the axis of the stripe or branch, and diverging at the bifurcation. Pores, fifteen in the eighth of an inch transversely, and eleven or twelve in the same space longitudinally. Width of stripe, one-half to three-fourths of an inch.

The character of surface in this species is much like *Stictopora;* but it differs from the type of that genus, in wanting the non-poriferous, striated

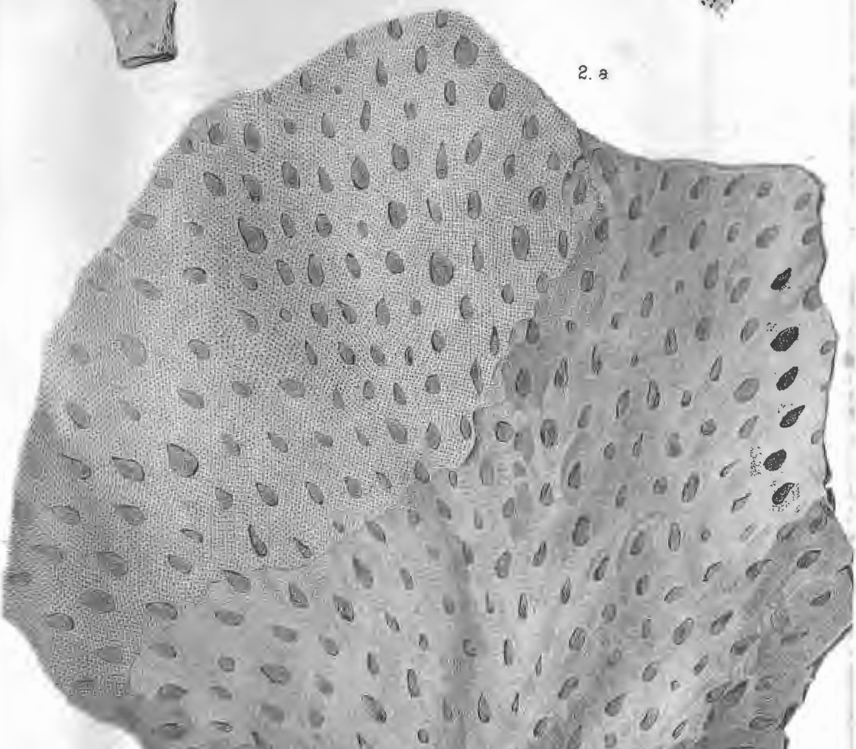
TRENTON LIMESTONE.

I.

1 b

2 b

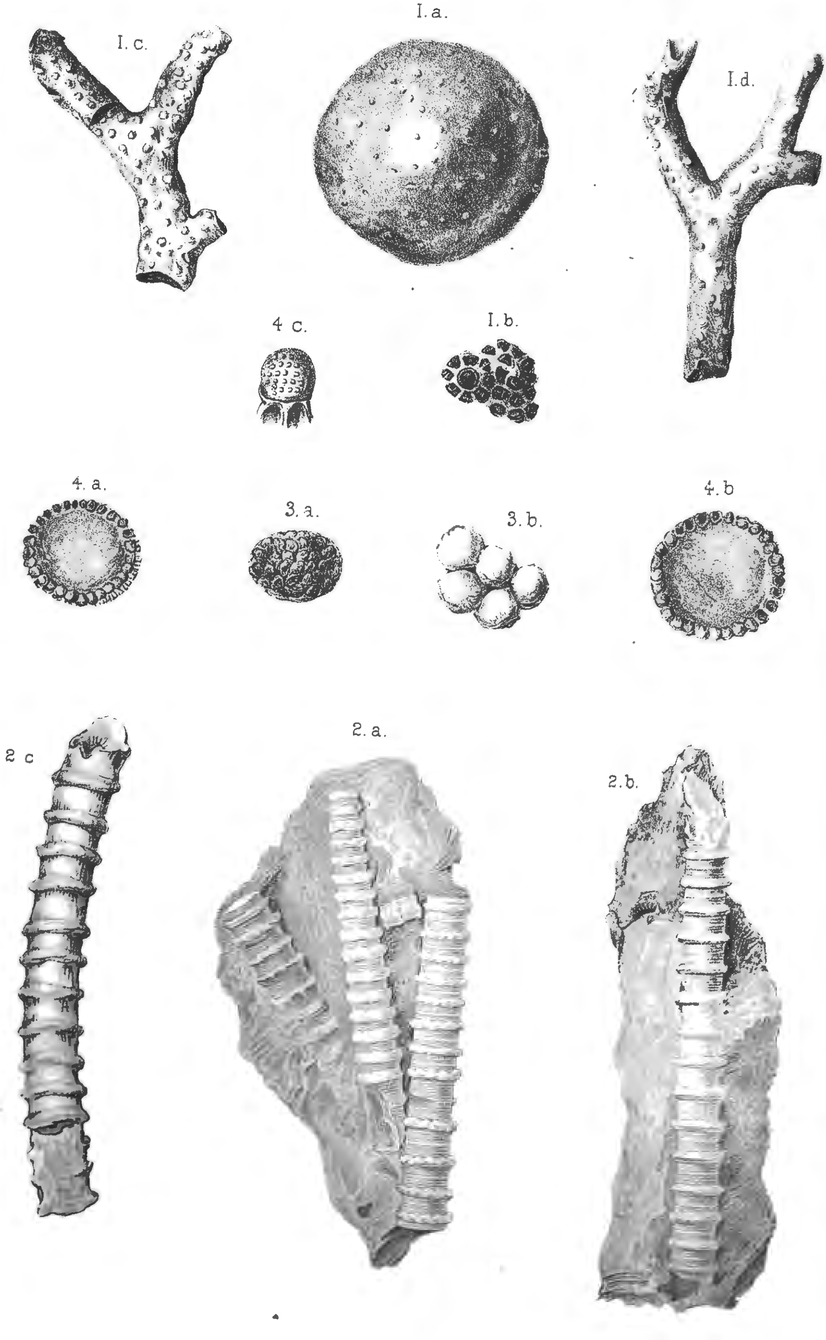
2. a



Ackerman Lith, 379 Broadway N.Y.

TRENTON LIMESTONE.

Plate. XXV.



Ackerman Lith 379 Broadway N.Y.

edges, and in the pores being arranged between longitudinal, elevated lines, which characters belong to a group separated under the above name.—*Palæontology of New York, vol.* 2, *p.* 46.

Fig. 1. *a*, Fragment of a specimen of this species.
Fig. 1. *b*, An enlargement of the surface.

Locality.—Banks of the Escanāba river, below Indian creek, in the Trenton limestone.

Clathropora flabellata. nov. sp.

Plate XXIV., figure 2, *a*, *b*.

Clathropora, Palæont. of N. Y., vol. II., p. 159.

Frond expanded, flabellate, somewhat plicate towards the base; perforated by numerous roundish, or oval openings of variable size; cells minute, rhomboid-oval, arranged between obliquely ascending lines or laminæ; axis concentrically striated and corrugated around the perforations.

This species bears a very near resemblance to *C. frondosa* of the Niagara group. In that one, however, the frond appears to be thicker, and the perforations smaller and more irregular. The cells in the present species are more oval, or elongated than in the Niagara species. The similarity of the two, however, is very striking, and requires a careful examination to distinguish between them.

Fig. 2. *a*, An individual nearly entire, showing the form from near the root to the margin on the upper left-hand side.
Fsg. 2. *b*, An enlargement of the surface.

Locality.—Banks of the Escanāba river below Indian creek, in the Trenton limestone.

Chætetes lycoperdon.

Plate XXV., figure 1, *a*, *b*, *c*, *d*.

Chætetes lycoperdon Say, Palæont. N. Y., Vol. I. p. 64, plate 23, figures 1, 2, 3.

I have heretofore described this species as occurring in hemispheric an ramose forms; the former, in many instances, graduating into the latter by the projection of branches from a solid, or spheroidal mass. It is possible that there are other minute branching corals often confounded with this species, since it requires a careful examination to distinguish them. All of the New York species, whether hemispherical or ramose, are smooth; but at the West and North-west, both forms become nodose, or have the surface covered with little stellate elevations. One of these has been described as a distinct species, and it may prove that there are several, since there is a considerable variety of surface presented. Under an ordinary magnifier, however, the cells all appear alike, and I have not yet been able to distinguish the different species by this means.

On the Escanaba river, where I observed a greater number of these corals than at any other locality in ths district, a large majority of the specimens, both hemispheric and ramose, have a nodose or stellate surface. This character is so remarkable as to deserve notice, since it appears to be peculiar to western localities.

Fig. 1. *a*, A small, hemispheric specimen of the natural size.

Fig. 1. *b*, A portion of the surface enlarged, showing some of the elevations to be solid, or pierced only by the cells, while others consist of elevated borders around a large cell.

Fig. 1. *c*, *d*, Two fragments of branching forms, the surface presenting the nodose character in different degrees.

Locality.—Banks of the Escanaba river, two miles below the mouth of the Indian creek.

Schizocrinus nodosus?

Plate XXV., figure 2, *a*, *b*, *c*.

Schizocrinus nodosus, Palæont. N. Y. Vol. I. p. 81, Plate 26.

The columns of this species are very abundant on the Escanaba river, and attain a much larger size than those of the same rock in New York, and other eastern localities. The great number and large size of these fragments indicate a more favorable condition for the growth of these animals than at any other locality I have examined. Slabs of several feet in extent are often thickly covered with fragments, as represented in Fig. 2, *a*. Some of the fragments measured half an inch in diameter. Many of them, either from age, or from having been worn down, do not preserve the nodes upon the joints, but, in well-preserved specimens of medium size, they are always conspicuous. Since the columns, with or without nodes upon the larger rings, are indiscriminately mingled together, and since we have no evidence from other parts of the animal for distinction of species, I include them for the present under one head.

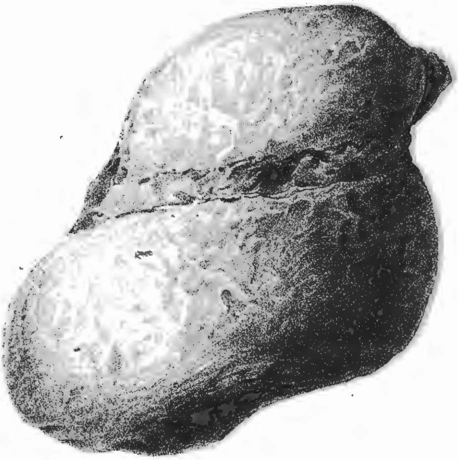
Locality.—The banks of the Escanaba river, two miles below the mouth of Indian creek.

Echinosphærites? nov. sp.

Plate XXV., figure 3, *a*, *b*.

The only specimen of this fossil obtained is a fragment less than half of the entire sphere. From the structure and arrangement of the plates, I

TRENTON LIMESTONE.



1.c.

1.a.

1.b?

have little hesitation in referring it to this genus. In the apparent form and size of the plates, it approaches *E. pomum,* but it is probably a distinct species which will require additional specimens for its full elucidation.

This is the first example, so far as I know, of the occurrence of this genus in our strata.* Whenever the region, where this was found, becomes more accessible to explorers, we may be able to present more complete illustrations of this and other species of the same family.

Locality.— Banks of the Escanāba river, two miles below the mouth of Indian creek.

Crinoideæ, or Cystideæ.

Genus ——— ?

Plate XXV., figure 4, *a, b, c.*

This body consists of a ring, or a sac, the upper edge of which only appears, composed of numerous plates joining by their broader edges. The upper, or exposed surface of the plates is sculptured, or granulated, convex, and not closely joined together at the upper angles, presenting the appearance of somewhat quadrangular tubercles; exterior margin of each plate furnished with a thin, wing-like expansion, marked by two diverging ridges.

This curious body is evidently crinoidean, from the character and structure of the plates. The ring presents an appearance very similar to the row of plates surrounding the valves which close the ovarian aperture in some Cystideans, but the number is far too great, being, in one specimen, twenty-nine, and apparently not less in the other. The inner faces of the plates, moreover, do not present any appearance, as if for the attachment of other plates, or valves. It is possible that it may be the elevated, marginal ring of some one of the sessile crinoids, though the arrangement of the plates is more regular than in any species known to me.

Fig. 4. *a, b,* Two individuals of this species, the one having the plates nearly one-third larger than the other.

Fig. 4. *c,* An enlargement of one of the plates.

Locality.— Banks of the Escanāba river, two miles below the mouth of Indian creek, in the Trenton limestone.

Murchisonia major. nov. sp.

Plate XXVI., figure 1, *a, b, c.*

Shell teretely conical; volutions about six; lower one ventricose; upper ones less prominent, and diminishing from near the base to the suture above.

The specimens are all casts, and the external makings are not preserved

* The numerous concavo-convex bodies found on the glades of Tennessee, and which, at first view, appear to belong to this genus, are different bodies, although I can refer them to no other than some organism of this class.

In its form, it resembles *M. bellicincta*, but the volutions ascend more rapidly and are not so ventricose. The shell attains a large size and is quite abundant.

Fig. 1. *a*, A specimen of medium size, nearly entire.
Fig. 1. *b*, A longitudinal section of a larger individual.
Fig. 1. *c*, The two lower volutions of a large individual

Locality.—Western shore of Green Bay, in Trenton limestone

Asaphus Barrandi. nov. sp.

Plate XXVII., figure 1. *a, b, c, d,* and plate XXVIII.

Broadly oval; length about once and a half the width, (length $5\frac{3}{4}$ inches breadth 4 inches); head semi-circular; the posterior angles prolonged into spines which reach backwards beyond the segments of the thorax, upper surface imbricate, striate; anterior and lateral margins with an elevated border; glabella clavate, broad and prominent towards the front, depressed at the neck and marked by two slight, sharp, transverse grooves, with a slight prominence in the centre, as shown in the cast, above the neck-furrow; eyes large, placed a little behind the middle of the head and close to the furrow separating the glabella from the cheeks; hypostome arched at the base and deeply crescentiform at the apex, each horn presenting a strong, elevated fold along the inner margin; anterior to the base of the horns, is a strong tubercle, and between and behind it, a depression; thorax composed of eight slightly-arched articulations; axis well-defined, and as broad in the upper part as the length of the pleuræ; pleuræ straight for about half their length, and from thence gradually bent downwards, furrowed from the base about two-thirds of their length; extremities broad and flat; tail, nearly semi-circular, being a little longer, but scarcely narrower than the head, (length $2\frac{1}{8}$ inches, width $3\frac{1}{16}$ inches); axis prominent, gradually narrowing, and terminating abruptly at the flattened margin a little less than three-fourths the entire length of the tail, marked by about fifteen ridges; the lateral lobes, marked with eight or nine furrows which extend in the upper part two-thirds, and in the lower part one half, of the width; the margin of the tail broad and concave; entire surface marked by elevated lines which ramify and inosculate in a beautiful manner.

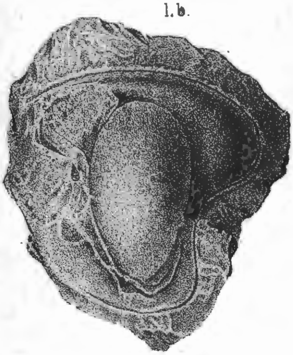
I have but a single tolerably perfect specimen, all the others being fragments. In the larger and nearly entire one, the upper part of the head has been removed, showing the lower plate with the hypostome attached and in its proper place, though the whole head appears to have slipped downwards so as partly to cover the first articulation. The impression of the posterior spine is shown extending backward as far as opposite the fourth articulation of the axis of the tail. The crust is, in a great degree, removed, and on what remains, the imbricating striæ are coarse and strong. In other specimens of smaller size, these striæ present the beautiful appearance described. The rings of the axis of the tail are obsoletely nodose, there still remaining the appearance of a double row of flattened nodes down the axis. The number of furrows in the axis of the tail appears to be as many in the

TRENTON LIMESTONE

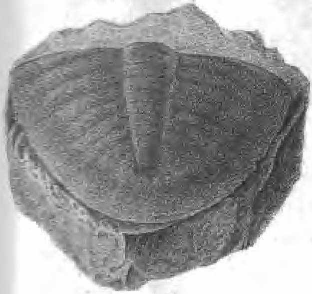
1.c.

1.a.

1.b.



1.d.



2. a.

3. a.

3. b.

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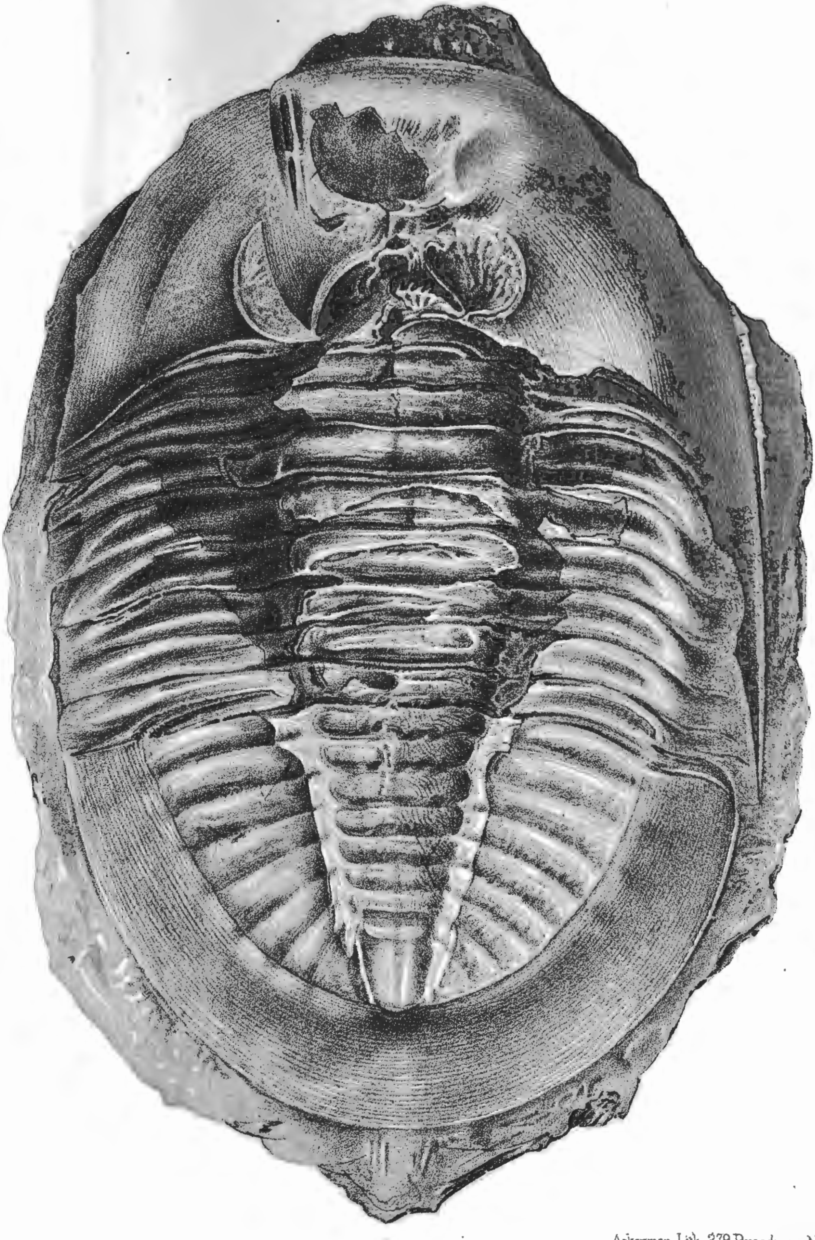
Plate XXVIII

TRENTON LIMESTONE



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smaller specimens as in the larger; and in the large one figured they are very obscure, from compression of the specimen and the removal of the crust. In young specimens the tail is very convex, but in all of the larger ones it is flattened. This difference, however, appears to be due to the character of the rock in which the latter are imbedded, while the small specimens, in the limestone, preserve their natural forms.

This species has considerable resemblance to *A. tyrannus* of Murchison, the most prominent differences being in the prolonged spines of the buckler, and the shorter and proportionally broader tail in one species. The pleuræ, also, arch downwards towards the extremities more than in the figures of *A. tyrannus*. The glabella is proportionally longer, and the form of the hypostome different, the horns at the extremity presenting a wider arch.

Figure 1. *a*, the glabella and part of the cheeks of a large specimen.

Figure 1. *b*, the glabella, showing the anterior raised margin, and the course of the facial suture from the eye forward.

Figure 1. *c*, the cheek shield of a large individual, showing the prolonged spine, which is imperfect at the extremity.

Figure 1. *d*, the tail of a small individual, very entire, and preserving the crust over a large part of the surface.

Plate XXVIII., a nearly entire individual of large size, the crust from the upper side of the head having been removed.

Geological Position.—I first noticed this species in the limestone of the age of the Birds-eye, on the St. Mary's river. Subsequently, I saw it in the same position near Plattsville, Wisconsin, at a locality shown me by the Rev. John S. Lewis. At the latter place it occurs in a limestone which holds the place of the Birds-eye, possessing many of its characters, as well as some of its peculiar fossils. It also occurs in some shaly or flaggy layers, associated with the thin stratum of limestone, and in them the finest specimens have been found. It is from a layer of this kind that the large specimen figured was obtained, by Mr. Pickard, of Plattsville. The lithological character of this layer is almost precisely the same as some specimens of Llandeilo flags, containing *Ogygia Buchii.*

HARPES ESCANABIÆ. nov. sp.

Plate XXVII., figure 2, *a*.

A single marginal plate, or shield, of the head of this fossil, is all that has fallen under my observation. The lower portion is exposed for about an inch on one side, and more than half as much on the other. It gradually diminishes in width from the front backwards, and is marked by rows of pores, the outer and inner of which are larger than the intermediate ones. The marginal rows of pores are regular and parallel to the margin; of the intermediate ones, there are three or four in front and one at the most posterior portion visible.

This portion of the fossil bears some resemblance to *H. Doranni*, of Portlock, but is, nevertheless, a distinct species.

Geological Position.— Trenton limestone, on the banks of the Escanaba river, below Indian creek. It is here associated with *Chætetes lycoperdon, Leptæna alternata, Orthis testudinaria, Phacops callicephalus, Ceraurus pleurexanthemus*, and many other fossils of this group. It is the first example, to my knowledge, of the occurrence of a species of this genus in the lower Silurian strata, and a genus hitherto unknown in this country, unless, as I suspect, the fossil figured and described by me as *Ceraurus? pustulosus* (Palæont., N. Y., Vol. I., page 246) prove to be a species of Harpes, the crust being removed, which gives the pustulose appearance. Should it prove to belong to this genus, it is still quite a distinct species from the one now described.

Phacops callicephalus.

Plate XXVII., figure 3, *a. b.*

Phacops callicephalus, Palæont., N. Y., Vol. I., p. 247.

This species occurs in considerable numbers in the Trenton limestone upon the Escanaba river. I have seen only the separated heads and tails, but these are in greater numbers, at this one locality, than all I have seen in the state of New York.

Fig. 3. *a*, The head of this Trilobite.
Fig. 3. *b*, The eye enlarged.

The individuals observed at this locality are smaller than those in the same limestone in New York. The same is true of the *Ceraurus pleurexanthemus*, which also occurs here. It is probable that the admixture of arenaceous matter, while it does not appear to have interfered with the production of species, has diminished their size. This fact is true of the *Crustacea* and *Mollusca*, while the crinoidal columns are of a larger size than at any other locality observed.

Catenipora gracilis. nov. sp.

Plate XXIX., figure 1, *a. b.*

Coral massive, or hemispheric; cells quadrangular, or sub-oval; walls thin; interspaces rarely thicker than the walls; arranged in a single series, in wide irregular reticulations.

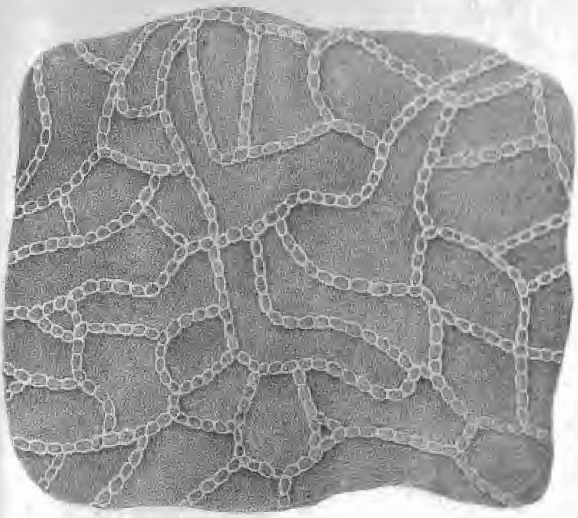
This species differs from the *C. escharoides* in the almost quadrangular form of the cells and the extremely thin walls, the reticulations are wider and the whole aspect less solid than in that species. From *C. agglomerata*, it differs essentially in the form and arrangement of the cells.

Fig. 1. *a*, A part of the surface, natural size.
Fig. 1. *b*, An enlarged portion.

Geological Position.—This species occurs in the green shales near the

HUDSON RIVER GROUP

1 a.



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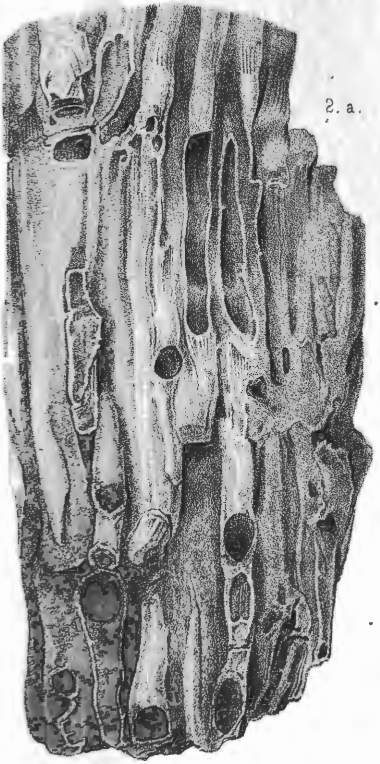

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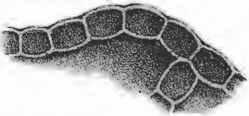

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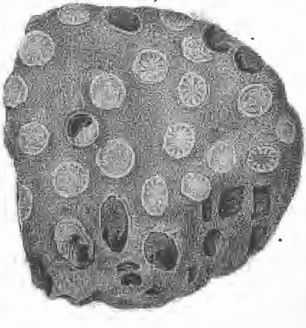

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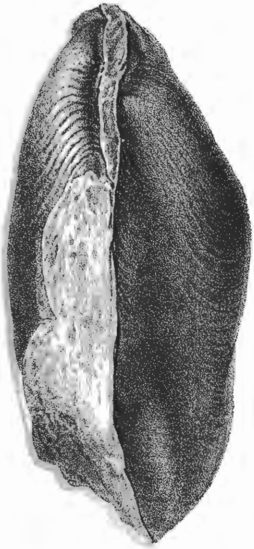
HUDSON RIVER GROUP.

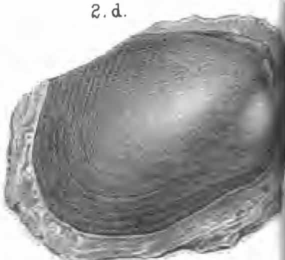
1.



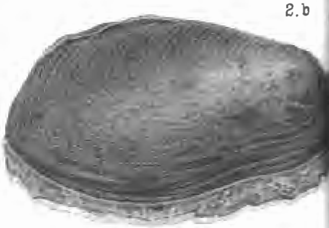
3.

2. a.

2. d.



2. b



2. c.

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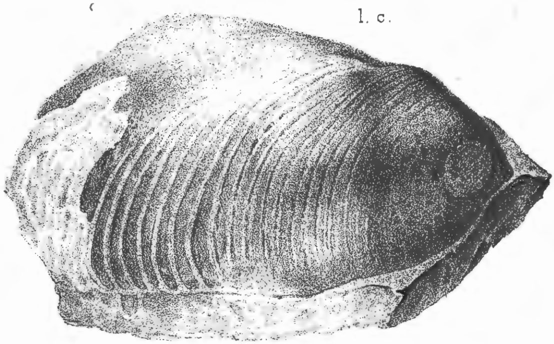
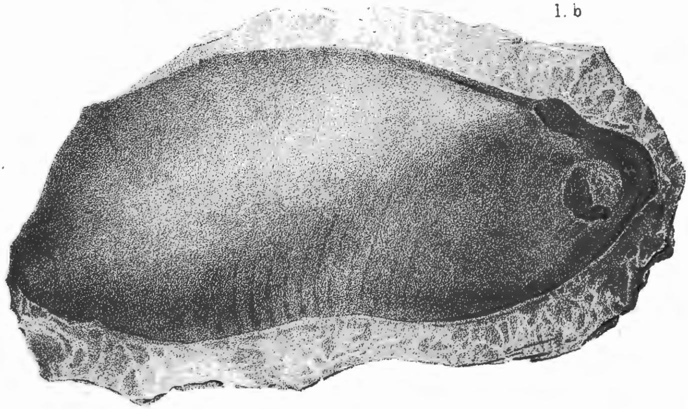
HUDSON RIVER GROUP

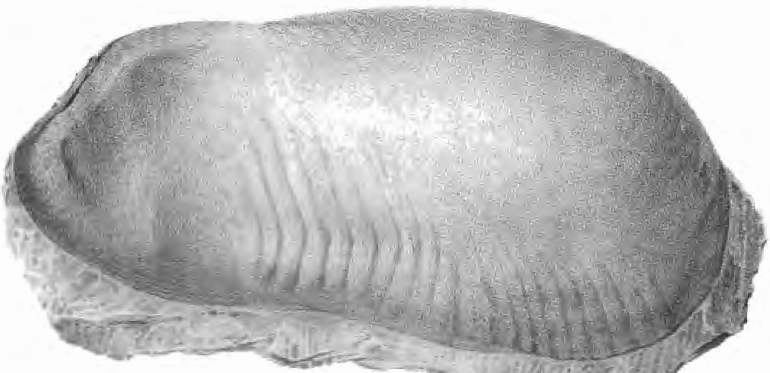
1. c.



1. b



1 a



Ackerman Lith

per part of the Hudson-river group, and, so far as I know, is the first te that a species of this genus has been found in the lower Silurian series.

Locality, eastern shore of Green Bay, Wisconsin.

Sarcinula? obsoleta. nov. sp.

Plate XXIX., figure 2, *a*, *b*.

Coral cespitose, composed of irregular, cylindrical stems, which are connected at intervals by lateral processes; internally rayed and with transverse septa; externally striated

The internal structure is obscure, since both the rays and septa have been removed and the interior is empty, or partially filled with crystalline matter.

This species occurs in immense numbers, forming, in some places, almost continuous beds.

Geological Position.—This species occurs in the shales in the upper part of the Hudson-river group, associated with *Catenipora gracilis*. It forms continuous layers on the eastern shore of Green Bay, above the entrance to Sturgeon Bay; also, on the west side of Big Bay des Noquets, where it has once formed a continuous stratum, in the same position.

This coral is of a type not observed by me in the lower Silurian series of New York, or elsewhere.

Being associated with the *Catenipora*, a genus heretofore known only in the upper Silurian series, the beds containing these fossils become of exceeding interest both to the geologist and the palæontologist, for it will be in such beds, if any, that he will trace a continuation, or passage, of organic beings from the lower to the upper divisions of the Silurian system.

Fig. 2. *a*, A longitudinal view of a group of these stems.
Fig. 2. *b*, A transverse section.

Locality, eastern shore of Green Bay and of Big Bay des Noquets

Modiolopsis pholadiformis. nov. sp.

Plate XXX., figure 1, *a*, *b*. *c*, and Plate XXXI., figure 1.

Shell oval-obovate, elongate; base slightly arcuate in the middle; convex in the middle and compressed towards the posterior extremity; umbones prominent, hinge-line slightly arched, and, in some specimens, nearly straight; muscular impression, large and strong, near the anterior extremity; surface marked by strong folds or ribs, which, originating on the hinge-line, diverge and curve gradually downward to the base.

All the specimens of this peculiar species, which I have examined, are more or less distorted, so that we may not be fully acquainted with the form. The peculiar surface-marking, however, is unmistakable, and in nearly all the specimens is preserved, in some degree, in the casts. There appears to be considerable difference in the size of these ribs in different specimens, and it is possible that we have among them two species, which, for the present, however, we prefer to regard as one. The form in many specimens is similar to that of *M. modiolaris*, but in the surface-markings, it is very distinct. In some specimens, however, from the same locality, which appear to belong to the *M. modiolaris*, I have observed concentric ribs similar to those in the species now described. In that species, however, they appear more arched, and confined to the region of the hinge-line, gradually losing themselves in the concentric striæ, and are quite obsolete towards the base. Nevertheless, we have never observed this feature in the New York specimens, and these western ones, thus marked, prove a distinct species.

Fig. 1. *a*, The left valve of a large individual.

Fig. 1. *b*, The right valve of a smaller individual, imperfect at the posterior extremity.

Fig. 1. *c*, The right valve of an imperfect specimen, with ridges more closely arranged.

Plate XXXI., Fig. 1. Cardinal view of the individual, fig. 1, *c*, of the preceding plate.

Geological Position and Locality.—This species occurs in the marly beds, constituting the higher portions of the Hudson-river group, on the eastern shore of Little Bay des Noquets. It is associated with *M. modiolaris* and *Ambonychia radiata*, with two or three species of Orthoceratites.

Modiolopsis modiolaris.

Plate XXXI., figure 2. *a, b, c, d.*

Modiolopsis modiolaris, Palæont. N. Y., Vol. I., p. 294.

The specimens figured present the same variety of form as those described in the Palæontology of New York. In several of them, however, the concentric striæ become strongly marked along the back of the shell, forming, as in the preceding species, ridges, or costæ. The distinction between this and the preceding species is readily detected in tracing the costæ from the hinge-line towards the base, the one continuing distinct, and terminating along the lower margin, while, in the other, they become merged in, and take the direction of, the concentric lines of growth.

It would be desirable to compare a large number of specimens from different localities, in order to arrive at an explanation of these variations of character in what appear to be identical species. The specimens in my collection from Cincinnati and Madison, Ia., as well as those from New York and Canada, show scarcely any evidence of this character; and, it is not a little interesting to observe, that a locality, affording another species so strongly marked, should also afford one simulating the same characters.

Fig. 2. *a*, Cast of a left valve, showing the muscular impression. The form is rather wider in proportion to the length than is usual in this species.

Fig. 2. *b*, Cast of a smaller specimen, showing the strong ridges near the hinge-line.

Fig. 2. *c*, Cardinal view of the same.

Fig. 2. *d*, A short and broad form of the same species.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Geological Position and Locality.—This species occurs, with the preceding, in the higher marly beds of the Hudson-river group, on the east side of Little Bay des Noquets.

AMBONYCHIA CARINATA.

Plate XXXI., figure 3.

Ambonychia carinata, Palæont. N. Y., Vol. I., p. 294.

This species is abundant and finely developed on the eastern shore of Little Bay des Noquets. The individuals are larger than usual, and their forms generally well-defined; but, owing to the crumbling nature of the rock in which they are imbedded, it is difficult to obtain entire specimens.

CLINTON GROUP.

TRACKS AND TRAILS OF VERTEBRATES ?

As already remarked, few characteristic fossils of this period were recognized in this district. The argillaceous limestones, which, for the most part, represent this group, contain few fossils. The argillaceous sandstones, which, in New York, represent the lower portions of the series, were observed at only one place, on the eastern shore of Green Bay, particularly described in one of the preceding chapters. The surface of the slabs of this sandstone is covered with numerous tracks and trails, made at the time of their deposition, some of which differ so widely from those hitherto observed, as to require a detailed description.

One of these, which is very remarkable, not only on account of its size, but for other peculiarities, is represented in plate XXXII. This track, or trail, occurs on the surface of a shaly sandstone, thinly laminated, indicating that the laminæ were due to successive depositions. The materials were highly comminuted, and deposited in comparatively shoal and tranquil water, since the marks of the rippling waves are impressed upon the slab. The markings consist of a continuous depression, or groove, placed midway between a series of imprints, made in succession and at regular intervals, having a uniform character, as if made by the same organs. These imprints consist at first, as seen on the left hand side of the slab, of a single series on each side of the trough-like depression, each one presenting a duplicate. Almost from the starting point, however, there are faint impressions of a second series, *without* and a little in the *rear* of the inner series. These, farther on, are observed to be of the same form, but less distinctly duplicate and less deeply impressed. For a part of the distance, these outer impressions are quite distinct on one side, but for the remainder, they are visible beneath the superimposed laminæ of sandstone. On the other, or right side of the trough, the outer series is very indistinct, appearing at only one or two points, being entirely obscured by the deposition of mineral matter. The imprints cut the stone rather abruptly on the anterior side, while on the posterior side, it is less so, and behind each one the stone is elevated in a little ridge, or node.

In some parts, the markings present the appearance of three or four toe-like impressions, less deep than where the duplicate character is only perceptible. There is nothing to indicate the attachment of long claws, or fimbriated appendages.

The median groove is more shallow in some parts than in others, and, in this respect, the foot-like imprints correspond in faintness and distinctness. The distance from the centre of the median groove to the outer margin of the second series is uniformly two inches, making the whole width four inches. The distance of the imprints from each other, in the line of progression, is one inch and three-sixteenths, there being only one or two slight deviations, in twenty-four of these steps.

The slab, from which the figure is taken, is three feet long; at the left side, which is not represented in the figure, the imprints commence at the edge,—the continuation in that direction being broken off—where both the median groove and the foot-prints are slightly impressed, though still quite distinct. As they advance to the right, they become more distinct, but, before reaching the other extremity of the slab, they are concealed by layers of sandstone which cannot be removed. The course of the median groove is still perceptible from the depression of the laminæ above it, and there are even slight depressions corresponding to the foot-prints, neither of which is represented in the figure. On this part of the stone, covering the track, there are numerous trails and imprints, apparently produced by organic bodies, but which are too obscure to admit of any satisfactory determination.

It is very evident from an inspection of these impressions, that they have been made by some animal in voluntary motion; and it would appear as if in the direction from left to right, for the reason already given.

When, however, we would offer an opinion, as to the nature of an animal producing such a track upon the surface of an oceanic, or estuary beach, it becomes a subject of no little difficulty. From all the previous facts in our possession as to the character of the fauna which existed at this period, our preconceived notions are strongly opposed to the admission of the existence, at this period, of quadrupedal animals, contemporaneous with corals, crinoids, mollusks, and crustaceans, and the rare occurrence of fishes, as indicated in a few and ill-preserved fragments of ichthyodorulites.

We have already been made aware of the trails of mollusks, during this epoch, which have been preserved on the surface of the rocky strata; and there are others which may have been made by planarian worms, the bodies of which may not have been preserved. I have also described other tracks like imprints, possessing toe-like impressions, which *possibly* may have been made by fishes. The impression under consideration, however, has a character differing widely from all the former, and only, in some degree, allied to the latter.

If we were, for a moment, to regard this track as having been produced by an articulated animal, with an elongated body, and possessing lateral appendages, capable of making a double series of lateral imprints, we must first compare them with those made by similar animals, before we can become satisfied that such was their origin. In all of the trails I have seen, which could be referred to mollusks, or to planarian worms, whether made by existing worms, or by those which have left their impressions on the rocky strata, there is positive evidence of the body having been pushed forward through the superficial sand, or mud, since there is raised up, on each side of the groove, a ridge continuous with the groove itself. In instances where these evidences of lateral appendages are observed, they have marked, at close intervals, the adjoining surface. In the present instance, the shallow groove is not lined with a ridge, as in those just mentioned, but appears to have been produced by a body drawn over the surface, while the anterior extremity was elevated above that level, and, consequently, none of the mud, or sand, has been pushed out of the track to accommodate the animal. The lateral appendages, therefore, of whatever nature they may have been, may be presumed to have elevated the anterior portion of the body above the surface. These appendages, also, were of sufficient strength and power to bear the weight of the body upon their extremities, as shown from the impressions being firm, decided, and shows their depth that they were supporting a body of considerable weight, while the interval between the extremities and the junction with the body is clearly raised above the surface, and produces no imprint.

Such, then, are some of the facts which ought to be regarded in forming an opinion of the animal by which these tracks were made. Whatever may have been our preconceived opinions, we find none of the characters, pertaining to this track, resembling those of known articulated animals; and, if we would suppose that there may be large articulated animals capable of producing such impressions, it appears to me that we have, moreover, to suppose them provided with few—no more than four—lateral appendages, for locomotion, and that they were, by these, capable of raising their bodies partially above the surface, and of moving by steps, instead of the gradually advancing motion characteristic of those animals of this class with which we are acquainted.

I have made these observations for the purpose of presenting the facts in as clear a light as possible, and would cheerfully adopt an explanation which would satisfactorily refer these peculiar markings to an articulated body with the usual appendages. It now becomes important to find out the nature of the animals capable of making such tracks as these and others, which flourished during this period.

In doubting that they were made by articulated animals, I have been wholly uninfluenced by the opinion of Professor Richard Owen, with regard to the nature of the tracks found in the Potsdam sandstone of Canada

If we admit the existence of quadrupedal (chelonian) animals, during the period of the Potsdam sandstone, we should find less difficulty in supposing that they flourished during the deposition of the Clinton group. It must be remembered, however, that every step in the progress of geology has shown the occurrence of the remains of higher orders of animals in deposits of an earlier date than we had a right to infer that they existed; and, although discoveries of this kind were, on their first announcement, received with incredulity, yet ultimately geologists were compelled to yield to the force of the evidence. It is not long since it was supposed that the mammalia did not extend below the tertiary; subsequently, they were found in the lias, and now, it would appear, they extend as low as the keuper. The tracks in the sandstone of the Connecticut valley are now admitted to have been made by birds; but for a long time the evidence was regarded with distrust. The remains of air-breathing animals have now been found as low as the coal, and the tracks of supposed reptilians below all the coal-seams.* The ripple-marks and mud-cracks even so low as the Potsdam sandstone and the evidence of beaches in a higher position prepare us to admit that there may have been conditions possible, at least, for the existence of air-breathing animals, even during these lower Silurian epochs.

The tracks here described bear a strong resemblance to those found in the Potsdam sandstone, in the village of Beauharnois, on the south side of the St. Lawrence, twenty miles above Montreal, by Mr. Logan, the director of the Canada survey.† Its similarity has also been recognized by Mr. Hunt, of the Canada survey, who is familiar with the specimens collected by Mr. Logan.

It would appear highly probable, that the track in the Clinton group was made by an animal of the same class as that in the Potsdam sandstone, at a time when similar conditions prevailed in the palæozoic ocean, and when, in some degree, it was tenanted by similar organic forms, the Lingula being the prevailing fossil at both periods.

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* Mr. Logan was the first to announce the occurrence of foot-marks in the coal measures of Nova Scotia, which appeared to Professor Owen to belong to some unknown reptile.

In 1844, Dr. King, of Greensburg, Pa., announced to the Academy of Natural Sciences, the occurrence, in the coal measures of that state, of the tracks of two Saurian reptiles. Lyell subsequently visited the locality, and considered them as belonging to the genus *Cheiritheroum.*

In 1850, Mr Lea, of Philadelphia, announced to the Academy of Natural Sciences, the discovery of the foot-prints in bas relief, of a reptilian quadruped, lower in the series than had before been observed, which he provisionally named *Sauropus primevus.* They occurred in a gorge of Sharp mountain, near Pottsville, Pennsylvania, in the red shale, or number eleven of Professor Rogers's classification. The position of these foot-marks is about 8500 feet below the upper part of the coal formation, which there is 6750 feet thick.

Within the present year (1851), Professor Rogers has found, in the same basin, similar tracks to those described by Mr. Lea, as well as another set of smaller ones, reptilian in character, several hundred feet lower in the series. F. & W.

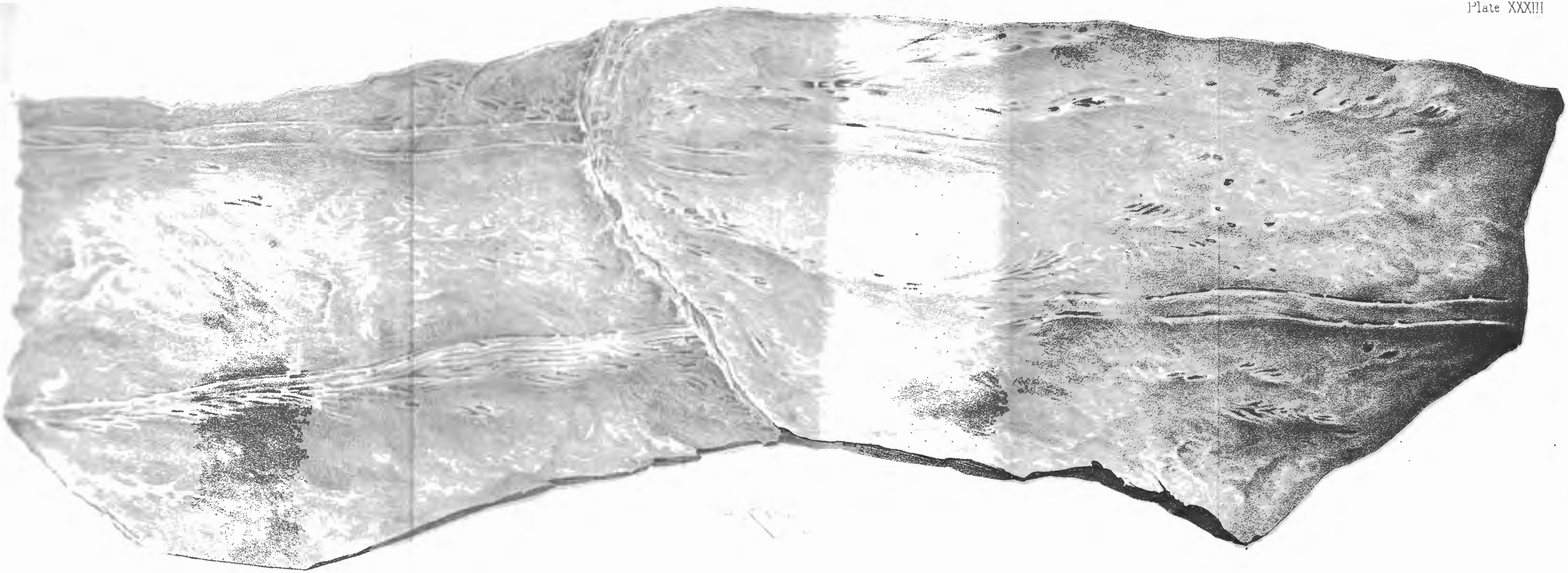
† Professor Owen, of the Royal College of Surgeons, who examined a slab of these sandstones, on the upper surface of which the foot-prints are impressed, and a plaster cast of the remainder of the continuous trail, in all twelve and a half feet long, brought to London by Mr. Logan, has communicated to Sir Charles Lyell the following description, which the latter incorporated into his anniversary address, (February 1851.)

"The impressions are more numerous in regular succession than any that have been previously discovered; so that the evidence of their having been made by successive steps, afforded by the succession of corresponding prints at regular intervals, is the strongest we possess. They are in pairs, and the pairs extend in two parallel linear series with a groove midway between the two series. The outer impression of each pair is the largest, and it is a little behind the inner one. Both are short and broad, with feeble indications of divisions at their fore-part—they succeed each other at intervals much shorter than that between the right and left pair.

"The median groove is well-defined, and slopes down more steeply at its sides, than towards its bottom, at some parts of the track. I conclude, from these characters, that the animal which left the track was a quadruped, with the hind-feet larger and farther apart than the fore-feet; with both hind and fore-feet very short, or impeded by some other part of the animal's structure from making any but short steps; that the fore and hind limbs were very near each other, but that the limbs of the right and those of the left side were wider apart; consequently, that the animal had a short, but broad trunk, supported on limbs, either short, or capable of only short steps; and that its feet were rounded and stumpy, without long claws. As to the median impression, that may be due either to a thick, heavy tail, or to the under surface of the trunk, dragged along the ground. The slope of the body and the structure of the limbs, indicated by the above described character of the steps, accord best with those of the land, or fresh-water tortoises, and the median groove might have been scooped out by the hard surface of a prominent plastron.

The disproportion in the size of the fore-and hind-feet, is such as we find in some existing Terrapenes e. g. the *Emys geographica.*"

Plate XXXIII



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Tracks of Crustaceans?

Plate XXXIII.

Impressions consisting of two parallel linear imprints, or shallow grooves, extending continuously for short distances and again repeated at irregular intervals, either in the same or a slightly varying direction. Wherever there are several of these impressions near each other, only two lines are parallel, one with the other, and have no connection with any other series. The two lines are about three-sixteenths of an inch distant from each other, usually direct, sometimes undulating and sometimes making an abrupt curve. These linear grooves are usually of nearly equal depth throughout their length, but in some instances there is a decided pit at one extremity, as if the mud had been struck by a pair of parallel claws which were pressed backward, and the grooves gradually dying out in that direction. In one or two places, there appears to be a line of distinct, pitted impressions, continued in the same direction as the groove.

In addition to the linear parallel grooves, there are, upon the slabs, numerous pitted impressions like those just noticed which are often in a continuous series, quite separate from any grooved lines, many of which are simple, while others present markings as of claws, or toes, like specimens from the same rocks in New York. (Pal. Vol. II. p. 26, *et passim.*) Those now described appear to be due to crustaceans, rather than to any other animal, since they resemble, in some degree, marks made by existing species of that class of animals. The surface of the specimen on which these tracks are made, is covered with a thin film of shaly matter, in which are imbedded, apparently, the remains of the macerated skeletons of several Bryozoa, the structure of which is so obliterated, that their generic relations cannot be established.

We have known, for many years, that the Clinton group of New York contains numerous trails made by different species of animals, or by animals of different size which may have been mollusks; we have others which, by the peculiar fimbriated character, indicate other forms; and we have those making distinct imprints, like foot-marks, with distinct toes, which clearly belong to still another class. To these three classes, we may now add those just described, which are quite distinct from either, and were unquestionably made by animals of a very different organization.

We have, then, tracks and trails of five distinct types, which existed during the deposition of the Clinton group.

Regarding, at the same time, the fact that no special attention has been given to the examination of these objects, the specimens being mainly those which have fallen under my observation while devoting myself to other objects of pursuit, we may feel assured that we have much to learn in this field, which thus far has remained comparatively unexplored, but the results of which will richly reward him who undertakes it.

Geological Position and Locality.—I have already spoken of the geological position and locality of the argillaceous and thin-bedded sandstones which bear these markings, being in the lower portion of the Clinton group, but above the Medina sandstone, as now restricted in New York. They are associated with strata which occur at the commencement of the upper Silurian epoch, belonging to that period of disturbance which preceded the formation of all those calcareous strata of the upper Clinton and Niagara groups, so highly charged with the remains of corals, crinoids, mollusks and trilobites.

NIAGARA GROUP.

The fossils found in this group are chiefly those which have been elsewhere described; many of which have been mentioned in the preceding pages, and, therefore, it is unnecessary to repeat them here, farther than to remark, that *Catenipora escharoides*, and two or more species of *Heliolites*, with one or two species of *Astrocerium*, are the characteristic ones of this group, throughout its range in this district. Nearly all the larger corals are identical with those in the same group, in western New York, and in Canada West, while the smaller ones are much less numerous in the Lake Superior district than at more eastern localities. The remains of Trilobites are extremely rare, and only some few fragments have been observed. The characteristic Brachiopoda are, also, almost entirely wanting at all the localities which I examined. Several species of Orthoceratites have been observed at different localities; but they are so poorly preserved in the rock, that they are of little interest.

Among the more interesting fossils of this rock, are those peculiar forms described by Dr. Bigsby, in his paper on the geography and geology of Lake Huron, as HURONIA.*

In that paper, they were regarded as the remains of corals; but, subsequently, Mr. Stokes corrects this opinion, and regards them as the probable siphuncles of Orthocerata.

They are analogous, indeed, in their form and general appearance, to this portion of the Orthocerata; but it is still very remarkable, that, in the numerous examples observed by Dr. Bigsby and Mr. Stokes, not one should have been found preserving some remains of the septa, or outer shell. The example of *Huronia Portlockii*, given by Mr. Stokes, (Geol. Trans., Second Series, Vol. V., p. 710, Pl. IX., fig. 5,) does exhibit the appearance of septa; but it appears to me that this one is very different from the typical forms of the genus, and may well be referred to Ormoceras. If the examples, such as *Huronia Bigsbii*, and *H. vertebralis*, which are often found of considerable length, and in numerous individuals, prove to be the siphuncles of Orthocerata, they form an exception to the general condition of preservation in these bodies; for, in the strata where the remains of this family occur in the greatest abundance, and in all degrees of preservation, there are only rare examples of the siphuncle having been preserved without the septa. In fact, both are one and the same thing: an extension of a lamina of shell from the siphuncle, forming a septum, or, *vice versa*, the laminæ of the septa curve around and enclose the open sippon tube.

The rare examples alluded to in Ormoceras and Endoceras, where the siphuncle is preserved separate from the septa and outer shell, present a

* Geol. Transactions, Second Series, Vol. I. See, also, a paper by Mr. Charles Stokes on Orthocerata Ib. Vol. V.

Fig. 1.

Fig. 2.

Fig. 3

Fig. 4.

Ackerman Lith 379 Broadway N Y

tube of a different character from that of Huronia, and one which is at once recognized as belonging to the Orthoceratideæ.

The apparent insertion of one joint within the other, in some species of Huronia, is a character much more like that of Cornulites, and their shell, the exterior of which is rarely preserved, is very like specimens of this genus. It may be due to the extreme concavity of the septum, and the enlargement of the siphuncle at the point where it is joined by the septum.

Whatever may have been the original nature of those fossils, it appears to me that, even admitting them to have been siphuncles of some Orthoceratite, they still preserve characters which entitle them to a separate generic description.

Huronia vertebralis.

Plate XXXIV., figure 1.

Huronia vertebralis, Stokes, Geol. Trans. 2d Series, Vol. I., p. 202; Plate XXVIII., figure 2.

Tube elongated; composed of joints, or articulations, of which the upper extremity is the largest, and the smaller and lower extremity of the succeeding one is apparently inserted within the upper edge of the preceding; upper edge expanded and somewhat deflected. The surface sometimes presents longitudinal striæ; but I have been unable to detect any other structure, though, in some parts, the entire shell appear to be still remaining.

A comparison of this fossil with some specimens of Cornulites, where the shell has been partially removed, shows a striking similarity in the structure and arrangement of the parts, except that in the latter fossil, the joints of which it is composed, diminish much more rapidly than in the Huronia. It is an interesting fact, however, that all known species of Cornulites belong to the Clinton and Niagara groups, and are of the same epoch of the Huronia.

The specimen figured is somewhat distorted by pressure, but the proportion of the parts and general form indicate the species described under this form by Mr. Stokes.

Geological Position and Locality.— This, and other specimens, were found by Messrs. Whittlesey and Desor, at Orthoceras Point, about eight miles east of the Detour, on the north shore of Lake Michigan, and from the position of this place, they occur in the central, or higher portions of the rock; thus affording a new locality for these singular fossils.

Huronia annulata. Nov. sp.

Plate XXXIV., figure 4.

Compare *Huronia Bigsbii*, Stokes, Geol. Trans., 2d series, Vol. I., p. 203; Plate XXVIII., figure 1.

Tube, or column, cylindrical, or slightly tapering; composed of joints which are of nearly equal diameter throughout, except the abrupt enlargement at one extremity, which forms a strong annulation; length of the joints about two-thirds their diameter.

In this species, the smaller end of the joint does not seem inserted into the expanded portion of the other, but to rest upon it, and in many of them, it appears as if expanded equally with the lower one, and that the two meet on the centre of the annulation, as shown in the figure by the dark line, which, in the specimen, appears like a suture. In this character, it presents a very remarkable similarity to a vertebral column and I should at once have referred it to *H. vertebralis* of Stokes, but that in his description the tapering downwards, and the inflation above are regarded as prominent characters. Our specimens agree better with the characters given to *H. Bigsbii*; but in the figure of that species the length and breadth of the joints is much more nearly equal than in our specimen; the form of the joints is also more tapering, though I have observed this character in a few of the joints in the specimen figured. This character is somewhat apparent towards the right hand extremity of the figure. The extremes of measurement given by Mr. Stokes, however, are sufficient to make us hesitate in determining the species from the length and diameter of the joints.

In this specimen, towards the right hand extremity, as shown in the figure, there is an appearance like a tube penetrating the interior, a character noticed by Mr. Stokes.

When the specimen is broken, the interior presents an eccentric, tubular cavity, lined with crystals of carbonate of lime. In the present condition of the specimen, it is not possible to ascertain any connection between this tube and any other part.

Both the specimens figured are in a light-grey sub-crystalline limestone from the same locality. The associated fossils are the following species of *Discosorus* and some trochiform Gasteropoda.

Discosorus conoideus.

Plate XXXIV., figures 2 and 3.

Discosorus conoideus, Palæontology of N. Y., vol. II, p. 99, Plate XXVIII, figure 13, *a*, *b*, *c*.

A conical body composed of a series of rings or discs, with rounded outer edges, and flattened above and below. Each succeeding ring, or disc, increases in size from the apex towards the base.

These discs are composed of a thick crust, or shell, having a fibrous structure, which radiates from a small, central, tubular cavity, or space, filled by a different kind of material. This cavity may, perhaps, communicate with the internal, conical cavity, formed within the entire series of rings. The structure of the ring, in specimens of this fossil from New York, resembles more nearly that of the Belemnite than anything else with which I am acquainted. The specimens from Lake Michigan afford no new facts regarding the structure of this fossil. One of the specimens has the two broader discs crushed, giving them apparently an abruptly increased diameter; but this appearance is entirely accidental. The oblique direction of the discs and the curved form of the specimens are, in like manner, due to pressure. The other specimen has the edges of the discs worn down, the interior being crystallized, leaving only a thin exterior shell. This crystallized interior does not represent the cavity before alluded to, but is the substance of the thick shell, or crust, crystallized and partially removed, leaving a cavity.

These fossils were first noticed by Dr. Bigsby, on Drummond's island, and were described and figured in the geological transactions before cited, but without a name, and, so far as I know, they have remained without farther notice, until the description cited above. I am unable to find any characters by which to separate the species, now described, from those found in the Clinton group in New York.

Geological Position and Locality.— The specimens figured were found with Huronia, at Orthoceras Point, in limestone of the Niagara period; and also in the same rock on Drummond's island.

UPPER HELDERBERG LIMESTONES.

Above the Niagara group, the first fossiliferous rocks belong to the age of the upper Helderberg limestones of New York, the intermediate space being occupied by the Onondaga salt group, which, so far as observed, is non-fossiliferous throughout the district.

I have had no opportunity of examining any fossils of the rocks of this age, except those from Mackinac, among which are several corals, indentical with those of the upper Helderberg, a Trilobite resembling *Phacops bufo*, a few Brachiopoda, which, from their condition, are not reliable, and those figured on Plate XXXV., which are recognized as species of the upper Helderberg group.

DICTYONEMA FENESTRATA.

Dictyonema, Palæont. N. Y., Vol. II., p. 174.

Plate XXXV., figure 1, *a*, *b*.

Frond flabellate; branches slender, bifurcating, and slightly divergent; united laterally by slender transverse filaments of the same substance as the branches.

The substance of the fossil is carbonaceous, crumbling under pressure, and leaving only a black stain.

This species resembles very nearly the *Dictyonema gracilis* of the Niagara group, but the substance of the branches is thicker, and it does not show the striæ or indentations so conspicuous on that one. In the species under consideration, I have not observed the separation of a thin horny crust from the internal portion of the branches, as is distinctly visible in *D. gracilis*.

Geological Position and *Locality.*—In the argillaceous limestone of Mackinac, associated with corals of the genus Callopora.

PRŒTUS ——?

Plate XXXV., figure 2.

Tail having the axis marked by about nine or ten annulations, which are broad and rounded in the crust, but thin and sharp in the cast; lateral lobes marked by six or seven ribs, which are slightly grooved on the upper side; these all terminate in a narrow, thickened margin; the axis scarcely reaches this marginal fold, but terminates near enough to allow the space of the longitudinal furrows to pass around the apex.

This fragment, which has a portion of the crust removed and otherwise not entire, so nearly resembles a species in the Schoharie grit, that I cannot doubt their identity. The number and character of the rings in the axis and the ribs on the lateral lobes correspond in the two species, and even the papillose markings on each side of the groove, in the lateral ribs of the tail, are the same in both. In the Schoharie specimen, the thorax has ten articulations, the eyes are large and reniform, and the head is margined by a broad expansion, separated from the cheeks by a distinct narrow groove. The posterior angles of this marginal expansion were probably continued into spines, but in the specimen before me they are broken off.

Geological Position and Locality.—The specimen figured was found about half way up the cliff, at the Arched Rock, Mackinac.

PHACOPS ANCHIOPS.

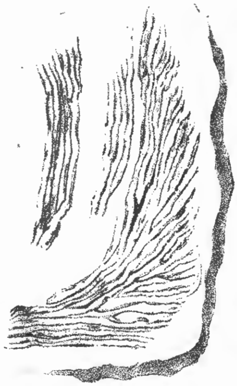
Plate XXXV., figure 3, *a*, *b*.

Calymene ——, cited with much doubt by Brongniart as being the *Calymene macropthalma.* "Crustaces Fossiles," page 16.
Calymene anchiops, Green, Monograph, page 35.
Asaphus laticostatus, id. ibid. page 45.

Head somewhat semi-circular, with the posterior angles extended into spines; a strong spine proceeding backwards from the centre of the base of the head; glabella very narrow behind, but abruptly expanding before; eye large and very prominent; a broad, strong tubercle on the inner side of each eye, and separated from it by a furrow. The furrow separating the glabella from this tubercle is marked in the cast by two deep pits; thorax with the usual number of articulations; tail large and strong, projecting into a long and strong spine; axis with ten to thirteen rings; lateral lobes with seven to nine ribs.

This fossil varies to an extreme degree in its general appearance, from the presence, or absence, of the crust which in the prolongation of the head

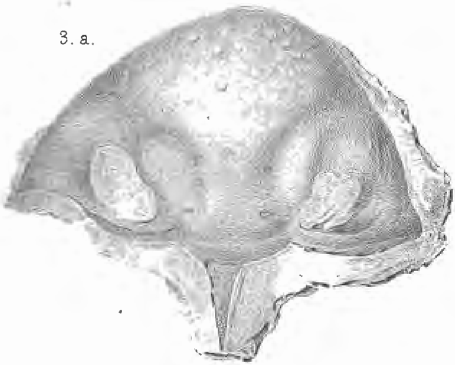
1 a.



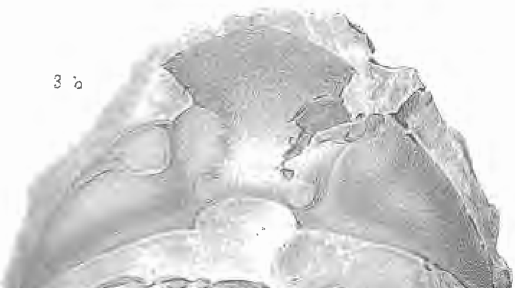
1 b.

2.

3. a.



3 b



Ackerman Lith, 379 Broadway, N.Y.

and the tail, gives to it very marked and positive characters. The specimen referred to by Brongniart, is a nearly entire individual, with the exception of the extremity of the tail and the spines at the base of the head, which are broken off, and the eyes somewhat mutilated. It was a cast of this specimen, now in the collection of the Albany Institute, which was sent by Dr. Hosack to the Academy of Sciences at Paris. It is the same specimen which Professor Green describes under the name of *Calymene anchiops*, in his monograph of the Trilobites of North America. The *Asaphus laticostatus* of the same author, is the tail of that species entirely denuded of the crust, and presenting the rounded form, shown in the cast accompanying the monograph.

This Trilobite is so peculiar in the form of the glabella and of the tubercles within the base of the eyes, that these characters alone serve to distinguish it, even in the absence of others. In one of the fragments before us, the form of the glabella and the eye is well-preserved, and, at the base of the head, the impression of the central spine with a part of it still remaining. In this one, the lateral portions are broken off; but, in another specimen, this part is better preserved, though, in other respects, less characteristic.

Fig. 3. *a*, A part of the head preserving the form of the glabella, the bases of the eyes and the large tubercles within the base of the eyes. The base of the central posterior spine of the buckler is preserved, and its extension shown in the stone enclosing the fossil.

Fig. 3. *b*, Another fragment of the buckler, preserving the lateral angles. The central portion, with the spine, is broken off.

Geological Position and Locality.—These fragments occur in the cliff of the Arched Rock on the island of Mackinac. The facts bearing on the position of this rock have already been given, and the associated fossils would alone offer conclusive evidence of its age. The Trilobite here noticed is known in New York, everywhere restricted to the lower member of the upper Helderberg group — the Schoharie grit. The species of Proetus which occurs in the same locality, at Mackinac, is found only in the Schoharie grit, in New York. The same rock contains a species of Phacops of the form of *P. bufo*, but having a row of spines down the axis of the thorax. At a quarry in Mackinac, I found the impression of a similar Trilobite.

We are already pretty well acquainted with the Trilobites of our successive groups, and though we may expect to find many new species, it is not to be, for one moment, regarded as probable that we shall find such an association of species passing from one rock into another; for, thus far, we know that they are remarkably restricted in their geological range. It is quite probable that a more careful examination, at Mackinac, would enable us to detect the three distinct members which compose this group in the eastern part of New York.

I here append a list of the fossils found within the Lake Superior district, as far as they have been determined. Of course it cannot be considered as very complete; but, it is not probable that the number will be very considerably increased for a long time to come; the region is too remote, and the exposure of the rocks too few to afford much encouragement to collectors.

LIST OF FOSSILS.

Potsdam Sandstone

Plants.

Fucoides? duplex.

Brachiopoda.

Lingula prima.

Crustacea.

Dikellacephalus.

Calciferous Sandstone.

Plants.

Palæophycus tubularis.

Cephalopoda.

Orthoceras.

Brachiopoda.

Lingula —— ?
Theca-like bodies.
[In the lower part of this rock, or the upper part of Potsdam sandstone.]

Chazy Limestone.

Corals.

Stictopora fenestrata.
Stictopora ——?
Chætetes ——?

Brachiopoda.

Leptæna fasciata.
Atrypa acutirostra.
A. plena.
A. altilis.

Acephala.

Ambonychia —— ?

Gasteropoda.

Maclurea magna (specimen shown me said to be from St. Joseph's Island).
Raphistoma staminea, Escanāba river.

Birds-eye, Black-river, and Trenton Limestones.

Plants.

Palæophycus ——?
Buthotrephis succulens.
Phytopsis tubulosum.

Corals.

Chætetes lycoperdon.
Streptelasma corniculum.
———— profunda.
Stictopora ramosa.
S. elegantula.
S. —— n. sp.
S. —— n. sp.
Phenopora multipora. n. sp.
Escharopora recta.
Clathropora flabellata. n. sp.
Aulopora arachnoidea.
Graptolithus amplexicaulis.

Crinoidea.

Schizocrinus nodosus.
Homocrinus ——?
Echinosphærites —— n. sp.
———— nov. genus.

Brachiopoda.

Lingula æqualis.
Orthis testudinaria
O. subæquata.

Pla[illegible]

POTSDAM SANDSTONE.

Ackerman Lith 379 Broadway, N.Y.

O. pectinella.
O. disparilis.
Leptæna alternata.
L. filitexta.
L. sericea.
L. deltoidea.
L. tenuistriata.
Spirifer lynx.
Atrypa increbescens.
A. recurvirostra.

Acephala.

Ambonychia obtusa.
Nucula levata.
Tellinomya dubia.
Edmondia ventricosa.

Gasteropoda.

Subulites elongata.
Murchisonia major.
M. bellicincta.
M. ——— n. sp.
M. angulata.
Pleurotomaria lenticularis.
P. umbilicata.
P. rotuloides.
P. subconica.
Bucania bidorsata.
Bellerophon bilobatus.
Cyrtolites compressus.
Carinaropsis —— n. sp.

Cephalopoda.

Orthoceras multicameratum.
O. fusiforme.
Ormoceras tenuifilum.
Endoceras proteiforme.
Gonioceras anceps (west of the limits of the district.) Many fragments of Orthoceratites not determined.

Crustacea.

Isotelus gigas.
Illænus crassicauda?
Calymene Blumenbachii, var. senaria.
Phacops callicephalus.
Ceraurus pleurexanthemus.
Asaphus extans.
A. Barrandi. n. sp.
Harpes escanabiæ. n. sp.
Lichas trentonensis.
Cytherina fabulites.

HUDSON-RIVER GROUP.

Plants.

Buthotrephis subnodosa.

Corals.

Chætetes lycoperdon (in great numbers and variety of form.)
Favistella stellata.
Streptelasma. n. sp.
———? nov. genus and sp.
Catenipora gracilis. n. sp.
Syringopora obsoleta. n. sp.

Crinoidea.

Columns of Heterocrinus and Glyptocrinus.

Brachiopoda

Lingula quadrata.
Orthis testudinaria.
O. occidentalis.
O. subjugata.
O. subquadrata.
Leptæna alternata.
L. sericea.
Atrypa increbescens.

Acephala.

Ambonychia carinata.
Avicula demissa.
Modiolopsis modiolaris.
M. pholadiformis. n. sp.
M. anadontoides.
Nucula ——?
Lyrodesma ——?
Cleidophorus planulatus.

Gasteropoda.

Murchisonia gracilis.

Bellerophon bilobatus.
Cyrtolites ornatus.

Cephalopoda.

Orthoceras lamellosum.
Ormoceras crebriseptum.

Crustacea.

Isotelus megistos.

CLINTON AND NIAGARA GROUPS.

Numerous remains of marine plants.

Corals.

Caninia——n. sp.
Diplophyllum cæspitosum
Conophyllum niagarense.
Favosites niagarensis.
F. favosa.
Astrocerium venustum.
A. parasiticum.
Heliolites pyriformis.
H. spinipora.
Stromatopora concentrica.
Catenipora escharoides.
C. agglomerata.
Syringopora multicaulis?

Crinoidea.

Fragments of columns too imperfect for recognition.

Brachiopoda.

Atrypa reticularis.
Spirifer.
Pentamerus oblongus (abundant throughout the district.)

Acephala.

Avicula——n. sp.
Modiolopsis? ——?

Gasteropoda.

Murchisonia subulata.

Cephalopoda.

Orthoceras undulatum.
O. virgatum.
Huronia vertebralis. *Incertæ Sedis.*
H. annulata. *Incertæ Sedis.*
H. ——. n. sp. *Incertæ Sedis.*
Discosorus conoideus. *Incertæ Sedis.*

Crustacea.

Fragments undetermined.
Tracks of various animals upon the surface of the argillaceous sandstones of the Clinton group.

UPPER HELDERBERG LIMESTONES.

Corals.

Favosites gothlandica.
F. striata?
Callopora. n. sp.
Cladopora. n. sp.
Cyathophyllum (several species.)
Fenestella ——?
Dictyonema fenestrata.
Lichenalia.

Brachiopoda.

A. reticularis.
A. ——?
Spirifer ——?

Acephala.

Avicula ——?
Cypricardia—n. sp.

Crustacea.

Proetus ——?
Phacops anchiops.
P. ——?

GENERAL REMARKS ON THE ABOVE LIST

The preceding catalogue may be extended by the addition of a few species in the lower groups; but it is not probable that any large number will be added to the list here given. In the Niagara group, in all probability, the number of corals may be augmented by new discoveries; though, from what I have already seen, it does not appear that many of the smaller bryozöoid forms will be found in this district, unless some locality should be found, more favorable for their growth than any yet observed on the northern shores of Lakes Huron and Michigan. Judging from the character of the rock, it seems hardly possible that we shall be able to obtain, in anything like a perfect condition, the species of Crinoidea which characterize the Niagara group farther east. Few of the Brachiopoda of this group have been recognized; indeed, so unsatisfactory are the fragments of shells of this family, that, with one or two exceptions, they have been omitted from the list. These fragments indicate that *Spirifer niagarensis* and *S. sulcatus*, have extended westward through this district, and that they are known still farther west. Several of the strongly plicated species of *Atrypa* have existed in this district, but they occur only in fragments, or in a condition too imperfect to be recognized.

The entire list numbers about one hundred and fifty species, of which more than one hundred are from the lower Silurian strata; twenty-six from the upper Silurian; and sixteen from strata regarded as of Devonian age. It seems scarcely possible that, for a long time to come, the number of species from the Silurian strata of this district can reach two hundred; while we have already, from rocks of the same age, in their eastern prolongation, more than seven hundred well-known species. Notwithstanding, therefore, that some of the localities appear to be abundant, both in species and individuals, there is not to be found the great variety which characterizes more eastern localities. We have already shown the diminution in thickness of all the lower Silurian limestones, though we can recognize the period of each one, both by its representative beds, and by its characteristic fossils. It is true, that in the upper Silurian period, there is an augmentation of the calcareous beds; but this increase is not accompanied by a corresponding accession of species, to what we find in the same beds, even when not so thick as in this district.

The almost entire absence of the schistose and arenaceous beds has had some influence in diminishing the number of species of fossils; for, in the Niagara group particularly, the smaller corals, the crinoids, and the Trilobites, are confined to the shaly limestone and marls. The shaly and arenaceous beds of the Clinton group, with some calcareous bands of minor importance, afford, in the state of New York, more than one hundred species of fossils. These are scarcely represented in the Lake Superior district, and, therefore, it is not proper to include the entire grouping in our comparison.

The following table will present at once, without the necessity of farther explanation, the means of comparison:

Table of the number of species of fossils found in the State of New York and the Lake Superior District.

	Lake Superior District.	New York.	
Potsdam sandstone	3	3	
Calciferous sandstone	4	13	
Chazy limestone	10	45	
Birds-eye, Black-river, and Trenton limestones	64	220	and thirty species common to the Trenton and other groups.
Hudson-river group	31	54	besides thirty species common to this and the preceding groups
Clinton group, Niagara group	26	298	
Upper Helderberg series	16	?	

The great diminution of species, which is here so apparent, would seem to be due to other causes than those which would be assumed at first sight. We know that it is not always the deposits of the greatest thickness which afford the largest number of species, but that other conditions influence their scarcity or abundance.

The small number of new, or undescribed, species which have been collected over this wide area, is another surprising fact. Those which have been found to be new, have been collected almost entirely from strata of lower Silurian age, and amount to about ten per cent. of the whole number obtained. A few more could be added from the collection already made, which would, perhaps, increase the proportion to fifteen per cent., or about four per cent. of the whole number of species now known in the American lower Silurian strata. In a collection of lower Silurian fossils made in Tennessee, by Professor Safford, I recognized about one hundred known, and about fifty undescribed species, making, in all, about one hundred and fifty. In the region from which this collection was made, the formations are entirely calcareous, and occupy an extent much less than in the Lake Superior district, yet the proportion of new species in the former is four or five times as great as in the latter region. In both, we find new corals of the bryozöoid type; but in Tennessee, in addition to a much larger number of these, we find several new species of the larger, true corals, while all those hitherto described as occurring in rocks of this age, are found there. We cannot, therefore, hesitate to regard the palæozoic ocean, in the region of Tennessee, as having been more favorable to the growth of corals than that of the Lake Superior district.

Tracing the same formations across to the Mississippi river, we find that the corals continue to be few in number, and new species have been rarely recognized. The whole series has, it is true, greatly diminished in thickness, and the supply of calcareous matter has disappeared, to a great extent, at the same time with the corals, so that the argillaceous matter predominates.

The formation of these calcareous beds we know to have been dependent on the corals, crinoids, and other organisms, whose remains constitute the mass, and it becomes a question of much interest to know from what cause they ceased to exist, and how we can account for the increase of calcareous matter towards the south-west, and its great diminution in the north-west.* Either the temperature of the ocean was there unfit for the development and growth of these animals, or the depth of the water was unsuited to their existence. Should we find that these formations, in their northern extension, everywhere assume the same characters and undergo the same changes, we might be justified in concluding that there were some climatic influences operating to produce a diminution in the number of species in the north; while towards the south, there is a constantly increasing ratio. The facts here briefly stated do exist; the conclusions drawn from them may, perhaps, be modified, after more extended observations and collections have been made, both at the north and the south.

These deductions, however, do not apply to the upper Silurian groups, since the facts show that, as far north as these strata have been traced, there has been an increase of calcareous matter; and we find the remains of corals in great abundance, though the number of species is not always very considerable in proportion to the amount of individuals.

Whatever may be the final view with regard to the decrease of the lower Silurian limestones in importance and thickness, and the diminution of the number of species of fossils, we can confidently assert that the conditions of the ocean had undergone a change during the interval between the deposition of the upper member of the lower Silurian, and the lowest beds of the upper Silurian and Devonian age.

In considering the character of the palæozoic strata of the west, we ought not to lose sight of the fact, that, although there is an absolute augmentation in the amount of calcareous matter in a south-westerly direction, yet this increase is by no means so great as would appear from a superficial examination. We shall probably find that, in a south-westerly direction from New York, there is a large increase in the thickness of all the groups, with the exception of the lower Silurian limestone. But as we go west and north-west beyond Lake Michigan, it is doubtful whether their aggregate thickness is greater than in New York. The increase of the calcareous strata is made more prominent by the absence of the schistose and arenaceous beds which occupy so conspicuous a place in the series, in the more easterly localities.

* These remarks refer to the fossiliferous beds above the calciferous sandstone, or lower magnesian limestone.

CHAPTER XIV.

ON THE SUPERFICIAL DEPOSITS OF THIS DISTRICT.

BY E. DESOR.

Division into Drift, Terraces and Alluvial Deposits.—Drift-Phenomena of the Northern Coast of Lake Michigan and Western Coast of Green Bay.—Of the Menomonee.—Of the Valley of the Manistee.—Of the White-fish.—Of the Escanāba.—Glacĭal Furrows and Striæ.—Rocks broken by Drift-agencies.—Origin of the Limestone Pebbles of Lake Superior.

The three succeeding chapters, comprise the observations of Mr. Whittlesey and myself, on that portion of the superficial deposits of the Lake Superior district, which has not already been described. It extends over the northern shore of Lake Michigan, the western shore of Green Bay, the Big Bay des Noquets, and the valleys of the Menomonee and Manistee.

The superficial deposits which were met with throughout these districts, correspond, in the main, with those of the northern slope along Lake Superior, as described by me in 1849, and may be arranged under three heads:

I. The drift proper, composed of strata of clay, sand and gravel, with boulders interspersed.

II. Terraces, belonging to a later epoch.

III. Alluvial deposits.

The first division is by far the most important, forming, as we shall see, bluffs and ridges a hundred feet, or more, in height. In this connection, we shall describe the diluvial striæ and furrows which have been observed at several points, the direction of which corresponds in a remarkable degree with those on the opposite slope.

The coarse drift, described in a former report as occurring beneath the drift proper, at several points along the shore of Lake Superior, seems to be entirely wanting in this district.

DRIFT PHENOMENA.

The North Coast of Lake Michigan and West Coast of Green Bay.—Although these coasts are lined with superficial deposits, which in some instances are very conspicuous, for instance, the dunes of Pointe aux Chênes and the gravel terraces of Mackinac, yet they do not generally belong to the true drift, but the alluvial period. The true drift deposits seldom approach the shore; but, in ascending the rivers, they are met with at no great distance. Thus, on Pine river, we meet at first with banks composed of silicious sand to the height of eight or ten feet; but, at the distance of a mile from the mouth, there is seen a stratum of tough, red clay, cropping out from beneath, in every respect similar to that bordering the outlet of Lake Superior, near Saut Ste. Marie, and, in all probability, it might be traced continuously from one lake to the other, since the intervening land does not here rise to any great height. In like manner, as will be shown, the drift deposits of the Menomonee, White-fish, Escanāba and Manistee, are relatively situated with regard to the lake.

It is necessary that this peculiar distribution of the drift should not be lost sight of, for, otherwise, the geologist, who should merely coast along the shores, might infer that it occurred only in isolated patches, whereas it covers nearly the whole intervening country between the two great lakes. Its absence from many parts of the coast is the result of a subsequent denudation, when the waters of the lake stood at a higher level than at the present time.

I shall first describe the drift phenomena as observed along the coast, and next those of the interior, as observed in the valleys of the principal streams.

The first locality to be mentioned lies in the vicinity of Pointe aux Chênes. For a distance of six miles west, towards Manitou, or Payment Point, the coast is lined with dunes, or heaps of blown sand; but before reaching it, there may be seen, at the bottom of the bay, a ridge rising immediately from the water's edge to the height of one hundred and sixty-two feet, and running parallel with the shore. Having ascended to the summit, we found a kind of undulating plateau, intersected by ravines, which appeared parallel to the bearing of the ridge. The most marked feature, however, was its steep slope—being, as we estimated, nearly 40°—which would render the ascent difficult, but for the trees which grow upon it. Its structure is peculiar, inasmuch as it is composed throughout of a very fine and homogeneous sand, similar to that which forms the dunes farther east, and one might be tempted to regard the whole as a gigantic dune, were it not for the regularity of its outline, which is not in accordance with the hillock-shaped form of the latter. Its considerable slope is equally at variance with this feature; for their slopes, in numerous examinations I have made, are seldom found to exceed 32°. It could not, therefore, be anything more than the accumulation of very fine and homogeneous drift-sand; and any doubt that I might have entertained originally, vanished when I afterwards found extensive tracts of the same materials along the Manistee river.

There is no similar accumulation of drift to be observed along the northern shore of the lake; the whole coast, from Payment Point to the entrance of Big Bay des Noquets, being composed of projecting spits of flat limestone and wide bays lined with blown sand.

The eastern coast of Big Bay des Noquets presents a totally different aspect from that of the northern shore of Lake Michigan. After having passed Pointe Detour, the limestone strata are observed to rise in ledges to a moderate height; but continue to increase in altitude until they attain one hundred and fifty feet, in a long and picturesque bluff at Bay des Noquets; and beyond they attain a greater elevation, being two hundred and fifteen feet. The same feature is maintained along the eastern shore of the bay, until we approach its extremity, where there is seen rising from the background, from amidst a flat country, a high ridge covered with pines. The occurrence of this kind of timber, which is altogether wanting on the top of the limestone cliffs, is, in itself, an indication of a change in the nature of the soil; and on examination, we found that the apparent ridge was merely the margin of a plateau which was seen stretching, for some distance, in an E.S.E. direction, and rising to the height of one hundred and thirty-six feet. The material was a fine and nearly homogeneous sand, like that before described, but more loamy, with occasional pebbles of limestone, which showed that it was a sedimentary deposit, undoubtedly of the age of the drift. At the foot of the ridge, a spring was seen to issue, flowing perhaps over an impervious stratum of clay, although none was visible.

The various islands near the entrance to Big Bay des Noquets are not without importance, in reference to the distribution of the superficial deposits. The lower ones are generally destitute of drift, their margins, like the coast of the main land, being merely lined with seams of alluvial deposits, either limestone pebbles or fine silicious sand. On some of the larger islands, for instance, that of Potawatomee, the summits of the cliffs are covered with a thick deposit of loamy drift-sand, intermingled with pebbles and boulders, very much like that of the Menomonee. Chambers's island, in Green Bay, is formed entirely of these materials, no rock whatever being visible.

To conclude, the drift deposits near the head of Green Bay, although not strictly within the limits of our district, are too intimately connected with those of the interior, about the sources of the Mississippi, to be overlooked. There may be seen on the banks of the Fox, or Neenah river, opposite Fort Howard, a stratum of tough red clay beneath the alluvial belt, belonging, no doubt, to the same formation of drift clay which occurs in the Menomonee region, and which, according to Mr. Whittlesey, forms a high bluff on the margin of Lake Winnebago. A short distance back of the river, this clay stratum is covered by the drift sand, forming a continuous plateau, on which the upper part of the town is built, and thence it spreads far into the interior. The thickness of the drift deposits at Green Bay has been ascertained, by boring, to be one hundred and eight feet.

This same reddish drift sand continues along the lake shore for some ten miles to the north-east of the village, to near the French settlement, where it forms bluffs some fifty feet in height; but, according to Mr. Whitney, without being underlaid by clay.

Drift of the Menomonee Valley.—Having followed this river from its mouth to near the junction of the Machi-gămig and Brulĕ, where the united streams take the name of the Menomonee, and made excursions, at several points, into the interior, we had an opportunity of observing the drift over an extended area.

It will be recollected that, along the shore of Lake Superior, on the opposite slope of the axis, stratified drift deposits of clay, sand and gravel were found as high as eight hundred and eighty-seven feet above the lake, in the vicinity of the iron mountain — township 47, range 27 — and that pebbles and boulders were also found at a height of one thousand feet.

We did not attain so high a point on the southern slope, and I am therefore unable to describe, from personal observation, the character of the detrital formations near the summit-level of the country; but, according to Mr. Foster, there are accumulations of gravel and pebbles, occupying extensive reaches along the Machi-gămig, at a height of one thousand feet above the level of Lake Superior; and, at a higher level, there are numerous obstructions in the stream caused by an aggregation of hornblende and granite boulders, around which it is necessary to make portages. In fact, boulders may be said to be perched upon the very summit of the country.

There is no country where the drift plays a more conspicuous part than near the junction of the Machi-gāmig and Brulē. In many places, especially between the Twin and Great Bekuenesec falls — township 40, range 30 — the river banks are composed of drift, forming bluffs one hundred feet and more in height. A remarkable instance may be seen a few miles above the latter falls, on the left bank, where the whole mass is, for some distance, laid bare from its summit to its base, so as to afford a most admirable section. It is composed chiefly of a loamy sand, very indistinctly stratified, with several layers of gravel, more or less coarse, interspersed through it. Boulders were scarce, except near the summit, where they seemed rather crowded together, so as to form a sort of stratum. On the opposite or right bank, the detrital deposit rises still higher, forming a terrace of some forty feet, above which there is a steep slope leading to a plateau nearly one hundred feet higher, with numerous boulders scattered over the surface.

Although the bluff on the left bank formed a natural section of nearly one hundred feet; yet, no evidences of a clay stratum were revealed. If it exists at all, it must be beneath the level of the river; but it will be seen hereafter that the clay occurs only at low levels.

There are other places in the neighborhood, where the drift deposits rise still higher; but, instead of forming steep bluffs, they are fashioned into hills, covered with dense vegetation. Having ascended one of these hills, opposite the mouth of Muskos river, which, from its form and outline, was supposed to be granite, I was much surprised to find that it was composed of the same materials as the bluffs.

Since fires had recently swept over the whole of this region, an opportunity was afforded for noticing the contour of the ground over a wide range. It was found that the drift hills were not merely limited to the borders of the river, but stretched far inland, especially on the right, where they assumed the form of a wide plateau with numerous ridges, giving it an undulating surface, like the rolling prairies of Illinois. The ridges appeared to be composed of rather coarse materials, and along their slopes and over their summits were scattered numerous boulders, composed of such rocks as were known to occur in the region to the north; such as hornblende and talcose rocks, with some blocks of saccharoidal limestone.

From the Twin falls, where the same character prevails, we proceeded in a northern direction, in search of the limits of the older sandstone strata, crossing, first, an elevated plain of drift sand, about two hundred feet above the bed of the river, and several miles wide, covered with aspen and dwarfed pines. (*Pinus Banksiana.*) This is bounded on the north by a series of low ridges, apparently of the same drift-sand, when we come to a small lake, to which we gave the name of Lac Fumèe. To the north, the surface suddenly rises in steep ridges, attaining an elevation of two or three hundred feet above the water. The drift with which these ridges are covered is no longer fine sand and gravel; but very coarse rubble, sometimes wholly composed of rounded boulders. These ridges extend northward for some miles, to near the Correction line between townships 40 and 41, where the drift gradually disappears, leaving the surface bare along the whole range of hills

Proceeding along the line eastward, the hills, for several miles, consist of quartzose rocks, with very little loose material, except huge boulders, derived from the adjacent ledges. The prominent ledges showed distinct traces of glacial action on their northern slopes; but, on the south, they were generally rough and precipitous.

At the corner of sections 32 and 33, range 29, there may be seen naked quartzose knobs, with vertical walls sixty feet high, fronting the south, while the northern slope is rounded and smoothed,—thus showing, in a striking manner, the contrast between the lee and the strike-side. Striæ were also observed on some of these rounded and polished rocks.

The range of hills near the Correction line does not, however, mark the limit of the drift, for, in proceeding northward, Mr. Whittlesey again found these deposits, together with boulders, in great quantities, as far as the centre of township 41, where they again disappear. Returning from the northern limit of this township towards the Menomonee, he describes the country as follows:

"Along the line of the section, from the northern extremity to the middle of township 41, the rocks are principally bare of drift; for the next three miles, or half a township south, they are concealed by a deep covering of drift, which here consists of a mixture of sand and gravel, bearing, as usual, a great number of excellent pines. After crossing the range of syenite and quartz rocks, which are exposed for three-fourths of a mile along the Correction line, the land rises rapidly between sections 10 and 11, and is composed of a prodigious mass of rounded boulders, from one to three feet in diameter. Here, although there is scarcely any dirt or gravel, but only heaps of large stones, the white cedar flourishes in great abundance. Passing over this rise of, say, one hundred and fifty feet, we descend to a stream, along the line between sections 14 and 15, and ascend the next range, which rises about two hundred feet. Its northern slope, like the last, is made up of a mass of large boulders, without an admixture of earth. Among them were seen all the varieties of the rocks which occur to the north, but the quartz and quartzose rocks predominated. The drift of the southern slopes is sometimes coarse, but never composed wholly of rounded boulders."

The lower portion of the basin of the Menomonee is, in every respect, more uniform. As an interesting feature, however, may be mentioned the occurrence of ridges with steep slopes; which is the more extraordinary, as the surrounding country is rather level. In a pine opening, on the left bank, three miles above the upper saw-mill, a ridge of this character is seen stretching, for a long distance, in a south-south-west direction, about forty feet in height above the surrounding plain, and sixty-one above the river, the drift terrace, on which it rests, being eighteen feet. The average width of this ridge is about ten feet, and its average slope from 25° to 30°, but its maximum is 34°.

This ridge reminded me strongly of similar ones found in the vicinity of Andover, Mass., where they go by the name of Indian ridges, it having been supposed by some that they were the work of the aborigines. It also reminded me, more vividly than any others which I saw in the West, of those curious ridges in eastern Sweden, familiar to European geologists, under the name of osars, or giant roads.

Another striking peculiarity is, that the ridge itself is composed of very coarse materials, with many pebbles and boulders; whereas, the plateau on which it rises is composed of fine, homogeneous sand, indicating a disturbed condition of the waters posterior to the quiet deposition of the drift-sand.

Descending from the head of the Menomonee towards its mouth, the drift deposits on its banks decrease in thickness, and at the same time become finer. This change is peculiarly striking in the vicinity of the White rapids, where they are seen at a considerable elevation; but, farther down, they seldom reach higher than fifteen or twenty feet. There is, however, one place in the Big Bend, below Kitson's trading-house, where it is observed at a height of fifty-four feet, while at the Pemenee falls, at one place, the drift terrace is only six or ten feet high.

At Grand rapids, it is only six feet, the material being generally a fine, loamy sand, with indistinct traces of stratification and diagonal stratification, such as frequently occurs in the superficial deposits. Occasionally, however, the drift terrace rises to the height of twenty-five or thirty feet, as for instance at the saw-mill, sixteen miles above the mouth of the river.

Drift-clay was met with at four places along the river, and always near the water's edge. The following are the localities where we observed it: near Menomonee City; at a place some miles above the saw-mill; below Sturgeon falls and at the head of Sandy portage, where it occurs; for some distance in the bottom of the river, as we had occasion to observe when poling, our poles sticking in the stiff clay; we found it to be very adhesive, and of the same red color as that on the borders of Lake Superior.

Although the width of the valley increases as we descend the river, yet it is narrower than that of some other rivers of less importance, as for instance that of the Manistee. There are many places where it is lined by the drift terrace, on either bank; although, in most cases, one bank is lined with drift, while the other is alluvial.

The phenomena of glacial furrows and striæ are abundantly displayed along the Menomonee, as will be seen in a subsequent chapter. There are, besides, many localities where the rocks, without being striated, exhibit those rounded and smoothed outlines, known as fleecy rocks (*roches moutonnèes*), and which, to the geologist, are conclusive evidence that the localities where they occur have been subjected to powerful glacial action. As a locality where this feature is seen on a grand scale, I would mention the portage around Sturgeon falls. The rock is here composed of a crystalline talcose slate, somewhat syenitic in its appearance, and which, from its tough nature, is is admirably fitted for resisting the destructive influence of the atmosphere. When walking over these rounded and smooth ledges, along the deep chasm, in which the Menomonee rushes and falls in a series of cascades, I might easily have imagined that I was again wandering along one of the torrents of the Alps, so great is the similarity, both in a picturesque and geological point of view; but, above all, in reference to these peculiar appearances of the rocks.

Drift of the Valley of the Manistee.—This river, which empties into lake Michigan, is composed of two main forks—the one coming from the west and forming on its way the Manistee lake; the other coming from the north, where its sources interlock with those of the Tequamenon of Lake Superior.

The whole area drained by this river is a vast swamp, the rocks being visible only in a few places in its bed, where they occasionally give rise to rapids; but rising nowhere, as far as our investigations go, above the water. The banks are composed either of drift, or of alluvial deposit. In many places there are no banks at all, the river winding its way through a succession of swamps and low lands. As a farther peculiarity of this river, the main rapids are near its mouth, there being none in its upper course; whereas, in most rivers they are concentrated near their sources.

Starting from the saw-mill at its mouth, we found the river-bed much wider than we anticipated; its brown swampy waters flowing, with a gentle current, between banks of fine alluvial sand. These are at first only a few feet high, and of doubtful origin; but, ere long, they grow somewhat higher and their true character becomes apparent. Ascending first the right fork, we soon reached the Manistee lake, with the little thriving Indian village on its northern shore. The Niagara limestone, which appears in regular and horizontal layers in several places, and especially in the vicinity of the village, is covered by a layer of reddish, sandy loam, containing granitic pebbles, intermixed with those of limestone. We could not, therefore, fail to recognize in it the representative of the true drift, such as is found on Lake Superior, and on the summit of the island of Mackinac. It seems to afford a good agricultural soil, for we saw there, not only potatoes, but also corn and peas thriving finely, cultivated by a settlement of Indians, who, to their credit be it said, form here an industrious and prosperous little colony.*

Proceeding from the lake up the river, we passed through a low, marshy country, being for many miles one continuous swamp. There are but few places where the banks rise much above the river. Near the main fork, however, township 42, range 17, where the river cuts through a ridge about twenty feet high, the banks are composed of fine, homogeneous sand, apparently without stratification, so that it might readily be mistaken for an ancient dune of blown sand. On closer examination, however, I discovered several granitic pebbles, which are sufficient proof that the whole ridge belongs to the drift.

We were informed by Mr. Merryweather, of the corps of linear surveyors, whom we met here, that the same character prevailed throughout the whole neighborhood; the country being composed of swamps with occasional pine ridges similar to that above described.

Drift of the Main Branch of the Manistee.—The main branch of the Manistee has a more uniform character than the one described above. It is a quiet and fine stream without either rapids, narrows, lakes, or islands; but flows through a regular channel all the way from the confluence of the left branch to near its origin; so that were it not for the rafts caused by the accumulation of timber, the river would be easily navigable for boats and canoes.

Throughout its whole length, it has, almost everywhere, a well-defined margin, although of rather unequal height; high banks sometimes succeeding abruptly to low ones, or the bank on one side being very high, while that of the other is quite low. This contrast is particularly striking vicinity of the Upper forks. Here, however, it is very crooked, and I noticed that the high banks were generally at the head of the meanders. This led me to examine more closely into the composition of both the

* They not only cultivate the soil to supply their own wants, but, as we were informed, had saved some money in order to buy the land, when it is brought into market.

higher and lower bluffs, and I found that, whereas the latter were composed of a loamy sand without any gravel or stones whatever, the higher bluff, although composed likewise of fine materials, contained in some places strata of gravel and even pebbles,— the latter being partly granitic and partly limestone. We had, besides, noticed in several places a layer of clay beneath the sand of the higher bluff, which was nowhere to be seen in the lower. Thus, we could not fail to recognize in the higher, true drift deposits, whereas the lower are undoubtedly alluvial. There is occasionally some difficulty in ascertaining this fact, on account of the considerable thickness of the alluvial deposits and their great similarity to the true drift.

The width of the valley of the Manistee, which, according to our estimates, averages nearly a quarter of a mile, is another remarkable feature, when we consider that the valleys of other rivers of larger size, as for instance that of the Menomonee, are much narrower. There, we have seen, that in many places the drift terrace occurs on both banks of the river; but this is never the case on the Manistee, at least not in its lower and middle portions. In consequence of the great width of the valley, the river frequently keeps at a distance from either bluff, and is lined only by alluvial banks; but, wherever it has a serpentine course, it invariably intersects the drift bluff at the head of the meander.

It is quite a striking feature that the vegetation on the drift bluffs, at the head of the meanders, is entirely different from that of the opposite bank, it being composed of pines (red and white) with some aspen; while the alluvial bank opposite is invariably covered with elms and maples, and sometimes with white cedar. At first, I ascribed this distinction to the mere fact that the drift bank was higher and dryer, and, therefore, more appropriate for pine growth; but, afterwards, became satisfied that the composition of the drift-soil was not without its influence, for I found the same character of vegetation growing on these terraces, where their level was not higher than that of the alluvial terrace. Thus, in descending the river, we could always know, from the mere appearance of the vegetation, whether we were upon the alluvium, or the drift.

The drift clay, without being as conspicuous as along Lake Superior, is well marked, in many places, below the drift sand. It does not generally reach more than four or five feet above the river, although in one place I found it to be ten feet thick. It is very tough, and generally flesh-colored, but in one instance it was perfectly white. There were observed, in several localities, rather coarse pebbles of limestone, and even flat stones, intermixed with the upper layer of clay, near its contact with the sand. This was especially the case at the first high drift-bluffs which we met with, a few miles below the forks, in ascending the river. Continuing on, the drift-bluffs increase in height. Between the confluence of the two upper branches, (township 43, range 14,) their height is from sixty to seventy feet. This, however, does not prevent the adjacent country from being very swampy. Having been obliged to leave our boat, on account of a large raft near the township line between townships 42 and 43, we decided to proceed by land till we should find the outcrop of the Trenton limestone. Having thus crossed the country in several directions, we are enabled to say that at least one-half of the surface drained by the left branch of the Manistee, is composed of cedar swamps. In some places—as, for instance—in township 44, range 13, the dry spots are so limited, that they appear actually like islands in a sea, being composed of sand-ridges covered with yellow and white pine.

A similar belt of pine land lines the river, or rather the valley, throughout its whole length, and the approach to it is always indicated, in this region, by a strip of dry soil, which is no doubt owing to the drainage. The timber is, however, smaller than on the rivers emptying into Green Bay.

In connection with this subject, I cannot refrain from alluding to a circumstance which has often surprised and perplexed me. When we consider the materials of which the drift of the Manistee region is composed—very fine, silicious sand, forming bluffs, in some places as high as seventy feet, without any impermeable layer except the clay at its base, which does not rise higher than ten feet—it seems but natural that the banks of the river should be dry for a considerable distance. This, however, is not always the case. In climbing up the bluff, I was often astonished to find that the timbered portions occupied but a narrow belt, as it were a mere embankment to the extensive swamps in the rear. This is the case at a locality on the river, in township 44, range 13. The bluff is here some sixty feet high, composed, throughout, of fine sand, except at the base, where there is a layer of clay eight feet thick. But, in spite of that, the belt of pine land is less than one hundred yards wide; it then slopes down fifteen feet, and immediately the pine trees are replaced by cedar and tamaracks, growing on a wet ground. A distance, therefore, of less than one hundred yards is sufficient to prevent the drainage, although the swamp is forty-five feet above the level of the river. In order to ascertain if the swamp was not occasioned by some impermeable layer near the surface, I examined carefully the roots of the fallen logs, and found them enclosed in the same fine, silicious sand which forms the bluffs. Having submitted the question to my friend M. Lesquereux, of Ohio, an eminent botanist who has thoroughly investigated these subjects, I beg leave to insert here his views. In a communication, dated December 12, 1850, he says:

"The fact you point out is not new; it almost always occurs in this formation of peat bogs, or, indeed, of cedar swamps, which are the same thing. If you examined attentively what you call the fine sand of the banks of the river Manistee, I think you must have observed that it is not a true sand, but a loamy, argillaceous, impermeable alluvium. This sand is found in all the peat-bogs of Europe: in Switzerland, in Germany, in Sweden, in Denmark and Holland—everywhere it is the same. I have invariably found, on putting a handful or two of this sand into a funnel, that it resisted the passage of water to a really astonishing degree.* But, even supposing your designation to be correct, and the sand of the Manistee be really permeable, the following explanation is none the less satisfactory: When a river overflows its banks, the slimy sediment is deposited, of course, at the edge of the current, and where its force ceases; and thus a ridge is formed along the banks, behind which, on the retreat of the river, there remains stagnant water. This is the origin of peat-bogs. The first growth of the still water is the Chara, a plant of a peculiar composition, containing a large quantity of silica, and to the decomposition of which I attribute, in a great measure, the formation of the clay found in peat-bogs. The idea of

* The sand of the Manistee is entirely different from this loamy alluvium alluded to by M. Lesquereux.

attributing a geological formation to vegetable decomposition may seem to you extraordinary, at least; but, if I am able to complete my work on the influences of vegetation, I hope to establish this, and other facts at least as curious. Next to the Chara comes the Sphagnum. To enable these plants to grow, requires only a hollow, in which moisture can lodge, and a few fragments of woody fibre. My examinations of these curious mosses have proved that, in moist climates, on the banks of rivers, or on mountains covered with clouds, their existence and their growth is by no means necessarily dependent upon the soil which they cover; for these mosses, by their peculiar conformation, are so exceedingly hygroscopic that they imbibe moisture in all parts of their tissue, both from the base upwards, and by their leaves, stalks, &c. This peculiarity is not due, as some have supposed, to a mechanical capillarity; but to the nature of their tissue, to the disposition of their fibres, and to the entire absence of chlorophyl, wherein these plants resemble the most simple substances; for vegetable tissue, as you know, is hygroscopic in proportion to its freedom from particles of a foreign nature. I shall give a more satisfactory exposition of this matter in a special work; but you have often observed, without doubt, the curious hygroscopic power of Sphagnum; for, if you pull off a tuft, even from the driest part of a swamp, on pressing it between your fingers, you will always find water running from it, as from a sponge. These plants, in this way, imbibe moissure from the atmosphere, if they cannot obtain it from the soil. Thus, a tuft of Sphagnum, weighing, in a completely dry state, three pennyweights, twelve grains, suspended in the air during a foggy night, absorbed seven grains of water. On the other hand, evaporation by the tissue is excessively slow and out of proportion to the absorption. Another tuft of Sphagnum, about twenty-two inches in superficial extent and four and one-half high, and weighing, when dried, one ounce, twenty-one penny-weights, was put into a vase having at the bottom a hole of half an inch in diameter. Through this hole, and touching the water with one-fourth of a line of the ends of its stalks, the tuft became completely saturated in less than two hours, having absorbed a pound of water. The same tuft, being then exposed to the air and sun for thirty-six hours, lost only five ounces by evaporation.

Upon the basis of these facts, you may easily follow the operations of nature in the formation of cedar-swamps.

When a little water remains in a hollow, and becomes saturated with humic acid, by the decomposition of vegetable substances, sphagnum immediately establishes itself. You know how it grows, in compact tufts, and even if the water should escape, it will continue to grow, and by degrees will cover very dry soils; for we see it in moist climates, for example, in the mountains of Ireland, in the Vosges, in the Harz, climbing up slopes of 25° and 30°, and covering bare granite rocks. A little moisture on the soil, in the spring, is sufficient to make the spores germinate, the atmosphere furnishing the necessary moisture for subsequent vegetation. I remember, in this connection, that one day as I was descending the slope of the Brocken, I slipped on a wet rock, and coming down upon my back, found myself buried under a carpet of Sphagnum more than a foot thick, from which I had some trouble in extricating myself.

You, yourself, remark that the pines are not fond of moisture. As these mosses spread, they exclude the air from the roots of the pines, when they die and disappear; whilst a favorable soil is formed for the cedars, which represent, in America, the *Pinus pumilio* of Europe. On the sandy banks of the river, where the slope favors drainage, Sphagnum cannot grow, and thus the pine and spruce thrive.

You ask me why it is that the Sphagnum does not form peat? It is because the slow combustion of wood, which forms this substance, cannot take place except under water, and where there is a permanent supply. So soon as it runs off, the air reaches the lower part of the stalks, the increase of oxygen decomposes and destroys them, so that, after ages of these little vegetables, (which nevertheless contain more woody substance in proportion than the hardest oaks and pines) there remains only a very thin layer of black earth mixed with sand."

En résumè; as a peculiar feature of the drift of this part of the district, I would farther mention the almost entire absence of boulders, either in it, or over its surface. In various excursions, we did not observe more than three; the largest one, of hornblende, in township 44, range 12, did not measure more than three feet in length.

DRIFT OF THE WHITE-FISH RIVER.

Throughout the whole region drained by the White-fish and its branches, according to Mr. Whitney, drift is spread over nearly the entire surface to a considerable depth, so as to effectually conceal the rocks, except in the beds of the rivers, and other places where it has been removed by the action of water since its deposition. On the trail from the mouth of this river to the shore of Lake Superior, opposite Grand island—a distance of some fifty miles—not a rock in place is to be seen; even boulders are few in number. The drift is spread very uniformly and evenly over the southern portion of this region, and is made up of fine, reddish, quartzose sand, with but few pebbles, forming nearly level plains, covered with a fine growth of Norway pines, particularly in township 42, range 20. These plains are occasionally varied, for a short distance, by ridges and knobs; but, in general, present a great uniformity and monotony of aspect. Along the course of the White-fish, the drift has been excavated so as to leave a wide swamp on each side, in which the rock lies near the surface. The thickness of this sandy deposit is from fifty to one hundred feet. As we approach Lake Superior, the country becomes more broken and diversified wtih ridges, but is still deeply covered with drift. A few granite boulders are seen, even on the highest point of the dividing ridge, which is not over four hundred feet above the lake. The same sandy plains extend west, through townships 44 and 45, to the Escanāba, and cover several hundred square miles. The same is true, also, of the region lying to the east of the White-fish, and that about the sources of the Manistee. The descent of these streams is gentle, and little broken by rapids.

DRIPT ALONG THE ESCANABA.

The drift along the Escanāba resembles, in many respects, that of the Menomonee and of the Manistee, as will be seen from the following observations, made by Mr. Hall:

"At the mouth of the Escanāba, and along the west side of Little Bay des Noquets, there is a great accumulation of fine drift, mostly sand above, with pebbles below. Above the first fall of the river, and particularly eight or nine miles from the mouth, there is much coarse drift, covered by fine materials, fifty feet or more deep. Beyond this place, to the second fall, and for several miles above, in fact to the forks of the river, there is scarcely any drift visible, the rock being covered merely by a deposit of impure peat from two to four feet thick. Above the forks, we again find the fine sand and small pebbles, the lower part coarse all the distance. Near the junction of the stratified rocks with the igneous, or from the point where I last saw the stratified rocks, until I came to the igneous masses, the accumulation of drift is greatest. Just below the syenitic ridges, I found ridges of drift from twenty to fifty feet high, some distance from the river. I examined these, supposing that they might be of rock, but found nothing except, here and there, a boulder. I learned from Mr. Sinclair, that the sand continues from the mouth of the river northward, and extends to within a few miles of the eastern branch all the way to the forks; but that, on the west side, this kind of drift is hardly seen below the forks, unless farther than he had penetrated, or farther than I travelled, on that side. I saw the same kind of material at Fort river. I saw no clay stratum, except at the meadow, nine miles above the mouth, where it occurs beneath gravel, with sand above."

GLACIAL FURROWS AND STRIÆ.

The phenomenon of glacial furrows and striæ, on the southern slope of the upper peninsula of Michigan, is much more marked than might, at first, be expected, considering that the prevailing rocks are limestone, of a more or less destructible kind.

Starting from Mackinac westward, we noticed glacial furrows in the following localities:

1. At the bottom of St. Martin's Bay, two miles north of Pine river, on a point composed of almost horizontal ledges of limestone. The surface of the rock was well-polished, with many distinct furrows, some of them measuring one quarter of an inch in width, and extending over wide areas. Their average direction is from east to west, some running N. 80° E., and others S. 70°, and 80° E. There are, besides, well-defined troughs, occurring in the same direction.

2. At Payment Point, the rocks are distinctly smoothed and rounded, in spite of the many small cavities which are scattered through them. At the bottom of the cove, the furrows are very distinct; but, at the Point itself, they are indicated chiefly by a greater regularity of the small cavities. One might almost believe that the formation of the latter had been influenced by the furrows, the direction being from N. 50° to N. 60° E.

3. At the bottom of Big Bay des Noquets, on the west shore of the eastern cove, there are seen distinctly polished and striated surfaces on a stratum of limestone belonging to the Hudson-river group. The direction of the striæ, which are here rather fine, is from east to west.

4. At the mouth of the Escanaba, in Little Bay des Noquets, the surface of the Trenton limestone ledges was observed by Messrs. Whitney and Hall to be, in several places, most admirably polished, with fine striæ running north-east and south-west.

5. At Oak Orchard, on the west shore of Green Bay, we found the

direction of the striæ, which are here very distinct, from N. 15° to N. 20° E.

6. The banks of the Menomonee afforded various opportunities for observing the effects of glacial agents on the rocks.

At the saw-mill, near the mouth of the river, the strata of Trenton limestone are distinctly polished, and marked by striæ running nearly east and west. At a locality six miles above Kitson's trading-house, there may be seen, in the river, several islands of tough talcose slate, most admirably polished and rounded (*moutonnés*), with indications of striæ running E.N.E. and W.S.W.

At another locality, three miles above Sturgeon falls, the striæ occur on a very hard greenstone rock, running N. 65° E.

At the foot of the lower Bekuenesec falls, on a hard talcose rock; direction N. 70° E.

At the lower Twin fall there are smoothed and fleecy rocks, with striæ running from N. 60° to N. 70° E.

Finally, the upper Twin falls deserve a special notice, there being no other place along the river, and, I may say, in the whole district, where glacial phenomena are more distinct than at the foot of this fine cascade. The rock, a hard and black slate, is so well polished that it glitters in the sun like a mirror, and most of the striæ are as distinct as if they had been engraved but yesterday. Their direction is from N. 65° to N. 70° E. I noticed, however, that the polish and striæ did not extend beneath the water, but that the surface of the rock was rough, and, as it were, corrugated, so far as the waves caused by the cascade reached. A conclusive proof that they had not been formed by water.

There are, besides, many places where the ledges are merely rounded or *moutonnés*, the structure of the rock having been too coarse to retain the striæ; as, for instance, at Pemenee and Quiver falls, and especially over the portage of Sturgeon falls. The rock, at this latter place, being coarse-grained and highly crystalline (a kind of protogine), and its rounded outline looking like a succession of large wool-sacks, heaped up one above the other, reminded me strongly of the similar masses which I had observed near the Scandinavian cascade of Trolhätta.

In addition to the above localities, I may be allowed to mention here the following, which were observed by Messrs. Hall and Whittlesey, on their way from Green Bay south-westward, in Wisconsin.

At Mehoggan Point; large polished surfaces, with striæ running N.E. by E. and N.N.E.

At Mehoggan falls, on Niagara limestone, the striæ running N.E. by N.

At a locality three miles west of Milwaukee, polished* slabs of Niagara limestone, with striæ bearing N.E.

At Strong's landing, (Fox river), on metamorphic slate, N.E. by E.

By comparing the direction of the striæ in the various localities abovementioned, it will be seen that their average distribution is from N.E. to S.W.—the extreme deviation being N. 70° to 80° W.; whereas, no locality was noticed with striæ running west of north, or even north and south. This average direction agrees very well with the prevailing direction on the

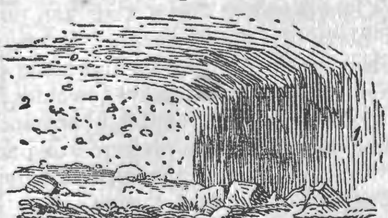
* I visited this locality myself, the year previously, in company with Mr. Lapham, and, having taken the exact bearing of the striæ at the top of a quarry close by the road, found it to be N. 60°E.

southern slope of Lake Superior, as described in my report for 1849. The only difference to be noticed between the two slopes is this: that while there are, on the shore of Lake Superior, some sets of striæ running north and south, we find here, on Lake Michigan, other sets running east and west, but the prevailing direction, in both districts, is the same; thus showing that the agent which engraved them, whatever may have been its nature, acted independently of the inequalities of the soil; for even the high ridge, between the two slopes, did not interfere with its direction.

ROCKS BROKEN BY DRIFT AGENCIES.

In connection with this general direction of the drift agencies from north to south, as indicated by the direction of striæ and furrows, as well as by the transportation of the boulders, I would mention another very curious feature, which was noticed on the southern shore of Lake Superior. Near the Jackson forge, on Carp river, the talcose slates are seen in a low ridge, where the rock has been quarried, to some extent, for building the forges. The slates stand nearly vertical; but the upper portion of the ledge is seen to have been abruptly broken off at a depth from ten to fifteen feet below the surface. The broken and shattered portion of the rock has been carried forward in the direction of the drift-current; and lies embedded in the drift, on the southern side of the ridge, as represented in the annexed figure:

Fig. 23



Broken Strata at Jackson Forge.

1. Slates. 2. Drift-gravel.

Similar fractures of the strata have been noticed in other regions. One of particular interest, from its extent, occurs at Guilford, Vt., at a locality known as the Bruce slate-quarry, and has been fully described by President Hitchcock, in his report on the geology of Massachusetts. The cause of this curious phenomenon was considered by him, in accordance with the views of Mr. Darwin, to have been the sudden impact of a large mass of floating ice against the projecting ridge. What gives a peculiar interest to the broken strata at the Jackson forge, is the fact that the broken masses of slate have been carried forward in the direction of the drift current, and are imbedded in strata of drift, as seen in the diagram, thus showing that the break must have taken place, previous to, or rather during, the deposition of the drift—the broken portions being both overlaid and underlaid by it. The extent of the broken strata is, in itself, sufficient evidence that nothing but a sudden, or violent stroke, such a one as we might imagine would be caused by the shock of an iceberg,—would account for such a break. On the other hand, the sharp edges of the broken portions, and the manner in which they are found abutting against the vertical strata, show that they must have been buried in the drift, soon after the fracture took place.

ORIGIN OF THE LIMESTONE PEBBLES IN THE DRIFT OF LAKE SUPERIOR.

It is not uncommon to find limestone pebbles intermixed with the granite pebbles and boulders, in the drift of the upper lakes. Along Lake Michigan, their occurrence is easily accounted for by the fact that the rock, *in situ*, is mostly limestone. It is not so in regard to those found along the beaches and terraces of Lake Superior. Limestone is nowhere to be found on the north shore of that lake, and, on the south shore, we know there occur merely some isolated patches in Sturgeon valley, belonging to the lower Silurian, from which the pebbles along the beach, both on the north and south shore, are entirely different, both in their lithological character, and in their fossils. They are of a pure white limestone, and contain fossils which are characteristic of the Niagara group, such as *Cyathophyllum*, *Favosites*, &c., which are occasionally so well preserved that they can be identified without the least difficulty. Among the specimens collected on the south shore, near the mouth of Chocolate river, there is a specimen of Favosites four inches in diameter, which is so well preserved, that its finest partitions are recognizable.

The question naturally suggests itself, where is the source from which they were derived? There having been thus far no indications of any limestone formations north of Lake Superior,* it was suggested by some that they might possibly have come from the limestone districts to the south and south-east; such a supposition, however, would have been in direct opposition to what we know of the general course of the drift agencies. Rather than adopt such an opinion, I preferred to derive these limestone pebbles from some distant portion of the British territory, where similar

* From information derived from Mr. Ballenden, of the Hudson's Bay Company, we became aware, several years ago, of the occurrence of the Silurian and Devonian series, on the northern slope of the axis between Lake Superior and Hudson's Bay. These series are intersected in crossing from Michipicoten river to James' Bay, the southern arm of Hudson's Bay. Mr. Ballenden described the strata on the shores of Lake Winnipeg, as consisting of limestone, in nearly horizontal strata, filled with fossils. Within the last year, Sir John Richardson, in the Quarterly Journal of the Geological Society, mentions that the Silurian series occur on both sides of the axis, in an undisturbed position, and continue to the Arctic Ocean. The fossils found in the superficial deposits along the shores of Lake Superior, are not exclusively confined to the Niagara limestone, but range from the Devonian to the Trenton limestone. Some of the cyathophylla are from the Devonian, while, at the mouth of Black river, in the south-west extremity of the lake we have collected one or two trilobites, as old as the Hudson-river group. When we consider the relative positions of Lake Temiscomeng, and the south-western portion of Lake Superior, where also the fossils of the Niagara group occur in the superficial deposits, it would be unphilosophical to infer that they were derived from a single point; for, if this were the case, the drift current by which their transport is supposed to have been effected, must have swept in a course a few degrees south of west, a course not coincident with the striæ on the rocks. Since it is pretty certain that we have a belt of Silurian rocks on the north of the brim of Lake Superior, there is little difficulty in accounting for the presence of fossils in the transported materials. Those of the Niagara group are more abundant, for the reason that they are generally silicified, whereas those of the Hudson-river group are not, and therefore more liable to be ground up and destroyed. F. & W.

limestones are said to occur along the north-western lakes and the Mackenzie river; although I could not but confess that their transportation from such a distance was rather uncommon.

All the difficulties have since been removed by the recent discovery made by the Provincial Geologist of Canada, Mr. Logan, of an extensive deposit of white Niagara limestone on Lake Temiscomeng, fifty miles north of Georgian Bay; and since the rock, according to Mr. Logan, presents the same lithological features which are exhibited by the fragments scattered throughout the drift and alluvium of Lake Superior, there can be hardly a doubt as to this being the source from whence the latter have been derived. This is the more satisfactory, as Lake Temiscomeng is situated to the north-east of Lake Superior, in a direction, which, as has been shown in the previous pages, is also that to which most of the striæ of this district seem to point, thus showing, that the two operations — the grooving of the rocks and the transportation of the materials — have taken place in the same direction from north-east to south-west.

CHAPTER XV.

SUPERFICIAL DEPOSITS — CONTINUED.

BY E. DESOR.

Terraces of Mackinac.— Their Composition.— Their Similarity with those of the Baltic.— Terraces of the adjacent Coasts and Islands.— Their relative Age.— Lacustrine in their Origin.— Denudation of the Drift.— The Period of its Denudation.

Terraces of Mackinac.— In my last report,* I briefly alluded to the gravel terraces which skirt this island, as among its most remarkable features. At that time, the age of the corresponding terraces of Lakes Huron and Erie had not been ascertained, nor was it known whether they were of marine or fresh-water origin. I therefore refrained from entering into any speculations as to their precise age, but merely stated that they were more recent than the drift, and ranked them among the alluvial deposits.

Meanwhile, Mr. Whittlesey has succeeded in finding fresh-water shells in the clay and loam deposits of the south shore of Lake Erie, and was led to infer that they belonged to the age of those lacustrine deposits in the valley of the Rhine, known as *loess*, which are intermediate between the drift and recent alluvium.

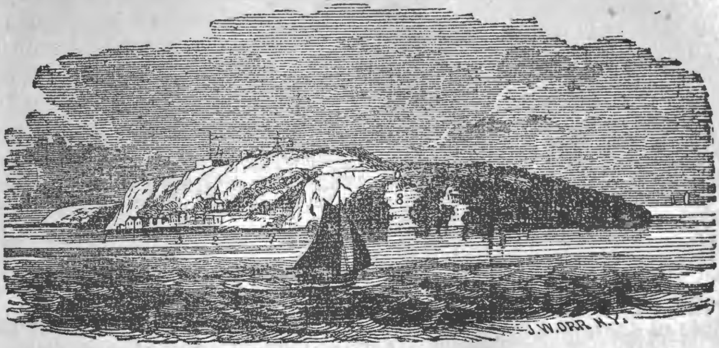
Although the terraces of Mackinac differ widely in composition from the loam, or loess, of Lakes Erie and Huron, yet, the fact that both are posterior to the drift and occur at similar heights on the coast of the same lake, seems to warrant the conclusion that they may have been simultaneous. The next inquiry would be, how far their peculiarity of structure can be accounted for by their insulated and exposed position in the straits. This island, situated at their eastern entrance, is as interesting in a geological, as in a picturesque point of view. It rises to the height of three hundred and fifteen feet, and its base and precipitous cliffs, occasionally crowned with clumps of foliage, at once arrest the attention of the traveller, more especially since the whole western coast of Lake Huron is low and void of scenic interest.

The sketch on the following page (Fig. 24) represents a distant view of the island, approaching from the eastward. Its main features, when seen from the wharf, at first appear exceedingly simple. A cliff of limestone, white and weather-beaten, with a narrow, alluvial plain skirting its base, is the first thing which commands attention; but, when following along the gently curving bay, towards the Mission house, if the geologist happens to cast his eye upon the terrace which rises in the rear of the house, he will notice that the cliff is no longer composed of solid rock, but of loose materials consisting of limestone-gravel, with larger pebbles intermingled — differing in so marked a degree from all other detrital deposits seen along the shores of the upper lakes, that his curiosity is at once aroused. He would,

* Report Part I., p. 213.

at first sight, be disposed to class it with alluvium, were it not for the height at which it occurs, namely, eighty feet.

Fig. 24.



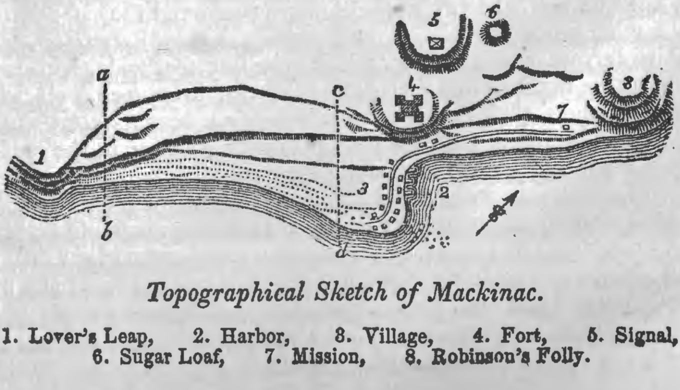
Mackinac.

1. Lover's Leap. 2. Harbor. 3. Village. 4. Fort. 5. Signal. 6. Sugar Loaf. 7. Mission. 8. Robinson's Folly.

These loose materials disappear, as soon as we reach the top of the terrace, being merely heaped up against the cliff, so as to form an external covering, and are also lost sight of in going southward towards the fort. If, from this point, we proceed towards the signal at the summit of the island, we find at first the surface of the plateau destitute of detrital materials, with the exception of a few isolated boulders. It is only when approaching the foot of the signal, that they rëappear; but essentially different in composition, being composed of rolled materials, as stated in a former report, characteristic of the true drift. It is evident to the observer that deposits so essentially different cannot belong to the same period.

If, from the harbor, we follow the coast south-westwardly, towards the headland known as Lover's Leap, we meet with features still more interesting. Instead of one terrace, we meet with a series of them, the relative position of which is indicated in the following topographical sketch:

Fig. 25



Topographical Sketch of Mackinac.

1. Lover's Leap, 2. Harbor, 3. Village, 4. Fort, 5. Signal, 6. Sugar Loaf, 7. Mission, 8. Robinson's Folly.

The terraces are most striking in the immediate vicinity of the promontory, where, from their being crowded together in a narrow space, they appear like a gigantic stair-case. They are less distinct in the vicinity of the village, on account of their being farther apart, still there is no difficulty in tracing the principal levels, as will be seen by the sections below, (Figs. 26, 27.)

The materials composing these terraces are limestone-gravel, with hardly any admixture of foreign rock; which is the more remarkable, since there are many granite pebbles and boulders in the drift, at the summit of the island.

In surveying the position and structure of these terraces, which contract near the head, and expand under the lee of the promontory, we become convinced that they were formed by a current setting from the south-west, which, after having passed the point, subsided in velocity and dropped the materials transported from the adjacent shores.

The following sections (Figs. 26, 27), taken at two different places across them (*a–b* and *c–d*, Fig. 25) exhibit the relative height and width of the terraces at these points:

Fig. 26.

Fig. 27.

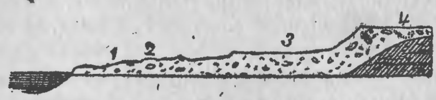


Fig. 26. Section along the line *a b*, in Fig. 25.
Fig. 27. Section along the line *c d*, in Fig. 25.

The first section was taken immediately east of the Lover's Leap, where the terraces are in close proximity. Starting from the beach, which, at the time of the measurement (June 22, 1849,) was five feet above the lake-level, we found the following order of succession:

No.	*Width.*	*Height.*
1. A terrace	10 feet.	9.5
2. " "	10 "	22.
3. " " more distinct	50 "	42.
4. " " with a slope of 50°	55 "	105.
5. Summit of a limestone ridge		147.

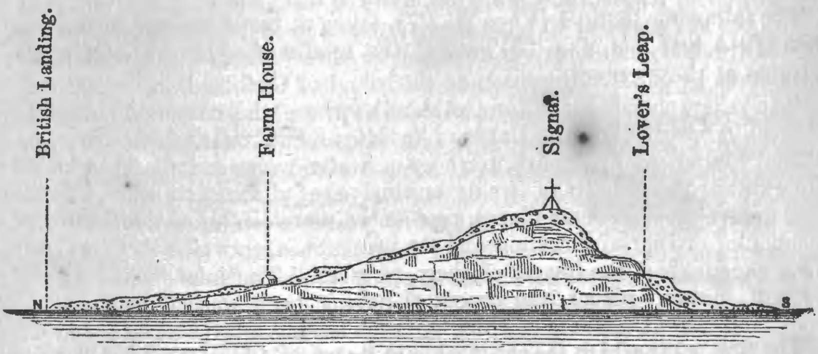
In the next section, the two upper terraces preserved the same level, but they are farther apart.

The third terrace which, in Fig. 26, is only fifty feet wide, here assumes a width of three hundred and fifty, while the two lower are replaced by a succession of ridges, with double slopes, like recent beaches.

There can be no doubt that this change is owing mainly to the configuration of the coast. By referring to the diagram (Fig. 25), it will be seen that the cliff recedes, as we proceed N.E., and thus a wider space is allowed for the expansion of the materials; and as the current abated in velocity, it lost its excavatory power, and hence the terraces expand in width, until, farther on, where the wearing ceased altogether, they disappear and are replaced by unaltered beaches.

Along the south-western shore of the island, there are no indications whatever of terraces; but the northern shore is lined with a succession of beaches, not unlike those before described, except that they extend over a wider area. Along the road leading to the British landing, they occupy a space not less than three-fourths of a mile in width, extending nearly to the farm-house, where the boulders reappear. There is here a remarkable ridge of large limestone pebbles, which appears to correspond with the highest terrace on the opposite side of the island, and to mark the limit between the drift and the ancient beaches. The exact level at which the latter disappear on the north side of the island was not determined with precision, but was estimated at seventy or eighty feet. As will be seen by the following diagram, which represents a section of the island of Mackinac, there is

Fig. 28.



Section of the Island of Mackinac.

a most striking contrast between the two shores. On the one side, we have distinct terraces with stair-like slopes, and on the other a series of beaches with gentle slopes; and yet the materials of both are identical. This difference is chiefly owing to the form of the coast. On the southern side, where the space is narrow and the slope abrupt, there was a wearing off of the beach after the upheaval of the land. These terraces are due to successive upheavals, and the base of each marks the limit of the periods of repose. On the northern side, the coast is low, presenting a long and gentle slope. There was, therefore, room enough for the formation of beaches at each change of level, which, after having been raised above the reach of the waves, remained unaltered. Hence, a succession of uniform beaches is produced on those parts of the island exempt from the wearing action of currents, but those portions exposed to this action are characterized by terraces.

These beaches gradually decrease, as traced from the British landing, and, after having turned the north-east corner of the island, entirely disappear—the shore being again lined with high limestone cliffs, which extend uninterruptedly to the eastern promontory known as Robinson's Folly. Yet this portion of the island is not entirely destitute of detrital deposits, for there is to be seen, a short distance beyond the Arched Rock, a terrace with steep slopes, consisting of limestone pebbles, and rising to the height of about twenty feet; its top and sides are overgrown with large trees, showing that it is not of very recent origin. Like the terraces at Lover's Leap, it abuts against a promontory; and as it does not extend beyond, it is evident that its formation is due to the shelter afforded by it; the cave in the rear causing an eddy, in which the currents deposited a part of their materials. This is farther confirmed by the fact that there is a recent beach, of considerable extent, abutting against the promontory, and separated from the terrace by a small marsh.

The most important feature, however, is the fact that both beach and terraces occur on the north-west side of the promontory, thus showing conclusively that they were formed in the lee of the east wind; whereas the terraces of Lover's Leap, as well as the beaches on the north side, near the British landing, were evidently in the lee of the south wind. This is, in itself, sufficient evidence that the gravel terraces, like the actual beaches, were accumulated under the influence of local causes, at a time when the topographical features of the region, and the distribution of the winds, must have been very similar to what they now are.

It will not be uninteresting to compare these observations with similar ones made by Sir R. Murchison on the island of Gothland, in the Baltic:*

"In many ancient bays (of Gothland), where the coasts do not present bluff-cliffs washed by the Baltic, like Hög-Klint, on the east coast, and Mount Hoburg on the south, terraces of water-worn and flattened shingle are exhibited at heights of twenty or thirty feet above each other, of which four or five may, in some places, be counted, between a low interior (or ancient) cliff or scar of limestone and the present sea, to which there is usually a long slope from the lowest of these terraces. The inland cliffs or scars present, in many places, the aspect of having been washed by the waves, and the different terraces of shingle, (each having a level surface, and each exactly like that which the sea washes at its present level) bespeak as many distinct upheavals, and are evidently quite unlike anything which could have resulted from the gradual upraising of the island. As the nature and relative position of numerous raised sea-beaches, or shingle banks, in different parts of Norway and Sweden, lead to the same conclusion; the bearing of this view upon our subject, consists, not merely in establishing a submarine condition of things, totally irreconcilable with the application of former glaciers to such tracts, but is, as will be seen, of some theoretical value in accounting for the motive power of those waves of translation, to which I have elsewhere referred, and which, independent of all glacial action, may, by sudden upcasts, have produced the violent transport, and consequent rounding and rolling onwards of much gravel and detritus.

"Now it is important to observe, that these terraces in Gothland, simply consist of the limestone locally rolled and flattened into shingle, such as is actually formed on the sea-beach; and it is only after having passed over them, and when we have reached to the height of a hundred feet more, that we meet with the "Osar" drift of foreign, coarser boulders, mixed with limestone débris, and surmounted here and there by great angular blocks."

So striking is the resemblance between these two localities, that we need only substitute the island of Mackinac for that of Gothland, to have a true picture of the relation between the drift and the gravel terraces. It is true, the shingle beaches of Gothland do not attain so high a level as those of Mackinac; but the height of thirty feet is sufficient to warrant the conclusion that they have not been heaped up by the mere action of the waves

* Quarterly Journal of Lond. Geol. Society, 1846, p. 360

and surf; but that they must have undergone an upheaval since their deposition, which brings them into the same category with the terraces of Mackinac.

Terraces, in every respect similar to those of Mackinac, occur on the neighboring coasts and islands. On Round island they attain an elevation of forty-six feet, by the south shore, between the two hooks. On the west coast, Mr. Whittlesey found them at the height of eighty feet. I noticed that the gravel, although composed of the same limestone as that at Mackinac, was much finer, the pebbles rarely exceeding a chestnut in size.

A similar terrace, but of less height, measuring some twenty feet, may be seen at the foot of Rabbit mountain, on the north coast of Lake Michigan. At Pointe St. Ignace,* it rises to a greater height, connecting, as it were the various promontories of limestone, which stand out like bastions in a huge wall. The terraces are still more remarkable in the vicinity of Gros Cap, the uppermost attaining an elevation of one hundred and thirty feet. Two miles east of the promontory, I noticed one at the height of eighty-five feet.

It can be safely inferred from the terraces of Gros Cap, as well as those of Mackinac, that the upheaval took place at successive intervals, and that the waters were stationary for some time at the foot of each. It will, perhaps, be possible, at some future day, to trace these various levels around the islands, and thus to ascertain whether or not the upheaval has been uniform throughout the whole range.

Age of these Terraces.—That the terraces of Mackinac and the adjacent shores are more recent than the drift, needs no farther demonstration, since the latter, as was shown previously, is only found at higher levels, to which the terraces do not reach. Nor can they be mere alluvial beaches, for they occur at too great heights to be due to the mere fluctuations of the lake-level. To account for their actual position, we are compelled to assume a rising of the land at successive epochs. Now a change of one hundred and five feet, which would be required to account for the highest of the terraces at the Lover's Leap, supposes such a change in the distribution of land and water, and such a change in the aspect of the surrounding country, that it is, in itself, a sufficient reason for separating the terraces from the beaches, the latter being decidedly alluvial.

On the other hand, the position and distribution of the terraces are not without some importance, in reference to their age. We have found them, for the most part, occurring on the east side of the island, and especially under the lee of the promonotory of Lover's Leap, where they are sheltered from the south-west winds and currents; whereas none are found to the west. The inference, therefore, is plain that the materials must have been carried from south to north, or in a direction opposite to that of the drift; and this may be considered as another proof that the deposits have nothing in common.

If we now consider the geographical position of the island, it can hardly be expected that a sheet of water with the current coming from the south-west, could have been anything else than an inland sea. No fossil remains have, as yet, been found among the terraces to throw light upon their origin, and it is not probable, from their structure, that they will yield any.

* The reader must not confound St. Ignace and Gros Cap of Lake Michigan with those of Lake Superior.

The question as to their being of marine, fresh water, or brackish origin, cannot be decided by the evidence of fossil contents, and we are compelled to resort to such evidence as is afforded by other ancient terraces and beaches, of the adjacent lakes. Those of Lake Erie and Huron, as before stated, have been ascertained to be of lacustrine origin. From their extent and position, there can be no doubt that they are at least as ancient as those of Mackinac; and, if the changes of level by which they were brought into their present position were all uniform, the surface of this ancient lake must have reached as high as the uppermost terrace of the island. There is, therefore, no necessity of resorting to local changes and disturbances, in order to account for the lacustrine origin of these terraces; and, since we have in the terrace of Cleveland direct evidence of the existence of such an extensive fresh-water basin, posterior to the great body of the drift and previous to the alluvium, there seems to be some reason for referring the terraces of Mackinac to the same epoch:—at any rate, they cannot be more ancient.

There are, however, some difficulties in the way, which I feel it necessary, in all candor, to state. I mean the absence of similar terraces farther west, along the north shore of Lake Michigan and Green Bay. It has been shown, in the preceding chapter, that at Pine river, the Manistee and Menomonee, the true drift may be found a short distance from the coast, and at no considerable height above the lake-level, sometimes as low, even, as twenty feet. Now, it is evident that, if the lake ever reached, in these places, the same height as at Mackinac, we should find there similar terraces *above* the drift. The difficulty might, however, be met by supposing that the upheaval which raised the terraces of Mackinac to their actual height, did not operate to the same extent west of the island. At any rate, this circumstance is, in itself, a proof that the change could not have been brought about by a mere lowering of the water; but that they must, at all events, be referred to a gradual, but unequal rise in the land.

As in many other instances, there appears to be, on the island, something like a gradual transition from the upper terraces to the highest beaches. It would be difficult to trace the line of demarcation between the two; but we need only consider the position of the latter, in such places where there can be no doubt as to their having been merely the result of the lake action within historical times, to be convinced that they nowhere exceed eighteen or twenty feet. It seems, therefore, not unreasonable to refer to an earlier period, all such terraces and deposits of the Island of Mackinac, as occur above that level; whereas, those which are below it must be referred to the recent period. With regard to the latter, the reader is referred to the latter part of the succeeding chapter, by Mr. Whittlesey, on the ancient and present beaches of Lake Michigan.

DENUDATION.

It has been shown, in a previous report, that the position of the drift on the island of Mackinac is such, that it cannot be supposed to have been deposited originally in this manner, it being in the nature of the drift deposits in general, to fill up the depressions and spread over the plains, rather than to occupy the summits. I was thus led to the conclusion that the absence of the drift, on the lower portions of the island, was owing to a denudation caused, probably, by violent currents along the main channels; since a similar denudation is observed, both along the straits of Mackinac and the valley of the St. Marys' river, where the banks, on either side, for some distance, are destitute of drift. The question arises, at what epoch did this denudation take place? The terraces at Mackinac afford us the means of solving this problem, at least in part, as far as the island and neighboring shores are concerned. A careful examination of the terraces has shown, that they all rest immediately on the subjacent rocks, there being, nowhere, any trace of drift beneath them. The inference, therefore, is, that the drift must have been removed from the surface and from the slopes of the island, *previously to the formation of the terraces.* As to the nature of these denudating currents, we are inclined to the belief that they were chiefly owing to the retreat of the waters of the drift epoch, when the continent, after having been subsiding for a long period, began again gradually to rise. The beginning of this rising, which might thus be considered as cöincident with the beginning of the denudation, would then represent the true limit between the drift epoch and the highest terraces of Mackinac.

CHAPTER XVI.

SUPERFICIAL DEPOSITS—CONTINUED.

BY E. DESOR

Alluvial Deposits.—Sand Beaches.—Pebble Beaches.—Marshes.—Flats.—Subaqueous Ridges.—Hooks, or Spits.—River Belts.—Bars.—Origin of Hooks and Belts.—Dunes.—Their Origin.—Ancient Beaches and Terraces.—Boulders of Saut Ste. Marie.—Ancient and Present Beaches of Lake Michigan.—Their Recent Origin.—Sections at Various Points.—Supposed Cause, the Deepening of the Channel at the Outlet of the Upper Lakes.

It has been repeatedly stated, in the preceding chapters, that, while the interior of the upper peninsula of Michigan is covered with extensive drift deposits, the immediate shores of Lake Superior, where they are sufficiently low, appear to be lined with deposits belonging to the recent epoch: to wit—the ALLUVIUM. Under this head I shall include the recent beaches, whether of pebbles or sand; the marshes and flats; those heaps of blown sand, known as dunes, or downs; and, finally, those beaches and terraces which seem to indicate a higher level in the waters of the lakes at some former period.

Sand Beaches.—The voyageur, who coasts along the northern shore of Lake Michigan, cannot fail to notice those deposits of fine, white sand which line the shore, sometimes for a long distance, and form the bottoms of nearly all the bays and coves. This sand, when examined microscopically, is found to be composed of minute grains of nearly pure white quartz. Similar sand beaches have been noticed as occurring in many places along the shores of Lake Superior. They assume, however, a special interest in reference to Lake Michigan, for the reason that the surrounding country is exclusively calcareous. The question, therefore, naturally arises in the mind of every geologist, as to the source from which this silicious sand was derived. There might be some difficulty in answering it, if we had simply explored the coast; but, knowing that the drift exists almost everywhere in the interior, and that, though lss homogeneous in structure, it is yet composed of a large admixture of sand and gravel, we are not at a loss to assign its origin to this source. Every stream that flows down from the wide drift-covered districts in the interior, carries with it a quantity of sand and gravel, which, when brought wthin the influence of the waves, becomes thoroughly assorted; the calcareous particles are probably dissolved, while the silicious grains are distributed according to their size and specific gravity; and, when thrown upon the beach, occasion those accumulations of white, homogeneous, quartzose sand which are seen so generally lining the coast.

Pebble Beaches.—The occurrence of these is to be expected on all rock-bound shores. I mention them here in consequence of their extraordinary extent along the shores of some of the islands at the entrance to Green Bay. The pebbles are chiefly limestone, varying in size from that of a chestnut to that of a melon; so few, indeed, are the specimens of igneous, or metamorphic rocks, that I have often walked for hours along the beach without observing their presence. On some of the islands they are piled up, like an immense wall, from six to eight feet in height.

Extensive pebble beaches also occur on the southern shore of Lake Superior, especially along that extended reach of coast to the east of Grand Sable. The pebbles here are almost exclusively granitic and entirely foreign to the rock in place (Potsdam sandstone).

For a distance of several miles east and west of Two-hearted river, the shore is lined with an uninterrupted beach of pebbles of rather uniform size, rarely exceeding that of an apple. This is the more extraordinary, as the only deposit visible in the rear of the beach is fine drift-sand. Another similar pebble beach is seen lining the coast for a long distance west of White-fish Point. Occasionally, however, the pebbles are replaced by a homogeneous sand beach.

The beaches along Keweenaw Point consist for the most part of trappean pebbles of large size, with an occasional admixture of granite; and this remark is applicable to those in the vicinity of the Porcupine mountains and on Isle Royale. They have been derived, in the main, from the destruction of the trappean conglomerate, and of the associated igneous rocks, while the granitic pebbles have been transported by drift agencies; where long reaches of sandstone occur along the coast, few pebble beaches are observed.

In the vicinity of Granite Point and Middle island, granite and greenstone pebbles greatly preponderate. As a general rule, the character of the beaches is determined by the character of the neighboring rocks; but there are many phenomena which can be explained only after a close and elaborate study of the outline of the shore, the depth of the water, and the nature and force of the current. Such knowledge could not be acquired in a hurried coasting expedition, in which investigations of this nature were of subordinate interest.

Alluvial Marshes.—I place under this head those extensive accumulations of alluvial matter which line the coast *uninterruptedly*, for a great distance, and which, in consequence of their low level, are generally swampy. A striking instance of this character occurs along the western coast of Green Bay, which for a distance of more than thirty miles, to wit,—from the mouth of the Menomonee to that of the Fox river,—is lined with a continuous belt of low swampy ground, from a few rods to half a mile in width. This marsh yields a luxuriant crop of wild hay, sufficient to supply numerous herds. The soil consists of the same fine silicious sand, before described as occurring on the beaches, and its marshy character results from its low position. The inquiry naturally suggests itself, why this marshy belt should be confined to this particular locality, there being nothing like it on the eastern coast of Green Bay, or the northern coast of Lake Michigan. I cannot but think that, in this case, it is owing to the sheltered position of the coast and its nearly uniform level, resulting from the horizontality of the strata, which allow the particles of sand brought down by the rivers to accumulate and spread in regular layers, without being much disturbed by westerly gales.*

* This is also the origin of many marshes of less extent along the shores of Lake Superior.

Flats.—There may be seen on the same western coast of Green Bay extensive flats, which are simply the continuation under water of the alluvial sand, forming the soil of the marshes. Indeed, so gradual is the transition, that it is difficult to draw the line of separation between them.

The origin of these flats can be referred, with still greater certainty than that of the alluvial marshes, to the action of rivers, from the circumstance that they are more extensive in the vicinity of their embouchures. Thus, at the mouth of the Peshetigo river of Green Bay, the flats are not only very wide, but a bar extends for a long distance into the bay.

The fact that the silicious sand deposits can be traced back to the agency of rivers is sufficient proof that they are nothing more than the detritus of the drift—the analogues, though on a small scale, of the flats, bars, and sand beaches, now forming on the Atlantic coast.

Subaqueous Ridges.—An example of this character occurs on the northern shore of Lake Michigan, not far from the Fish station of Bark Point (*Pointe aux Ecorces*), under the lee of a promontory, designated on the map as Point Patterson. Here, the shore, after running due east and west for some distance, bends abruptly to the north-east. The voyageur coming from the west, after having passed Point Patterson, is struck by the appearance of several bands of shallow water, indicated by a yellowish tint. These bands, which appear to start from the extremity of the point, are caused by subaqueous ridges, which spread, fan-like, to the distance of nearly half a mile to the east, being from three to ten yards wide, and from five to ten feet above the general bed of the lake, at this point. They are not composed, like the flats, of fine sand, but of white limestone pebbles, derived from the adjacent ledges, with an admixture of granitic pebbles, some of which are a foot in diameter. It is difficult to conceive of currents sufficiently powerful to transport and arrange such heavy materials, and yet we know of no other means by which this aggregation could have been accomplished.

These subaqueous ridges afford, on a small scale, an interesting illustration of the formation of similar ridges now above water. If the north coast of Lake Michigan were to be raised only twenty feet, such a rise would lay dry a wide belt of almost level ground, on which these ridges would appear conspicuously, not unlike those which occur on the south shores of Lakes Erie and Ontario, and thus confirm the views of Mr. Whittlesey, that most of these ridges are not ancient beaches, but have been formed, under water, by the action of currents.*

Hooks, or Spits.—There are to be seen along the lake-shores, as well as along the sea-shores, belts of loose materials, either sand or gravel, which extend into the water beyond the rocky boundaries, and form low barren spits, or points. These spits are frequently curved at their extremities, and have therefore received the name of *hooks*. A striking instance of this character may be seen at the south-western extremity of Round island, opposite Mackinac, which presents, as ascertained by measurement, the following form (Fig. 29):

* I have elsewhere expressed the opinion that the pebble and sand ridges of the prairies of Illinois have originated in like manner, or that they are (like the so-called Indian ridges of New England, at Andover, Massachusetts, and in Maine, where they are provincially termed horse-backs) the analogues of the Swedish osars.

Fig. 29.

Hook at Round Island.

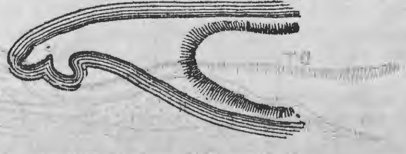
A similar hook was measured on one of the Summer islands, in the vicinity of Death's door (*Porte des morts*). I found it a general rule that, at the extremity of the spit, where it assumed the form of a hook, the convexity was in the direction of the prevailing winds. The nature of the materials has but little influence on the formation of the hooks. Thus, where the beaches are composed of limestone pebbles, the hooks partake of this character; and where beaches are composed of sand, the hooks consist of the same material. I have noticed, however, that where the hooks are made up of shingle, the smaller pebbles occupy the extremity.

The hooks combine, in various ways, with the more extensive alluvial deposits, and, in many instances, it is difficult to draw the line of separation between them. As an instance, I would mention White-fish Point on Lake Superior. Not only is its extremity terminated by a regular hook, which stretches eastward, but the whole area, extensive as it is in its structural relations, belongs to the hook formation. It will be seen, by inspecting the map, that it is situated at the extremity of a long and almost straight coast, succeeded by a wide bay known as Tequamenon.

Two causes have probably combined to produce this hook. The prevailing current of the lake strikes the Canada shore—which consists of firm igneous and metamorphic rocks, opposing an effectual barrier to the encroachments of the lake—and is thence deflected southward into the bay, whose margin is lined with less coherent sandstone. The tendency of this current would be to wear away the hook on the eastern side; but the loss is repaired by the prevailing winds which sweep from the north-west, accumulating detrital materials on the western side of the hook. They may, therefore, be regarded as compensating forces, the one counteracting the effects of the other, and thus preserving the outlines of the point almost unimpaired from year to year.

Nowhere did I see the hook-form so well represented as at Grand Marais harbor, east of the Pictured Rocks. The projecting spit (Fig. 30) at its entrance presents the following outline, platted from the measurements of Mr. Whitney:

Fig. 30.



Hook at the entrance to Grand Marais Harbor.

It is impossible to look at this little hook, without being struck with its resemblance to some of those on the oceanic border,—for instance, that of Cape Cod. Not only is it curved in the same manner, at its extremity; but, inside of the outer hook, there is a second and smaller one, which seems a miniature of the first. This is the case with Cape Cod; the inner hook enclosing the Bay of Provincetown. Thus, the same causes which construct the alluvial deposits on the Atlantic coast operate, though on a less extended scale, to build up the spits of our inland lakes.

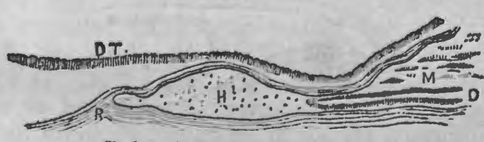
Similar hooks occur along the shores of the lower lakes, Ontario and Erie. As a remarkable instance, I would mention Sandy Point on the British side of Lake Erie, and the hooks which enclose the harbor of Erie on the American side. On Lake Ontario, the most remarkable hook is that which shelters the harbor of Toronto.

Hooks, like these, are of the highest importance, being sometimes the only natural harbors along low flat coasts. Even the smaller hooks are not without interest, for they often, on the upper lakes, afford a welcome shelter to the coasting-boats.

River-belts.—It is not unfrequent for a river, before its debouchure into the lake, to pursue for some distance a course parallel to the shore. Their deflection is caused by an accumulation of sand, or gravel, very similar to that of the hooks in composition, and deposited by the same causes. These deposits, generally in the form of a narrow spit, are elevated but slightly above the water. I shall designate these as *river-belts,* in order to distinguish them from the immersed ridges, known as *bars,* which are formed across the mouths of rivers. As might be expected, the bars are, in many cases, but a continuation beneath the water, of the belts. Sometimes, when the current is not strong enough to keep an open passage and the mouth of the river becomes silted up, the bar is transformed into a belt and the water percolates through the sand and pebbles, and thus gains access to the lake. Numerous instances of this kind have been observed on the south shore of Lake Superior, and on those of Isle Royale. During a freshet, the water cuts through the belt in a direct line, but as it subsides, the channel is again destroyed, or deflected for a long distance, parallel with the coast.

Belts and bars are to be found only where the shores are flat; but they are wanting where the coast is bold and the water deep. As examples of the former, on the northern shore of lake Michigan, I would mention a small river near Biddle's Point, and another near Pointe aux Chênes, and the Menomonee and Peshetigo rivers. They are still more conspicuous on the south shore of Lake Superior; as examples may be cited the mouths of the Ontonagon, of the Traine, and of the Two-hearted rivers, but especially that of the Chocolate river, which is represented in the following sketch (Fig. 31), in which the proportions are correctly represented:

Fig. 81.



Belt of Chocolate River.

D. T. Drift-terrace. H. Hook. D. Dune. M. Marsh. R. River.

The belt extends from west to east, and is composed of a fine yellowish sand, identical with that of the beach westward, but different from that of the drift-terrace which lines the river on its right bank. As a peculiar feature of this belt, I would mention that it is covered towards its origin witha ridge of dunes, thus showing that, however recent the belt may be, the dunes are still more so. The recent origin of the dunes is confirmed by the fact that they are found embedding half-decayed elders, which, being particularly fond of a wet soil, could never have grown on this spot, under the present conditions.

The most remarkable of all the belts of Lake Superior is that at the mouth of the St. Louis river, the extent of which may be seen by inspecting Bayfield's chart. It is of such magnitude that it can be compared only to similar phenomena on the ocean shore. Occurring, however, as it does, within another geological district, and not having given it a personal examination, I must pass it by without farther comment.

If it were asked to what extent a river may be deflected from its natural course by the increase of its belt, we might refer to many along the southern coast for an answer. The Carp river is a marked example. The present embouchure is but little deflected from the straight course; but there is to be seen at the left, an ancient channel through which it formerly flowed.

It would appear that many of these rivers, after flowing for some distance in a direction parallel to the coast, encroach gradually upon the belt, until it can no longer resist the pressure of the current, when it gives way and allows the waters to flow directly into the lake. By and bye, the beach-sand accumulates outside of the river, and the latter again begins to be deflected. Similar changes are often effected during a gale of long continuance. The mouths of many of the rivers are changed to an opposite direction, and the old belts are destroyed and new ones formed.

The belts assume a uniform direction, where the winds prevail from a certain quarter. On the north shore of Lake Michigan, and on the south shore of Lake Superior, they commonly run from west to east; but on the north shore of the latter lake, I am informed, their general direction is from east to west.

Bars.—It need hardly be stated that the bars are only modifications of the river-belts, and that they are formed on the same principle; in other words, they are merely the continuation of the belts under water. There is hardly a river along the flat portions of the shores of Lake Superior, or Lake Michigan, where this continuity is not observed. Unless the current be strong enough to keep an open channel, these bars become like those of the ocean, a serious impediment to navigation. This is the case with regard to the Menomonee; the bar cannot be passed by steamers, or even schooners, otherwise the river would be navigable to the first rapids. The mouth of the Peshetigo—a very considerable stream south-west of the Menomonee,—is hardly accessible to a coasting-boat.

Origin of Hooks and Belts.—Hooks and belts are due to a common origin, and hence they present a similarity of features. Both are the result of an eddy, or a diminished velocity in the current. It is an admitted principle of hydrography that any current, holding sand or other materials in suspension, will drop a portion of its freight whenever its velocity is diminished. When, during a gale, the waters loaded with sand, after rushing around a point, pass into a sheltered bay, they immediately drop a portion of the materials held in suspension. A deposit, thus commenced, goes on increasing during every gale; but, at the same time, a current, which is no longer kept in a steady direction by the resistance of the shore, will be deflected towards the bay, and the deposit will consequently assume an arched form. The hooks, occurring at the outlet of a river, or where it assumes a lake-like expansion, or where it bends abruptly, are the result of the same principle. The hooks of islands, like those of the main shore, occur in the direction of the prevailing winds. Thus, for example, on the islands near Death's door (*Porte des morts*), the sheltered, or lee side, will be to the S.E.; the waters rushing from the N.W. will glide on both sides along their shores, until they meet at the opposite extremity, with a relative eddy, which causes them to deposit a portion of their freight in a similar manner as in the sheltered bays and coves of the main shore. The degree of curvature in the island hooks depends chiefly on the comparative inequality of the currents on either side. If the island is so situated as to allow the current to reach the lee, or sheltered coast, only on one side, the curvature will be great; but, if the currents reach the lee of the island with equal force from either side, there will be no curvature; — on the same principle that the sand, which accumulates on the lee-side of the pier of a bridge, is arranged in a straight line. As a whole, the island hooks are less curved than those of the main land. That deposits of a similar kind should occur at the mouths of rivers is but natural, if we consider that river-belts are also the result of a relative eddy. If a current, either constant or remittent, sets along a shore, it will continue to flow with equal strength as long as there is no obstacle interposed; but, when it meets in its course the current of a river debouching at right angles, the latter will cause the former to abate in velocity, and thus a state of comparative quiet is produced, in consequence of which, a portion of the materials are thrown down at the point of confluence — the river here acting the same part as a bay in the former instance. The width, however, of a river-belt is not generally greater than is required for the discharge of the waters, and hence it follows, that the belt cannot encroach on the river; therefore, instead of bending inward, it increases in a straight line, parallel with the beach.

As to the origin of the materials of belts, it will be found that they consist of sand and pebbles, similar to those of the neighboring beach; thus showing that they were heaped up from without and not from within. This is especially striking in places where the materials of the river differ from those of the beaches. Occasionally, we may find the inner margin of the belt partly composed of river materials, but they are seldom mingled with those of the outer margin.

It follows, from the foregoing remarks, that belts, as well as hooks, must go on increasing beneath the water for sometime before they appear at the surface; and, indeed, it is not unfrequent to see the subaqueous portions extending for some distance beyond the subaerial ones, — the former being indicated by the different hues of the water. These hooks and belts afford us the most simple and natural explanation of the formation of bars, which are nothing but immersed belts.

The occurrence, to such an extent, of hooks, belts, and bars, on the borders of our lakes, cannot but have some bearing on the views entertained as to their origin along the shores of the ocean, where they are developed on a larger scale. Their formation has been mainly ascribed to the action of the tidal currents; but it is sufficient to have shown that they are phenomena of common occurrence along the lake-shores to prove that tidal action is not necessary for their formation, although there can be no doubt that, when there is a tidal current, it must play an important part, in conjunction with other causes.

Dunes.—Under the name of dunes, or downs, we designate those irregular heaps of fine sand which are accumulated by the winds on certain shores. They are generally composed of fine silicious sand, without any stratification. Their most conspicuous feature, however, is their irregular outline, which is so striking that it cannot fail to attract the notice even of those who are not particularly engaged in geological inquiries. Not only are the hillocks of very irregular size and height, but they are often shaped in the most fantastic manner; some being very steep, others with a gentle slope, and others with rounded outlines. They have not improperly been compared to oceanic waves suddenly solidified.

Dunes are especially conspicuous on the oceanic shores; and there are countries in which they are of paramount importance, both in a geographical and economical point of view. Holland owes its prosperity chiefly to the shelter which the dunes afford to its navigation, by forming a natural and most valuable barrier against the invasion of the sea; whereas, in other countries, they are dreaded on account of their encroachment upon cultivated and fertile soil; as, for instance, on the coast of Suffolk, in England, and in Gascony, France.* It appears that, in some countries, they advance with great regularity, so much so that they have been represented as natural chronometers, the rate of their advancement affording a means of calculating approximately the epoch when they first began to accumulate.

Although the dunes, as a whole, are less frequent on this side of the Atlantic than on the other, yet there are some striking instances of their occurrence on the shores of New England, especially at Cape Cod, where they have been described by Professor Hitchcock. There, too, we may witness considerable changes from year to year, in their outlines. Nay, the movements of the blown sand have been deemed serious enough to attract the attention of the government, and it has been attempted to devise means to prevent the harbor of Provincetown from being eventually filled up. This object has been partially attained by planting beach-grass along the shore, whereby the single grains of sand are arrested in their course, and the onward progress of the dune stopped.

The dunes of the upper lakes are of peculiar interest, affording, to my knowledge, the only examples of their occurrence on the borders of an inland sheet of water. Nor are they in any way inferior in height to those of the ocean shore. The average height of the latter is indicated, by M. Elie de Beaumont, at from twenty to sixty feet; and it is only in extraordinary cases that they rise to the height of one, two or three hundred feet. Those of Cape Cod do not exceed eighty feet, although they have been described as being higher; whereas, it is reported that some of the dunes, on the eastern shore of Lake Michigan, attain a height of three hundred feet.† One of the hills, which from its striking appearance is called the Sleeping Bear, is said to be nothing but a huge dune.

*There are, in both countries, instances on record where whole villages have been invaded by the dunes and converted into deserts.

† The hills called Grand Sable, east of the Pictured Rocks, on Lake Superior, are sometimes ranked among the most remarkable instances of dunes; but I have shown in my former report that they belong to the drift formation.

Those of the north shore of Lake Michigan, although not quite as high, are nevertheless very striking. The most remarkable for size, or extent, occur at Pointe aux Chênes, a locality some twenty miles west of Mackinac. The shore rises suddenly to the west of the point, in hills which, from their singular shape and bare surface, would be recognized at once, even from a distance, as dunes. They are composed of a fine quartzose sand, with a little admixture of colored grains, which impart to the whole a yellowish tint. Having measured several of the hills with my pocket-level, I found them to average, near the point, from eighty to one hundred feet in height. The highest, however, at a distance of half a mile from the point, I found to be one hundred and twelve feet, extending, uninterruptedly to the west, a distance of some six miles; but at the same time decreasing in height, until they are reduced to hillocks, not exceeding twenty-five feet. I noticed, besides, that they became more and more covered with vegetation towards the west, this being without doubt the most ancient portion. There are nowhere any traces of stratification to be seen in them; nor could I detect a single pebble in the mass, except some few scattered ones in the depressions between the hillocks, where they were thrown up by the waves, in severe gales, as is also the case on Cape Cod.

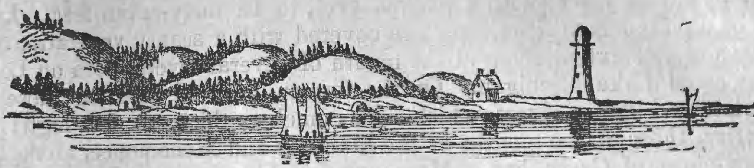
In following the summit of the upper dune-ridge at Pointe aux Chênes, I noticed that the back slope was very steep, and at the same time very constant. I found its inclination to be 32°; this being, without doubt, the greatest natural slope which this kind of loose sand is capable of assuming, when sheltered from the winds.

Whenever the dunes exhibit some regularity, or are so situated as to form a succession of ridges perpendicular to the coast, this greater steepness of one slope is always noticeable. Moreover, it is invariably found that the gentle and long slope is towards the windward side, and the steep side to the lee. This feature is especially striking near the western extremity of the dune-ridge of Point aux Chênes. The same feature is repeated in several places along Lake Superior.

As a peculiarity of the dunes, in both places, I would mention that they are often covered with trees of considerable size, such as, to my knowledge, do not occur on any of the oceanic dunes. One white pine, which I measured near the top of one of the highest ridges of Pointe aux Chênes, was found to be eight feet in circumference; thus showing that the dune has, at least, remained unchanged in this spot, for some length of time. The trees unquestionably act as barriers to prevent the sand from spreading further inland; and there is but little doubt that if they were cut down, the scanty vegetation which covers the summit and the back of the dune-ridge, would prove insufficient to resist the action of the winds. The sand would be laid bare, and the whole range of dunes would spread inland, as it is known to do in several parts of Europe. A peculiarity of this character was observed on the summit of the country back of the Grand Sable of Lake Superior. Here, numerous clumps of trees rise up like islands, in a wide waste of shifting sands, and struggle to gain a precarious support.

Next to the dunes of Pointe aux Chênes, the most remarkable within the upper peninsula of Michigan are those of White-fish Point, on Lake Superior, an outline of which is given in the following sketch by Mr. Foster (Fig. 32).

Fig. 32.

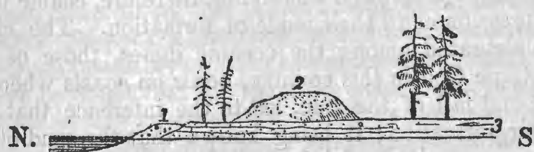


Sand-dunes at White-fish Point.

Although very conspicuous when seen from a distance, the dunes of White-fish Point are, nevertheless, smaller than those of Lake Michigan. The most elevated hills do not attain the height of the light-house, which is built among them, and which is seventy-five feet high. As to their extent, it is doubtful whether they cover more than a square-mile; yet their position in front of the projecting promontory is such, that they necessarily attract the notice of all travellers on Lake Superior; and hence their great celebrity.

An interesting instance of the instability of the dunes is afforded at the western extremity of White-fish Point, as seen by the following sketch (Fig. 33).

Fig. 33.



Section of a Dune at White-fish Point.

A dune (2) some twenty-five or thirty feet high, is seen rising near the shore; and between it and the gravel beach (1) are seen several dead pine trees, buried partly in the sand of the dunes. Now, it is hardly probable that the shore was as barren as it is now, when the trees first grew in that place. Being apparently of the same kind as those in the rear of the dune, which are rooted in the alluvial soil of the point, it is but natural to suppose that they belong to a similar soil, and attained their full size before the dune was formed. Thus it would follow that the dune has taken possession of the soil subsequently to the growth of the pines, which have probably been killed by its encroachment.

A similar instance of the recent increase of dunes has been previously mentioned as occurring near the mouth of Traine river, where young elders may actually be seen buried to the limbs in the sand of the dunes; and there is hardly any doubt that, like those of White-fish Point, they will die, if the sand is not removed.

Dunes also occur, to some extent, along the shore of Keweenaw Point, west of Eagle Harbor. They here line the coast for a considerable distance, but do not exceed twenty-five or thirty feet in height.

The mouth of Eagle river is likewise lined with a succession of dune ridges; the highest of which, and also the most distant from the beach, I found, by measurement with a pocket-level, to be forty-seven feet. Like those of Pointe aux Chênes, they are covered with a scanty vegetation.

Dunes of less extent occur at the mouth of several rivers, both on Lake Superior and Lake Michigan. On the former, I would mention those of Chocolate and Traine rivers, which are as much as thirty-six feet high; on the latter, those at the mouths of the Manistee and Menomonee, along the western shore of Green bay. More extensive dunes occur, I am told, on the north shore of Lake Erie, on that extensive spit or hook called Long Point, where they appear, from a distance at sea, as a chain of very singular hills. Mr. Murray mentions, also, dunes in several places along the east shore of Lake Huron. At Port Franck they rise to the height of one hundred feet and more.

The occurrence of dunes, more frequently at the mouths of rivers than elsewhere, is probably to be accounted for by the fact that the beaches are here more extensive, and offer a greater supply of sand.

Origin of the Dunes.—It need hardly be stated that the dunes are nothing else than the sand of the beaches, raised by the winds when dry, and heaped up in these irregular hillocks. This process may be witnessed on every sand beach where the wind has free access; besides, we need only compare a handful of the dune sand with the sand of the beach, where it is homogeneous, to be convinced that the two are identical.

The dunes which we have been describing, therefore, enable us to correct an erroneous impression as to their mode of formation. The circumstance that the most celebrated among the oceanic dunes, those of Holland in Europe, and of Cape Cod in this country, occur on coasts where there is a considerable rise and fall of the tide, led to the inference that tides were necessary to their formation; it being known that the sand of the beach frequently becomes sufficiently dried, during the ebb, to be carried off by the winds. The above mentioned instances of dunes on the shores of the upper lakes will suffice to refute this opinion, by showing that tides are not necessary to their existence, and that the mere action of waves is sufficient to supply the materials for their formation on an extensive scale.

Another feature of dunes, both on the shores of the ocean and of the lakes, which I would mention, is, that they occur only on flat coasts, where the waters are subjected to considerable motion, either from currents, or from the action of the winds, or from both these causes combined.

Now, this law is strikingly illustrated by the dunes of the upper lakes. As was stated before, the most conspicuous ones occur on the eastern shore of Lake Michigan, in those regions which are most exposed to the winds. The dunes of Pointe aux Chênes, which we have just been describing, are also exactly in the direction of the prevailing winds; and, moreover, it can be shown that they were formed from west to east; whereas, the western coasts, both of Green Bay and Lake Michigan, are entirely destitute of them. It is true that dunes are equally wanting on the eastern shore of Green Bay; but this is owing to the steep limestone bluffs which line the coast, and do not favor any considerable accumulation of sand on the beach. The dunes of White-fish Point are also in the direction of the prevailing gales, which blow here from the north-west.

Considering the phenomenon of the dunes, as a whole, it would appear that it exclusively belongs to the present era; at least, we do not know of any instance of their occurrence referrible to a previous epoch; whereas, they are frequently found covering the most recent of the quaternary deposits. Thus, it is not uncommon to find them resting upon peat bogs, both on this side of the Atlantic and on the European coasts; and I feel confident that similar instances might be discovered along the upper lakes. At any rate, the fact that they are composed of sand gathered from the beaches is, in itself, sufficient evidence of their very recent origin; it having been shown, in the foregoing pages, that the sand beaches, together with the sand flats of the upper lakes, belong to the most recent deposits. Indeed, so manifold are the evidences of the modern origin of dunes that M. Elie de Beaumont has even proposed to designate the actual period as the *Era of dunes.* It would appear that, since dunes began to form, no change of any consequence has taken place in the relative distribution of land and water, either along the ocean, or in the region of the great lakes.

Dune-like Ridges.—There are various localities along the upper lakes where the dunes seem to pass gradually into sand-beaches, or, at least, assume such a regular outline that it is sometimes difficult to identify them. As an instance, I would mention a series of low ridges near the mouth of Traine river, on Lake Superior, where they cover a surface of at least a mile in width, stretching from N.E. to S.W., and separated by trough-like depressions, generally filled with water. They are also covered by a fine growth of white, yellow and black pines (*Pinus Banksiana*); so regular and so parallel indeed are these ridges that, when crossing them in going from the interior towards the shore, they appear very much like ancient beaches, and it would be but natural to consider them as such, were it not for their homogeneous composition. In proportion as we approach near the shore, the vegetation disappears, the trees become less abundant, and, at last, the ridges graduate insensibly into the barren dunes which line the river. Now, there can be no doubt that the latter are genuine dunes; and since they are parallel and identical in composition with the ridges in the rear, the inference is but natural that the latter have originated in the same manner. Very probably they are the result of the combined action of wind and waves. A series of similar ridges or parallel dunes occur at the mouth of Miners' river, and also in various places between Grand Marais and Two-hearted river. Near the mouth of the latter river, they rise to the height of eighty feet. When the dune ridges are too crowded, their unequal slope is sufficient to indicate their true origin—the lee-slope, which is here the eastern, being much steeper and shorter than the opposite or western slope. When, however, as it sometimes happens, the ridges are so crowded as to obliterate these features, it is not always easy to distinguish them from the underlying sand deposit, especially when the latter is composed of fine and homogeneous materials. By closer examination, however, I generally succeeded in discovering some place along the shore where the base was stratified; whereas, the ridges above were not.

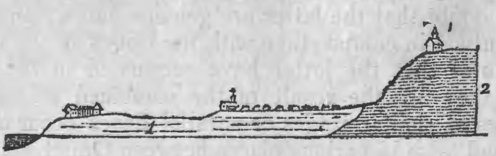
It may still be asked whether these ridges, in spite of their want of stratification, might not have been formed under water through the agency of some current which would have prevented a regular stratification; and, likewise, if their unequal slope might not be owing to some subaqueous cause. Without denying the possibility of such an origin, I would remark, that none of the shoals or submarine ridges with which I am acquainted, exhibit any such feature, and, moreover, they generally contain some pebbles either intermingled with them or occurring in their immediate vicinity. At any rate, if it should be proved that they are not true dunes, but the result of aqueous action, they can by no means be recent beaches, for their direction far from being parallel to the shore, is almost perpendicular to it. Besides, the recent beaches, in the vicinity of Two-hearted river at least, are entirely different in their composition, consisting almost exclusively of rounded and water-worn pebbles.

Ancient Beaches and Terraces.—The various kinds of alluvial deposits, which we have thus far been examining, can all be readily explained by the action of existing causes, without recurring to any change in the relative level of land and water. There are others, equally independent of any great geological changes, which seem to indicate, however, a higher stage of the waters along the lakes and rivers at the time of their formation, or such changes as may be explained by the prolonged action of actual agencies. A most striking example of this kind occurs at Saut Ste. Marie, near the outlet of Lake Superior. There is to be seen on the left bank of the river, an extension terrace, on the margin of which the fort and the village are built. Its height at the fort is twenty-one feet above the water; thence, it stretches for nearly a mile to the foot of the drift terrace, near the Mission farm; but in the rear of the village there is an abrupt rise of seven feet, especially conspicuous near the Baptist mission. From this point to the foot of the drift terrace, the ground is covered with an endless variety of boulders, which are so numerous in places, as to render the soil unfit for cultivation.

The following section (Fig. 34) will show the relative height and position of these terraces.

Fig. 34.

5. 4. 3.



Terraces at Saut Ste. Marie.

1. Alluvial terraces. 2. Drift terrace.
3. Mission farm. 4. Mission.
5. Fort Brady, below the Rapids.

The materials of the two alluvial terraces (1) are a fine yellow sand, somewhat loamy, and exhibiting in various places marks of cross-stratification. The appearance is so very different from that of the drift of the upper terrace (2) that it must be evident, at first sight, that they cannot by any means belong to the same formation. On the other hand, when we consider the extent of the terrace and the abrupt manner in which it breaks off at the fort, we feel naturally inclined to ascribe it to a different origin from that of the ordinary alluvial deposits, and I was at first tempted to regard it as belonging to the loëss, rather than the alluvium. This impression, however, vanished when I came to examine the topographical features of the locality in detail. The highest terrace at the fort, although twenty feet above the river, is almost on a level with the beach at the head of the rapids.

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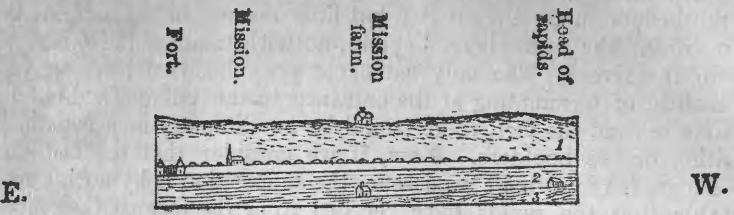
BOULD RS AT S UT STE M R

Fig. 35.



Alluvial terrace at Saut Ste. Marie.

1. Drift terrace.
2. Alluvial terrace.
3. Rapids.

The above profile distinctly shows that the height of the terrace above the river, at the fort, is merely the result of the fall of the rapids. If, instead of terminating near the upper part of the village they extended as far down as the fort, the small terrace by the Baptist mission would not by any means exceed the average height of the ordinary alluvial beaches. Now there is, as we shall see farther on, some ground for believing that in former times the rapids extended farther down. At that time the ground on which the fort now stands must have been a wide flat over which the boulders were carried, probably by ice-rafts, and stranded beyond the temporary shore, which is indicated by the little terrace near the Baptist mission. There are, besides, near the head of the rapids, patches of alluvial sands and boulders at a still higher level, belonging to the same deposit; nor is it at all improbable that some of the terraces mentioned by Mr. Bela Hubbard in his report, as occurring along the shore of Lake Superior, may belong to this earliest stage of the alluvial period.*

Boulders of Saut Ste. Marie.—In a former report, I alluded to those remarkable accumulations at this point. My object then was merely to show that they did not belong to the drift but the alluvial epoch. Of this we need no better proof than the fact that they are found scattered in great numbers over the surface of the alluvial terrace just described. The lithographic sketch, Plate XX, represents their accumulation on the right bank at the foot of the rapids, although very conspicuous in the western portion of the village and along the road leading to the head of the portage, and they are still more abundant in the rear of the fort. At the Baptist mission they are found twenty-eight feet above the foot of the rapids, and it is plain that no freshet or gale could have raised the river so as to strand them there; but, when we take into account the peculiar topography of the country, and start from the level of the river, at the head of the portage instead of below, it will be found that their distribution can be accounted for by the operation of such causes as are now in action, and without the necessity of recurring to any considerable change in the level of the country. It would appear that a rise of but a few feet would enable the lake to reach the level of the main tracks of the boulders between the head of

* According to Mr. Hubbard, "these ridges without doubt once constituted the shores of the lake at an era when its waters were, for a considerable period, at an elevation of about twenty-five or thirty feet above the present level. Their greatest distance inland from the present coast is two and a half miles."—*Report on the Geology and Topography of Lake Superior.—Documents accompanying the President's Message for* 1849, p. 899.

the rapids and the village of the Saut. Here, however, a difficulty arises with regard to those which extend beyond the rapids. We can readily conceive how those near the head became stranded, especially when encased in ice and heaped upon the shore; but how are we to account for those which occur at the same level beyond, notwithstanding the twenty feet descent in the river? The only satisfactory explanation is this. If the rapids, instead of terminating at the entrance to the village, had extended at one time beyond the fort, there would be no difficulty in accounting for the position of the boulders. Now, if we consider that the bed of the river is excavated in a fissile sandstone, the supposition is by no means unwarrantable that the rapids have receded from the fort to their present position, within the alluvial epoch. So far as I know, the boulders extend but a short distance below the rapids, thus shewing that their transportation, by whatever means it may have been accomplished, was limited to the immediate neighborhood: consequently, according to this hypothesis, it would not be necessary to assume a recession beyond the limits of a fair analogy. But, suppose farther that the head of the rapids were somewhat higher at that time than now; we would not only account for the boulders of the neighborhood, but for the alluvial terraces and ancient beaches along the shores of Lake Superior. Mr. Whittlesey has applied this hypothesis to explain the origin of the ancient beaches along the straits of Mackinac.

Assuming that the distribution of the boulders at the Saut resulted from the retrocession of the rapids, it will be conceded that their transportation must have taken place gradually and at different periods, since they occur at all levels from the margin of the lake to the distance of ten and fifteen feet above its level, forming in many places groups as though they had been stranded in the same direction. Thus, these boulders, like the dunes and flats of the upper lakes, are to be ranked among the most recent monuments of the quaternary period; and there is but little doubt that many have been stranded within the memory of man, although I have not been able to gather any direct information on this point.

As another striking instance of stranded boulders, I would mention those of Round island, opposite Mackinac. They occur mainly at the water's edge, on the north-eastern shore; and, since there is no drift in the neighborhood from which they could have been washed out, there can hardly be a doubt that they were transported by ice-rafts from distant points,—perhaps from the northern or north-eastern shore of Lake Huron.

We here append an account of the ancient and present beaches of Lake Michigan, by Mr. Whittlesey, as illustrating still farther the phenomena of the superficial deposits of this district.

The ancient and present Beaches of Lake Michigan,

BY MR. WHITTLESEY.

On the subject of the ancient and present beaches of the upper lakes it will not be necessary to dwell at length. The profiles and sections which accompany this chapter will show, at a glance, their uniformity and their characteristic features. They unquestionably belong to the recent period, and are due to fluctuations in the surfaces of the lakes, since the era of the drift. They are the natural modifications of the drift and shingle deposits, arising from the action of the waves on the shore. The most elevated and those intermediate cannot be distinguished in form or composition, from those now being formed at the water's edge. They are, however, deserving the name of "ancient beaches," as compared with those of the historical period, as is evident from the fact that they are covered with growing trees, such as elms and cedars of very great antiquity. The height to which the action of the waves reaches, and, consequently, the height of the present beaches, depends upon the exposure of the shore, and the force and direction of the prevailing winds.

The following sections (Figs. 36, 37) will serve to illustrate their nature:

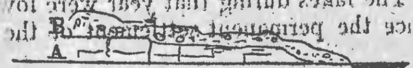
Fig. 36.

Beaches at Lime island, St. Mary's river: Distance, ten rods.

A. Niagara limestone. B. Water-worn limestone gravel. Nos. 1, 2, 4, 6, and 12, represent the height in feet.

The following section (Fig. 37), occurs on the north shore of Lake Michigan, on the south side of point St. Ignace:

Fig. 37.



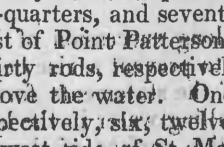
Beaches at St. Ignace.

The distance is fifteen rods, and the height between the water line and the most ancient of the beaches, is eighteen feet. The underlying rock A, consists of the Niagara limestone, covered with water-worn materials, B. There are here no less than five beaches.

Numerous sections of this character have been observed at different points. Thus, one mile east of Biddle river, there are four ancient beaches, within the distance of twenty rods, respectively rising ten and one-half, thirteen, fifteen and three-quarters, and seventeen and one-half feet above the water. Two miles east of Point Patterson, there are no less than five, within the distance of thirty rods, respectively rising three, four, six, fifteen, and eighteen feet above the water. One mile west of Seul Choix, there are three, rising, respectively, six, twelve, and fifteen feet.

The coast bluffs on the west side of St. Martin's island present a section somewhat like the following (Fig. 38):

Fig. 38.



A. Niagara limestone. B. Coarse, water-washed limestone gravel, fourteen feet above the lake-level.

On the north-east side of Potawatomee island, the cliffs of limestone rise to the height of eighty feet; but, resting on a projection, as in the above section, is seen the remnant of an ancient beach, eighteen feet above the lake-level. It is deemed unnecessary to give further examples.

By referring to the subsequent chapter on the fluctuations of the surfaces of the lakes, it will be seen that Lake Michigan and Lake Erie have, since the beginning of the present century, varied about six feet. In case that the waters of lakes Michigan and Huron have stood for a considerable length of time—say one or two years—at an elevation of six feet above the level of the summer of 1850, the ridges within twelve feet of the water-line on the above sections would have been formed.

It will be perceived that a majority of these sections have four ridges, often less, but in only one instance more. Four stages of considerable prominence are thus indicated, and the effects of the lake waters, in no case, are perceived at a higher elevation than eighteen feet.

The two most interesting cases of water-washed beach gravel, raised to considerable elevations, are at the cliffs of St. Martin's and the Potawatomee islands. These are upon perpendicular or shelving rocks, with no shingle at their base.

It will be perceived that the fourth and oldest beach is very uniform in height. In few places it does not fall below sixteen, or rise above eighteen feet. On the supposition that a beach of eighteen feet indicates a stage of water six feet below the crest of the ridge, as it does, generally, at the present time, the most elevated stage of the lake must have been twelve feet above that of 1850. The lakes during that year were low, but not so low as they have been since the permanent settlement of the country by the whites.

Allowing six feet as the greatest known and recorded fluctuation, it places the stage of water, which formed the most ancient of the beaches, more than six feet above the highest known stage. May not this state of things occur again? It has not, evidently, taken place within several centuries, since trees are found flourishing on the third and fourth beaches. Such an event would be of no great detriment to wild beasts or savages, but would prove a great calamity to a civilized people. It is evident, from our own observations on the rise of the lake waters, that the outlets are not sufficient to allow a rapidly accumulating surplus to pass off within several years.

Suppose that there was a long succession of humid seasons over the whole area; there is nothing to prevent a rise beyond what we have yet observed. An examination of the statements furnished in the succeeding chapter, as to the amount of falling water in the lake country, the loss by evaporation, and the comparative surface of the reservoirs into which it must flow, will show that a much greater rise might, in a certain combination of circumstances be reasonably expected.

On the other hand, it is probable that the outlet of Lake Huron, at Fort Gratiot, has been deepened, if not widened, by the action of a strong and ceaseless current, operating for many centuries on a sand and gravel bottom.

The outlets of lakes Superior and Erie, being over a rocky bed, have not probably changed as much. So far as my observations go, there are not to be found around their borders, ridges and beaches of recent origin, as high as those of Huron and Michigan. The former, if their debouchures have remained entire, have been exposed to the same meteorological causes, and should therefore show evidences of equally high water. I infer, therefore, that the beaches of lakes Huron and Michigan afford probable evidence of a change in their outlet, by widening and deepening the channel. I do not allude, in this connection, to those terraces and ridges which border all the lakes at an elevation ranging from thirty to two hundred and fifty feet. These are due to a much more ancient and permanent elevation of the waters,—phenomena which have been discussed in a previous portion of the report.

CHAPTER XVII.

ON THE ELEVATION OF MOUNTAIN CHAINS.

Importance of the Study of the Structure of Mountain Chains.—Object of this Chapter.—Structure of Mountains.—Contraction of the Earth the fundamental Cause of the Elevation of Mountains.—Parallelism of Systems of Elevation of the same geological Age.—Investigations of Elie de Beaumont.—Systems of Elevation in North America.—Systems of Elevation in Europe.—Comparison of the Directions of European Systems with those of America.

Among the many interesting subjects of investigation to the geological observer, there are few which can so justly claim a large share of his attention as that of the structure and relations of mountain chains. Next to the division of the surface of the earth into land and water, the direction, height, and form of the elevated ridges, which traverse the land, play the most important part in its physical history. While the student of philology, ethnography, and physical geography alike see the immense influence which the position and direction of mountain chains have exercised in the distribution of languages, in the migration of races of men, in giving form and outline to continents, and in the modification of climate; the geologist acknowledges in them the grandest and most imperishable record of the great cycle of events, the study of which is his peculiar province.

Hence those inquiries, which have for their object the determination of the nature of the dynamical forces which have given origin to the great features of the earth's surface, the laws which have regulated their direction and their chronological succession, will be readily acknowledged to be of the highest importance.

To these investigations the attention of geologists has been especially directed by the comprehensive labors of Elie de Beaumont, who for the last twenty years has made this the particular subject of study, and whose researches have been distinguished by the most admirable ingenuity and perseverance.

The object of this chapter is to call attention, we will not say to the theory, but to the great facts which have been developed by De Beaumont, in the course of his investigations, and then attempt to compare some of these results with corresponding ones on this side of the Atlantic; and especially such as have been obtained by us in the region of Lake Superior.

In order to a clear understanding of this subject, it will be necessary to consider the internal structure of mountain chains; and also some of the principal theories which have been proposed to account for their formation, or elevation. Here, however, it is important to bear in mind that the observations of De Beaumont are entirely independent of any theory with regard to the peculiar mode of upheaval of mountains, or the causes by which the ridging and folding of the earth's crust have been produced. His great object has been, simply to trace out, on the surface of the globe, the direction of the great lines of fracture and uplift, and to ascertain their relative orders of succession. The result of his investigations has been to accumulate a great mass of facts which seem to show a very near approach to parallelism in the mountain chains, or lines of fracture of the same geological epoch throughout the continent of Europe, which has been the principal field of his researches. He has, however, not confined his investigations to that continent only, but has traced out, in other countries, several of the systems of elevation which he has recognized in Europe, and shown a marked coincidence in their direction,—indicating that certain movements of the earth's crust had taken place simultaneously, and in parallel lines over a large portion of its surface.

The whole subject of the parallelism of mountain chains, and the determination of their relative ages, depends on the arrangement and position of the different stratified groups which have been disturbed and elevated at the epoch of their formation; or which, since that period, have been deposited in a nearly horizontal position upon the previously disturbed strata.

If the stratified beds on the flanks of a mountain dip away from it at a considerable angle, it is evident, that, having been originally deposited in a nearly horizontal position, the elevation of the mountain, which was the cause of their disturbance, must have taken place after their deposition; or, in other words, that it was a more recent geological event. If a group of strata dip at a high angle from the central elevated mass, and is again covered by another group inclined at a less angle than the former, but still having a considerable dip, it would be equally evident that there had been two successive epochs of disturbance; one after the deposition of the first group, and a second after another set of strata had been deposited horizontally upon the first. If, on the other hand, the elevated strata, dipping at a considerable angle from the mountain, are covered by others resting horizontally on them, it is plain that the elevation of the central mass took place at a period between the deposition of the first and second series. Thus the relation of mountain chains is fixed, by reference to the age of the strata which had been deposited at the epoch when the disturbance or uplift took place.

On examining the structure of mountain chains, however, it is not unfrequently found that the phenomena which they present are of a more complicated character, since the action of the elevatory forces was not exerted in such a manner as to produce a single ridge, from which, on either side, the strata dip at an equal angle. There may be a succession of parallel ridges or flexures, in which the strata assume a great variety of positions, according to their relative distance from the line from which the disturbing force is supposed to have acted.

Thus in the admirable sections of the Professors Rogers across the great Appalachian chain, we have a series of plications or flexures more abrupt near the line of disturbing action, and gradually opening out as we recede from it. In the Alps of Switzerland, we have abundant examples of the folding of a whole series of sedimentary beds in numerous and abrupt plications. Here, indeed, large masses of strata are sometimes bent back upon themselves, so that the lower members appear to overlie the upper; and instances occur, in which beds of an older geological epoch are inverted, and appear for a great distance, superimposed on those of a much newer epoch.

Besides this, there are many instances where the elevation of the strata has not been attended by any actual protrusion of igneous matter, forming a ridge or crest, but in which the direction of the elevating forces must be inferred from the prevailing strike of the strata. Thus the direction of actual mountain ridges is not only to be taken into consideration, but the general direction of the stratified masses becomes an essential element of such investigations.

Almost all geologists are agreed in opinion as to the great fundamental cause of the wrinkling or ridging of the earth's crust; or, in other words, the formation of mountain chains. The theory now almost universally adopted is founded on the combined results of the most careful observations of distinguished physicists and geologists, and the profoundest calculations of astronomical and mathematical science. According to this theory, it is inferred that the earth was once at a much higher temperature than at present; indeed, that, in all probability, it has been in a state of liquid fusion; that, among the first results of the cooling process, was the formation of a solid crust, thin at first, but gradually increasing in thickness over the still liquid interior; and that, as the secular refrigeration continued, the interior gradually contracted, while the exterior shell or portion was ruptured, or bent and folded, in endeavoring to accommodate itself to the shrunken nucleus on which it rested.

General as is the adherence among geologists to the idea of the wrinkling of the earth's crust having been the result of the cooling of the exterior, they are much divided in opinion with regard to the laws which have governed the action of this great cause, and the precise nature of the chain of events by which the present state of the surface has been brought about. Every year, however, seems to indicate a nearer approach to uniformity of opinion among those engaged in these investigations; in fact, the two great leaders in theoretical geology, in the Geological Society of France, have admitted that their differences of opinion related in reality to the use of words, rather than the facts themselves. The principal question which still remains in discussion between them is, whether the word *elevation* can be properly applied to the designation of a phenomenon dependent on the sinking of the earth's crust; M. de Beaumont maintaining that, inasmuch as the chief visible effect is to produce a comparative elevation of a certain portion of the surface, therefore, the word elevation may with propriety be retained in use to designate the formation of mountain chains.

It is to the Danish philosopher, Steensen, that we are indebted for the first recognition of the fact that strata of different ages may be distinguished from each other by their discordance of stratification, while to Humboldt is due the credit of having first called attention to the constancy of direction in the so-called primary schistose strata. To Elie de Beaumont must be ascribed the first distinct attempt to investigate systematically the laws which have governed the upheaval of mountain masses, and the recognition of the parallelism of elevation of the same geological age over different portions of the earth's surface; these researches, which have been carried on for many years with untiring patience, have been communicated to the world, principally through the medium of the publications of the Academy of Sciences and the Geological Society of France.

In his most recent publications on this subject, De Beaumont has coördinated his observations and placed them upon a mathematical basis, by connecting all his great circles of comparison into one vast net-work, the position of which upon the surface of the globe is determined by the geographical position of a single point, and the direction of a great circle starting from that point. This net-work has for its base fifteen great circles cutting each other, so as to divide the surface of the spheres into regular pentagons; while from these pentagonal areas, other supplementary circles are developed according to certain simple mathematical laws. The great result of these investigations is, that the wrinkling of the earth's crust has been effected in a series of arcs, the directions of which cöincide with the lines of most easy crushing of a sphere, gradually contracting in its dimensions.

Our object in this chapter is to call attention to the investigations of geologists in this department of dynamics; and, so far as is in our power, to furnish the materials for a comparison of the systems of elevation observed in this country, and especially those which we have recognized in our own district, with those which have been determined by De Beaumont.

For this purpose, we shall first describe some of the principal systems of elevation which have given configuration to the continent of North America, and particularly those which form the rim of the Lake Superior basin; we shall then proceed to enumerate some of the more important of De Beaumont's systems, and particularly such as from their age and direction appear to be of more importance in this country. The number of these systems has gone on increasing as the researches of geologists have gradually extended, and new facts have been accumulated; and it is to be expected that every year will add to this list, and accumulate new data of comparison for such as have already been adopted.

SYSTEMS OF ELEVATION IN NORTH AMERICA.

There are three grand systems of elevation which appear mainly to have determined the outlines of North America.

1. The first we denominate THE LAKE SUPERIOR SYSTEM, since it is developed on both shores of the lake, forming the divortia aquarum between Hudson's bay on the one hand, and between the river systems of Lake Superior and Lake Michigan on the other. The rocks comprising it consist of granite, gneiss, hornblende, talcose and chlorite slates, and belong to the azoic series. The lowest member of the Silurian series, wherever observed in the basin of Lake Superior, is found to rest undisturbed upon the upturned edges of these slates, or to occupy prëexisting depressions in the igneous rocks, leaving no doubt that these schists were elevated and folded before the dawn of the Silurian epoch. The direction of the lines of bearing is about N. 80° E., S. 80° W.

This system, as developed on Lake Superior, is but a portion of a continuous belt which stretches from Labrador to the sources of the Mississippi—forming the northern brim of the St. Lawrence valley—and probably beyond, even to the flanks of the Rocky mountains. Northwardly, according to Sir John Richardson, it extends to Coronation gulf in the Arctic sea. Upon the northern flanks of this belt, as upon the southern, the Silurian groups rest unconformably.*

If we examine a good map of North America, we find that this belt of country, lying between Hudson's bay and the Rocky mountains and embracing nearly 30° of latitude, is furrowed with ridges, the prevailing direc-

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* London Quarterly Journal, Geological Society, v. viii., p. 212.

tion of which is a little north of east and south of west; among these may be mentioned the Arctic hills, the High hills, and the Caribou mountains. The trend of the principal lakes conforms to this direction. This is the case with the Great Bear lake, near the borders of the Arctic sea, Slave lake, Athabasca lake, and Lake Superior. The trend, however, of Great and Little Winnepeg is at nearly right angles to this direction, and it may have resulted from a transverse fissure. The trend of lakes Michigan and Huron, also, may be said to be a deviation from this east and west system, but we have shown that this has resulted from denudation rather than from subsidence.

The Great-fish, the Unjiguih, or Peace river, the Assiniboin, and Saskatchewin rivers appear to flow along longitudinal valleys; while the Mackenzie, Slave, and Athabasca rivers apparently flow through a transverse fissure of the age, it may be, of the Rocky mountain system.

The granite and schists composing this system formed the ancient continent of North America, whose culminating points, in the Lake Superior district, rose not more than a thousand feet above the waters of the Silurian sea. It stretched out in a long and narrow belt, east and west, from Labrador to the sources of the Mississippi; and north and south, from the borders of Michigan to the Arctic sea. At that time, the Appalachian and Rocky mountain chains had not been elevated, and, with the exception of a few isolated patches in the form of islands, the whole area of the United States constituted a portion of the bed of the primeval sea.

2. The second may be designated as THE APPALACHIAN SYSTEM, which has given configuration to the eastern slope of North America; and the period of its elevation may be referred to the close of the carboniferous epoch. It commences near the outlet of the St. Lawrence, and terminates in northern Alabama; pursuing a course nearly north-east and south-west. The series of rocks composing it, according to the Messieurs Rogers, present an almost unbroken succession of conforming strata from the lowest members which repose immediately on the primary, or metamorphic rocks, to the highest carboniferous strata. The New red sandstone, which extends continuously in a narrow belt from the valley of the Connecticut to beyond Virginia, reposes immediately on the folded strata of this chain, and furnishes not the slightest indication of having been disturbed by the movements which produced the numerous axes beneath.*

3. The third may be denominated THE ROCKY MOUNTAIN SYSTEM, which, according to Sir John Richardson, "has a general course for two thousand five hundred miles,—or, from the thirtieth parallel of latitude to the Arctic sea,—of N. 26° W., S. 26° E., or N.W. by N."† It spreads out into a belt nearly one thousand five hundred miles in diameter, between the Mississippi valley and the Pacific ocean, consisting of numerous gentle corrugations, as shown by Fremont, but occasionally swelling into lofty ridges.

There is little doubt, from the concurrent testimony of all the explorers, that its age is as recent as the cretaceous period, and therefore among the most recent of those geological events which have modified the outlines of continents. On both sides of the equator it is, in places, flanked by calcareous strata containing, according to Von Buch, fossils characteristic of the chalk. These were also observed by Humboldt between Guambos and

* Transactions of the American Geologists, (1840–'42) p. 522.
† Quarterly Journal, before cited.

Montan, nearly one thousand three hundred feet above the sea; and Neocomin fossils were obtained by Tschudi in the cordilleras of Peru.

The explorations of Frémont and others, in the Rocky mountains, confirm these views as to the recent age of this system.

These are the three great systems which appear mainly to have determined the outlines of North America; but there are, in the Lake Superior district, subordinate systems which we will proceed to describe.

4. THE SYSTEM OF KAMINISTIQUIA.—This is developed on the north-west coast of Lake Superior, between Pigeon river and Thunder bay. Its direction is nearly north-east and south-west, and traces of it are to be observed in the parallel course of the principal rivers which enter Hudson's bay from the south-west, among which may be enumerated Moose, Albany, Severn, Nelson and Churchill rivers, extending through at least fifteen degrees of longitude.

This is the most ancient, so far as we yet know, of all the systems of North America; and the age of its elevation was prior to the close of the azoic period, since the upper portions of the azoic slates rest undisturbed upon the granite axis.

5. THE SYSTEM OF ISLE ROYALE AND KEWEENAW POINT.—This embraces the crystalline greenstone of the Copper region, which lifted up the bedded trap, sandstone and conglomerate at angles varying from 40° to 70°. The precise period of its elevation cannot be determined, but it probably took place near the close of the lower Silurian epoch, since we find that the Trenton limestone of the Sturgeon river valley has been disturbed by it. The direction of these axes is somewhat variable. On Isle Royale, they are N. 65° E.; but, on the southern shore they bear N. 52° E.,* though subject to minor deviations,—the trap ranges in many places assuming crescent-shaped forms. Although the great mass of rock has been subject to no intense disturbance since the close of the Silurian epoch, yet it has experienced a succession of widely-extended oscillations, which have been discussed under another head (Chapter IX).

Thus, it would appear that, in North America, the oldest lines of fracture pursue an easterly and westerly direction, while the more recent ones pursue a northerly and southerly direction.

Having thus given an outline of the great systems of elevation which have, as we conceive, during different epochs, gradually brought about the present form of this continent, we proceed to consider the European systems.

SYSTEMS OF ELEVATION IN EUROPE.

In his first publication,† in 1829, De Beaumont recognized only four systems of mountain chains, but the year following he augmented the number to nine,‡ to wit:

1. System of the main chain of the Alps; direction E. and W., which raised the older diluvial deposits.

2. System of the western Alps (from Marseilles to Zurich); direction N. 26° E., which raised the upper tertiary.

* This is the direction of a line drawn from the southern limits of the trap, on the Montreal river, to the southern limits on Keweenaw Point.

† Recherches sur quelques unes des révolutions de la surface du globe, Comptes Rendus de l'Academie des Sciences.

‡ Annales des Sciences, &c.: Tomes. 18, 19.

3. System of Corsica and Sardinia; direction N. and S., which raised the lower tertiary.

4. System of the Pyrenées and Appenines; direction N.W. and S.E., which raised the chalk and green-sand.

5. System of the Cote d'Or (Burgundy), the Erzgebirge (Germany); direction S.W. and N.E., which raised the Jura limestone.

6. System of the Vendée, Thuringia, and Bohemia; direction N.W. and S.E. which raised the Trias.

7. System of the Rhine; direction N. and S., or N.N.E. and S.S.W., which raised the sandstone of the Vosges (which he considers distinct from the variegated), and zeichstein.

8. System of the Netherlands and South Wales; direction N.E. and S. W., which raised the coal measures.

9. System of the Ballons (Vosges) and Bocage, Western France; direction N. 74° W., S. 74° E., which raised the carboniferous limestone.

In his last principal communication,* De Beaumont has shown that there are at least three different systems of elevation included in the above-named direction; and since M. Rivière had previously noticed another ancient system on the south-western coast of the Vendée, the direction of which was nearly N.W. and S.E., this system was added to the other three, making four, all of which are older than the oldest in the above list.

To these four ancient systems, still another must be added, which was also observed by Rivière, in the Vendée, and supposed by him to be the oldest known system of Europe. These five systems are as follows,—beginning with the oldest and proceeding in the order of their relative age, as determined by De Beaumont:

1. *System of the Vendée;* direction at Vannes,—latitude 47° 39′ 26″ N., longitude 2° 46′ W.—N. 22° 30′ W. Age, anterior to the system of Finisterre.
2. *System of Finisterre;* direction at Brest—latitude 48° 23′ N., longitude 4° 29′ W.—N. 68° 15′ E. Age, posterior to the oldest schists of Britanny.
3. *System of Longmynd;* direction at the Binger-loch,—latitude 49° 55′ N.; longitude 7° 50′ E.—N. 31° 15′ E. Age, after the deposition of the green slates of Wales and the feldstones.
4. *System of Morbihan;* direction at Vannes, N. 51° 45′ W. Age, posterior to the Bala limestone of Wales.
5. *System of Westmoreland and the Hundsrück;* direction at the Binger-loch, N. 58° 30′ E. Age, posterior to the Silurian and a part of the Devonian, but anterior to the Old red sandstone.

In a still later communication,† De Beaumont recognizes twenty-one systems as having been determined with more or less precision, but none of the new ones which he has adopted are as old as those given above; Durocher, however, has recently announced the existence of six new systems of upheaval, in Scandinavia, older than the lower Silurian, or belonging to the azoic period. Besides these, he recognizes the existence there of the four oldest systems of De Beaumont, enumerated above. The data of direction and relative age of the new systems proposed by Durocher are so

* "Notes sur les systemes de montagues les plus anciens de l'Europe:" Bulletin de la Société géologique de France: Ser. II. T. 4, p. 864.
† Comptes Rendus, Vol. 31, p. 325.

indeterminate, only an abstract of his observations having as yet appeared, that we have not attempted to trace their analogy with any of the lines of direction of the strata in our own district.

For the purpose of making a comparison between our own systems of upheaval and those of Europe, it will be especially necessary to fix, as nearly as possible, on the equivalency of the older systems of rocks in the two countries, since the age of the oldest systems of upheaval are determined by De Beaumont, principally by reference to certain groups as developed in England, Wales, and Britanny.

The following scheme is as accurate as could be expected, in the present state of geological knowledge. For a critical examination of the data on which this parallelism is founded, the reader is referred to the succeeding chapter by Mr. Hall.

AMERICA.	EUROPE.
	Azoic System.
Crystaline schists, limestones, and quartzose rocks, with intercalated traps, of Lake Superior, &c.	Sandstones of Barmouth and Harlech, in Wales; island of Anglesea, England; gneissoid rocks of Scandinavia and Britanny.
	Lower Silurian.
Potsdam sandstone; Calciferous sandstone.	The green slates and feldstones of Wales; the slates and porphyries of Bohemia; the lower sandstones of Scandinavia; the Obolus sandstone of Russia.
Chazy, Birds-eye, Black-river, and Trenton limestones.	Bitumious slates, and Orthocerate limestone of Russia.
Utica slate, and Hudson-river group.	Bala limestone of Wales; Llandielo flags and Caradoc sandstone of Great Britain.

The above comparison of the lower Silurian groups of the two continents seems to accord with the results of the geological survey of Wales. There, according to a communication of Barrande to the Geological Society of France,* in which he gives the result of his own examination of the materials collected by the survey, the Caradoc sandstone is distinctly recognized as being between the upper and lower Silurian divisions, while the Bala limestone and the Llandeilo flags form the upper portion of the lower Silurian, corresponding with the Hudson-river group in this country.

We now propose to inquire how far the ancient systems of upheaval, recognized by De Beaumont as existing in Europe, agree with those previously enumerated as occurring in North America. Four of the European systems are shown by De Beaumont to be prior in age to the deposition of the Caradoc sandstone, and we have enumerated three which are of at least as high antiquity in the region of Lake Superior. While, however, two of our systems are shown conclusively to be older than the palæozoic epoch, the age of the oldest European systems, with regard to the oldest strata containing organic life, is by no means so clearly settled.

In order, however, to institute a comparison between these oldest

* Bulletin, Ser. II. T. 8, p. 207. (January, 1851.)

systems of Europe and those recognized by us, we have calculated the direction which they would assume if transferred to the region of Lake Superior.*

1. The system of the Vendée; the direction of which, at Vannes, is N. 22° 30′ W., becomes—in longitude 87° 30′ W., and latitude 47° 30′ N.,—N. 79° 53′ E.

2. The system of Finisterre; the direction of which, at Brest, is N. 68° 15′ E., becomes—in latitude 42° 22′ N. and longitude 72° 32′ W.—N. 38° 20′ W.

3. The system of Longmynd; the direction of which, at Bingerloch, is N. 31° 15′ E., becomes N. 53° 40′ W.

4. The system of Morbihan; of which the direction, at Vannes, is N. 51° 45′ W., becomes N. 60° 30′ E.

On comparing these results with the directions of the systems of upheaval, before indicated as occurring in the Lake Superior region, we find that the direction of two of these systems coincides very nearly with that of two of those which have been calculated above.

The Lake Superior system agrees with the system of the Vendée; the former being about N. 80° E., S. 80° W., and the latter, transferred as above, N. 79° 53′ E., S. 79° 53′ W.

With regard to the age of the system of the Vendée we quote the following from the last publication of Rivière on this subject: "I have united all the normal directions of the gneissoid rocks of the Vendée into one system of dislocations, to which I have given the name of the *system of the Vendée*. * * * This is probably the most ancient normal system; at all events, it is the oldest system known; if it was preceded by other systems, these must be sought for in the north of Russia or in America, where the transition strata appear to be nearly horizontal. * * * The gneissoid formation is completely distinct from, and anterior to, the transition (Silurian or Cambrian) strata."

We may, therefore, presume that there is no doubt that both these systems, the European and American, are anterior to the deposition of the oldest fossiliferous strata, and thus far the agreement of the two in age and direction is sufficiently satisfactory.

The system of Kaministiquia, which seems to be the oldest which we have been able to recognize in America, appears to be older than any system of upheavals thus far admitted by De Beaumont. A coincidence will, perhaps, be found, after farther observations shall have been made as to its precise direction in this country, and after the numerous systems of the azoic period in other regions shall have been worked out with clearness and precision. As the region to which this system is confined in this country lies without the limits of our district, we have not been able to fix its direction with the precision requisite for a comparison with those of other countries.

The system of Keweenaw Point agrees very nearly in its mean direction with that of Morbihan, of which the direction, when transferred to the region of Lake Superior, becomes N. 60° 30′ E. The coincidence of this direction with that of Isle Royale had already been noticed by De Beaumont, who drew the inference that the sandstone and conglomerate of that island could not belong to the New red sandstone, as maintained by Dr. C. T. Jackson.

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*The substance of this chapter was communicated to the American Association for the Advancement of Science, at a meeting held at Cincinnati in May, 1851.

If, however, we proceed to inquire as to the coincidence in age of the systems of Keweenaw Point and Morbihan, we find that there is good reason to suppose that they may belong to the same geological epoch. The elevation of the sandstones, conglomerates and bedded traps of the Lake Superior region appears to have taken place at a period not far removed from that of the deposition of the Hudson-river group. This is inferred from the position of the deposit of lower Silurian limestone near L'Anse, which appears to have been disturbed by the same causes which produced the elevation of the trap and conglomerate of Keweenaw Point. As was shown in Part I. of this report, the age of the highest beds of this deposit is not more recent than that of the Hudson-river group; so that as far as can be known, this elevation must have taken place during the lower Silurian epoch.

According to De Beaumont, the age of the system of Morbihan is anterior to the deposition of the Caradoc sandstone and posterior to that of the Bala limestone. If it were admitted that the Caradoc sandstone is the equivalent of the Potsdam, we should be unable to recognize any agreement in the ages of the two systems in question. The age of the Caradoc sandstone, as well as that of the Bala limestone, seems at the present time to be better understood than when De Beaumont published the article before referred to, in which the ages of the older systems of elevation are so ably discussed.

If we consider, as we are authorized to do by the most recent authorities,* the Caradoc sandstone as forming the upper portion of the lower Silurian, and overlying unconformably the Bala limestone, the next inferior member of the same group, we shall have a perfect correspondence in the age of the system of Morbihan, in Wales, with that of Keweenaw Point, in the Lake Superior region. This parallelism of the groups in the two countries is conformable to the results of Mr. Hall's investigations, as given in the succeeding chapter.

As to the Appalachian system, De Beaumont was at first inclined to refer it to that of the Pyrenées, but now considers it as belonging, partly at least, to the system of the Ballons, the direction of which is N. 74° W.; but which, when transferred to the meridian of Washington, becomes N. 46° 42′ E., a direction which almost exactly agrees with the outcrop of the principal ridges. There is also another direction to be noticed in the Alleghanies, which is nearly parallel with the meridian, although at many localities it becomes merged with the former. This is known as *the oldest meridional system* of Hitchcock, and is supposed by him to embrace the White mountains of New Hampshire; "and it would appear," he remarks, "as if the strata had been deranged by the N.E. and S.W. system, which would go to show that the latter was more recent."†

The Messieurs Rogers maintain that these two directions have originated simultaneously, and are intimately connected in their whole composition; but, admitting that they are distinct in age, and discarding the existence of the so-called Taconic system, the meridional system remains an anomaly, not only as to its age, but in its parallelism with any of the older systems of Europe.

As to the Rocky mountain system, its parallel is to be sought in Asia rather than in Europe. Erman states that the great chain of Alden in eastern Asia, which forms the water-shed between the river systems of the Arctic

* Bulletin of the Geological Society of France; Series II. Vol. 8, p. 207.
† Geology of Massachusetts, p. 710.

and Pacific oceans, if protracted in the direction of a great circle, or following the shortest course from point to point, would intersect several of the principal summits of the Rocky mountains between 40° and 45°, thus indicating that, though widely asunder, they belong to one great fissure.*

It is worthy of remark that this chain, like the Rocky mountains, is in many places covered with volcanic materials, and several of the highest summits consist of active volcanoes. We have no information as to the character and age of the sedimentary rocks which repose on its flanks.

We have thus attempted to trace a parallelism between the mountain systems of the two hemispheres. We are disposed to regard these axes of elevation, not simply as irregular lines of limited extent, but as possessing much uniformity in direction and traversing entire continents; but we admit that, in the present state of geographical and geological knowledge, absolutely certain conclusions cannot be attained. Our object has been to call the attention of American geologists to one of the most interesting problems in this science—one which, thus far, has not received the attention which it deserves. We have had another object in view. Many European physicists have represented this continent as being emphatically *new*—not simply in reference to its settlement and civilization, but to the period when it first emerged above the ocean. We have shown conclusively, we think, that the period of its emergence was at least contemporary with, if not prior to, that of the eastern continent, although its outlines were very different from what we now behold.

In the succeeding epochs we witness the operation of the same great forces, though not perhaps in all instances simultaneously exerted in the two hemispheres. The seas swarmed with the same types of animal life, and the same forms of vegetable life clothed the land.

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* Reise um die Erde.

CHAPTER XVIII.

PARALLELISM OF THE PALÆOZOIC DEPOSITS OF THE UNITED STATES AND EUROPE.

BY JAMES HALL.

Field of Investigation in this Country a very extended one.—Circumstances affecting the Nature of the Fauna of the same Deposits at various Points.—Parallelism of the Palæozoic Groups in England and the United States.—Lower Silurian System.—Potsdam Sandstone.—Calciferous Sandstone.—Chazy, Birds-eye, and Black-river Limestones.—Trenton Limestone.—Utica Slate and Hudson-river Group.—Upper Silurian System.—Clinton and Niagara Groups.—Lower Helderberg Series.—Upper Helderberg.—Devonian System.—Species common to the Devonian and Carboniferous.—Tabular Comparisons.

So much has already been said upon this question, that it might appear superfluous to add anything more at the present time. We are, however, constantly learning more of our own systems of stratified deposits, and, of course, gradually becoming better able to compare them with what we regard as the equivalent systems in Europe. It was natural and agreeable to us, when we began our serious investigations into the condition and age of our palæozoic strata, to desire to identify what we found in this country with that which had been previously described on the other side of the Atlantic. In our too ready willingness to believe that nothing would be found here, except what had an equivalent abroad, we seized upon evidence and formed conclusions which farther investigations have proved to be erroneous.

The publication of Murchison's "Silurian System" gave the first clue to anything like a satisfactory recognition of our strata, and their identification with their European equivalents. The subsequent publication of the "Palæozoic Fossils of Devon," &c., and the establishment of a Devonian system in England, left us in no doubt as to the exact equivalency of some of our groups. The facts, if facts they shall prove, that many Silurian fossils exist also in Devonian rocks, seemed to us, however, strangely at variance with those in our own country, where we certainly have had opportunities of examining as wide an area, and of deriving our information from beds as well marked in character, and far less distant in position. Our data, collected over fields of wide extent and admirably adapted for such examinations, had shown us that the fossils were far more restricted in their geological range than had hitherto been supposed. We were able to subdivide what appeared to be the equivalent of the systems and groups recognized in England; and, in some instances, that which had previously been regarded as one group, has been found to be made up, in this country, of two or more distinct and widely separated members. Even after this subdivision, we were still able to recognize and trace other and minute divisions over a large section of country. Although we have been charged with impeding the progress of geology by these minute subdivisions, introduced in the geological survey of the State of New York, we have adhered to a system based on researches made over an extent of many thousand square miles, and by so doing we believe that an impulse has been given to the study of geological science and to the collection of fossils; and the more careful and minute the subdivisions, the more fully and completely have the observers been able to work out the details. By this system we have a better knowledge of the changes which took place in the bed of the palæozoic ocean, and the consequent variations in the character of its fauna, than has yet been obtained in many other parts of the world, where the series of strata has been studied for a much longer period.*

The thinning out and disappearance of a single member of even a subordinate group, and the consequent disappearance, in part or entirely, of its fauna, is a point of great interest in our geological investigations, and it is by this kind of study that we have found a clue to the character of our palæozoic fauna, which has not yet been reached in the exploration of the deposits of more modern geological epochs.

Although many of these minor subdivisions cannot be recognized in remote parts of the United States, yet the knowledge of their existence at another point enables the observer to detect their absence and to direct his attention to certain horizons, in order that he may ascertain whether the fauna of the absent member of the series has ever existed at all at that remote point, or whether it may have been mingled with that of a higher member of the same group with which it was contemporary. It is true that the greater subdivisions are more readily recognized, because they require less scrutiny to detect them than the more subordinate members. I may farther add that, until we are willing to study our formations with this degree of minuteness, we can have no positive knowledge of the duration of species, nor of the value of groups of species in the identification of strata. If we would determine whether species have ceased to exist in one part of the ocean, while they have flourished long afterwards in a distant region, it can only be done by a critical study of the subordinate groups, and the individual members of every group in the series.

The simplest principles of elementary geology teach us that sedimentary beds, having the same thickness and the same lithological characters, cannot have spread over an area so wide as that now included between the European and American continents. All sedimentary deposits must vary in character at remote points, as the physical conditions of the ocean cannot be presumed to have remained the same over a wide extent of surface. Under such circumstances, absolute parallelism is not to be sought for or expected. Calcareous deposits, as would naturally be supposed, have been found to be more persistent and more uniform in the character of their fossil contents; but these, over some portion of their extent, have often been invaded by argillaceous and arenaceous sediments, and the fauna is found to be in a greater or less degree influenced by such circumstances. In distant and disconnected localities, we are compelled to base our opinions of the equivalency of beds, upon the organic remains which they contain; and when we reflect that the nature of the sediment may in a great degree influence the character of the fossils, we shall not fail to recognize the necessity of keeping the character of these lithological changes in view.

* I might instance here as an example the carboniferous system of England, of which the details are, as yet, but little known.

The coarse conglomerates and grits, which are so frequently found intercalated in the series, indicate not only disturbance in the waters of the ocean, but also the proximity of the land; since we know that the efforts of the waves, as manifested at this day, is to confine these materials to the shore, or if they are transported by currents, the velocity soon becomes so far diminished, as to allow of their deposition in comparatively shoal water. As a general rule, therefore, the former class may be regarded as deep-sea deposits, while the latter may be regarded as littoral. When, too, we consider that marine life is greatly modified by the character of the sea-bottom, we ought not to look for a fauna specifically identical in the different classes of deposits. The conglomerates and grits, for the most part, are barren of organic life, while the limestones are richly stored with it. We have shown that the coarse grits in the New York series, are restricted in their range, while certain limestone groups spread out over an immense area.

Besides the changes which take place in the nature of the sediment deposited upon the bed of the ocean, we are to look to other important conditions which may affect the fauna, and, consequently, our conclusions regarding the equivalency of formations. Among the most important of these is the depth of the ocean in which the animals lived, since we know that certain species are confined within certain zones, depending on the depth of the water.

There are other conditions which sensibly affect the distribution of organic life, such as temperature, pressure and light; but as these have been fully discussed by Messrs. Foster and Whitney, in a previous part of this report (p. 183), I need not here pause to inquire as to the extent to which these conditions operate. In investigating the fauna of past ages, we see nothing to lead us to believe that the same great laws which regulate the distribution of species, did not then operate with as great effect as at the present time.

COMPARISON OF THE PALÆOZOIC GROUPS IN DIFFERENT PARTS OF THE UNITED STATES.

Before proceeding to compare the palæozoic series of the United States with those of the same age in Europe, it will be necessary to institute some comparison between the successive groups as they occur in different parts of our own country. The succession, which has been clearly made out in the eastern extension of these deposits, has not been determined on with the same degree of precision at the West, and this for want of that knowledge which can only be obtained by a minute examination of all the intermediate points. We have already, in the preceding pages, alluded to the changes which have been recognized in tracing the development of the palæozoic series from the east towards the west.

In order to facilitate the comparison we are about to make, we give below a table of the successive groups which have been determined in the State of New York. It is here that the series is more complete than in any other portion of the globe, and to this standard it is most convenient and satisfactory for us to make reference in our critical discussion.

Table of the palæozoic Series in New York; from the Base to the highest Group recognized.

1. Potsdam Sandstone.
2. Calciferous sandstone.
   Upper sandstone of Wisconsin and Minnesota, similar to the Potsdam sandstone.
3. Chazy limestone.
4. Birds-eye and Black-river limestone.
5. Trenton limestone.
   Galena or lead-bearing limestone of Wisconsin, Iowa and Illinois, not recognized at the East.
6. Utica slate. } Included in the Hudson river group
7. Hudson-river shales. } Included in the Hudson river group
8. Grey sandstone. } Included in the Hudson river group
9. Oneida conglomerate.
10. Medina sandstone.
11. Clinton group.
12. Niagara group, coralline limestone of Schoharie.
13. Onondaga salt group.
14. Tentaculite or water limestone. } Lower Helderberg group.
15. Pentamerus limestone. } Lower Helderberg group.
16. Delthyris shaly limestone. } Lower Helderberg group.
17. Encrinal limestone. } Lower Helderberg group.
18. Upper Pentamerus limestone. } Lower Helderberg group.
19. Oriskany sandstone.
20. Cauda-galli grit. } Upper Helderberg group.
21. Schoharie grit. } Upper Helderberg group.
22. Onondaga limestone. } Upper Helderberg group.
23. Corniferous limestone. } Upper Helderberg group.
24. Marcellus shale. } Hamilton group.
25. Hamilton group. } Hamilton group.
26. Tully limestone. } Hamilton group.
27. Genessee slate. } Hamilton group.
28. Portage group.
29. Chemung group.
30. Sandstone and shale of the Catskill mountains.
31. Grey and yellow sandstone.
32. Great carboniferous limestone.

These members are all more or less strongly characterized, possessing either marked differences in lithological character, in their fossils, or in both together. The area over which each one has been traced is quite sufficient to establish its distinctive character and relative importance. On the left hand I have indicated the grouping which has been found to agree best with the prevailing palæozoic features, and with the lithological characters. The lower Silurian limestones from the Chazy, including the Trenton limestone, have not the same intimate relations with one another, which the upper and lower Helderberg groups have, since these form two very distinct and natural groups. The upper part of the Clinton group is very intimately related to the Niagara group, and the lower part with the Medina sandstone; and, though treated as distinct in the State of New York, for reasons already given, it may hereafter be found best to unite the shaly and arenaceous beds with those below into one group, while the calcareous portion may be included with the Niagara. This arrangement would be more natural than the present subdivision.

We shall, in the first place, inquire into the relations which these groups have to those occupying the western and north-western States. I have already alluded to one of the most striking features of the geology of the west, namely, the almost entire absence of schistose and arenaceous deposits, from the termination of the Potsdam sandstone, to the commencement of the shales and sandstones succeeding the corniferous limestone. The real and apparent importance of the calcareous deposits is much augmented, when we view the series as a whole. Looking to this fact, we expect to find the difficulty of recognizing the individual members considerably increased, since the intercalated masses of sandstone or shale often mark, in a conspicuous manner, the line of separation of the two distinct deposits.

It has already been shown, in the preceding pages of this report, that the lower sandstone of the Lake Superior district is a continuation of the Potsdam sandstone of New York, which has been traced, by the Canadian geologists, through Canada and along the northern shore of Lake Huron. This sandstone has been shown to dip beneath a series of calcareous beds in which we recognize, as shown above, the calciferous sandstone, the Chazy, the Birds-eye, the Black-river and Trenton limestones, characterized by the same fossils which they contain in New York. We have shown that these successive members of the series have greatly diminished in thickness, the entire vertical range being, at several points, less than one hundred feet. In tracing them across to the Mississippi river the same tenuity is observed in all the four limestones; but the calciferous sandstone augments in thickness till it acquires the same development which it has in New York. At the extreme westerly points where we have examined these limestones, we find that their lithological character has undergone an essential change; but this has been a gradual one, so that we have been able to trace its progress in our examinations from east to west, and recognize many of the characters which might otherwise have escaped our observation. The fossils, though diminished in numbers, are, for the most part, identical with those which we have everywhere learned to regard as characteristic of the different groups.

Thus far we have had brought to our notice two or three important differences in the succession of the rocks at the West and in New York. These are the alternation of the lower beds of the calciferous sandstone with the higher part of the Potsdam, by which several successive bands of greater or less thickness are presented near the line of junction; farther, we have above the calciferous sandstone a bed of sandstone resembling the Potsdam, and which is from fifty to eighty feet thick. The occurrence of this bed, which I have indicated in the table above, shows that the causes which operated to give origin to the deposit of the Potsdam sandstone first became intermittent at the base of the calciferous, and then again became active after the final deposition of that rock. In addition to this, we have, succeeding the Trenton limestone, a thick-bedded, porous or cavernous, and usually friable limestone in which the great deposits of lead are found. This rock, though included with the cliff limestone of the West, is now known to be a distinct member of lower Silurian age, and one which thus far we have not recognized in our New York series. To make up for the diminished thickness of the Trenton and associated limestones in the West, we have this important and distinct mass, the geographical extent of which has not yet been fully determined.

We next turn our attention to the Hudson-river group, under which term we include the Utica slate, the shales and sandstones of Pulaski,* and the grey sandstone. In tracing this group towards the north-west, we find that the arenaceous beds gradually disappear; the calcareous matter, on the other hand, gradually increases, forming with the argillaceous beds of marl, or, by itself, occasional bands of impure limestone. We are able to trace this group continuously as far as the shores of Lake Winnebago in a westerly direction; and, at the south-west, we find it in the vicinity of Cincinnati and extending into Indiana and Kentucky. Thus, the Hudson-river group of New York, by the accession of calcareous matter forming marls and thin-bedded limestones, has become the typical "blue limestone and marls" of Ohio and of the North and South-west. This term has been extended to include the representatives of the Chazy, Birds-eye, Black-river and Trenton limestones, which appear about Frankfort in Kentucky, and again on the upper Mississippi.† I have already given the detail of the facts which prove the truth of this assertion.

Of the Oneida conglomerate, we know nothing at the west. It is an important member of the New York series, and extends from thence southerly through New Jersey and Pennsylvania, forming a well-marked geological horizon. The Medina sandstone has been traced to the north-west, through Canada; and it may be possible that the green marly bed below the Clinton group, on Green bay, is the equivalent of that rock. Farther to the west, or south-west of the great Alleghany coal-field, it has not been recognized.

The Clinton group is, for the greater part of its extent west of Lake Huron, merged in the Niagara group; or, in other words, the calcareous portion is so intimately united with that of the Niagara, that the two are hardly to be distinguished. The shaly and arenaceous portions of this group appear only at rare intervals, and form no important feature in the geology of the western States. There, the Niagara and Clinton groups are not recognized as distinct from each other, but both form a part of the

* These two are usually denominated the Hudson-river group, but since all those rocks along the valley of the Hudson river are more or less disturbed and metamorphosed, it is important to distinguish the individual members. Moreover, the four together form a natural group, which may either be studied as a whole, or, in favorable localities, in its individual members.

† The localities about Cincinnati do not expose strata below the age of the Hudson-river group, including the Utica slate.

"cliff limestone," or "upper magnesian limestone," so often spoken of, and which is one of the most prominent groups of the western states. This term, however, designates an extensive series of groups, since it includes the Galena limestone, the Clinton and Niagara limestones, (the shales and sandstones of the former group being absent), and the upper Helderberg limestones, all the intermediate groups being wanting in the states north of the Ohio river.

This will be better understood, perhaps, by the inspection of the following table, in which the equivalency of the Cliff limestone with the New York groups is shown:

Cliff Limestone.

CORNIFEROUS LIMESTONE.	
ONONDAGA LIMESTONE.	
SCHOHARIE GRIT.	
CAUDA-GALLI GRIT.	Wanting at the West and South-west.
ORISKANY SANDSTONE.	
UPPER PENTAMERUS LIMESTONE.	Wanting in the States north of the Ohio river.
ENCRINAL LIMESTONE.	
DELTHYRIS SHALY LIMESTONE.	
PENTAMERUS LIMESTONE.	
TENTACULITE LIMESTONE.	
ONONDAGA SALT-GROUP.	Wanting west of Lake Michigan.
NIAGARA GROUP.	The Niagara and the calcareous portion of the Clinton.
CLINTON GROUP.	
MEDINA SANDSTONE.	Wanting at the West.
ONEIDA CONGLOMERATE.	
HUDSON-RIVER GROUP.	Wanting at the East and South-west.
GALENA LIMESTONE.	
TRENTON LIMESTONE.	

The union of the Galena limestone with the cliff has been induced by the almost entire absence of the Hudson-river group, where the lead-bearing limestone occurs, and from the similarity of the latter to the Niagara.

The Niagara group, in the form of a heavy-bedded limestone, can be recognized throughout all the western States, both to the north and to the south of the Ohio. The Onondaga salt-group and the lower Helderberg limestones have not been recognized in the States to the north of the Ohio; nor has the Onondaga salt-group been observed to the south of that river. In Tennessee, the cliff limestone of Ohio is reduced in thickness and importance, and is nowhere recognized except as a single formation. Still, among its fossils are to be recognized many of those of the Niagara, and of the upper and lower Helderberg groups. Among the latter are *Pentamerus galeatus, Spirifer macropleura, S. rugosus,* and several species of *Atrypa,* which are known in New York only in the limestones of the lower Helderberg.

This interesting fact is not to be lost sight of, for we shall have occasion again to refer to it. We perceive that, over all that area of the palæozoic ocean, now occupied by the States north of the Ohio, this important group of limestones is wanting. Their absence can only be accounted for by supposing, either that the bed of the ocean was so far elevated that no deposition could be made upon it; or that it was so far depressed that its depth was too great to admit of the existence of corals and other marine animals with which they are associated, and the consequent production of calcareous deposits. Although represented in Tennessee, it is only by a few of the characteristic fossils, the formation not becoming one of importance in the series.

In numerous localities which have been examined, the upper Helderberg limestones rest upon the Niagara limestone, but are sometimes separated from it by a band of argillaceous limestone, which is, probably, an indication of the Onondaga salt-group. In some instances, there is evidence of a denuding action upon the surface of the Niagara limestone, previous to the deposition of the upper Helderberg limestones; and we can suppose this to have occurred only in a shallow ocean. Whether this was the condition of the ocean during all the intervening period, we cannot pretend to decide at present; it seems not improbable, however, that, during the first part of the interval, the ocean was too deep to admit of the growth of animals; and that, subsequently, or at the period of the Oriskany sandstone, its bed was elevated, and, after some slight oscillations, it remained at that uniform elevation over the entire area, thus admitting of the formation of this extensive coral reef which marks the period of the upper Helderberg. The limestones of this period, either in their several parts, or as one rock, are recognized throughout the West and South-west, having everywhere an unmistakable character, and filled with the same fossils as in the state of New York.

Of the groups above the corniferous limestone, which is the terminating rock of the upper Helderberg series, we have but a meagre representative in the States west of the Ohio river. Here, we know that some portions of the Hamilton, as also of the Portage and Chemung groups still remain, but they gradually die out in a westerly direction. In Canada West, and in the southern part of Michigan, the Hamilton group is well marked by many of its characteristic fossils. In many parts of Ohio, Indiana and Kentucky, the corniferous limestone is immediately succeeded by a black slate, the exact age of which may be regarded as undecided. It appears not to more recent than the Genessee slate, and we should expect to find some representation of the Portage and Chemung groups above it. Thus far, however, it is only in the lithological character of some of the shaly sandstones above this black slate, that we see any resemblance to these groups.

The shales and the sandstones of the Catskill mountains, we know, have thinned out and disappeared before reaching the western part of New York; and these have no representation at the west. Succeeding the black slate, however, there is a group of shales and sandstones which, from the fossils they contain, are regarded as belonging to the carboniferous period. This group is succeeded by the great limestone deposit, which is usually termed the *carboniferous*. Neither of these has as yet been satisfactorily recognized at the east.

Thus far, up to the present time, having traced the actual continuation of the several rocks and groups to the westward, and perceiving the difficulty which exists in determining in detail the parallelism of the different members of the palæozoic series, even where no ocean or mountain barrier exists, we shall be prepared to appreciate the obstacles in the way of arriving at an exact parallelism of our series and those of Europe, separated as they are by an intervening space of 3000 miles of ocean. In making any such comparison, it is highly important for us to possess a knowledge of the changes which take place in the nature of deposits which are absolutely continuous, and strictly synchronous in their origin, having been deposited in the same ocean during the same period of time. We have an opportunity of comparing these in a country where there have been no disturbances to produce faults, dislocations, foldings or metamorphism of the beds, and where the general elevation varies but a few hundred feet. Here there can be no mistake in the observations, and the conclusions drawn from them must be allowed to have great weight. We perceive that entire groups of strata are unrepresented at the West, since the species in the upper Helderberg limestones, where they rest upon the Niagara group at the West, are identical with those of the same rocks in New York, where they overlie the Oriskany sandstone.

The very interesting species marking the period of the Hamilton group are entirely wanting in the western and south-western States, and we have very few representatives of those of the Portage and Chemung groups, and none at all of the Catskill mountain shales and sandstones.

Such being the state of things at the West, it is easy to point out the line of demarcation between three or four groups, but this kind of grouping will not help us elsewhere. One of these groups which physically is a natural one in some parts of the country, contains fossils of three distinct periods, viz: the Niagara, the lower and the upper Helderberg. Were these animals living contemporaneously, or did they succeed each other in the order of time, as elsewhere shown? And, if they thus succeeded each other, did the same interval elapse in those localities where they form one apparent group, as in those places where each one is represented by a distinct geological formation and a fauna peculiar to itself? These are questions to be answered only after mature investigation; they arise with others when we take into consideration our palæozoic series, in its entire geographical extent, and consider the varied phases which it displays over the space stretching from the Atlantic to the Mississippi, and from Alabama on the south to Lake Superior on the north.

PARALLELISM OF THE PALÆOZOIC SERIES OF EUROPE AND AMERICA.

The series of deposits which we have to consider lies between two well marked limits; namely, the base of the palæozoic beds on one side and the period of the coal on the other. These two points are of equal importance as geological horizons. On the continent of Europe and in the United States, there is little difference of opinion in regard to the point of the commencement of organic life. In England the question is not so well determined, and it is here that we need further information before we can make satisfactory comparisons. M. de Vernueil has rémarked* that one of the

* I should not proceed farther without making due acknowledgment for the very lucid and philosophical memoir of de Verneuil upon the "Parallelism of the Palæozoic formations of America with those of Europe." (*Bulletin de la Soc. Géo. de France*, Ser. II. T. IV. translated and published in Sill. Am. Jour., Series II. No. 14,) which has done more than all else to elucidate this subject. The paper by Mr. Sharpe on the "Palæozoic rocks of North America," (Quar. Jour. Geol. Soc. London, Aug., 1848) is filled with valuable critical matter and affords useful hints upon the subject. M. Elie de Beaumont, in his "Note sur les systémes de Montagnes les plus anciens de l'Europe," published in 1847, has also introduced the subject of parallelism in connexion with his views of mountain systems and their epochs of elevation. Beyond these, we have our own papers on this subject, which were the results of observations made several years since.

principal difficulties, in the comparison between American and European systems is, that, in America, the series is more complete than in Europe. It cannot then be expected that we should find representatives for all our groups, but only for the most persistent of them. The very completeness of the palæozoic series in this country presents another difficulty, since it destroys those sharp lines of demarcation, and those wide and positive distinctions which are very conspicuous where many of the beds or groups composing the series are wanting. If there be any changes in the character of the animals marking successive stages, then every later group is marked in some degree by these changes; thus, the absence of any one or more of the intermediate groups leaves those on both sides in stronger contrast with each other.

All the attempts to show that the parallelism of American and European palæozoic deposits have been with a view to find a correspondence with the European standard, where the series is confessedly incomplete, and where it has suffered, during its deposition or subsequent to it, many disturbances. In speaking in this manner, we do not mean to detract from the great merit of this standard of classification, the result of labors of which we, who study the various groups almost undisturbed, can have but little idea; we mean only to claim for the most complete series, that one where physical and zöological characters are best developed, the preëminence which is due to it as the most perfect exponent of nature herself. It has been said that our groups are of very unequal importance; but to this it may be remarked that it was not always possible to say what were and what were not important groups. For example, the Niagara limestone, in its eastern extension, is only a few feet in thickness, and might well be united with the lower Helderberg series, which are separated from it by less than twenty feet; and these two groups were so united up to the year 1838: but, following out these deposits in a westerly direction, the Niagara group expands to an important one, and the thin mass separating it from the lower Helderberg attains a thickness of a thousand feet. What are apparently unimportant beds, in one place, may become very important in another. It is, indeed, true that this attention to minor groups does diminish the value of the lines of division between the so-called systems; thus, throughout New York, the line of separation between the Niagara and the lower Helderberg limestone is as strongly marked as that between upper and lower Silurian, or that between the lower and upper Helderberg, which is now regarded as the line between the Silurian and Devonian. In this instance, we have no hesitation in saying, that the line of separation between two of the subordinate groups of a system is as well marked as that between the two divisions of that system into upper and lower, or between that system and the succeeding one. If it be argued that, in the South-west, these two groups of the lower Silurian system coalesce into one physical group, so also does the upper Helderberg (Devonian) coalesce equally with the other two, the whole forming but a single physical group. The Oriskany sandstone is often less than five feet in thickness, and yet it separates the lower and upper Helderberg limestones as effectually at those points, as where it is a thousand feet thick. The Marcellus shale, a subordinate member of the Hamilton group, is not more than one hundred feet thick, and still it contains a group of fossils specifically unlike all those in the succeeding rocks. It is certainly worthy of separation as a distinct member of the series, and its importance is likely to increase rather than to diminish. The black slate of the western and south-western States, which immediately succeeds the corniferous limestone, has no greater thickness than the Marcellus shale, and yet its importance is there fully acknowledged. It occupies the interval between the corniferous limestone and the carboniferous sandstone, which, in New York, is filled by three distinct groups having a total thickness of little less than five thousand feet.

A review of all the facts, and the conditions under which we find the successive groups developed, brings us back to our original conclusion, that, where the series is most complete, there will be recognized no lines of systems; and that the whole series, from the commencement of organic existence to the period of the coal, is one system, composed of a series of deposits succeeding each other without those marked changes or intervals which have usually been considered to exist.

LOWER SILURIAN GROUPS.

The Potsdam sandstone, with its associated conglomerates and shales, which exist in some parts of the United States, lies at the base of the fossiliferous series. It has now been traced from Canada, west to the Mississippi river, and south-west to Alabama. This rock is represented in Russia by the beds containing *Obolus* and *Lingula*; and in Scandinavia by sandstones, which rest unconformably on the gneissoid and schistose rocks, composing the azoic system. M. de Verneuil remarks: "These are, in the two continents, the most ancient fossiliferous rocks; and, when we reflect upon their antiquity, we are astonished to find a genus of shells in them which still appears in the existing creation, proving that the conditions of existence were not very different then from what they are at present." It is not yet certain that any beds exactly equivalent to this sandstone have been found in Great Britain, though it is not impossible that some of the beds in North Wales may be so. In the same connection we may include the calciferous sandstone, which does not appear to be recognized anywhere in Europe with the same distinctness as in America.

The Chazy, Birds-eye, and Black-river limestones, which, in New York, form a group distinct from the Trenton limestone, are not very clearly recognized in Europe. It is probable that some part of the Orthoceratite limestone of Sweden is the equivalent of the Black-river mass; but we have no evidence, from fossils or otherwise, that there are any representatives of the two lower rocks. I have shown that, of the eighty-three species found in these lower limestones, four pass upwards into succeeding beds, two are doubtful, and seventy-seven are restricted to the group. Of this number of species, the *Lituites convolvans* is the only one which I can consider as an European species; the *Illænus* of the Chazy, which I regarded with doubt as *I. crassicauda*, being a very distinct species.* For these reasons I consider the limestones in question as having no representation among British strata; and, if at all represented on the continent, it can be only in a very partial manner.

The Trenton limestone, the Utica slate, and the Hudson-river group are represented in northern Europe by the Orthoceratite limestone of Sweden and Russia, and by the shales with Graptolites, which succeed to that limestone. In Great Britain, the Llandeilo flags and Caradoc sandstone are

* *Columnaria alveolata* of Goldfuss is an American fossil.

clearly the equivalent of these groups. It is here that we first find a number of species identical with European ones, and which enable us to institute a comparison. It will be found, however, that the species in the Hudson-river group correspond most nearly with the European forms, and that it may be doubtful if the base of the Trenton limestone has been reached in Great Britain. I am quite aware of the opinion expressed by Mr. Sharpe, who speaks of the fossils of the

TRENTON LIMESTONE, UTICA SLATE, HUDSON-RIVER GROUP,	Blue limestone of Ohio.

as being, many of them, common to Europe, where they characterize the middle part of the lower Silurian system; it must be recollected, however, that Mr. Sharpe includes in the lower Silurian series, the

GREY SANDSTONE,
ONEIDA CONGLOMERATE,
MEDINA SANDSTONE,
CLINTON GROUP.

The three latter we cannot include within the lower Silurian, for reasons elsewhere given; but especially because, by thus doing, the line between the upper and lower Silurian would be drawn in the midst of species and types continuing upwards into the upper Silurian. We must also recollect that the larger part of Mr. Lyell's collection was made in western localities, and that he could not have had a fair representation of the species of the Trenton limestone, as we know them in New York.

I have now satisfied myself, from actual examination over many hundred miles, that the blue limestone, as it appears at Cincinnati, is only the Hudson-river group; and that the Trenton and other limestones, or their equivalents, lie below it. This opinion was published by me in 1841, and though I was, at one time, disposed to modify it from the observations and published accounts of others, later examinations have confirmed me in my position. The argument of Mr. Sharpe, therefore, when we look at the facts, is strongly in favor of the view we have expressed; for, taking away the three groups, as we are compelled to do, we show that the fossils he was examining were from the upper part of our lower Silurian series, and not from the middle. These correspond very well with the Caradoc sandstone, which, in its zöological character, is clearly the equivalent of our Hudson-river group.*

In studying the fossils from the Trenton limestone, Utica slate and Hudson-river group, (regarding the latter as composed of the Frankfort slate, the Pulaski shales and sandstones, and the grey sandstone,) I found, restricted to the Trenton limestone, one hundred and eighty-eight species; and, beyond

* There can be no longer any ground for sustaining the opinion of M. Elie de Beaumont, that the Caradoc is the equivalent of the Potsdam sandstone. This opinion I presume to have been formed from the erroneous views published in this country as to the position of the Potsdam sandstone with regard to the metamorphic slates and other schistose rocks of eastern New York and western New England. Since there is now but one opinion regarding the age of these rocks, it is no longer necessary to offer any argument to prove their real position and relation to the Potsdam sandstone.

this number, twenty species common to the Trenton limestone and Hudson-river group, and two species common to the Trenton limestone and the Utica slate. In the latter rock, I found eight species restricted to that rock, and three others occurring in both this rock and the Hudson-river group. In the latter group, fifty-four species are restricted to it, and there are twenty which are common to it and the Trenton limestone, and three common to it and the Utica slate.

The list, given by Mr. Sharpe, of the European species found in these groups, is as follows:

Leptæna alternata.	Spirifer biforatus.
——— depressa.	Terebratula bidentata.
——— imbrex.	——— reticularis?
——— sericea.	Strophomena grandis.
Orthis parva.	Bellerophon bilobatus.
——— testudinaria.	Porcellia ornata.

Of these species every one, which is included in our list, is common to the Trenton and Hudson-river group, or restricted to the latter, as is the case with *Terebratula bidentata** and *Porcellia ornata*.† This does not reach the case; and unless we have evidence that some small portion of this one hundred and eighty-eight species, restricted to the Trenton limestone, are identical with British species, we shall not feel disposed to admit that this period is there represented. It is probable, however, that the Llandeilo flags, and some associated limestones, may be the equivalent of this rock in the British isles. When we recollect that, according to Professor Sedgwick, all the bands of limestone in England, below the carboniferous series, are purely local phenomena, which appear only at intervals, we shall not be surprised to find that our lower Silurian limestones are not there represented by strata of the same lithological character.

In comparing our fossils with those of Ireland, we find several species identical and others closely resembling those of the Trenton limestone. Among them may be named, *Isotelus gigas* (which rarely occurs in the Hudson-river group), *Illænus crassicauda*, *Phacops callicephalus*, (allied to *P. Dalmani*), and *Lichas trentonensis* (allied to *Lichas* (*Nuttainia*) *hibernica*).

We recognize in the fossils of this period some which are identical with those from Sweden and northern Europe. M. de Verneuil has indicated the following:

Calymene Blumenbachii, (var. senaria.)	Trinucleus caractaci.
C. Eischéri.	Orthoceras communis, or duplex.
C. punctata.	Lituites convolvans.
Illænus crassicauda.	Bellerophon bilobatus.
Lichas laciniata.	Spirifer lynx.
Ceraurus pleurexanthemus.	Orthis testudinaria.
Phacops Dalmani.	—— Verneuili.

* *Atrypa dentata*, Hall. Pal. N. Y., Vol. I. p. 33, Fig. 14, not *T. bidentata*, Hist. Leth. Suec. I have since become satisfied that this is a Hudson-river species.

† *Cyrtolites ornatus*, Conrad.

These may be regarded as characteristic of the lower Silurian age in Europe and America. When we compare the formations given by Hisinger, and the lists of fossils under each, we can have no doubt but that we have represented in the "*strata schisti argillacei*" and the "*strata schisti alumnaris*," our Hudson-river group and Utica slate; and that the "*strata calcarea antiquiora*," with their numerous Trilobites and Orthoceratites, Orthis, &c., some of which are identical with our species, and many closely related in form, are equivalent to our Trenton limestone, with a meagre representation of the beds below.

If the Orthoceratite limestone of Sweden extended into Great Britain, it seems scarcely possible that it should not have been recognized, since it contains an abundance of that remarkable form, the *Endoceras,* but a single one of which, *Orthoceras bisiphonatum*, is figured in Murchison's "Silurian System," and this one is from the Caradoc sandstone. The fossils from the Llandeilo flags are, to so great an extent, identical with species from the Caradoc, that we cannot suppose these beds to extend below the horizon of the upper part of the Trenton limestone; or, in the absence of the calcareous element, they may possibly hold the place of this limestone; but of this we have no positive evidence, for the want of materials for comparison.

In America, the Hudson-river group terminates the deposits of the lower Silurian period. The commencement of the succeeding period is marked by some great disturbance, which, though not visible in its effects upon the preceding beds, is indicated by the production of a coarse sandstone and conglomerate, spread widely over the deposits of a more quiet period. This reason alone might not be sufficient to induce us to draw the line of demarcation at this point; but, in the fossiliferous beds succeeding this rock, we find ourselves in the midst of a fauna which is entirely new, or at least where preëxisting forms are so rare and obscure that they are scarcely appreciable in our consideration of the whole. This entire change in the fauna is equally characteristic over large areas of country, where the sandstone before alluded to has not extended. The epoch of this conglomerate, however, was followed by alternate periods of disturbance and repose; for we find, in the Medina sandstone, a vast accumulation of argillaceous matter mingled with the arenaceous deposits; and, the Clinton group, whose organic remains become numerous, consists of shales, sandstones and conglomerates. At the commencement of this period, therefore, as at the beginning of the palæozoic epoch, we have the evidences of those disturbances which have charged the ocean with coarse materials, transported by violent currents, and spread widely over the bed of a previously quiet sea.

The change in the fauna is equally conspicuous where the sandstone or conglomerate, which ushers in this period, does not exist, that is to say, at the West and North-west.* We have already shown this in tracing the formations from Drummond's island to the Mississippi river. If any further facts or arguments were needed to sustain this view, we have them in the fossils already described from the Clinton group of New York, which amount to more than one hundred species; and we have not yet recognized five which are known in the lower Silurian rocks of America.

* M. de Verneuil says, that near Galena, the line of separation is not so distinctly marked, and the magnesian limestone contains, at its base, the fossils of the lower Silurian period. We regard this as already sufficiently explained in what we have said of this lead-bearing or Galena limestone, which has heretofore been united with the cliff, or upper magnesian limestone, but which is decidedly separated from that, and is a lower Silurian limestone, which sufficiently accounts for its containing lower Silurian fossils.

UPPER SILURIAN GROUPS.

In the upper division of the Silurian system, we include the rocks from the Oneida conglomerate to the lower Helderberg limestone inclusive. Of these groups, the Clinton and Niagara have a very wide extension, as we have already shown, in a westerly and south-westerly direction, while the lower Helderberg limestones extend in a southerly direction, following the palæozoic deposits, and can be more or less distinctly recognized from New York to Alabama.

The Clinton group, with its beds of *Pentamerus oblongus*, represents what in England is regarded as the upper part of the Caradoc sandstone;* but we find it, not only above this well-marked horizon, which we have already indicated, but associated with numerous species of fossils, some of which are known as upper Silurian forms in Europe, and others pass into forms characteristic of the Niagara group in this country.

The Niagara group, with its shale and limestone, would seem, at first view, to be the exact equivalent of the shale and limestone of Wenlock and Dudley in England, and of Gothland in Sweden, so numerous are the identical species in these groups; but, on examination, we find that there are numerous species included in these rocks in Europe, which occur only in the lower Helderberg limestones, and which are separated from the Niagara by the enormous deposit of the Onondaga salt group. It is clear, therefore, that in the Wenlock formation of England, and its representatives in northern Europe, are included parts, at least, of two distinct groups in the order of time,—distinct both in their physical and zoölogical features; and we cannot institute a proper comparison between the rocks of our own country and those of Europe, while we regard that as one group. The condition, both in England and on the continent, is doubtless similar to what we find in Tennessee and Virginia, where, from the absence of the intermediate groups, not only the Niagara and lower Helderberg are united together, but even the upper Helderberg limestones are superadded.

M. de Verneuil regards the five inferior beds of the Helderberg as equivalent to the Ludlow formation of England, and, at the same time recognizes many Wenlock species among them. Mr. Sharpe remarks that "a large proportion of their shells correspond with those of our Wenlock formation, and there can be no doubt that they must be classed with that deposit." We certainly admit the propriety of recognizing these divisions — the Niagara on one side and the lower Helderberg on the other — as equivalent to the Wenlock formation. Mr. Sharpe remarks, however, that, with these shells of the lower Helderberg, he finds some which have been regarded as Devonian, and mentions *Orthis resupinata* and a *Productus*, which we can only suppose to have found their way into this collection by accident.† We are not prepared to say what relation these five members,

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* It appears to me highly probable that the breccia and conglomerate of the upper part of the Caradoc may represent our Onondaga conglomerate, and there, as here, occupy a lower position than the Pentamerus beds.

† It is true that there is, in the upper Pentamerus limestone of the lower Helderberg, an *Orthis* resembling *O. resupinata*, and another in the Delthyris shaly limestone, which bear some resemblance to that species; both, however, are quite distinct. I have, in my own collection, three different species from England and the continent, all under the name of *O. resupinata*, but entirely distinct from each other; and Mr. Sharpe will, I am sure, recognize them as distinct, whenever he shall direct his attention to them. I have seen *Productus* below the upper Helderberg limestone, where we know that it occurs.

forming the lower Helderberg group, bear to the Ludlow rocks; but we know that few of the fossils are similar to those of that division, while many are identical with those of Wenlock and Dudley. We have yet seen no reason to change our opinion as to the similarity of the fossils of the upper Helderberg and Hamilton groups, with those of the Ludlow division, though there are some very important and characteristic ones known only in the lower position.

Among the species of the Niagara group, which are apparently identical with those of Wenlock and its equivalent on the continent, we may mention the following:

Catenipora escharoides.
Heliolites pyriformis, and allied species (Porites of Lonsdale).
Stromatopora concentrica.
Limaria fruticosa.
——— clathrata?
Numerous bryozöoid corals, identical with Dudley species.
Ichthyocrinus lævis.
Eucalyptocrinus decorus, and
Cystideæ of closely allied forms.
Orthis elegantula.
——— hybrida.
Leptæna depressa.
——— transversalis.
——— subplana?—Orthis pecten?
Spirifer bilobus.
——— sulcatus.
——— crispus.
——— radiatus (S. cyrtæna, Dal.)
Atrypa reticularis.
——— imbricata; or a closely allied species.
——— bidentata.
——— interplicata.
——— cuneata.
——— brevirostris?
——— plicatella?
——— aprina.
Orthoceras imbricatum.
——— virgatum,
——— undulatum.
Conularia niagarensis. (Compare with C. quadrisulcata in Murchison's Sil. Syst.)
Cybele punctata.
Ceraurus insignis.
Bumastis barriensis.
Phacops lingulurus.
Calymene Blumenbachii.
Homalonotus delphinocephalus.
Proetus Stokesii, and species of Onchus.

This list might be considerably extended, if we were to add species so closely similar to European forms, that there may still be some question as to their identity.*

Remembering that, above this group, we have the Onondaga salt-group, which, in its greatest development, is one thousand feet thick, we turn to the next succeeding, or lower Helderberg group. In this group we recognize:

Orthis pisum, a species closely allied to O. hybrida.
A species allied to O. hybrida.
A species allied to O. elegantula.
O. orbicularis.
Leptæna depressa.
Spirifer varicus, allied to S. bilobus.
Spirifer, two species resembling S. crispus, and S. sulcatus, but much larger.
Atrypa reticularis.
Atrypa tumida?
——— Wilsoni?
——— Stricklandi?
Pentamerus galeatus.
Avicula naviformis.
Bellerophon profundus, allied to B. dilatatus.
Phacops Hausmanni.
Homalonotus ——— ? allied to H. delphinocephalus.
Acidaspis ——— ?

* In this list I have included none which are restricted to the Clinton group.

The number of species identical with European forms will doubtless be much increased, when a critical comparison shall have been made of all the specimens we now possess from this group; and, even at the present time, the list of allied species might be considerably increased, if it were desirable to do so. Among those enumerated, not one is known in the Niagara group, and among them are *Phaçops Hausmanni and Pentamerus galeatus*, which are well-known European species of the age of the Wenlock division. Among the corals are numerous forms closely allied to the Niagara species; but they have not yet been fully compared with those of Europe.

To show still farther that these are distinct zöological groups, I may mention, that three hundred and twenty species have been described from the Clinton and Niagara groups; and among more than two hundred known species of the lower Helderberg, I have not recognized a single one identical with those of the Niagara group. Again, the Niagara and Clinton groups extend from New York far to the westward, everywhere recognized by their physical and zöological characters; while to the north of the Ohio, we do not recognize the lower Helderberg limestones, beyond the central part of New York. These two groups, from the thinning of the Onondaga salt group, approach within a few feet of each other along the base of the Helderberg, but, nevertheless, continue far to the south-west, separated by a remnant of the Onondaga salt group, till at last this disappears, or is no longer recognized.

In the comparison, therefore, with European groups of upper Silurian age, we find that our Clinton group is merged, by European writers, in the lower Silurian period; the Medina sandstone, on the other hand, appears not to be recognized; or, if existing in any form, is classed with the preceding. The Onondaga salt group is not represented in Europe, and the Niagara group and lower Helderberg limestones, which exist there only partially developed, are merged in one, while, in the United States, they mark two important epochs in the upper Silurian period. That this is the true state of the case we feel the more confident, inasmuch as it is analogous to what we find to be true in this country.

GROUPS ABOVE THE LOWER HELDERBERG.

Turning our attention to a comparison of the divisions succeeding the lower Helderberg, we first meet with the Oriskany sandstone and Caudagalli grit. The former has no great thickness in New York, but acquires a greater development in Pennsylvania and Virginia. It has, however, entirely thinned out in western Tennessee and is nowhere met with in the States west of the Appalachian chain. This rock, however, is geologically of great importance; for, along the Atlantic slope it forms a very prominent dividing line between limestone series which, in their physical aspect, are very similar to each other. In its organic contents it contrasts strongly with the rocks which have preceded it. Although in many places superimposed directly upon the upper Pentamerus limestone, yet, the moment we enter it, we discover that we have left all those forms which were characteristic of the strata below. In its prominent and abundant fossils it has almost as little connection with the succeeding fossiliferous rocks as with those below.

The production of this rock undoubtedly marks a period of physical disturbance, which resulted in the formation and distribution of this detrital matter. It appears to have been only in remote parts, or in those points distant from the source of this deposit, that organic beings flourished in any considerable numbers. The succeeding deposit, which is a detritus of gritty material, both argillaceous and arenaceous in its character, is very limited in its extent, and contains scarcely a vestige of organic life, while the fossils of the preceding division are entirely cut off by it.

From all that we have been able to learn, these two rocks are not represented in Europe, or at least they have not been recognized as of any geological importance. The Oriskany sandstone, however, marks an important horizon, since we now regard it as commencing the Devonian period. In Europe, and more particularly in Great Britain, the limits between Silurian and Devonian have not been clearly traced; since we observe many disputed species, and others which are said to pass from one system into the other. A farther comparison of specimens shows us, that, though specifically distinct, many of the Oriskany sandstone species possess peculiarities not noticed in those of lower groups, but which are characteristic in the higher ones.

DEVONIAN SYSTEM.

With this preliminary notice, we enter upon the consideration of the rocks which are regarded as forming the equivalent of the Devonian system in Europe, excluding the two just mentioned, which are not recognized here either by their physical or zöological characters. These are the Schoharie grit; the Onondaga and Corniferous limestones, which are intimately connected by their fossils; the Marcellus shale; the Hamilton, Portage and Chemung groups, together with the sandstones of the Catskill mountains. We have already shown how far these can be recognized at the West and South-west, and it remains to consider how far they are represented in Europe by the groups known as Devonian.

It has been a difficult point to fix the lower limit of the Devonian system in the United States. We were able to recognize the extension of the series equivalent to the Wenlock formation, as high as, and including, the lower Helderberg limestones, of which we have been speaking; but we were unable to find beds corresponding to the Ludlow rocks, unless by including those groups which were much higher up in the series; in fact, by taking into the classification the Hamilton group. The large number of forms figured in Murchison's "Silurian System" from the Ludlow beds, and which can nowhere be recognized, even in their analogues, below the Oriskany sandstone, convinced us of the impropriety of including the upper Helderberg and Hamilton groups in this part of the Silurian series; nor have we yet seen sufficient reason to change this opinion. If the Devonian system is so extended as to include all the groups alluded to, then it must also include some of those beds heretofore referred to the Ludlow rocks. We think that this argument has some force, from the fact that in the country where this system was first promulgated, no less than twenty species are described from the rocks of Devonshire which had been previously described by Murchison in his "Silurian System," and nearly all of them from the Ludlow beds; giving more than twenty-five per cent. of all the Ludlow species, exclusive of fishes, which are not included in the enumeration. This number, moreover, amounts to ten per cent. of all the Devonian fossils described by Phillips. We say, without fear of contradiction, that there is no such mingling of species, no such passage from one group to another on the American continent, even among the most insignificant of the New York subdivisions. More than this, it seems unphilosophical to separate rocks into different systems, when so great a similarity of organic life is shown. It may seem presumptuous, for one not having been on the ground, to offer remarks thus opposed to the conclusions of eminent English geologists, but before the appearance of the "Palæozoic fossils of Devonshire," we had in this country, as we supposed, been able to recognize something like the equivalent of the Ludlow series, and the species present themselves to us still in the same light. If the relation of the Ludlow rocks to the Devonian system is clearly made out, and they are shown to constitute an intermediate group, then we must of course admit that there is an important hiatus in our series; but until this is done, we are willing to believe that it is more perfect than that of other parts of the world.

Before proceeding farther, we will devote a few lines to fossils of the Ludlow beds, as figured in the plates of Murchison's "Silurian System."

Lituites Biddulphii (Sil. Syst. p. 211, Fig. 8).—We have in the Schoharie grit fragments of a fossil scarcely distinguishable, in any respect, from the one figured; covered, moreover, with the minute *Spirorbis tenuis*, as in the Ludlow specimens. In the same association is another species quite similar to *Lituites articulatus*, and numerous others of this peculiar type of fossils, which we know in no other rock. Fragments of other chambered shells, referred to *Phragmoceras*, are also found in the Schoharie grit. In the same rock we have the *Calymene platys* of Green, which is undistinguishable from *C. Blumenbachii*, var. *major* of Murchison. It is only in a higher position, principally in the Hamilton group, that we find *Loxonema nexilis*, and forms like *Modiola semisulcata*, *Cypricardia solenoides*, *Cardiola fibrosa*, *Cypricardia amygdalina*, *C. undata*, (which is of the type of many of our Hamilton forms, and clearly belongs to the same genus, *Grammysia*), and *C. cymbæformis* (a decided Hamilton form). Among the Orthoceratites we find such forms as *O. ibex* and *O. articulatum*, and I might go on to increase the list, were it necessary. There is not, in the whole series of illustrations, any which strike us more forcibly than those just cited, since they are, if not positively identical, at least closely allied species.

Prof. Phillips's list of the Devonian fossils includes the following species, described by Murchison as characteristic of the Ludlow or upper Silurian series:

Turbinolopsis bina.	Cypricardia impressa ?
——— elongata.	Nucula (Cucullæa) ovata.
Cyathophyllum turbinatum.	Orthis semicircularis.
Favosites polymorpha.	——— compressa.
——— gothlandica.	Loxonema sinuosa.
——— spongites.	Bellerophon trilobatus.
——— fibrosa.	Orthoceras ludense.
Stromatopora concentrica.	——— imbricatum.
Pullastra ? complanata.	——— ibex.
Cypricardia (Modiola) semisulcata.	Brontes signatus.

It is certainly not a little remarkable that so many Silurian fossils should pass upwards into the Devonian system, a case quite unexampled with us even among groups of the same system, and what we cannot conceive of as occurring in different ones.

We will next turn to the American species identified with Devonian forms in Europe. Mr. Sharpe, in his paper, cites the following species from the Oriskany sandstone, Cauda-galli grit and Schoharie grit, as identical with European forms, viz:

Spirifer arenosus,
—— Urii,
Terebratula reticularis;

and from the Onondaga and Corniferous limestones,

Leptæna depressa,
Orthis resupinata,
Terebratula reticularis.

We have not had the good fortune, personally, to see *Spirifer Urii* in so low a position. *S. arenosus* is a characteristic species of the Oriskany sandstone. *Terebratula reticularis* is a species which passes from the Clinton to the Chemung group, and is worthless, simply as a species, in identifying strata. *Leptæna depressa* passes from lower Silurian beds to the corniferous limestone inclusive, and must stand in the same category with the preceding. *Orthis resupinata* can be of no value till its character or geological range is defined; and we are thus reduced to a single identical species.

We would ask, whether all those remarkable forms from the Schoharie grit, so much like those of the lower Ludlow, and numerous others of the corniferous limestone, equally peculiar and characteristic, are to pass unnoticed, as of no value in the determination of strata, while a few forms, whose geological range is indefinite, are made to decide the question of parallelism?

In the Marcellus shale, Hamilton group; Tully limestone, and Genessee slate, Mr. Sharpe identifies the following species as European:

Avicula Boydii.
—— quadrula.
Athyris concentrica.
—— lamellosa.
Orthis Michelini.*
—— eximia?
—— opercularis.
Strophomena Sharpei.

Spirifer Urii.
—— macronotus.
Productus fragaria?
—— scabriculus?
Terebratula reticularis.
—— aspera.
—— borealis.
—— nucula?
Orthoceras articulatum?

In the Chemung group, the same author recognizes as European species:

Avicula Boydii.
—— Damnoniensis?
Athyris concentrica.
Strophomena umbraculum?
Spirifer Urii.
—— aperturatus.

Productus plicatilis?
—— fragaria?
Terebratula reticularis.
—— aspera.
—— borealis.
—— nucula?

* *Orthis Michelini* does not occur in the Hamilton group of New York.

The whole number of species being twenty-one, of which eight are doubtfully identified, and one (*O. Michelini*) not identified; and from the number remaining we may subtract *Terebratula reticularis*, for reasons before given. With this evidence alone, we do not consider that the parallelism of the groups enumerated with those of England can be regarded as positively established; for we believe that a complete collection of our fossils from the lower members of this division would offer stronger proof of their identity with the Ludlow rocks. It is probable, however, that there are other circumstances, of which we are ignorant, which led Mr. Sharpe to this conclusion; for, upon similar grounds, we have a right to conclude that the Ludlow and Devonian rocks of England are equivalent, since they contain fully an equal number of identical species. If such a group as the Ludlow, divisible into upper and lower, separated by a limestone like the Aymestry limestone, does exist as distinct from the Devonian system, it presents a remarkable anomaly in the series, in containing so many species which are identical with, and so many which are similar to, those of the Devonian system.

It should be observed that the species cited by Mr. Sharpe are, with one exception, from the Hamilton and Chemung groups, and that at least seven of the number are of those which pass from one group into the other. The number, all together, is less than one-twentieth of the whole; and the other nineteen-twentieths, which are the most characteristic of the group, are not taken into consideration in the comparison.

The arguments of M. de Verneuil, in favor of placing all these groups in parallelism with the Devonian of Europe, are certainly very satisfactory, after we have once admitted the principles advanced in the outset; but, at the same time, it appears that the question of the Ludlow series is left undetermined. They have, in England, a group of shales and flags with earthy limestone — a limestone of importance — and this again succeeded by soft, micaceous, thin-bedded, greenish-grey sandstones, the whole having a thickness of two thousand feet, which it seems difficult to recognize, even on the continent of Europe.

This author regards it as incontestible, that the red sandstone of the Catskill mountains is upon the same horizon as the old red sandstone of Scotland and Wales; that the Chemung, and Portage groups, the Genessee slate, the Tully limestone and Hamilton group represent the series of the Eifel, and of Devonshire; and that the Marcellus shales are equivalent to those of Wissenbach, in the Duchy of Nassau. The Onondaga and corniferous limestones, he places in the same horizon as the inferior part of the Eifel and the Harz; while the Oriskany sandstone is regarded by him as equivalent to the fossiliferous schists upon the borders of the Rhine. Following the views of this author, the presence of the genera *Productus*, *Goniatites*, *Nautilus*, *Pentremites*, and the larger ganoid fishes, like *Asterolepis* and *Holoptychius*, constitute characters which are unmistakably Devonian. We are not aware of the appearance of *Productus* and *Pentremites*, before the period of the corniferous limestone; *Goniatites* and *Nautilus* follow in the Marcellus shales; while the first fish, of the character specified, is found in the Schoharie grit. Following this view, we have, from the corniferous limestone onward, the combination of types required to characterize the Devonian system; that is to say, — we have a single species of *Pentremites* and one of *Productus*, in the corniferous limestone;

and two of the latter and two of the former in the Hamilton group, where they are associated with *Goniatites*.

Leaving, for the present, any criticism upon the zöological value of these types, we would merely remark that the advent of *Productus* and *Pentremites* is what might have been anticipated, and is only another stage in the developement of types existing in the Silurian period. Of *Nautilus* and *Goniatites*, we have, at present, less positive information; but it seems to us that the peculiar Cephalopods, at the base of the upper Helderberg, are a link in the series, which it is necessary to consider before introducing the *Goniatites*.

The rocks, from the Oriskany sandstone upwards, form three very natural physical groups, which, to a greater or less degree, are marked by their peculiar fossils. These physical groups would give the Helderberg limestone as the lowest; the Hamilton group, including the Marcellus and Genessee shales, for the second; and the Chemung, including the Portage group as an enormous development of beds of passage, for the third.

The American fossils, recognized by de Verneuil as identical with European species, are:

Holoptychius nobilissimus.
Dendrodus, teeth of.
Asterolepis.
Phacops macrophthalmus.
Cryphæus calliteles.
Goniatites retrorsus.
Bellerophon striatus.
Murchisonia bilineata.
Chemnitzia nexilis.
Avicula Damnoniensis.
Pterinea fasciulata.
Modiola squamifera.
Inoceramus chemungensis.
Cardium loricatum.
Lucina proavia.
—— rugosa.
Grammysia hamiltonensis.
Sanguinolaria dorsata.
Terebratula cuboides.
Terebratula reticularis.
—— aspera.
—— concentrica.
Spirifer mucronatus.
—— macropterus.
—— cultrijugatus.
—— heteroclitus.
—— Verneuili.
Orthis striatula.
—— umbonata.
—— crenistria.
Leptæna depressa.
—— Dutertrii.
—— laticosta.
Chonetes nana.
Productus subaculeatus.
Favosites gothlandica.
Porites interstincta.
Stromatopora concentrica.
Pleurodyctium problematicum.

The greater part of these species have been recognized on the continent of Europe, and among them are only four or five which are included in the lists given by Mr. Sharpe. Still, it does not appear to us that the Schoharie grit, the Onondaga and the corniferous limestones are equally well represented with the groups above them. The fossils cited from the Schoharie grit are a species of *Asterolepis? Calymene Blumenbachii? Phacops macrophthalmus* and *Modiola squamifera?* Of these *C. Blumenbachii* is a distinct species peculiar to this rock, the *C. platys* of Greene already alluded to; the *Phacops* is not *P. macrophthalmus*, but a very distinct species, having a row of spines along the axis; so that certainly no more than two species are identified.

The species of the Onondaga and corniferous limestones are:

Phacops macrophthalmus.
Bellerophon striatus.
Chemnitzia nexilis.
Murchisonia bilineatus.
Lucina proavia.
——— rugosa.
Terebratula reticularis.
——— aspera.
Terebratula concentrica.
Spirifer mucronatus.
——— cultrijugatus.
——— heteroclites.
Leptæna depressa.
Catenipora escharoides.
Stromatopora concentrica.

From this list we exclude the two last entirely, since they are not known in these beds; and, if occurring, they would prove nothing, since they are Silurian species. *Terebratula reticularis* and *Leptæna depressa* are also Silurian species, and of little value for the purposes of identification. *Phacops macrophthalmus* is equally common in the Hamilton group; and *Chemnitzia nexilis, Terebratula aspera, T. concentrica* and *Spirifer mucronatus*, are comparatively very rare in these limestones, and only reach their maximum in the Hamilton group. Therefore, we must still regard these three calcareous deposits as but meagrely represented in the Devonian system on the other side of the Atlantic. In fact, we are unable to see, after all, any greater similarity to the Devonian than they have to the Ludlow series; and the number of species here cited from these two members of the upper Helderberg, which pass upwards into the Hamilton group, is not so great as the number of Ludlow species which rise into the Devonian of England, according to the authorities here cited.

We perceive here, as in the lists cited from the memoir of Mr. Sharpe, that there are comparatively very few Devonian species below the Hamilton group, and that these are by no means characteristic forms. Although we admit the conclusions of M. de Verneuil in general, yet we are still unable to appreciate the evidence which would place all these deposits in parallelism with the Devonian of Europe.

In a westerly direction, the upper Helderberg group, composed chiefly of the Onondaga and corniferous limestones, is continuous as far as the Mississippi river. Of the sedimentary formations succeeding these, all have disappeared save a black shale, which may be a representation of the Genessee slate of New York, but which holds the place of the Marcellus shale, resting directly upon the corniferous limestone.

The green shales and yellow sandstones of Ohio and Indiana, which succeed this black shale, have been recognized as carboniferous by their fossils, though there is still some doubt whether the lower part may not represent the Chemung group of New York; at least their connection with the groups below has not been fully shown. In these states, therefore, the equivalent of the Devonian of Europe is to be found in these limestones and the black shale immediately overlying them. This limestone is more uniform in its character than perhaps any other of the groups, and it is everywhere marked by numerous characteristic fossils. On the Mississippi river, we find that the shales and sandstones between this group and the great carboniferous limestone have entirely thinned out, leaving the latter rock resting directly upon the limestones of the upper Helderberg.

The contrast between the divisions of this period, at the East and the West, will be made more intelligible by a tabular comparison.

Black Slate of the West.

SHALES AND SANDSTONES OF THE CATSKILL MOUNTAINS
CHEMUNG GROUP.
PORTAGE GROUP.

GENESSEE SLATE. TULLY LIMESTONE. HAMILTON SERIES. MARCELLUS SHALE.	HAMILTON GROUP.

Upper Helderberg Series, including

CORNIFEROUS LIMESTONE, ONONDAGA LIMESTONE, SCHOHARIE GRIT.	Shelly limestone and upper coralline limestone, (upper part of cliff limestone), continuous with the Onondaga and corniferous limestones of New York.

Before concluding our remarks upon the parallelism of these several groups with the Devonian system of Europe, we will examine, for one moment, the zöological evidence. The occurrence of *Productus, Pentremites, Nautilus, Goniatites* and the scales of ganoid fishes are regarded as showing the parallelism of these deposits with those of Europe. In the first place, *Productus*, as now restricted, includes Brachiopods of a peculiar type, not known before the period of the Helderberg rocks. *Leptæna*, which, till recently, has been included in the same genus, is the earliest representation of the type; *Chonetes* is another form, coming in only at the upper Silurian period, and at about the same time *Strophodonta*, both forms making a nearer approach to *Productus* proper; and, after the lapse of these periods, the genus appears precisely in accordance with a law which has operated upon all the types from the beginning. *Pentremites*, as now constituted, includes some four or five distinct genera; but the type of this genus appears in upper Silurian rocks. This genus, like *Productus*, is *par excellence*, a carboniferous form; both appearing in small numbers and with few species during the Devonian period. The *Goniatites* appear, for the first time, in the Marcellus shales, associated with a nautiloid form, the *Discites* of M'Coy? In the black shale of the West, other species of *Goniatites* occur.

Now, as all these genera, in their most perfect development, are the acknowledged types of the carboniferous period, the inquiry naturally suggests itself, whether, at any point of time, or at any horizon in the series of deposits after the appearance of these genera, we can draw the limit between Devonian and carboniferous. If the advent of these forms is of importance enough to be regarded as the commencement of a system, we can conceive of no law, in the progress of these developments, which will permit us to draw any line separating the strata in which they predominate into two systems. If they are important, when occurring in small numbers, as characterizing the Devonian system, they are certainly as important when they become developed in greater numbers and more perfect forms. We have a right to contend, therefore, for the existence of the carboniferous system at any point where we can find a continuation of the genera *Pentremites, Productus, Goniatites* (*Cyrtoceras, Discites*), *Nautilus*, and the ganoid fishes. I contend that this is the legitimate conclusion, or else the carboniferous system is subordinate to the Devonian. We characterize Devonian rocks by the presence of these fossils; how shall we characterize the lower members of the carboniferous, except by the same genera? If we decide that certain species, or certain peculiarities of species, imply the existence of the carboniferous, are we not making it a subordinate system or group, since it is by these characters that we everywhere distinguish our subordinate groups? If we would establish groups or systems on zoölogical characters, then we are bound to maintain the principle with which we set out. It appears to me that we have regarded certain systems as established, and their limits as fixed, more from habit than from any expressed principle; and that we consider a certain association of species even of more importance than the advent of new types.

I have already shown that many of the Ludlow species of Murchison are very similar to, and others identical with, species from our higher groups; and this similarity might even be traced much farther. It is true, moreover, that, in the "Palæozoic Fossils of Devonshire," a number of Ludlow fossils are cited, equal in number and importance to those cited from American rocks, to prove their identity with the Devonian of England. In the paper of M. de Verneuil, a larger number of species, and some of them of more important forms are cited; but we still find the serious objection which we have just mentioned.

This would be made more apparent if we were to compare more fully our species with European forms. We will take, for example, the Marcellus shale, in which we have a beautiful group of Cephalopoda. Among them we have a species undistinguishable from the *Discites planotergatus* of M'Coy, a carboniferous fossil. Associated with this are forms very similar to *Discites castellatus*, *Temnocheilus coronatus*, and *Goniatites sphæroidalis*, with *Orthoceratites* &c., of the same author, and all from the same member. Now, even admitting that they are only similar species, and not positively identical, still it seems to us that this is too remarkable a combination to admit of the rocks in which they occur being very widely separated in point of time. Animals of this class have not often lived through more than a single growth, and, so far as we know, in our palæozoic series, are very reliable guides.*

In the Hamilton group we have a *Pentremites* of the form of *P. floreales*, a carboniferous fossil. We might mention a considerable number of Acephala, in the same group, having close relations with carboniferous forms of Europe. We have, in the Chemung group, numerous species of *Pecten* and closely allied genera, which are scarcely distinguishable from those of the carboniferous period of Europe. The *Holoptychius* is rather a carboniferous than a Devonian type, though *H. nobilissimus* belongs to the latter system.†

In the black shale of Rockford, Indiana, a few feet above the corniferous limestone, the *Goniatites rotatorius* and *G. princeps* have been found. These are carboniferous species of Europe, and indicate to us the same horizon in America. What arguments shall we offer in explanation of these

* Brachiopoda have been the most enduring forms, and have often passed through several geological divisions. Acephala appear to be next in the order of persistence; and after them the Gasteropoda, while the Crinoids have rarely lived beyond the group in which they first appear.

† I might here mention the fact, that Prof. Agassiz informed me, a few months since, he had seen, from the limestone of Columbus, Ohio, (corniferous limestone,) the tooth of a fish, which he had heretofore regarded as being a carboniferous genus.

facts, but that, in the carboniferous system of Europe, have been included, not only types and genera, but even species which began their existence at about the period of our Marcellus shale? How shall we be able to bring these deposits into parallelism, without bringing down the limits of the carboniferous to this horizon?

We have already, as we think, given sufficient evidence in the number of identical fossils, to show the equivalency of certain of our divisions, as far as the lower Helderberg limestones, which we place in parallelism with the Wenlock shales. We cannot agree with M. de Verneuil in placing them in parallelism with the Ludlow, for we have scarcely a single identical species of any importance, nor even analogous types. Leaving out of consideration the Oriskany sandstone and Cauda-galli grit, we feel disposed to regard the Schoharie grit as possessing zöological features more in accordance with those of the lower Ludlow series than any other rock in our classification, and we shall thus place it for the present.

In reference to the identity of groups above the lower Helderberg series, it is impossible to place our rocks in any distinct parallelism with those of Europe; since the published works of European writers represent a gradual passage of one system into another, and a want of well-defined limits, either by physical or zöological characters.

It should not, however, be understood from this, that the equivalents of the European systems do not exist with us. What we would say is this: that, so long as the Ludlow group and its subdivisions are maintained, together with a Devonian and a carboniferous system and their subdivisions, we can never reconcile our series with those of Great Britain or the continent of Europe. If those divisions and subdivisions do not exist, and the identification of the groups above this with the Devonian system be sustained, then we have an important hiatus to fill above the lower Helderberg limestone, which is unquestionably the place of the Ludlow deposit. Should we ever be able to fill this gap, we are but at the commencement of the difficulty. In the first place, we find in the Schoharie grit, as already cited, numerous forms closely resembling those of the Ludlow beds. In the Hamilton group we find others, of which the bivalves resemble, or are identical with those of the upper Ludlow. The numerous species of obliquely-cingulated shells, such as are figured in the geological survey of Great Britain, (Vol. II. Part I., Plates 17 and 18, together with such forms as are represented on Plates 19, 20, 21, 22 and 23,) are not to be found in our series, except in the Hamilton group and the associated strata.

We have therefore to reconcile in some way all these apparent discrepancies and real difficulties, before we can proceed one step beyond the lower Helderberg limestones. It is true, that, in the sandstone of the Catskill mountains, we have the remains of *Holoptychius Dendrodus* and other fishes of Devonian types; and, as already remarked, the higher groups correspond with the Devonian of Europe; thus, were it not for the previous difficulty in recognizing the Ludlow series, together with another which now appears, we could feel some security in the conclusion that this part of our series corresponds to the Devonian of Europe. But here we are met by the difficulty of accounting for carboniferous types which, according to the present views of palæontologists, disappear here; and not only the types, but numerous identical species.

I have already given a list of species which are recognized by Professor Phillips as common to the Ludlow and Devonian beds; and when we examine farther among published species, we find numerous Devonian types among the carboniferous strata, as shown by the list given below, which is only from a single work.

Devonian fossils cited by M'Coy in his Synopsis of the Carboniferous fossils of Ireland. (The names are principally those given in Phillips's "Palæozoic Fossils.")

Orthoceras laterale.
Goniatites excavatus.
——— spiralis.
Clymenia plurisepta.
——— sagittalis.
*Nautilus subsulcatus.
Bellerophon wenlockensis.
Loxonema tumida.
Euomphalus serpens.
Acroculia carinata.
——— sigmoidalis.
——— vetusta.
Sanguinolaria lirata.
Pleurorynchus minax.
Cypricardia deltoidea.
Cucullea angusta.
——— complanata.
——— Haidingeri.
†*——— trapezium.
*——— unilateralis.
*†Leptæna sordida.
Orthis arachnoidea.
——— arcuata.
——— compressa. (S. D & C.)
†*——— crenistria.
——— granulosa.
†*——— interlineata.
——— longisulcata.
——— orbicularis. (S.)
——— parallella.
——— resupinata.
——— semicircularis.
*——— tenuistriata.
Spirifer aperturatus.
*†——— calcaratus.
——— crispus. (S & C.)
*†——— disjunctus
*——— extensus.
†*——— giganteus.
——— grandævus.
——— inornatus.
——— megalobus.
——— mesomalus.
Nucula lineata.
Modiola amygdalina.
†*Posidoina Becheri.
†*——— lateralis.
†*——— tuberculatus.
Pecten arachnoides.
——— granulosus.
——— polytrychus.
†*——— transversus.
Producta caperata.
——— fragaria.
——— laxispina.
——— membranacea.
*Leptæna depressa. (S, D & C.)
——— nodulosa.
——— convoluta.
——— hardrensis.
——— lata ? (S.)
†*——— plicata.
——— interstrialis
Atrypa anisodonta.
*——— oblonga.
*——— squamosa.
*——— fallax.
*——— indentata.
Terebratula bifera.
——— canalis.
——— compta.
†*——— desquamata.
——— ferita.
——— insperata
*†——— juvenis.
——— laticostata.
——— romboidea.
Calymene granulata.
——— lævis.
——— Latreillii.
Adelocrinus histix.
Pentremites florealis
Platycrynus interscapularis.
Isocrinus macrodactylus.
Cyathocrinus ellipticus.
——— geometricus.

*Spirifer pulchellus.
——— rudis.
——— ostiolatus.
†*——— nudus.
——— simplex.
†*——— subconicus.
——— phalænus.
*†——— plebius.
——— protensus.
——— microgemma.
*†Atrypa decussata.
*——— hispida.
*†——— angularis.
*——— lachryma. (S.)
Favosites polymorpha. (S.)
†*Cannopora placenta.
†*Stromatopora polymorpha.
Verticillopora abnormis. (S,)
Millepora gracilis.
——— similis.
Cyathocrinus megastylus.
——— pinnatus.
——— variabilis.
Actinocrinus tenuistriatus.
Amplexus nodulosus.
——— tortuosus.
Turbinlopsis bina. (S.
——— celtica.
——— pauciradialis.
†*Astrea pentagona.
Syringopora bifurcata
Manon cribrosum.
Pleurodictyum problematicum.
Favosites fibrosa. (S.)
——— gothlandica.
Gorgonia assimilis. (S.)
Glauconome bipinnata.
Ptylopora flustriformis.
†*Fenestella antiqua.
——— laxa.
Hemitrypa oculata.

Species thus marked (*) are from those described in Sedgwick and Murchison's paper "On the Physical structure and Older stratified deposits of Devonshire," (Geol. Trans. II. ser. vol. 5). Those thus marked (†*) were first described by Sowerby in the Geological Transactions cited above, and also recognized by Phillips in his "Palæozoic Fossils." S, D, and C, or either of these letters, denote that the species belong also to the Silurian, Devonian or Carboniferous.

The entire number of Devonian species, here recognized as passing upwards into carboniferous strata, is one hundred and twenty-five. This is nearly half of the whole number published by Professor Phillips in his "Palæozoic Fossils of Devonshire and Cornwall." Of the entire number, however, eleven are species published in the paper of Sedgwick and Murchison before cited, and which are not included in the work of Professor Phillips. If we now take from the remaining Devonian fossils, the Ludlow and other Silurian species, the list is still further reduced by some twenty species; thus more than one-half the number of fossils described in the above-mentioned work of Professor Phillips, are found to occur in Silurian and carboniferous strata; and the small number of restricted species reduces the importance of the system to the value of some of our subordinate groups.

Let us next compare the proportion of so-called Devonian species in the "Synopsis of the Carboniferous fossils of Ireland." This work embraces descriptions of about nine hundred species, of which, as just remarked, one hundred and twenty-five have been recognized in Devonian and older deposits. This gives, of the whole number of species, between thirteen and fourteen per cent. as belonging to the older divisions. In the Brachiopoda of the work there is a still larger proportion, or sixty-three species, which is about twenty-six per cent. of the whole, chiefly in the Devonian system. Among the corals there are twenty-four species, or about twenty-three per cent. of the whole; and among the Crinoids, ten species, or about twenty per cent. of Devonian and Silurian species. This last fact is of high importance; since, of all our fossils, the Crinoids are among those which are the most restricted in their range.

The proportion of species here represented, as passing from Devonian to carboniferous, is so enormously great, that we find no parallel to it in any preceding period. It is even nearly twenty times greater than the proportion of lower Silurian species now known in the upper Silurian groups of North America, and in the same proportion more than are common to the two divisions of the upper Silurian. We are even prepared to say, that the subordinate members of the Hamilton group do not present an equal number of species passing from one to the other. We will go further and say, that, if the Hamilton group, as it exists in the State of New York, were broken up, and a space twenty-five miles in width to the east of Cayuga lake were metamorphosed so as to obliterate the fossils, the eastern and western portions would scarcely present an equal proportion of identical fossils, with the Devonian and carboniferous systems of Europe, as shown in the works above cited. If, therefore, physical conditions have wrought out such changes in the fauna of a particular period, in the space of three hundred miles, in what we know to be a continuous formation, we are certainly warranted in believing that changes as great as these may have occurred elsewhere.*

The arenaceous and argillaceous deposits, which we trace uninterruptedly over so wide an area, and which present to us such gradual and almost imperceptible changes in the fauna when studied continuously, would, if broken up and isolated so that they could not be traced consecutively, present the same phases which are exhibited by the systems in Europe to which they are related.

From all these facts there seems to be but one conclusion, and that is, in the British islands particularly, either there are remarkable exceptions to the general law in the continuation of species from one to another, or that there is no foundation for a distinction between the Devonian and carboniferous systems.

We are quite aware of the objections which may be offered to these arguments; but, before we can admit them, we must inquire on what principle have the systems of our palæozoic strata been established? We hailed with gladness the promulgation of the "Silurian System," which developed from

* Referring to the paper of Mr. Sharpe before alluded to, we find the greater part of the species cited from the Hamilton and Chemung groups to be Brachiopoda, which, particularly in the Hamilton group, occur in the western division, while they are few and comparatively rare, in the eastern part of the State of New York. Of the list of species from this group, I find *Avicula Boydii*, *A. quadrula*, *Atrypa nucula* and *Orthoceras articulatum*, (one-fourth of the whole) identical with Ludlow species. The *Avicula* and other Lamellibranchiata are abundant in the Hamilton group in the eastern part of the State of New York, and comparatively rare in the western part. Now in Mr. Sharpe's table of species common to the two countries, we find among the Lamellibranchiata, *Avicula*, of which there are seventeen species in Mr. Lyell's collection: of these, fourteen are placed under the head of Devonian, and recognized as identical with European species there occuring, while *two* of these are Ludlow species. Again, under *Cypricardia*, there are nine species in the collection, of which one is recognized as identical with a European species. Under the head of sundry genera, we find, in the same list, twenty-five species indicated as contained in the collection, of which not one is recognized as European. These twenty-five species are Lamellibranchiata, from the eastern part of the Hamilton group, and are of those very characteristic forms before noticed, which have a greater analogy with fossils of the Ludlow rocks than with any other. It is worthy of notice, that of forty-eight species of this family, placed by Mr. Sharpe under the head of the Devonian system, four only have been recognized as identical with European species; and of these four, two from the Hamilton group are identical with Ludlowspecies.

chaos and uncertainty that beautiful system, marked both by physical and zöological characters. The Devonian system came to us far less distinctly marked either by its physical or zöological features; for, on the one side it was clearly and unequivocally related to the Ludlow rocks of the Silurian system; and, on the other, as intimately connected with the carboniferous, by its zöological characters.

In the great development of strata holding this place in the series, we still find these characteristics. If what has been published in Europe as carboniferous, belongs really to that system, we can come to no other conclusion than that above indicated; for, in our undisturbed and continuous series, the order of succession is most clearly understood. In view of the facts which we have cited, we are unwilling to regard the question of parallelism as decided, and we insist upon the zöological evidence from those forms and those types best entitled to give the character. The distinction of systems by zöological characters is not to be made in one case upon primary, and in another upon subordinate and secondary characters; and if the whole palæozoic series is to be divided on a certain principle, it must be applied in every instance equally.

We cannot avoid the conclusion, that, if we adopt the Devonian system with the limits suggested by foreign writers, we must drop forever the attempt to recognize the Ludlow division of the Silurian system. We can hope for no species equivalent to the peculiar forms in the Schoharie grit and Onondaga limestone, and the numerous bivalves in the Hamilton group; and, in giving up this and attempting a reconciliation of our groups with the Devonian, we find that we are encroaching upon the preëxisting claims of the carboniferous system; and that we have no zöological types of sufficient importance to enable us to separate one from the other.

Although it is not difficult to find the evidences of a general parallelism in our successive groups with those of Europe, yet, when we come to more minute and critical comparisons, the difficulties increase rather than diminish. This is more especially true of those subsequent in age to the Wenlock group of Europe, which has its latest phase represented in our lower Helderberg limestones. If, for example, we attempt to find the exact equivalents of the several groups of shale, from the Oriskany sandstone upwards, by the general groups of species, and even by individual species themselves, as far as they have been identified with European forms, we meet with insurmountable difficulties. The relations of our divisions often appear to be in two directions, when we take for our standard the European classification; and it is impossible to account satisfactorily for the apparent divergence in the direction of groups as shown by the evidence afforded by the recognized species of European authors.

In the first instance, *Spirifer Urii* and *S. arenosus* are rather carboniferous than Devonian species in Europe, and should be regarded as a connecting link between these systems; while, in this country, they occur in the Oriskany sandstone, immediately succeeding the lower Helderberg limestones, which are positively identified with the Wenlock series of England. The Cephalopoda of the Schoharie grit and Onondaga limestone find their analogues in the Ludlow division. The Cephalopoda of the Marcellus shale, Goniatites, Discites, and others with which are associated one or two species of Productus, ally that group with the carboniferous system; and, if we can rely upon the position of the Goniatites of Indiana, we have positive carboniferous species in the black slate of the West. The

Hamilton group, in its numerous Lamellibranchiata, and some species of Orthocerata connects itself in a very positive manner with the Ludlow series; while, by its Brachiopoda, it is related to the Devonian and carboniferous systems. The Chemung group through its Brachiopoda is, on the one side, related to the carboniferous system; while, on the other, certain forms indicate a connection with the Devonian. The Lamellibranchiata of the same group are, in part, referable to Ludlow forms; while others are recognized as Devonian species. The few species of Cephalopoda known in this group ally it also with the carboniferous period. The Onondaga and corniferous limestones are related to the Devonian system through some species of Brachiopoda and Gasteropoda, which pass upwards into the Hamilton group.

If we attempt to express these ideas in a tabular form, so that the whole subject may be brought before the eye at once, we appreciate the difficulties in the way of arriving at satisfactory conclusions, so long as the systems of European palæozoic strata remain under the present arrangement, with the lists of species at present referred to each; nor will the difficulties be diminished until the absolute sequence of groups, from the Wenlock upwards, is determined in England and on the continent of Europe.

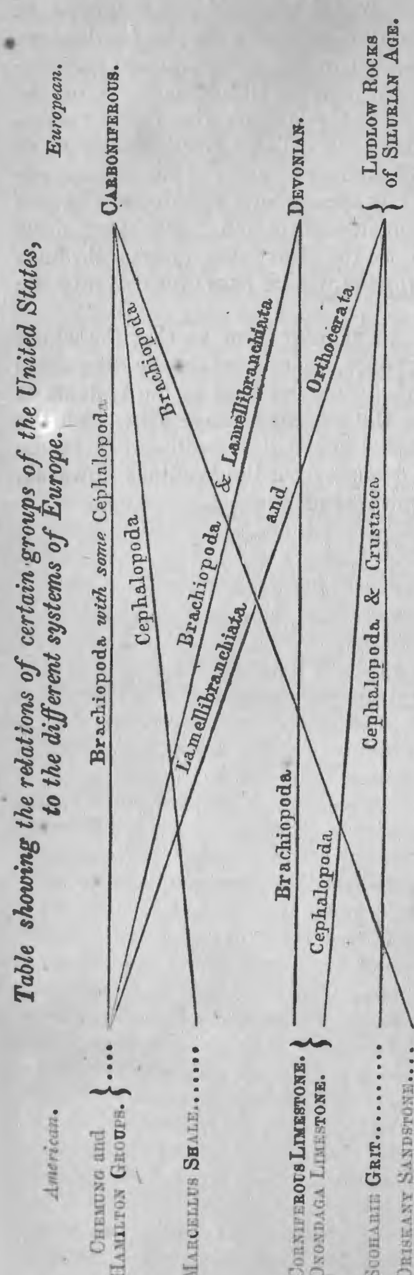

Table showing the relations of certain groups of the United States, to the different systems of Europe.

This diagram explains the views which we entertain, and which appear unavoidable, regarding the relations of our groups with those of Europe, where generic resemblances and the identity of species are made the foundation of our opinions. We have constantly before our eyes a more complete series of palæozoic strata, than has as yet been recognized in any other part of the world. We know that the order in which our groups are arranged is the order in time. Where the succession is made out from the examination of isolated deposits, the order may not always be the true one; or, at least, it will be impossible to make the proper allowance for range of species, or to distinguish so clearly the changes which may have resulted from littoral and deep-sea deposits. Our numerous subdivisions, though they may be united in fewer groups, are, nevertheless, important; for every one of them is marked by a distinct interval of time, and the changes in the character of the deposit indicate changes in the operating influences not to be disregarded. Where the records between two distinct points of time are the most numerous, and the intervals of least duration, there, certainly is to be found the most perfect record of the history of the period. In geological history, we must regard the series which presents to us groups of one age, of less consequence than another which presents such an apparently single group, subdivided into several; each one being the evidence of successive changes which are recorded in beds of different materials and characterized by hieroglyphics not to be misinterpreted. So long as we adopt zöological characters in the designation of groups, and acknowledge these as the most reliable evidence of the age of strata, so long must we recognize those physical subdivisions which contain peculiar groups of species, or types of certain genera; and such a group must be recognized as a zöological period.

The following table expresses the result of the comparison of respective groups made, both by European writers, who have examined our rocks and fossils, and by us. This comparison is founded on the arrangement adopted by Murchison in his "Silurian System," and the subsequently published species referred to that system.

Table of Equivalents.

LLANDEILO FLAGS.	? Trenton limestone, in part. ? Utica slate.
CARADOC SANDSTONE.	Hudson-river group. Clinton group, in part.
WENLOCK SERIES.	Clinton group, in part. Niagara group. Lower Helderberg limestones.
LUDLOW SERIES and DEVONIAN SYSTEM.	Upper Helderberg limestones. Hamilton group. Chemung group. Red sandstone and shale of Catskill mountains.

Or, with more detailed reference to our rocks, as follows:

UNITED STATES.	GREAT BRITAIN.	CONTINENT OF EUROPE.	REMARKS.
Potsdam sandstone	These members are not distinctly recognized in Great Britain, but are probably represented in some degree by the schists and quartzites, below the Llandielo flags.	Lower sandstone of Russia and Sweden, with Obolus and Lingula. Not distinctly recognized on the continent of Europe, unless merged in the schists and quartzites of L. Silurian.	Of more than seventy species of fossils restricted to beds below the Trenton limestone, not one has yet been recognized in Great Britain; and the prevailing forms of Llandeilo flags are allied to those of our Hudson-river group, with perhaps some of the Trenton limestone forms.
Calciferous sandstone			
Chazy limestone			
Birds-eye limestone			
Black-river limestone			
Trenton limestone	....	Orthoceratite limestone of Sweden.	
Utica slate	Llandeilo flags and Caradoc sandstone.	Alum schists and argillaceous schists of Northern Europe, with Graptolites, Olenus, Ampyx, &c.	
Hudson-river group			
Grey sandstone			
Oneida conglomerate			
Medina sandstone, in part	Not recognized.		
Clinton group	Wenlock beds, in part.		Both in England and on the continent, the Niagara group and the lower Helderberg limestones appear to be represented in a single calcareous deposit, though clearly indicating two epochs in the United States.
Niagara group, in part			
Onondaga salt-group	Not recognized.	Represented by the upper Silurian limestones of Sweden and Northern Europe.	
Tentaculite limestone	Represented by the Wenlock beds, in part.		
Pentamerus limestone			
Delthyris shaly limestone			
Encrinal limestone			
Upper Pentamerus limestone			
Oriskany sandstone	Not represented.		
Cauda-galli grit			
Schoharie grit	Represented in part by the Ludlow series and Devonian system, and, to some extent, also by the carboniferous system.	Represented in the limestones of the Eifel, by many identical species.	
Onondaga limestone			
Corniferous limestone			
Marcellus shale			
Hamilton group			
Genessee slate			
Portage group			
Chemung group			
Shales and sandstones of Catskill Mountains	Old red sandstone.		
Yellow sandstones and green shales of Ohio	Yellow sandstone, &c.		
Great carboniferous limestone	Carboniferous limestone.	Calcaire carbonifère. Berg kalk.	
Red shale	....	....	
Conglomerate	Mill-stone grit.		
Coal measures	Coal measures.	Terrain houillier.	

CHAPTER XIX.

ON THE OBSERVED FLUCTUATIONS OF THE SURFACES OF THE LAKES.

BY CHARLES WHITTLESEY.

Indefinite Character of the early Observations.—Sources of Information.—Supposed periodical Rise of the Waters erroneous.—Difficulty of reducing the Observations to a common Standard.—Annual Rise.—Different Zeros of Reference.—Depression of 1776.—*Rise of* 1802.—*High Water of* 1815.—*Low Water of* 1819–20.—*Tables, showing the various Stages of Water at Cleveland; at Detroit; at Black-Rock and Buffalo.—Effects of Winds in raising and depressing the Surfaces of the Lakes.—No observed tidal Movement.–Transcripts of Rain-gauges at various Stations.*

Those who have examined and compared the recorded observations of the rise and fall of the surfaces of the great lakes find themselves greatly perplexed in arriving at exact results. The earliest information, upon which any reliance can be placed, is given by the pioneer settlers who began to occupy the southern shore of Lake Erie as early as 1795–6. They, however, only give general impressions and recollections. In 1814–15 their attention was forcibly drawn to the subject by a very high stage of water, which interfered with their buildings adjacent to the mouths of rivers, which then served as harbors for the few schooners by which the western commerce was transacted.

About the close of the war of 1812, the late Brigadier-General Henry Whiting commenced a series of personal observations upon the fluctuations of the Detroit river, at Detriot, and these observations were resumed in 1828 by E. A. Hathan, a civil engineer connected with the water-works of that city.

In 1830, Dr. Douglas Houghton began his observations upon the rise and fall of the upper lakes, abstracts of which are given in the Michigan geological reports for the years 1839 and 1841. Since the opening of the New York and Erie canal in 1824, many observations have been made by the state engineers and referred to the mitre-sill of the guard-lock at Black Rock, as a zero. These have been published, from time to time, in the newspapers of Buffalo, particularly in the Commercial Advertiser, but we are not aware that they have ever been collected in a connected and systematic form.

In 1844, when Colonel T. B. W. Stockton took charge of the government works at the harbor of Cleveland, Ohio, he caused a meteorological table to be kept, which is very complete and reliable. From August 1845, to August 1846, inclusive, Colonel Stockton added a water-table. The observations were taken at 6 A.M., at noon, and 6 P.M., by Mr. George Tiebout, which, by the kindness of Mr. D. P. Rhodes, late disbursing agent, I have in my possession.

While connected with the geological survey of the state of Ohio, I collected some information relating to this subject, which was published in the report for the year 1838–9.

From August to December 1838, Mr. George C. Davis, of Cleveland, kept a daily register, and since that time I have made occasional measurements at the same place.

In the month of November, 1850, Mr. John Lathrop, a resident engineer of the New York State canal, commenced at Buffalo a register of the stage of the water at that place, twice each day, referred to the bottom of the canal as zero, a portion of which is given below.

These are the sources of information within my reach, and I deem the subject of sufficient importance to find a place in this report, not simply as a matter of general interest, but of practical utility; since all public constructions upon the lakes should be built in reference to the extreme fluctuations of the water-levels. There are sites of towns laid out during a low stage of water, which in after years have been flooded to the depth of several feet; and others surveyed in a high stage, counting upon a sufficient depth of water for harbors, docks and shipping, which were left by the reflux at an inconvenient distance from navigable water. An erroneous opinion prevails in the lake region, founded on Indian and French traditions, that the rise and fall of the water is *periodical*, occurring once in seven years, but an examination of the records of the past twenty-five years will afford no grounds for this belief. It has been the popular impression that there was something mysterious in these secular fluctuations, and that they were in no way connected with the vicissitudes of the seasons;—a belief which may be easily accounted for, when we take into account the immense size of the basins of the great lakes, and the length of time necessary for the accumulation of water in such capacious reservoirs to become sensible to the eye. A comparison of the rise and fall of the water of the lake with the recorded observations of the rain-gauge, will show conclusively that the surfaces of these great bodies of water rise gradually after an unusually large amount of rain has been falling during one or more seasons, and that, on the other hand, they fall after a long period during which the quantity of rain has been less than the average; obeying in this respect, the same laws which influence other collections of water.

It will be more satisfactory to the philosophical inquirer and more reliable for the use of future observers, to give the statements of different authors from which I have drawn some conclusions, in their own terms. It will be seen that it is no easy task to reduce the recorded observations to one standard, since some are made from memory alone,—such being the best and only authority prior to 1814—while others were taken on rivers a little distance from their outlets, where the stage of water was influenced by floods. Even those observations taken at the surface of the lake are subject to variations, resulting not only from visible causes, such as winds and storms; but from distant and invisible ones, such as swells and sudden risings.* Thus, at Cleveland, the surface has been known, in perfectly calm weather, to rise and fall suddenly from three to eighteen inches; but usually within a few hours the cause became apparent in the approach of a gale or storm. One of the uses of the magnetic telegraph is to inform the mariner in port of the prevalence of storms elsewhere, before they burst upon him.

The different lakes do not rise or fall at the same time, but in succession; as the several mill-ponds on a stream are known to fill, during floods, in

* See Chapter II. Part I. of Foster and Whitney's report.

order—beginning with those nearest the source, and to discharge themselves in the same order. The successive basins of the lakes are so many ponds or enlargements of the St. Lawrence. There is, besides, an annual rise and fall which is not equal in different years, and not precisely uniform over the whole area, during the same season. Taking the best observations at different points of the same lake, as for example, at Buffalo, Cleveland, and Detroit, for the same year and month and comparing them with each other, discrepancies are apparent in the amount of rise or fall for the same period as deduced from measurements at different places. Another source of difficulty arises from the different zeros referred to by the different observers. For the zero at Cleveland, in 1838, I made use of one of the courses of masonry on the east pier of the harbor at its southern extremity, being then, the bottom of the *first* course from the top; but since the coping has been laid, it is, at this time, the *second*. This line was used because it corresponded with the highest permanent stage of water within the memory of white men; and being intended to last so long as commerce shall be pursued on the lake, it was considered sufficiently permanent; but since that period, portions of the work have subsided a foot or more, and it has been found difficult to restore the zero-level by other marks. The zero of June 25, 1838, was six feet below the surface of the southern end of the parapet-wall as it now stands—October, 1851.

Dr. Houghton and General Whiting took the *lowest* known stage for their zero, which, according to their best information, occurred June, 1819; but other authorities—and they are numerous—fix the lowest known stage late in the summer of that year, and also in August, 1820. The difference between 1819 and 1838, at Detroit, is five feet three inches. It is a general tradition that in 1809 and 1810 Lake Erie was even lower than in 1819 and 1820. There is no evidence that, since the settlement of the region by the whites, Lake Erie has been higher than in 1838; but at Buffalo and at Detroit, the highest stage is said to have occurred in August, while at Cleveland it occurred on the 25th of June. During that month and the succeeding July, there were several swells which lasted for a few hours or perhaps a day, when the waters rose in the extreme, eighteen inches, flooding warehouses and offices; but these oscillations were too rapid to be classed among the regular fluctuations of the lake.

The Detroit river, with a strong current and crooked channel, is not as good an index of the flux and reflux of the water as the open lake itself, provided the observations are freed from the sudden influence of winds. With these cautions and explanations, I proceed to give full quotations from the authorities above cited.

In the year 1796, the water was low in Lake Erie, as all the early settlers in the Western Reserve agree. They state that they were able to travel with teams on the beach of the lake, most of the way from Buffalo to Cleveland—there being no road on the shore—and that it has never been so broad and continuous since.

In 1798, a rise was observed in the lake. Dr. Houghton* says that our oldest inhabitants agree in stating that the waters were high from 1800 to 1802, in proof of which it is alleged that the roads which had before been in use on the banks of the Detroit river were so completely

* Michigan Geological Reports, 1839, p. 22.

inundated as to be impassable.* As a comment on this, it should be observed that Detroit has been occupied by the French since 1702, and if, in the intervening century, there had been higher water, the recollection of the event would have been preserved by tradition, and their roads would have been laid at a greater distance above the river.

For 1806, the inhabitants along the shore of Lake Erie, in north-eastern Ohio, report the lake as low, and for 1810–11, as very low; at least six feet below 1848. "From the years 1809 to 1814, inclusive, the water was generally two feet lower than in 1820. The reefs between this (Buffalo) and Fort Erie were then entirely out of water, but now covered; and on Bird's Island, which, for many years past, has been almost wholly under water, buildings were erected."†

Mr. Alonzo Carter of Cleveland, who lived at the mouth of the Cuyahoga river in 1798, says, that the water was then three feet below the flood of 1838, and that the high water of 1815–16 was not equal to that of 1838. Mr. Solomon Juneau, the first settler of Milwaukee in 1838, remarked that the water had never, within his recollection, been so low as it was in 1820; and never so high as in June, 1838, when the old Indian race-course was six feet under water. The inhabitants along the southern shore of Lake Erie concur in their recollection of a rise from 1813 to 1816. In 1814, Captain Dobbin, of the revenue service, measured a rise of two feet six inches in three months. Mr. M. Sandford of Erie says, that he took out stone from a quarry in 1810, which in June, 1838, was six feet under water. In June, 1815, he built a ware-house five feet above water, to which the flood reached in June, 1838, and, during the year 1815, it advanced three feet.

"It is now a matter of record," remarks General Whiting, "that, in 1814–15, the Detroit river was unusually high; that the foundations of houses, and much land that had long been under cultivation, were submerged. These buildings had been erected many years before, and, of course, under

* We here append the testimony of the late Governor Dewitt Clinton, a highly competent observer, contained in the second volume (Part I.) of the Transactions of the New York Literary and Philosophical Society, which appears to have escaped the attention of Mr. Whittlesey. "Lake Erie began to rise in 1811 and continued to increase until 1815, when it was two feet higher than ever known. The overflowing of the waters destroyed trees on the low lands more than two hundred years old, and the inhabitants of Detroit, which is an ancient settlement, had never seen or heard of such a rise before. It fell a little in 1816, rose again in 1817, and decreased until 1822. In 1810, I walked on Bird's Island, situate at the outlet of Lake Erie. In 1816 it was almost covered with water and was scarcely visible. I am informed by an intelligent ship-master of the lakes that 'when he visited Detroit in 1797, the waters were at their height. He went South the following year and did not return to that place until 1802, when he found the waters considerably lower.' [There is great discrepancy between this statement and that contained in the text.] 'Having understood that there was a rise and fall every seven years, he determined to ascertain how great it was; for which purpose he caused marks to be made on a solid wharf, which had been built more than twenty years before, and was perfectly firm and immovable; and he found that the water declined about an inch a year for nine years. What the fall was for five years during his absence he did not know, but it may be fairly stated at three times as much yearly; that is, fifteen inches, if compared with subsequent occurrences of a similar character. The lake began to rise again in 1811, in the spring of which it rose six inches, but during the summer it fell two inches. In 1812 it rose fourteen inches and subsided three inches, leaving a nett gain of fifteen inches in two years. The surrender of Detroit to the British, in October, 1812, compelled him to leave the country; but in October, 1813, he returned with the fleet, and the water was then at its greatest altitude, having in that year gained twelve inches—in all twenty-seven inches. In 1814 and 1815, it was stationary. In 1816 and 1817 it fell at least eighteen inches."—*F. & W.*

† Buffalo Commercial Advertiser, November 12, 1841.

belief that they were aloof from all but extraordinary elevations. * * * In 1820, or about that time, the rivers had resumed their usual level and several wharves were built, at Detroit, between that year and 1828, at a height, as was supposed, sufficiently above the general level for convenience and safety. At the latter date, the river had again attained the elevation of 1815, and remained so until 1830."

Dr. Houghton* remarks, "I have been enabled to fix, with a considerable degree of certainty, upon the height at which the waters of the lake in 1819–20, when they were at their lowest level." From a comparison of his own observations on Huron, Michigan, and Superior, with those of Mr. Higgins, General Whiting, and Mr. Hathan, he was enabled to form a table of heights, for the month of June, in each year, taking the lowest stage of water for 1819–20 as the zero.

	Ft. in.	Heights.
June, 1819–20 - - -	0 00	0 00
" 1828 - - -	2 10+	2 10
" 1830 - - -	2 10+	2 10
" 1836 - - -	0 10+	3 08
" 1837 - - -	0 05+	4 01
" 1838 - - -	0 07+	4 08

Were the difference in height computed from February, 1820, to June, 1838, the total amount would be increased to about six feet eight inches.†

It will be readily seen, by the statements already given, how difficult it is to reconcile them to each other; and, before proceeding farther, I will refer again to the *annual* rise and fall, amounting to twelve and sometimes eighteen inches, which is strictly periodical, as will appear by the tables that follow, and wholly disconnected from the phenomena of the general rise and fall, which is very irregular, recurring at periods of many years duration. In this way, some of the conflicting reports as to the stage of the water, that every inquirer meets with, may be reconciled. The annual tide takes place, whether the lake be low or high, and is at its flood in the spring, after the rains of that season and the snows of winter, melted by the warm weather, have united in throwing a surplus of water into all the lakes. In the fall and winter — when the meteorological conditions are reversed, and the absence of rain and the presence of frost unite to check the discharge of water from the tributaries — the lakes, as might be expected, recede twelve, fifteen, and even eighteen inches.

Availing myself of the information derived from Messrs. Walworth, Merchant and others, who were engaged in the construction of the piers at the mouth of the Cuyahoga river, at Cleveland, from 1824 to 1837, I have constructed the following table:‡

		Ft. in.
1822, lowest stage, below my zero of June, 1838, at least		5 00
1825, " " " " " "		4 00
1826, general level, - - - -		2 10
1832, " " - -	2 ft. 6 in. to	3 02
1833, - - - -	2 ft. 8 in. to	3 08

* Geol. Rep. of Michigan, for 1839, p. 23.
† Geol. Rep. Michigan, 1839, p. 24.
‡ Geol. Rep. of Ohio, p. 51.

		Ft. in.
1834,	June, - - - -	2 07
1835,	June, - - - -	2 10
1835,	September, - - - -	3 04
1837,	January, - - - -	3 01 2/10
1837,	June, - - - -	2 07
1837,	September, - - - -	3 06
1838,	May 10, - - - -	1 00
1838,	June 12, - - - -	0 04
1838,	June 25, zero, - - -	0 00
1838,	July 12, - - - -	0 03
1838,	August 18, - - - -	0 09
1838,	October 18, - - - -	1 09
1838,	December 1, - - - -	1 11½

From the 18th of August to the 18th of October, 1838, Mr. George C. Davis, of Cleveland, kept, at his office on the dock, a floating register, which was noted many times a day. Considering the accuracy of these observations, which were freed from the sudden changes which result from winds, I give the weekly mean for those two months:—the numbers express the average of each week below my zero:

	Ft. in.
August 24, - - - - -	0 09.29
" 31, - - - - -	0 10.43
September 7, - - - - -	1 01.07
" 14, - - - - -	1 01.57
" 21, - - - - -	1 03.57
" 28, - - - - -	1 04.29
October 5, - - - - -	1 06.00
" 12, - - - - -	1 07.00
" 18, - - - - -	1 09.00

These measurements show how liable general statements, from memory, are to error. A very observing man might have taken the height of the water at Buffalo, in August, and, only a few weeks afterward, during the same season, at Cleveland, and reasonably have concluded, in the absence of strict data, that the surface at the former place had not materially changed in the mean time; but it is here shown, that a change of one foot in depression occurred in the space of two months. These rapid fluctuations give rise to doubts in all statements where the precise date is wanting. The same thing renders a reference of one set of observations, in one part of the lake, to another set, made at different seasons, in another part, a very complicated affair: nor is it entirely safe to take the same month, in different years, and compare them together; for neither does the spring rise nor the winter fall always happen at the same period of the year; nor is the annual flood-tide of one year equal to that of another.

Different observers do not agree as to the precise time of either the highest or lowest general stage of the water. At Cleveland it was unquestionably the *highest* about the 25th of June, 1838, when it was two feet five inches below the surface of the main wall at the south end of the east pier; two feet below the same wall four hundred feet from the south end; six feet four inches below the coping of the lock at the Cuyahoga river, at Merwin street (on the west wing-wall); three feet eighty-eight hundredths below the water table of the Commercial House, corner of Main and River streets, Ohio City; and was also on a level with the heads of the piles on the river, at the Morocco factory.

These marks and benches were established by Mr. Howe, the resident engineer of this division of the Ohio canal; by General Ahaz Merchant; by Col. T. B. W. Stockton; and by myself, independently of each other, and will probably, some of them, remain for future reference, through all time.

I am unable to find in these tables any confirmation of the popular belief, that there is a "seven years' rise and fall" of the water in the lakes.

The Detroit registers show a continual rise, from 1819 to 1838, or nineteen years. From 1838 to 1841, a continual decline of three years. In 1842 a slight rise. From 1842 to 1851, eight years, a regular decline.

At the other extremity of Lake Erie, accounts differ as to the fact of the lowest water being in 1819 or 1820; but the difference between those years was slight. At Black Rock, the highest stage of water is stated to have been in August, and not in June, 1838; but at Buffalo it is given in the month of June. Some observers place the lowest water in August, and some in the fall of 1819; others in that of 1820; and at Buffalo there is a tradition that in 1810 it was still lower. From 1838 to 1841 there was a decline of three years, the same as at Detroit. From 1841 to 1851, ten years, it has been fluctuating up and down, about as much rise as fall; that is, the total rise 2.75, total fall 2.56. At Cleveland, from 1796 to 1810–11, the water was low, fourteen years; from 1811 to 1816, five years, rising very rapidly; from 1816 to 1819, three years, falling rapidly to the lowest known point; and from 1819 to 1838, nineteen years, a steady rise. Since 1838 there has been a steady decline to March 1846, the lowest since 1819, and since 1846 considerable fluctuation and irregularity. Among all these periods, there is none of seven, and just one of fourteen years.

These tables demonstrate the effect of the change of seasons within the year upon the stage of water. They show an annual rise and fall entirely independent of the general height of water fluctuating a certain distance within each year, whether the general surface is high or low.

The average or mean annual difference of four well ascertained years, at Cleveland, is	1ft. 3in.
Of eight years at Detroit	1ft. 2½in.
Of four years at Buffalo	0ft. 10½in.
Mean of all annual differences	1ft. 1⅝in.

No observer of registers has discovered a daily or lunar tide.

The greatest range of general surface of the lake, at Detroit, was, between August 1838 and June 1819	5ft. 3in.
At Black Rock, between August 1838, and August 1819, or 1820,	5ft. 3in.
At Buffalo, between June 1838 and August 1819	5ft. 3in.
At Cleveland, between June 1838, and the fall of 1819	5 to 6ft.

The greatest extreme and temporary range noticed in the register, occurred between the same years, and are given as follows:

At Detroit	6ft. 8in.
At Black Rock	7ft. 1in.
At Cleveland	7ft. 0in.

Abstract of Colonel T. B. W. Stockton's Register for 1845 -6—*Cleveland.*

The figures show the *depression* of the water-surface below June, 1838, giving the *mean* of each week's observations three times a day.

The three lines of figures under the head of the month, represent the mean height at 6 A. M., at Noon, and 6 P. M., daily, for each week.

Month.	First week.	Second week.	Third week.	Fourth week.	Monthly mean.
					Below zero.
1845.					
August.			2 ft. 9 in.	2 ft. 8.9 in.	
	Wanting.	Wanting.	2 ft. 6.7 in.	2 ft. 8.9 in.	
			2 ft. 7.8 in.	2 ft. 9.1 in.	
September.	2 ft. 11.4 in.	2 ft. 11 in.	3 ft. 0.8 in.	3 ft. 1.7 in.	3 ft. 0.3 in.
	2 ft. 9.1 in.	2 ft. 11.3 in.	3 ft. 0.1 in.	3 ft. 0.6 in.	2 ft. 11.2 in.
	2 ft. 8.8 in.	2 ft. 10.7 in.	2 ft. 11 in.	3 ft. 0.9 in.	2 ft. 10.8 in.
October.	3 ft. 2.3 in.	3 ft. 2.3 in.	3 ft. 3.0 in.	3 ft. 3.7 in.	3 ft. 2.75 in.
	3 ft. 1.7 in.	3 ft. 1.3 in.	3 ft. 0.3 in.	3 ft. 3.9 in.	3 ft. 1.8 in.
	3 ft. 0.3 in.	3 ft. 0.9 in.	3 ft. 2.1 in.	3 ft. 3.8 in.	3 ft. 1.8 in.
November.	3 ft. 2 in.	3 ft. 5.7 in.	3 ft. 8.4 in.	3 ft. 8.6 in.	3 ft. 6.18 in.
	3 ft. 2.1 in.	3 ft. 6.1 in.	3 ft. 8.0 in.	3 ft. 7.4 in.	3 ft. 5.9 in.
	3 ft. 2.8 in.	3 ft. 4.3 in.	3 ft. 6.7 in.	3 ft. 5.6 in.	3 ft. 4.85 in.
December.	3 ft. 7.6 in.	3 ft. 7.8 in.	3 ft. 10.5 in.	4 ft. 2.0 in.	3 ft. 9.9 in.
	3 ft. 8.1 in.	3 ft. 7.8 in.	3 ft. 11.4 in.	4 ft. 0.6 in.	3 ft. 9.9 in.
	3 ft. 5.0 in.	3 ft. 8.1 in.	3 ft. 10.0 in.	4 ft. 0.0 in.	3 ft. 8.8 in.
1846.					
January.	4 ft. 0.0 in.	3 ft. 11.7 in.	4 ft. 1.3 in.	4 ft. 1.8 in.	4 ft. 0.7 in.
	4 ft. 0.8 in.	4 ft. 0.4 in.	4 ft. 0.5 in.	4 ft. 2.0 in.	4 ft. 0.9 in.
	3 ft. 11.5 in.	3 ft. 11.1 in.	4 ft. 0.0 in.	4 ft. 2.7 in.	4 ft. 0.3 in.
February.	4 ft. 2.1 in.	4 ft. 4.2 in.	4 ft. 6.1 in.	4 ft. 6.3 in.	4 ft. 4.7 in.
	4 ft. 2.5 in.	4 ft. 4.2 in.	4 ft. 6.4 in.	4 ft. 6.3 in.	4 ft. 4.8 in.
	4 ft. 2.3 in.	4 ft. 4.5 in.	4 ft. 5.7 in.	4 ft. 7.1 in.	4 ft. 4.9 in.
March.	4 ft. 8.8 in.	4 ft. 8.0 in.	4 ft. 6.5 in.	4 ft. 2.7 in.	4 ft. 6.5 in.
	4 ft. 6.3 in.	4 ft. 8.1 in.	4 ft. 4.7 in.	4 ft. 2.5 in.	4 ft. 5.4 in.
	4 ft. 5.3 in.	4 ft. 8.5 in.	4 ft. 6.3 in.	4 ft. 2.7 in.	4 ft. 5.7 in.
April.	4 ft. 1.5 in.	4 ft. 1.3 in.	4 ft. 0.3 in.	4 ft. 1.8 in.	4 ft. 1.1 in.
	4 ft. 2.3 in.	4 ft. 0.3 in.	3 ft. 11.8 in.	4 ft. 0.3 in.	4 ft. 0.6 in.
	4 ft. 1.3 in.	1 ft. 3.7 in.	4 ft. 11.3 in.	4 ft. 3.7 in.	4 ft. 2.0 in.
May.	3 ft. 6.3 in.	3 ft. 3.1 in.	2 ft. 9.0 in.	3 ft. 10.0 in.	3 ft. 1.2 in.
	3 ft. 6.6 in.	3 ft. 3.3 in.	2 ft. 10.0 in.	2 ft. 11.2 in.	3 ft. 2.0 in.
	3 ft. 5.6 in.	3 ft. 3.5 in.	2 ft. 10.9 in.	2 ft. 10.9 in.	3 ft. 1.7 in.
June.	2 ft. 8.5 in.	2 ft. 10.5 in.	2 ft. 10.5 in.	2 ft. 10.5 in.	2 ft. 10.4 in.
	2 ft. 11.4 in.	2 ft. 9.0 in.	2 ft. 10.1 in.	2 ft. 11.5 in.	2 ft. 10.5 in.
	5 ft. 10.2 in.	2 ft. 10.7 in.	2 ft. 8.1 in.	2 ft. 11.2 in.	2 ft. 10 in.
July.	2 ft. 7.0 in.	2 ft. 8.8 in.	3 ft. 0.0 in.	3 ft. 2.4 in.	2 ft. 10.5 in.
	2 ft. 8.8 in.	2 ft. 9.8 in.	2 ft. 11.3 in.	3 ft. 2.0 in.	2 ft. 10.9 in.
	2 ft. 9.4 in.	2 ft. 10.8 in.	2 ft. 8.8 in.	3 ft. 2.0 in.	2 ft. 10.7 in.
August.	3 ft. 1.8 in.	3 ft. 1.7 in.	3 ft. 0.9 in.	3 ft. 1.5 in.	3 ft. 1.5 in.
	3 ft. 1.4 in.	3 ft. 1.7 in.	2 ft. 6.7 in.	3 ft. 0.8 in.	2 ft. 11.6 in.
	3 ft. 1.7 in.	3 ft. 1.4 in.	2 ft. 10.9 in.	3 ft. 2.7 in.	3 ft. 1.2 in.

The lowest stage of 1846 was in the month of March........	**4 ft. 5.8 in.**
The highest stage of 1846 was in the month of June.........	**2 ft. 10.1 in.**
Greatest difference of the monthly mean for 1846...........	**1 ft. 7.7.**

The following average of each month in 1846 shows the perfect regularity of the *annual* elevation and depression. If we had as perfect a table for *several consecutive years* as we have for this, a *yearly abstract* would show the *general* elevation and depression in the same way.

			Ft. in.
September,	1845,	average	2 11.4
October,	"	"	3 02.1
November,	"	"	3 05.6
December,	"	"	3 09.5
January,	1846,	"	4 00.6
February,	"	"	4 04.8
March,	"	"	4 05.8
April,	"	"	4 01.2
May,	"	"	3 01.6
June,	"	"	2 10.1
July,	"	"	2 10.7
August,	"	"	3 00.7

At Buffalo and Black Rock there is less regularity than elsewhere, showing that winds, and the form of the coast, produce irregularities there that are local.

For five years high water occurred there; in July once, June once, May once, August once, and October once. For the winter months, when the water is low, the measurements are wanting.

At Detroit there are several years when there was little variation during two or three months. In four years (not consecutive, but those best ascertained) it was high in June and July three times, and August once, and January, February, and March once.

At Cleveland, in five years well ascertained, high water has been, in June four times; and June, July, and August once; low, in January once, December twice, March once, and August once.

So that out of fourteen cases, where the highest months have been registered, it has been high in June and July ten times, and in ten cases has been low in December and January six times. It is like other ponds and rivers, raised by the spring freshets, and lowered by frost and drought of winter.

At this time Lake Superior is unusually high. During the summer of 1851 it was about three feet above the general level of 1847, when it was unusually low. Lake Huron is stated to have been two and one-half feet higher at the Detour light than in 1847. Lake Michigan is reported to have been higher the past autumn than for several years. The upper lakes being full must discharge a large surplus into lakes Erie and Ontario, which will be felt in the coming spring. If we have a cold and wet season, it will operate at that time to assist the flood of water from the north in raising Lake Erie. If it is warm and dry, it will counteract the effect of a large supply through the Detroit river. Instead of regarding the rise and fall of water in the lakes as a mystery, it is rather to be wondered that there is so little fluctuation. Their stability is dependent entirely upon the regularity of the seasons, within the lake country, and if there should be a combination of wet and cold years, wherein the fall of rain should be great, and the evaporation small, there might be a rise or fall exceeding any thing we have on record.

Table showing the highest and lowest stage of water in Lake Erie, for each month, from August 1845 *to August* 1846, *inclusive, drawn at Cleveland, from Colonel T. B. W. Stockton's Meteorological Record. Zero of reference, the high water of June,* 1838.

Months.	Time.	Winds, etc.	High water.	Low water.	Greatest monthly difference.
			below°	*below°*	,
August, 1845.	Several times.......	wind southerly......	2 ft. 6 in.	....	....
	6 a. m. 14th.........	high south wind......	....	3 ft. 4 in.	0 ft. 10 in.
September.	a. m. of 5th and m. of 24th..........	heavy north-west....	2 ft. 6 in.	....	....
	Noon of 26th.......	light south-west.....	....	3 ft. 7 in.	1 ft. 1 in.
October.	3d, 6 p. m..........	high north-east......	2 ft, 8 in.	....	....
	24th, 6 a. m.........	light south:.........	....	3 ft. 10 in.	1 ft. 2 in.
November.	Eve of 2d and a. m. of 3d.............	gale north-east......	2 ft. 8 in.	....	....
	Morn of 19th, at 4 a. m. water settled to 6 ft. 2 in. B, for a short time.......	strong south-west...	....	4 ft. 8 in.	2 ft. 0 in.
December.	1st, morning.........	gale north-east......	2 ft. 6 in.	....	....
	16th, morning.......	breeze north.........	2 ft. 6 in.	....	2 ft. 5 in.
	27th, noon..........	fresh breeze south-west............		4 ft. 11 in.	....
January, 1846.	31st, morning.......	high north-east......	3 ft. 5 in.	....	....
	10th, noon..........	fresh south-west.....	....	4 ft. 9 in.	....
	18th, morning.......	fresh north..........	3 ft. 10 in.	4 ft. 10 in.	1 ft. 5 in.
February.	10th, morning.......	fresh north-west.....	3 ft. 10 in.	....	....
	21st, morning.......	high south-west......	4 ft. 0 in.	5 ft. 1 in.	1 ft. 3 in.
March.	30th, morning.......	fresh west...........	....	....	4 ft. 8 in.
	7th, noon...........	light west...........	3 ft. 6 in.	5 ft. 0 in.	1 ft. 0 in.
April.	25th, noon..........	heavy gale north-east.	....	....	....
	27th, noon..........	do do	3 ft. 6 in.	....	....
	30th, evening.......	do do	3 ft. 6 in.	....	....
	11th, evening.......	heavy west...........	....	5 ft. 0 in.	1 ft. 6 in.
	At 3 p. m. 5 ft. 6 in. B.				
May.	18th, evening, and 19th, morning.....	gale north..........	2 ft. 9 in.	....	....
	8d, noon............	light south..........	....	3 ft. 9 in.	....
	5th and 6th, noon....	light north-east.....	....	3 ft. 9 in.	1 ft. 0 in.
June.	2d, morning.........	fresh north-west.....	2 ft. 6 in.	....	....
	20th, evening.......	high north...........	2 ft. 6 in.	....	....
	21st, morning.......	gale north-east......	2 ft. 6 in.	....	....
	30th, morning.......	fresh south..........	2 ft. 6 in.	....	....
	14th, morning.......	breeze north.........	....	3 ft. 2 in.	0 ft. 8 in.
July.	11th, 6 a. m.........	light south..........	2 ft. 6 in.	....	....
	21st, 6 a. m.........	light south..........	....	3 ft. 4 in.	0 ft. 10 in.
August.	18th, noon [average of the 18th 2 ft. 0,6 in.]............	breeze north........	1 ft. 10 in.	....	....
	30th, 6 p. m.........	breeze north-east....	....	4 ft. 9 in.	2 ft. 11 in.
	At noon, 3 ft. 2 in...	....	....	....	....

It is apparent from this exhibit, that north-east winds and gales prevail over those of any other direction, and produce most uniform effects in heaping or *raising* the waters at this place; and also that south-west winds have the contrary effect, and drive out and depress the water of the lake.

Of twenty-one cases of extreme *high* water above given, eight are due to north-east winds, three to south winds, and three to north-west winds.

Of sixteen instances of low water, two are connected with north-east winds, two with westerly, and five with south-west winds.

High water occurred oftener in the morning than at noon or evening, and the same of low water, which is in consequence of the changes that occur in the land and sea breezes near the commencement and close of the day. The water has been high in the morning (6 A. M.) ten times, in the evening five, at noon twice.

It has been low in the morning seven times, at noon six, in the evening twice.

The greatest fluctuations take place in the morning; of which the most extreme case on these records occurred on the morning of November 19, 1845, after two days' light breeze south, changing to high south-west winds. The water then fell twenty inches below the bottom of the stone wall, or six feet two inches.

It is apparent, from the column of differences in the above table, how little reliance can be placed on a *single* measurement, and how necessary it is to have a daily register, in order to arrive at the mean surface of the lake. Winds, not felt at this point, may affect the stage of water materially.

My observations at Cleveland from 1838 to 1851 have not been sufficiently numerous or regular to be of much value—they are as follows:

		Below 0 of June, 1838.	Remarks.
March 11, 1841	- -	2 feet 9 inches.	
April 14, 1842	- -	2 " 6 "	
December, 1845	- -	2 " 5 "	
April 15, 1846	- -	3 " 6 "	
June 20, 1850	- -	3 " 0 "	
1851.			
Jan'ry 18,	- -	4 " 1 "	
June 5,	- -	1 " 11 "	calm.
" 15,	- -	1 " 11 "	wind at north-east.
July 2,	10 A.M. -	2 " 1 "	light off shore.
" 6,	" " -	2 " 1 "	" "
" 12,	" " -	1 " 11 "	wind at north-east.
" 20,	" " -	1 " 11 "	west after long north-east winds.
" 22,	11 " -	1 " 11 "	calm.
" 23,	" " -	1 " 10 "	calm.
" 27,	" " -	1 " 11 "	after strong W. wind
August 3,	" " -	1 " 11½ "	wind off shore.
" 7,	" " -	1 " 11 "	" at west.
Sept. 19,	4 P.M. -	2 " 3 "	calm.
Oct. 1,	5 " -	2 " 3 "	wind at north-east.
" 2,	10 A.M. -	2 " 9 "	" off shore.
" 8,	" " -	2 " 4½ "	calm.
" 11,	3 P.M. -	2 " 5 "	wind off shore.
" 27,	4 " -	2 " 7 "	" west, heavy.

The months of June, July and August, 1851, as here given, vary very little, the average being about two feet below; while in the corresponding months of 1838, there was a fall of nine inches. The results of the Cleveland observations are,

Mean annual difference of level (in four best ascertained years),				1ft. 3in.
Greatest annual difference of level,				2ft. 2in.
Least annual difference of level,				0ft. 0in.
Mean of observed fluctuations within the year (four best years),				2ft. 0in.
Greatest	do.	do.	do.	2ft. 3in.
Least	do.	do.	do.	1ft. 11in.
For 1845–6, the mean of the greatest transient fluctuation for thirteen months, as shown by the daily record, arising from winds and storms, within each month, is				1ft. 5in.
The greatest temporary height, from local and sudden causes, such as storms, stood (below zero),				1ft. 10in.
The greatest depression, from like causes,				5ft. 00in.

Mr. S. W. Higgins, in the Michigan geological report for 1841, has given a table of heights, referred to the same zero as those of Dr. Houghton in the report of 1838, but differing slightly as the extreme rise of 1838 above the depression of June, 1819. It is as follows:

1838.	Aug. 21,	highest water	- -	5 feet 3 inches.
1839.	Jan. 1,	minimum of that year	-	1 " 7 "
"	July 31,	maximum	- -	3 " 11 "
1840.	Jan. 30,	minimum	- -	0 " 9 "
"	July 4,	maximum	- -	2 " 7½ "
1841.	Jan. 1,	minimum	- -	0 " 6½ "

This table, like the one at Cleveland, exhibits a remarkably rapid decline between August 1838 and the close of that year.

Mr. Higgins has also given in detail, his measurements during the year 1840, referred to the same zero, or the minimum of the summer of 1819.

1840.			1840.		
Jan. 30,	-	0 feet 9 inches.	Oct. 1,	-	2 feet 1 inch.
April 25,	-	2 " 2 "	Oct. 12,	-	1 " 9½ inches.
May 9,	-	2 " 3½ "	Oct. 29,	-	1 " 9 "
June 8,	-	2 " 4½ "	Nov. 10,	-	1 " 10½ "
July 4,	-	2 " 7½ "	Nov. 24,	-	1 " 6 "
July 22,	-	2 " 4½ "	Dec. 10,	-	1 " 6½ "
Sept. 1,	-	2 " 2 "	Dec. 21,	-	1 " 4½ "
			1841.		
Sept. 13,	-	2 " 1½ "	Jan. 1,	-	0 " 6½ "
Sept. 20,	-	1 " 9 "			

This table, like that of Mr. Davis, exhibits a regular falling of the lake, from its maximum in July to its minimum in January. For 1840 as given above, the water fell from two feet seven and one-half inches to six and one-half inches—a decrease of two feet one inch in about six months; and reckoning back from July 1840 to January 1840, the fall was one foot ten and one-half inches.

Measurements of A. E. Hatham, Esq., referred to the Water Table of the Hydraulic Tower, Detroit, as zero.

Date.		Below zero.	Remarks.
		Feet.	
June, 1819.		8.45	Lowest stage.
do. 1830.		6.45	
do. 1836.		4.79	
do. 1837.		4.20	
August	1838.	3.20	Highest known stage.
September	do.	3.44	
October	do.	4.19	
November	do.	5.29	
December	do.	5.20	[Mean of fall of 1838, 4.25.]
January 1,	1839.	6.86	Lowest of 1839.
June 10,	do.	4.77	
July 30,	do.	4.52	Highest of 1839.
September 20,	do.	5.27	
October 28,	do.	6.02	
November 27,	do.	6.02	[Mean of 1839, 5.58.]
January 30,	1840.	7.68	Lowest of 1840.
April 25,	do.	6.27	
May 9,	do.	6.19	
May 19,	do.	6.28	
June 8,	do.	6.18	
July 4,	do.	5.83	Highest of 1840.
July 22,	do.	6.16	
September 1,	do.	6.39	
September 13,	do.	6.38	
September 20,	do.	6.70	
October 1,	do.	6.36	
October 12,	do.	6.66	
October 29,	do.	6.70	
November 10,	do.	6.57	
November 24,	do.	6.95	
December 10,	do.	6.91	
December 21,	do.	7.08	[Mean of 1840, 6.55.]
January 1,	1841.	7.92	
February 23,	do.	7.92	
March 17,	do.	7.95	Lowest stage 1841.
April 3,	do.	7.56	
May 22,	do.	7.65	
June 14,	do.	7.45	
July 8,	do.	7.03	
August 2,	do.	6.61	Highest stage 1841.
September 18,	do.	7.43	
October 1, 2, 3, 5	do.	8.75	Low water from strong west winds.
October 11,	do.	7.73	
November 18,	do.	7.75	[Mean of 1841, except October 1 to 5, 7.55.]
December 2,	do.	7.63	
January 31,	1842.	7.58	
October 24,	1847.	6.10	
March 21,	1849.	6.28	[Mean of 1839 below 1838, 1.33 ft.
			do. 1840 below 1839, 0.99 ft.
May 3,	do.	5.53	do. 1841 below 1840, 1.00 ft.
July 5,	1850.	5.58	Total.............. 3.32.]

At Black Rock, New York, we have, according to the Buffalo Commercial Advertiser of November 12, 1841, the following table of comparison:

Months.	Depth of water on mitre-sill.		Depression for 1841 below 1840.
	1840.	1841.	
	Feet.	*Feet.*	*Feet.*
May.	9.38	8.50	0.85
June.	9.90	8.24	1.66
July.	9.33	7.80	1.43
August.	9.40	7.30	2.10
September.	8.30	6.75	1.55
October.	8.10	5.86	2.24

Mean 1.63 foot.

The same paper contains the stage of water for the month of August, from 1820 to 1841, (with some omissions,) referring to the low water of the first-named period as zero.

				Ft. in.
Rise from August 1820,	to August 1828,	-	-	2 06
" " " 1828,	" 1830,	-	-	0 00
" " " 1830,	" 1836,	-	-	1 00
" " " 1836,	" 1837,	-	-	0 06
" " " 1837,	" 1838,	-	-	1 01
				5 01

				Ft. in.
Fall from August 1838,	to August 1839,	-	-	1 03
" " " 1839,	" 1840,	-	-	1 03
" " " 1840,	" 1841,	-	-	1 10
				4 04

The results of the various observations at Buffalo may be summed up as follows:

Mean annual difference of four best ascertained years,	0.89
Greatest annual difference - - - -	1.27
Least " " - - - -	0.37
Greatest temporary fluctuation within the year -	2.64
Least " " " " -	0.80
Mean fluctuations " " -	1.40

Weekly and monthly abstract of measurements, by John Lathrop, Esq., resident engineer, showing the height of the water at the foot of Commercial street, Buffalo.

[Taken twice a day—at 9 a. m. and 4 p. m. Zero, the bottom of the enlarged Erie canal, which is one foot below the mitre-sill of the guard-lock at Black Rock.

Date.	Above zero in feet.		Extreme monthly difference.	Extreme high and low water.	Course of wind.
	Weekly mean.	Monthly mean.			
			9.40	High night of 16th.	Wind strong east.
November, 1850	7.53		6.70	Low 22d, 4 P. M.	Wind light east.
	7.65				Wind east 9 days, west 4, north-east 2, south-west 5, south 3.
	8.00	7.73	2.70		
December, 1850.	7.67		10.50	Night of 26th.	South-west storm.
	7.53		5.90	p. m. of 28th.	Light east wind.
	8.30				Wind east 6 days, west 9, north-west 8, south-west 4, north-east 4, north 2.
	7.83	7.83	4.60		
January, 1851.	7.75		12.75	5 a. m., 17th.	Gale south-west.
	8.42		7.20	4 p. m., 21st.	Light south-west.
	7.46				Wind east 5, north-west 4, south-west 1, south 2, west 7, south-west 8, north 1.
	8.00	7.91	5.55		
			11.40	6 a. m., 15th.	Gale west.
February, 1851.	7.51		5.80	4 p. m., 8th.	Breeze east.
	7.92				Wind north-east 2, north-west 5, north 1, south 3, south-west 4, south-east 1.
	8.12	7.85	5.60		
March, 1851.	8.53		10.20	4. p. m., April 3d.	Storm south-west.
	8.32		7.30	9 a. m., March 5th.	Light east.
	8.41				Wind east 6, south-west 9, east 4, north-west 3, south-west 2, north 1, north-east 3.
	8.58	8.46	2.90		

Weekly and monthly abstract of Measurement, &c.—Continued.

Date.	Above zero in feet. Weekly mean.	Above zero in feet. Monthly mean.	Extreme monthly difference.	Extreme high and low water mark.	Course of wind.
			12.75	6 p. m., 8th.	Gale south-west.
April, 1851.	8.30		6.50	9 a. m. 5th.	East light.
	8.31				South-east 3, east 2, south-west 4, west 2, north-west 3, north-east 5, south 1.
	8.87	8.49	6.25		
May, 1851.	8.91		13.50	2 p. m., 1st.	Gale south-west.
	8.66		8.30	9 a. m., 22d.	Breeze south-west.
	8.86				North-west 2, west 3, south-west 17, north-east 2, south 1, east 2.
	9.17	8.90	5.20		
June, 1851.	9.18		10.10	9th.	Breeze south-west.
	9.41		8.80	5th.	Light north.
	9.41				East 1, west 5, north-east 2, south-west 13, north 2, south-east 1, north-west 1, south 3.
	9.35	9.33	1.30		
			10.30	9 a. m., 24th.	Gale south-west.
July, 1851.	9.34		8.80	9 a. m., 7th.	Light east.
	9.63				West 3, east 3, north-west 2, south-west 10, south 2, north 1, north-east 1.
	9.53	9.50	1.50		

Mean of nine months	8.44
Maximum month July	9.50
Minimum month November	7.13
Difference of level	1.77
Greatest temporary rise May 1st	13.50
Greatest temporary depression February 8th	5.80
Greatest fluctuation in nine months	7.70

The wind was south-west 72 times, west 39, north-west 23, east 33, north-east 13, north 6, south 13, south-east 4.—Extreme high water occurred during south-west winds 6 times out of 9, and low water 6 times in 9 during easterly winds.

It may be thought that the observations are, at this time, sufficiently numerous and accurate to warrant the construction of a general table of levels for the last fifty years. If this could be done, it would have very much reduced the length of this chapter; but there are so many discrepancies between the different registers which I cannot at present reconcile, that I have thought it best not to attempt to fix a general zero or plane of reference. A general and well arranged system of synchronous observations, kept up for some years at different points on the lakes, is needed before a complete comparison can be made.

If we follow the register at Black Rock, the water was four inches higher in August, 1838, than in June; while at Cleveland, on the other hand, it was nine inches lower. At Black Rock, in August, 1841, it was within nine inches of the lowest known level, that of 1819; but, at the same time, it was not so low at Detroit as in August, 1819, by one foot ten inches.

The average fall of the water at Detroit for the year 1841, was one foot; at Black Rock the average fall from May to October of the same year, was 1.63 feet; which is even less than it would have been for the entire year.

The average of the summer months of 1840, at Detroit, was two feet ten inches above the level of 1819, and at Black Rock, two feet two inches; thus showing a difference of eight inches in the amount of rise at the two places during the same period.

By using the observations which were made at Cleveland and Detroit during the months of September, October, November and December, we might determine the difference between the zeros of those two places, provided that the rise and fall of the river and lake were equal.

Thus the observations for four months at Detroit, according to Mr. Hathan, give for the level of the water at that place, four feet six inches below zero; the observations at Cleveland for the same period, give an average of one foot one inch below the zero of that place; making the zero of Cleveland three feet five inches below that of Detroit.

According to the observations made by Mr. Lathrop and myself during the months of June and July, 1851, at a time when the lake was little disturbed by winds, the average level of the water was, at Buffalo, 9.41 feet above the zero of that place, and at Cleveland 2 feet below the zero of that city; making the zero of Cleveland 11.41 feet higher than that of Buffalo.

But if we reduce the observations at Black Rock to the standard, we find that the low water of October, 1841, was below the level of 1819, when it is universally agreed that this was the lowest known stage. Mr. Lathrop remarks, that the depth of water on the mitre-sill of the guard-lock at Black Rock is very much influenced by the mills which are fed from that basin. The records show that, from some cause, the fluctuations are greater at Black Rock than at either Cleveland or Detroit, so that, whatever may be the cause of the error or difference, the registers at the eastern extremity o the lake are not a safe index of the level of the water elsewhere. The fall at Black Rock from August, 1838, to October, 1841, was five feet nine inches; while at Detroit, it was only three feet four inches during the same period. Cleveland is better situated than Buffalo for the purpose of registering accurately the fluctuations of the lake; for, while the former city is nearly midway between its two extremities, and opposite its widest part; the latter city, on the other hand, is placed at the vertex of a triangle formed by the sides of the lake, and at its eastern extremity, so that the waters are crowded by a south-west wind into a constantly narrowing space, and of course rise higher than they would otherwise do. Thus, during a gale, which blew down the lake on the night of the 18th of October, 1849, the water rose fifteen feet six inches above the point to which it fell during an easterly gale, on the 18th of April, 1848. The greatest sudden change noticed at Cleveland, was November 19th, 1845, when the water fell 25 feet. At Chicago the level of the lake is said to have oscillated through a space of four feet during twenty-four hours, in June, 1851.

The greatest range of one month at Cleveland, was in August, 1845, when the difference between the highest and lowest stage of water was, according to Colonel Stockton's tables, two feet eleven inches. The greatest range of the fluctuations, in 1845 and 1846, was three feet three inches. The registers of Colonel Stockton and Mr. Lathrop show that the greatest oscillations of the lakes are due to south-westerly and easterly winds; but these winds depress the water at Cleveland, while they raise it at Detroit.

If our materials were sufficiently ample to enable us to form a general table, expressing the mean monthly stage of the water for an uninterrupted series of years, the annual rise and fall could easily be exhibited by curves constructed upon the measurements as ordinates. The relations between the observations at Detroit, Cleveland and Buffalo, are, however, as yet too imperfectly understood, and the registers are incapable of being reduced to one plane of reference. They are here, therefore, collated and arranged for future use; but before leaving the subject, I will draw up a tabular statement, showing the time of the year when high or low water has been observed, and the amount of the annual rise or fall for the few years covered by the registers.

Table showing the annual Rise and Fall of Lake Erie.

Date.	High water month.	Low water month.	Greatest difference.		Place.
			Feet.	*Inches.*	
1837.		January			Cleveland.
1837.	June		0	11 rise.	Cleveland.
1838.	June				Cleveland.
1838.	August		8	8 fall...	Detroit.
1839.		January			
1839.	July				
1840.		January	3	2 fall...	Detroit.
1840.	July				Detroit.
1841.		Jan., Feb. and March...	2	1 fall...	Detroit.
1841	August				Detroit.
1842.		December, January	1	0 fall...	Detroit.
1846.		March.			
1846.	June		1	7 rise..	Cleveland.
1850.		November			
1851.	July		1	8 rise..	Buffalo.

Now it does not follow that if observations had been taken at all these places since 1837, the time of high and low water of each year would have been the same at each place, or even that it would have fallen in the same month. There are many circumstances to be considered, such as the unequal amount of water received and discharged by each lake; the different winds and the opposite effect of the same wind blowing over the different lakes; so that it is evident that there must be undulations of level and accumulations of water at one point, for days or weeks together. A south-west wind sweeping over Lakes Michigan, Huron and Erie operates quite differently upon their surfaces. While it accelerates the discharge of the water from Lake Erie, and lowers the surface of that lake at its western end, it checks at the same time the flow from Lake Huron; thus operating in a two-fold manner to depress its surface. A north-east gale, on the other hand, forces back the water of Lake Erie and increases the discharge of Lake Huron, so that there is a corresponding rise of the water at the western extremity of the former lake. Neither do all the lakes reach their maximum height at the same time, but successively, according to the combined action of the various meteorological causes.

In general, the great lakes rise and fall nearly together; but not absolutely at the same time, nor by an equal amount.

It is apparent from these statistics that there is no foundation for the popular belief that there is a rise and fall of the lakes during a period of fourteen years. Between 1796–8 and 1819–20, a period of twenty years, there was a gradual depression and rising of the lakes. From 1816 to 1819–20, the waters fell to a lower level than even their previous stage of depression. From 1819–20 to 1838, a period of eighteen years, there was a steady increase of elevation, when the water attained its greatest known height. The lowest stage of water, since that time, occurred in October 1841, which was less than three and a half years after the preceding great depression.

No person, who examines the daily registers, will find any grounds for the belief that there is in Lake Erie a daily or lunar tide, like that of the ocean.

As before remarked, the causes which produce changes in the levels of the lakes are the same as those which influence other collections of water; that is, the ever-varying amount of rain and evaporation. The records of the rain-gauge throughout the north-west are yet too meagre to enable us to determine the amount of falling water over the basins of these lakes; but I will avail myself of such materials as are in my possession.

From the rain-gauge kept at the Pennsylvania Hospital, we derive the following results:*

From 1810 (low water) to 1815, (high water) 5 years	185.68	inches.
Mean	37.13	"
From 1815 (high) to 1819, (low) 5 years	151.14	"
Mean	30.23	"
From 1827 to 1837, (high) 11 years	451.05	"
Mean	41.00	"

From the rain-gauge kept by Dr. Hildreth at Marietta, Ohio, we gather the following results:

From 1819 (low) to 1823, (rising) 5 years	202.83	inches.
Mean	40.56	"
From 1828 to 1832, 5 years	228.17	"
Mean	45.63	"

* Extract from the Michigan Geological Report for 1841, p. 26.

From the observations of the army surgeons,* we derive the following results:

Dearbornville Arsenal, near Detroit, mean annual fall of rain for 1836–8 and '9, 3 years, mean - -	31.29 inches.
Fort Brady, at Saut Ste. Marie, 1837–8 and '9, 3 years, mean - - - - - - -	31.89 "
Fort Howard, Green Bay, 1836–7–8 and '9, 4 years, mean - - - - - - -	38.33 "
Fort Winnebago, Wisconsin, 1837–8 and '9, 3 years, mean - - - - - - -	31.88 "

The following is a transcript of the rain-gauge kept at the Western Reserve College, Hudson, Ohio:

1838–9 and '40, mean - - - - -	34.115 inch.
1841 - - - - - - -	28.431 "
1842 - - - - - - -	36.114 "
1843 - - - - - - -	26.736 "
1844 - - - - - - -	35.730 "
1848, 1849, 1850, mean of three years, - -	39.365 "

The difficulty of making exact comparisons between the stage of water in the great lakes, and the amount of falling water from the clouds, arises from the want of rain-gauges in the North-west, previous to the high water of 1838. Those of Philadelphia and Marietta being out of the valley of the St. Lawrence, are not a certain guide in determining the amount of rain which fell within those periods, in the region of the lakes.

The observations at Hudson, and at the various military posts, do not extend back sufficiently far to enable us to draw certain conclusions. For periods of five years, there must be a similarity between the seasons of the lake-country and of Philadelphia. From the low water of 1810 to the high water of 1814–15, there fell, in Pennsylvania, 34.54 inches of rain more than for the years from 1815 to 1819. If this be true of the lake-region, the only wonder is that the rise of water was not greater. The area drained by the lakes is estimated as being four times as great as their surface, and the amount of water poured into them by their various affluents, unless checked by evaporation, would raise their surface twelve feet.

The mean of the eleven years prior to the flood of 1838 is very large, being forty-one inches, or eleven inches per annum greater than that of the preceding low water of 1819. So for ten years out of twenty, of the time of the gradual rise from 1819 to 1838, Dr. Hildreth's gauge, in the valley of the Ohio, one hundred and eighty miles south of Lake Erie, gives an average of 43.2 inches—a very large increase.

The great rise of 1838 is due to causes which operated in 1837 and years preceding, so that the reports of the army surgeons are divided in point of time; the years 1838 and 1839 belonging to a declining stage, while those of 1836 and 1837 belong to an advancing stage.

The records of Professor Loomis, and his successors at Hudson, begin in 1838, with the flood of that year, and continue with some intermissions to the present time. The lowest stage since 1838, happened in 1841. The

* Meteorological Register, p. 99.

mean of these four years is, for Hudson, 31.27 inches, which is a foot per year lower than that for ten years prior to 1838, at Marietta. The mean of three years since 1841, is 32.86 inches, and from 1848 to the present time 39.36 inches, showing a large increase, amounting to nearly seven inches per annum. For this period the measurements of the lake-surface are too imperfect to enable us to estimate the actual rise.

On Lake Superior the years 1845–6 were unusually dry, and in 1847 that lake had reached a very low stage of water. The years 1849–50 were in that region wet, and the lake as a necessary consequence is now (1851) very high; that is, from three to three and one-halt feet above the level of 1847.

CHAPTER XX.

MAGNETIC VARIATIONS.—COMPARISON OF TERRESTRIAL AND ASTRONOMICAL MEASUREMENTS.

BY CHARLES WHITTLESEY.

General Remarks on the Duties of the linear Surveyors.—Extent of the public surveyed Lands.—The Solar Compass.—Explanation of the Method adopted in the linear Surveys.—Convergence of Meridians.—Magnetic Variations in Michigan.—In Wisconsin.—Remarks on the Variations in Michigan.—Comparison of astronomical and terrestrial Measurements.—Errors to which the linear Surveys are liable.—How compensated.—Meridian and base Lines.—Their geographical Position.—Correction Lines.—Particular comparisons of Measurements.—Convergence of range Lines.

Having had occasion to pass for many hundred miles along the surveyed lines of the public lands in Michigan, Wisconsin, Iowa, and Minnesota, and to observe the practical workings of the present system of surveys, I deem it not out of place to devote a chapter to their examination. The records of surveys in these States have frequently been submitted to my inspection by the surveyors-general in charge, and I have frequently met with the deputy surveyors engaged in their toilsome labors, in the depths of the forest, remote from civilization, carrying their instruments, camp equipage, and provisions on their backs, through places where neither horse nor canoe could penetrate, and have thus had occasion to admire their perseverance and fortitude. In these expeditions, they are frequently buried for a whole season in the forest—far from human settlements, sometimes short of provisions, and always destitute of what are called luxuries; their clothing, especially towards the close of the season, in shreds, and, to an observer from a civilized region, they present an aspect by no means attractive. I have seen them under circumstances which required great promptness and energy, and have generally observed that they possessed inflexible integrity in fulfilling their contracts, where there were many discouragements and many temptations to slight their work.

There are, however, a few cases where fictitious field-notes have been returned; but, when we consider the number of persons engaged in this service, and the slight supervision to which they are subjected, as well as the inadequacy of their compensation, particularly in regions where timber abounds, they may be regarded as among the most scrupulous and meritorious of public officers. Many of them possess mathematical attainments of a high order, great general intelligence, and a degree of fortitude and perseverance which should command respect.

Having traversed the field of their labors and inspected their notes, I propose to institute a comparison between their results and those obtained by astronomical observations.

I shall first, however, present, with little or no comment, a series of magnetic observations taken along certain meridians and base lines, or parallels of latitude, which intersect each other in squares of about sixty miles. They will be useful as illustrating the intensity of magnetic forces, and of practical utility to those who may be commissioned to make the subdivisions into sections. The annual change in variation can thus be fixed; and they will serve as a standard of reference hereafter. Those taken by Burt's Solar compass,* which includes most of those given since the year 1839, may be regarded as reliable.

The surveys of the public lands, west of the Alleghany Mountains, extend over an area greater than that of any other surveyed portion of the globe, and if all the data repecting the variations of the needle were collected, they would afford a mass of facts worthy of reliance and unequalled by any collection thus far made. The parallels, or lines of equal variation, in the United States, could then be laid down for the present period with great accuracy.

Those who study the reported variations for the State of Michigan would do well to bear in mind that the Upper peninsula, west of Chocolate river, is a region of great local disturbance; and that the surveys on the Lower peninsula, below the second correction line, were not made with the Solar compass, and that, therefore, the results must be taken with some grains of allowance.

The rectangular system of surveys, adopted for the first time by the United States in 1785, on the recommendation of Thomas Hutchings, is so simple that the position of any surveyed township or section is known, at once, by reading the letters and figures, cut upon the witness and bearing trees. Each township of six miles square has a number different from every other; and to follow the variations given below, from point to point, it is only necessary to take the *meridian* as a starting line, when reckoning east or west; and the *base* when reckoning north or south. Numbering the townships north or south from the base line, they are called Towns; numbering east or west from the meridian, they are called Ranges. Thus, T. 20 N., R. 10, E., indicates a township one hundred and twenty miles north of the base line and sixty miles east of the meridian.

The latitudes and longitudes are not intended, as here given, to be authority, unless the name of the observer is indicated; they are necessary, however, to a full understanding of the position of the compass, when the variations were noted; but are generally derived from maps, or astronomical observations. So, too, the length of most of the lines given has been derived from maps, unless the length be given in miles and chains, or used for the express purpose of deducing longitudes by measurement, in order to compare with the reported astronomical results. These distances should, therefore, be regarded only as near approximations, and not as strictly accurate.

* This ingenious instrument, invented by William A. Burt, of Mount Vernon, Michigan, about the year 1836, does not appear to have attracted the attention which it merits. It is well known that the magnetic needle is everywhere subject to many fluctuations, regular and irregular, and that it will not mark a straight line. In the rough regions of the north, where the igneous rocks themselves often contain magnetic oxide of iron, and where there are immense deposits of iron ore, often magnetic, a common compass is frequently entirely useless. Transcripts, which are given below, show variations of 30°, 45°, and even 175°, in the distance of half a mile. Without the Solar compass the region could not have been surveyed, except at a cost exceeding the value of the land.

To provide for the convergence of the meridional or range lines, the first row of townships north, on a base or correction line, is made more than six miles broad, east and west; this excess, generally amounting to about three chains, is not the same in all latitudes, and even in the same latitude is not made equal by all surveyors. The last row to the north, or next south of the correction line (sixty miles northward) will be less than six miles, by about the same quantity, only a few of the townships that are midway being exactly six miles in breadth.

With these prefatory remarks, we proceed to give the variations furnished by the Surveyor General at Detroit, for the State of Michigan.

VARIATIONS IN MICHIGAN.

Variations on the Meridian of Michigan.

Lon. 84° 19′ 9″ W. (nearly) counting south from Base Line.

1824 — 1825.

T. 1 S.	V. 4° 25′ E.	T. 5 S.	V. 4° 39′ E.
2	4° 25′	6	4° 35′
3	4° 25′	7	4° 35′
4	4° 40′	8	4° 35′

49 miles to Ohio State Line.

North of Base Line to First Correction Line, 1826 — 1831.

T. 1 N.	V. 4° 25′ E.	T. 6 N.	V. 4° 55′ E.
2	4° 25′	7	3° 50′
3	4° 25′	8	3° 05′
4	4° 25′	9	3° 05′
5	4° 25′	10	3° 05′

Principal Meridian between First and Second Correction Line, 1831–2, 120 miles north of Base line.

T. 11 N.	V. 3° E.	T. 16 N.	V. 3° E.
12	3°	17	2° 55′
13	3°	18	2° 55′
14	3°	19	2° 55′
15	3°	20	3° 10′

Principal Meridian from Second Correction Line to Lake Huron, 1837 — 1840

T. 21 N.	V. 2° 40′ E.	T. 30 N.	V. 2° 55′ E.
22	2° 55′	31	3° 10′
23	2° 55′	32	3° 05′
24	3° 00′	33	3° 15′
25	2° 55′	34	3° 10′
26	2° 45′	35	2° 55′
27	2° 50′	36	2° 30′
28	2° 55′	37	2° 00′
29	2° 55′	38	1° 45

Principal Meridian Solar Compass, 1840.

T. 41 N.	V. 1° 50′ E.	T. 45 N.	V. 2° 30′ E.
42	1° 40′	46	1° 40′
43	1° 50′	47	1° 20′
44	2° 35′		

To Lake Superior, 280 miles.

Base Line of Michigan — East of Meridian.

Lat. 42° 30′ N.

R. 1 E.	V. 4° 40′ E.	R. 9 E.	V. 4° 39′ E.
2	5° 30′	10	4° 40′
3	4° 40′	11	4° 40′
4	4° 40′	12	4° 40′
5	4° 40′	13	4° 30′
6	4° 30′	14	4° 39′
7	4° 30′	15	4° 39′
8	4° 30′		

To Detroit River.

Base Line of Michigan — West of Meridian.
1825—31.

R. 1 W.	V. 4° 25′ E.	R. 9 W.	V. 4° 40′ E.
2	4° 30′	10	6° 00′
3	4° 40′	11	6° 30′
4	4° 45′	12	5° 50′
5	4° 45′	13	5° 30′
6	4° 50′	14	5° 20
7	4° 55′	15	5° 10′
8	4° 40′	16	5° 25′
		17	5° 30′

To Lake Michigan.

First Correction Line — East of Meridian.
1822—39.

Latitude 43° 22′ N.

R 1 E.	V. 3° 10′ E.	R. 9 E.	V. 3° 40′ E.
2	3° 00′	10	3° 35′
3	3° 00′	11	3° 35′
4	3° 30′	12	3° 30′
5	3° 15′	13	3° 50′
6	3° 00′	14	2° 30′
7	3° 00′	15	2° 55′
8	4° 00′	16	2° 55′

To Lake Huron.

First Correction Line—West of Meridian.

1831—37.

R. 1 W.	V. 3° 00′ E.	R. 10 W.	V. 3° 25′ E.
2	3° 00′	11	3° 40′
3	3° 00′	12	3° 25′
4	3° 35′	13	3° 40′
5	3° 20′	14	3° 45′
6	3° 15′	15	3° 47′
7	3° 20′	16	3° 50′
8	3° 25′	17	5° 00′
9	3° 45′	18	3° 55′

To Lake Michigan.

Second Correction Line—East of Meridian.

Latitude 44° 14′ N.

1838 and 1846.

R. 1 E.	V. 2° 50′ E.	2° 40′ E.	R. 5 E.	V. 2° 15′ E.	2° 10′ E.
2	2° 45′	2° 30′	6	2° 10′	2° 05′
3	2° 35′	2° 30′	7	2° 00′	2° 05′
4	2° 25′	2° 10′			

To Lake Huron.

Second Correction Line—West of Meridian.

1837—1849.

R. 1 W	V. 3° 00′ E.	R. 10 W.	V. 3° 30′ E.	1838.
2	3° 00′		2° 56′	1839.
3	3° 00′	11	4° 00′	1838.
4	2° 55′		2° 41′	1849.
5	3° 20′	12	3° 30′	1837.
6	3° 30′		4° 10′	1848.
7	4° 00′	13	3° 30′	1839.
8	4° 00′		3° 15′	
9	4° 00′ 1838.	14	3° 15′	
	3° 41′ 1849.	15	3° 15′	
		16	3° 00′	
		17	3° 00′	

To Lake Michigan.

Third Correction Line—East of Meridian.

Lat. 45° 2′ N.

1840.

R. 1 E.	V. 2° 30′ E.	R. 5. E.	V. 2° 20′ E.
2	2° 50′	6	2° 05′
3	2° 50′	7	1° 35′
4	2° 25′	8	0° 45′

To Lake Huron.

Third Correction Line — West of Meridian.

1839 — 1840

R. 1 W.	V 3° 00′ E.	R. 6 W.	V. 3° 20′ E.
2	3° 05′	7	3° 25′
3	3° 10′	8	3° 15′
4	3° 15′	9	3° 30′
5	3° 25′		

To Lake Michigan.

Between Townships 41 and 42, north — East of Meridian.

Lat. 45° 58′ N.

1840.

R. 1 E.	V. 0° 40′ E.	R. 5 E.	V. 0° 10′ W.
2	0° 30′	6	0° 10′
3	0° 25′	7	0° 00′
4	0° 25′ W.	8	0° 20′

To St. Mary's River.

Between Townships 42 and 43, north — West of Meridian.

1840.

R. 1 W.	V. 2° 10′ E.	R. 5 W.	V. 3° 25′ E.
2	2° 35′	6	3* 40′
3	2° 50′	7	3° 45
4	2° 40′	8	3° 45′

Fourth Correction Line — West from Lake Michigan to boundary between Michigan and Wisconsin.

Lat. 45° 52′ N.

Solar Compass, 1845–46.

R. 16 W.	V. 3° 20′ E.	R. 24 W.	V. 2° 30′ E to 5° 05′ E.
17	4° 25′	25	2° E. to 24° W. and from 24° W. to 7° 40′ E.
18	4° 30′		
19	4° 20′	26	1° 30′ W. to 5° 30′ E.
20	4° 10′	27	Fluctuating.†
21	5° 30′	28	6° 00′ E. average.
22	5° 30′ to 24° 10′	29	5° 00′
23	24° 10′ to 5° 35′	30	6° 00′ average.

Length of line 90 miles.

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* Variation increasing and decreasing regularly.

† Variation very fluctuating. Sec. 36, V. 28° W. to 154° W. or S. 26° W., 175° W., 183 W. Sec. 35, V. 36° E., 28° 30′ E. Sec. 34, V. 16° E., 10° 45′ E. Sec. 33, 8° 45′ E. Sec. 32 and 31, V. 7° and 7° 40′ E.

Fifth Correction Line — Going west.

Lat. 46° 48' N.

1844.

R. 26 W.	V. 5° 17' E.	R. 36 W.	V. 6° 45' E.
27	5° 23'	37	6° 10'
28	5° 16'	38	6° 10'
29	5° 35'	39	6° 45'
30	5° 30'	40	6° 00'
31	6° 12'	41	4° 45'
32	6° 00'	42	7° 00'
33	6° 00'	43	8° 10'
34	5° 30'	44	9° 30'
35	5° 30'		

To Lake Superior—Distance 114 miles.

VARIATIONS ON MERIDIAN LINES.—UPPER PENINSULA OF MICHIGAN.

South from Fourth Correction Line between Ranges 26 and 27 W.

Solar Compass, 1847.

T. 40 N.	V. 8° 25' E. to 5° 30'	T. 36 N.	V. 5° 40' E.
39	14° 15' to 5° 45'	35	4° 55'
38	5° 30'	34	4° 30'
37	4° 15'	33	5° 00'

156 miles west of meridian.

From boundary line North to Fifth Correction Line, between Ranges 32 and 33 W.

T. 42 N.	V. 5° 10' E. to 8° 30'	T. 46 N.	V1° 35' E.*
43	6° 05' to 7° 40'	47	.6° 10'
44	15° 00' to 9° 40' W.	48	5° 00' to 8° 20'
45	4° 10'	49	5° 30' to 7° 35'
		50	5° 55' to 6° 10'

To Lake Superior or Keweenaw Bay.

From Fifth Correction Line north between Ranges 3 and 34 W.

1844.

T. 51 N.	V. 6° 00' E.	T. 54 N.	V. 5° 15' E.
52	5° 30'	55	4° 20'
53	4° 40'	56	3° 07'

To Lake Superior or Keweenaw Point.

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* Fluctuating to 6° 30' W.; not higher than 10° 30' E.

MAGNETIC VARIATIONS IN WISCONSIN.

(From the Surveyor's returns at the office of the Surveyor-General at Dubuque.)

Fourth principal Meridian, counting northward from the base line or northern boundary of Illinois.

Longitude of Meridian about 90° 32′ 13″ W.
Latitude of base line about 42° 30′ N.

T. 1 N.	V. 9° 25′ E. 1832.	
2	9° 5′	
3	9°	
4	8° 50′ to 9° 25′	
5	9° 15′	
6	8° 55′	
7	8° 50′	
8	8° 30′	
9	8° 42′	1839.
10	8° 40′	
First Correction line from Illinois line.		
11	9° 38′	
12	9° 40′	1839.
12	9° 10′	1845.
13	9° 40′	1839.
13	9° 11′	1845.
14	8° 59′	1839.
	8° 10′	1845.
15	8° 35′	1839.
	8°	1845.
16	8° 35′	1839.
	8° 15′	1847.
17	8° 35′	1839.
18	8° 36′	
19	8° 36′	
20	8° 36′	
21	8° 10′	1846.
Second Correction line.		
22	8° 00′	1846.

T. 23 N.	V. 8° 00′ E.	
24	8° 15′	
25	8° 15′	1847, S. C.
26	8° 15′	
27	8° 10′ to 8° 25′	
28	8° 10′ to 8° 15′	
29	8° 15′	
30	8° 00′	
31	7° 40′	
Third Correction line.		
32	7° 00′	
33	7° 08′	
35	6° 00′	[gularity.
36	6° 15′ to 10° 00′	local irre-
37	6° 15′ to 9° 10′	
38	6° 10′	
39	7° 16′	
40	6° 51′	[9° 30′
41	6° 34′ disturbance	6° to
Fourth Correction line.		
42	7° 37′ disturbed 50° E.	
43	6° 51′	
44	5° 57′	
45	11° E. to 45° W.	
46	6° to 12° 30′;	average,
47	7° 19′	[8° 44′

To Lake Superior, 14 chains 77 links west of the mouth of Montreal river; by measurement, 281 miles 67 chains north of the base line at the northern boundary of Illinois.

Longitude of the mouth of Montreal river, according to Captain Cram, U. S. Topographical Engineers, 1841, 90° 44′ 30″ west; according to Bayfield, 90° 35′ 10″. Latitude 46° 38′ north.

Base line of the Wisconsin Surveys, or north Line of Illinois.

Lat. 42° 30′ N.

1832–33.

Beginning at the west end, on the Mississippi, opposite Dubuque.

R. 2 W.	V. 9° 25′ E.
1	8° 40′
Fourth Meridian.	
R. 1 E.	V. 9° 40′ E.
2	9° 30′
3	8° 45′ to 9° 25′
4	6° 30′
5	8° 00′
6	8° 00′
7	7° 30′

R. 8 E.	V. 7° 00′ E.
9	6° 30′
10	6° 30′
11	6° 50′
12	6° 00′
13	5° 55′
14	5° 57′
15	7° 30′
16 to 19	6° 30′
20	6° 00′ 6° 40′
21 to 23	5° 30′

To western shore of Lake Michigan.

Variations on the Second Correction Line of Wisconsin, according to the numbering of the surveys; it being the first correction line north of the Illinois boundary.

Lat. 43° 27′ N.

(The mean of each range is given from an observation taken at intervals of a mile, or six observations to a range.)

Solar compass — 1840.

Township 11, north — counting from fourth principal meridian, west.

R. 1 W.	**V. 9° 38′ E.**	**R. 5 W.**	**V. 8° 38′ E.**
2	**8° 50′**	**6**	**8° 20′**
3	**8° 40′**	**7**	**7° 45**
4	**8° 29′**		

38 miles to Mississippi river.

From Meridian, east.

Solar Compass, 1840.

R. 1 E.	**V. 8° 21′**	**R. 14 E.**	**V. 7° 45′**
2	**8° 17′**	**15**	**8° 30′**
3	**7° 26′**	**16**	**7° 25′**
4	**7° 18′**		**7° 10′ 1838.**
5	**7° 38′**	**17**	**6° 45′**
6	**7° 26′**	**18**	**6° 55′**
7	**8° 19′**		**7° 05′ 1836.**
8	**8° 45′ 1831.**	**19**	**7° 45′**
9	**8° 45′**		**7° 10′ 1836.**
10	**7° 45′ 1833.**	**20**	**7° 00′ 1835.**
11	**7° 50′**	**21**	**6° 30′ 1833.**
12	**7° 10′**	**22**	**6° 30′**
13	**7° 50′**		

To Lake Michigan.

Third Correction line of Wisconsin.

Lat. 44° 14′ N. Solar Compass.

On Meridian four, counting *west;* average variation of each range of six miles.

R. 1 W.	**V. 8° 00′ E.**	**R. 7 W.**	**V. 8° 30′ E.**
2	**8° 15′**	**8**	**8° 35′**
3	**8° 00′**	**9**	**7° 50′ to 9° 45′**
4	**8° 30′**	**10**	**8° 47**
5	**8° 30′**	**11**	**8° 15′**
6	**8° 10′**	**12**	**8° 50′**

72 miles to the Mississippi river.

From the same Meridian east, on account of the Indian territory on this correction line, the surveys were carried around, and the correction line is not yet run. It begins in range 14 east, on the Wolf river. Variations principally taken in 1833.

R. 14 E.	**V. 6° 30′ E. 1839.**	**R. 19 E.**	**V. 6° 09′ E. 1833.**
	6° 35′ 1843.	**20**	**6° 30′ 1833.**
15	**6° 05′ 1839.**	**21**	**6° 00′**
	6° 35′ 1843.	**22**	**6° 15′**
16	**6° 30′ 1838.**	**23**	**5° 35′**
17	**6° 20′**	**24**	**6° 10′**
18	**6° 15′ 1843.**		

To Lake Michigan.

On a Meridian 66 miles east of the Fourth Principal Meridian, between ranges 11 and 12, east, principally in 1833, counting from the base, or Illinois line, northward.

T. 1 N.	V. 7° 00′ E.	T. 9 N.	V. 8° 35′ E.
2	7° 30′	10	7° 45′
3	8° 17′	11	7° 50′
4	8° 40′	12	7° 15′
5	9° 00′	13	7° 00′
6	9° 10′	14	8° 10′ 7° 30′ 1831.
7	8° 45′	15	8° 35′
8	7° 25′	16	7° 45′

96 miles.

On the Meridian between ranges 21 and 22, east of the Fourth Principal Meridian, being sixty miles east of the foregoing, or 126 miles east of the Meridian, and near the west shore of Lake Michigan, counting from the Illinois line northward. Principally 1835 and 1833.

T. 1 N.	V. 6° 50′ E.	T. 22 N.	V. 6° 15′
2	6° 00′	23	6° 20′ Green bay.
3	6° 10′	24	5° 45′
4	5° 30′	25	6° 35′ 1839.
5	5° 30′	26	6° 30′
6	6° 05′	27	6° 30′
7 to 10	7° 00′	28	6° 45′
		29	5° 42′
Second Correction Line.		30	5° 55′
11	6° 30′		
12	7° 00′ 1833.	Fourth Correction Line.	
13	7° 10′ 1833.		
14	7° 15′ 1833.	31	5° 45′
15	6° 05′	32	6° 00′ 5° 50′ 1840.
16	7° 15′	33	4° 00′
17	7° 00′	34	5° 00′
18	6° 50′	36	5° 30′
19	6° 35′		
20	5° 55′	Region of igneous and metamorphic rocks.	
Third Correction Line.		37	5° 38′
		38	4° 44′
21	6° 00′		

To the Menomonee river, at Sturgeon falls, 225 miles north of the base line.

Fourth Correction Line, Wisconsin; third counting from the Illinois Line.

Lat. 45° 3′ 13″ N.

Counting west from the Fourth Principal Meridian.

Solar Compass — July and August, 1847. Mean of each mile.

R. 1 W.	V. 7° 52′ E.	R. 13 W.	V. 9° 02′ E.
2	7° 45′	14	8° 17′
3	7° 47′	15	8° 59′
4	7° 46′	16	8° 47′
5	7° 48′	17	8° 45′
6	8° 00′	18	8° 09′
7	8° 20′	19	8° 30′ St. Croix R.
8	8° 19′	20	9° 33′
9	8° 20′	21	11° 08′
10	8° 10′	22	11° 20′
11	8° 27′	23	11° 05′
12	8° 21′	24	11° 51′

To the Mississippi river, 141 miles west of the Meridian.

Fifth Correction line; the fourth from the Illinois line.

Lat. 45° 55′ 23″ N.

Or Township 41, north, counting west from the Fourth Meridian.

Solar Compass — October, 1848.

Mean of six variations in each range, one each mile.

R. 1 W.	V. 6° 42′ E.	R. 17 W.	V. 9° 30′ E.
2	6° 58′	18	9° 52′
3	7° 21′	19	12° 22′
4	7° 03′	20	13° 24′
5	7° 29′	21	13° 19′
6	8° 03′	22	12° 31′
7	8° 20′	23	10° 47′
8	7° 45′	24	10° 57′
9	7° 13′	25	10° 36′
10	7° 40′	26	9° 29′ Rum river.
11	6° 53′*	27	10° 49′
12	6° 45′*	28	10° 38′
13	7° 00′*	29	10° 13′
14	8° 49′	30	9° 44′
15	8° 31′	31	10° 38′
16	9° 11′ St. Croix river.	32	10° 33′

One hundred and ninety miles west to the Mississippi river, about 12 miles below Fort Gaines. The high variations west of the St. Croix river, are in a region of igneous and trappean rocks.

Range Line between ranges 17 and 18 west, 102 miles west of the Fourth Meridian, beginning on the Mississippi river in Township 24, north.

Solar Compass — May, 1847.

Mean of six observations in each township.

T. 24 N.	V. 8° 40′ E.
25	8° 31′
26	8° 41′
27	8° 33′
28	8° 42′
29	8° 40′
30	8° 48′
31	9° 25′
32	8° 43′

Range line between 18 and 19 west.

T. 33 N.	V. 7° 04′ E.
34	7° 24′
35	8° 03′ very variable.
36	6° 47′ trappean rocks.
37	9° 32′ August, 1849.
38	10° 02′
39	10° 03′
40	10° 04′

To the Fifth Correction Line, or Fourth from the Illinois line.

This completes the abstract of my minutes on the variations in the surveyed portions of Wisconsin, to the close of the year 1850.

If the lines, along which these observations were taken, be traced upon the map, it will be found that the magnetic variations are here given in squares or rectangles of from sixty to one hundred miles across, and that they thus represent, pretty nearly, the variations over the whole region.

I intended to have added those for IOWA, MISSOURI, and ILLINOIS, and then to have discussed the subject of variations in the United States, but find it impracticable to present all the data at this time. As far as these

* These three ranges are very irregular, varying from 4° 40′ to 10° 28′.

tables extend, they may be considered as the best authority which can be given on the subject, for this region, and may prove of service to those engaged in investigating the subject of terrestrial magnetism.

REMARKS ON THE VARIATIONS IN MICHIGAN.

By reference to the variations on the east and west lines between T. 41 and 42 N., near Mackinac, it will be seen that the line of no variation, or zero, touches the State of Michigan in R. 7 E., on Drummond's island. Mr. Higgins, in the geological report of Michigan, for 1841, has laid down, from the precise observations of William A. Burt, the line of no variation from Lake Huron to Lake Superior, and given much additional original information, to which reference is here made. The line is very tortuous, but keeps near the St. Mary's river, crossing different belts of rock, igneous, metamorphic and sedimentary. In 1820–24, Captain Bayfield, of the British Admiralty survey, took the variation on Lake Superior, at various places, some of which were as follows:

Michipicoten island,	lat. 47° 40′ N.,	long. 85° 20′ W.,	6° 00′ E.
Granite island,	46° 40′	87° 30′	8° 00′
Keweenaw Point,	47° 30′	88° 30′	9° 00′
Apostle islands,	47° 00′	91° 00′	12° 00′
Pic island,	48° 40′	86° 40′	8° 00′

Mr. Frederick Hubbard, assistant on the Michigan survey, made some observations upon this subject in 1840. In July of that year, he found the variation to be, at La Pointe, 8° 33′ E., or 3° 27′ less than Bayfield—indicating a change to that amount in the course of a little more than a quarter of a century. The variations for Keweenaw Point, in the tables above given for 1844, range from 4° 20′ to 8° 07′ E.—being much affected by local attraction in consequence of the trap rocks containing a large per centage of magnetic oxide of iron. The same remark will apply to Isle Royale, where, in 1847, the variation was from 4° to 14° E.

Between July 13 and August 1, 1839, Mr. W. A. Burt made very careful observations on the diurnal variation of the needle, at Mount Vernon, Michigan. The results were as follows:

Average of twenty days, at	5 h. 30 min. A. M.,	1° 39′ 53″
" " "	1 h. 00 min. P. M.,	1° 28′ 45″
" " "	6 h. 30 min. P. M.,	1° 33′ 06″

The difference of these numbers gives the diurnal variation as follows:

Between morning and evening	5′.93
Between morning and noon	11′.08
Between noon and evening	5′.15

COMPARISON OF ASTRONOMICAL AND TERRESTRIAL MEASUREMENTS.

Having thus adverted to the principal phenomena of variation in this region, so far as the materials in our possession will enable us to do, we now propose to compare the terrestrial measurements of the linear surveyors in the north-west, with the results of astronomical observations. And here a brief discussion of the two modes for the determination of longitude may not be inappropriate. Although the measurements of the surveyors, passing, as their lines do, over swamps, rivers, precipices, and thickets, are liable to many minute errors, yet these errors, in the main, counteract one another. As the work is done by many persons, using different instruments, it is hardly possible that small errors should accumulate; and if they did, the subsequent work, always closing upon that which was done before, would detect mistakes, or bad measurements, and become apparent in the returns to the office. The correction, base, and meridian lines, since the introduction of the Solar compass, have been generally surveyed with much care, particularly the principal meridians; so that they may be regarded as following very nearly parallels of longitude. The distances measured by the chain, along the base, correction, and meridian lines, may also be regarded as nearly accurate, as much so as could be expected from a single measurement, where so many obstacles are necessarily encountered. The interior township and range lines are not required to be made with so much care, because the principal exterior lines serve to stop the errors, if any accrue. This is why, as will appear from an examination of the convergence of range lines, in the tables given below, the width of the upper tier of townships is less than six miles; but this irregularity may be amended on the next correction line, by making full townships. Thus, the convergence of range lines, for sixty miles below latitude 46° N., being seven chains, sixty links, if the lower tier of townships on the correction line, sixty miles south, were made six miles, three chains, and eighty links, the townships midway would be exactly six miles wide, and those on latitude 46° would fall short, three chains and eighty links. It will make the subject more intelligible to refer to the manner in which the public surveys have been conducted. A principal meridian and a base line are first run through large tracts, generally embracing a State or States. These meridians are numbered from east to west. The First principal meridian forms the division between Ohio and Indiana, on longitude 84° 51′ west from Greenwich.

The Second principal meridian divides the state of Indiana north and south, terminating at its northern boundary.

There is a "Michigan Meridian," not numbered, which commences at the north line of the state of Ohio, twenty-two miles east of the first meridian, and, running through the Lower peninsula, crosses the straits of Mackinac and terminates at Saut Ste Marie.

The Third principal meridian begins at the mouth of the Ohio river, running north to the northern boundary of Illinois, where it terminates.

The Fourth principal meridian commences at the mouth of the Illinois river, at Alton, latitude 38° 58′ 12″ N., longitude 90° 29′ 56″.7 W., and extends through the States of Illinois and Wisconsin, terminating on Lake Superior, at a point fourteen chains, seventy-seven links, S. 65° W. along the shore, from the mouth of the Montreal river — its length being three hundred and forty miles.

The Fifth principal meridian starts from the mouth of the Arkansas river, on the Mississippi, and has been extended north through Arkansas, Missouri, and Iowa, to near latitude 43° 30′, being about twenty-five miles to the west of the fourth meridian. When we consider that it repeatedly crosses the bends of the Mississippi and passes through the broad, swampy marshes of Arkansas; and, further, as it was surveyed with the needle and not with the Solar compass, it cannot be regarded as very correct. From the mouth of the Illinois, where it overlaps the fourth meridian, to Dubuque, in latitude 42° 30′, these two meridians maintain about the same distance from one another; whereas, if they pursued their respective longitudes, they should converge, in that distance, about three miles.

At right angles to all these meridians are east and west correction and base lines, once in sixty miles, or about 52′ of latitude. Such are the lines made use of in the following computations. I know of no portion of the earth's surface on which there are so many and so regularly measured lines as in the Mississippi valley. This opportunity of making a mutual reference to the terrestrial and celestial methods of fixing points upon our planet is unequalled, and the results of theory and science may thus be placed in contiguity with those of actual measurements. If the discrepancies should be great and general, we must infer that there is, in one or the other, some imperfection which should be remedied; but, if it appear to be the case, that the results harmonize remarkably well, the accuracy of both modes is theoretically and practically established. The tables of convergence in parallels of longitude, through all degrees of latitude, are based upon a nice calculation of the oblate spheroidal form of the earth. The correspondence of these tables with the measurements which I shall introduce, extending over large areas, is a gratifying instance of the truth of philosophy and mathematics, demonstrated by a process familiar to the most ordinary minds.

The Superintendent of the Coast Survey is engaged in determining the longitudes of different places in the United States, particularly by means of the electric telegraph; and from this source I have been furnished with the results for Cincinnati and St. Louis.

The longitude of Cincinnati is 84° 29′ 48″.8. In time, 5h. 8m. 12s.: (Washington) 00h. 29m. 47s.

Longitude of St. Louis, 90° 12′ 57″.7. In time, 5h. 8m. 12s.+52m. 40s.=6h. 00m. 52s.

The determination of the longitude of the Cathedral at St. Louis, by Nicollet, differed from this, 2′ 16″.3 of arc, being 90° 15′ 16″.

The measured distance, by the public surveys, between Cincinnati and St. Louis, reduced to the parallel of latitude for the former place, and that corrected for convergence, is 310.32 miles, which is equal to a difference in longitude of 5° 45′ 57″.6; and the distance above given, according to the best authority, deduced from observations made by the aid of the telegraph, is 5° 43′ 15″—a discrepancy of 2′ 42″.6 of arc.

The western boundary of Ohio was doubtless established with care and should follow the true meridian. If it does, we can deduce, from Cincinnati, the longitude of the south end of the meridian of Michigan, which is twenty-two miles east of the first, or Ohio meridian, and two and one-half miles east of Cincinnati; making it, in longitude, 84° 26′ 50″ W. If this meridian has been well carried up, the longitude of the Falls of the St. Mary is the same, for this meridian terminates there, being about three hundred and thirty miles long.*

The next corresponding meridian to the west, is the Fourth, or Wisconsin

* On comparing the longitude of the point where this meridian meets the Falls of the St. Mary's river, as laid down on Bayfield's Chart (84° 33′ 40″), with that obtained for its southern extremity, as given above, we find a discrepancy of 6′ 50″ of arc, which can hardly be due to the error of so distinguished an observer as Bayfield. F. & W.

meridian, which runs from the mouth of the Illinois river to Lake Superior, the longitude of whose southern extremity is very closely known by reference to St. Louis. The distance between these meridians, measured west, on a parallel of latitude from the foot of the Michigan meridian, across Indiana and Illinois, is 318.10 miles; the distance between the upper, or northern extremities of these meridians, on Lake Superior, is very nearly 292.64 miles; showing a convergence of the ground of 25.46 miles.

I give the latitude of the southern end of the Michigan meridian only approximatively at 41° 54′ N., and that of the upper end, at Saut Ste. Marie, at 46° 31′. The latitude of the north end of the Wisconsin meridian, as given by Captain Cram, is 46° 33′. The theoretical convergence, by the tables from the south to the north end of these meridians, is 24.75 miles—differing from the result above given only .71 mile.

In the longitude of the mouth of the Montreal, as deduced from the surveys of William A. Burt, there is a discrepancy, when compared with the reported longitude, which indicates an error somewhere. The surveys have not been carried across from the Fourth meridian to the Mississippi, at the mouth of the Crow-wing river, near Fort Gaines, where a discrepancy is found in the position of that place.

The measured distance from the Fourth meridian, along the Fifth correction line, to the meridian of Crow-wing, is one hundred and ninety miles and nine chains; which, corrected for convergence, and converted into degrees and minutes of arc, gives 3° 58′ 30″ as the difference of longitude west.

The reputed longitude of the Montreal river is 90° 44′ 30″, and of Crow-wing 94° 22′ 45″, making a difference of 3° 38′ 15″, or 20′ 13″ of arc less than the surveys, and equal to about 16.2 miles. It becomes necessary to form a conclusion, whether the error is due to terrestrial or celestial measurements. The longitude of the southern extremity of the Fourth meridian, at Alton, Illinois, is closely determined from St. Louis, and is put at 90° 29′ 56.7″, and the same meridian passes within fourteen chains west of the mouth of the Montreal river. If it is well run, the longitude of its mouth should differ only about 12″ of arc, while the difference is 14′ 43″ to the west. From the longitude deduced from the Michigan meridian it differs 11′ also to the west.*

Though undiscovered errors, in running these lines, may exist, or in measuring the correction lines, the question arises, whether so great a mistake could possibly occur, as is shown here, of 8.5 to 10.5 miles.

The work of determining longitude chronometrically, on land, is known to be very difficult and requires much time devoted to observations. This

* The longitude of the mouth of the Montreal river, according to Bayfield, is 90° 35′ 15″ and taking that of Crow-wing, as given above on the authority of Nicollet and Lieutenant Derby, at 94° 22′ 45″, we have a difference of 3° 47′ 30″. Comparing this with the difference of longitude, as deduced from the linear surveys by Mr. Whittlesey, we have a discrepancy of 11′, which is considerably less than that which results from assuming the longitude of the Montreal river, given by Captain Cram. In like manner, using Bayfield's longitude of the Montreal river, and comparing it with that of Alton, as given above, we have a difference of 5′ 7.7″ between the results of the astronomical measurement of the longitude of the two places, which should have the same longitude, if the meridian was correctly run by the linear surveyors. The discrepancies in each of these cases are very considerable, but indicate that the position of the Montreal river was more accurately determined by Bayfield than by Captain Cram. Probably at least a part of the error is due to the nature of the ground over which the northern portion of the meridian in question passes, and the difficulty which the surveyors found themselves obliged to contend with in executing this work.
F. & W.

may not have been practicable at the Montreal and Crow-wing rivers,* and, until the details of the observations are examined, it would be impossible to say what weight is to be given them. To throw the errors entirely on the surveyed lines, it is necessary to suppose that it commenced in the First principal meridian, in Ohio, and that the same departure from the true meridian accrued in the same direction, in Michigan, and in the Fourth meridian, and that it has not been observed by those who ran the township lines adjacent to them.

At the Crow-wing river the discrepancy is to the east; thus bringing this point and the mouth of the Montreal river too near together, by 20′ 30″, of which 11′ to 14′ is shown as probably due to the observations at the Montreal river. The first named point is reported to be in longitude 94° 22′ 45″ west, and, as deduced from measurements, is 94° 32′—a difference of 9′ 15″.

CONVERGENCE OF RANGE LINES.

We next propose to examine the convergence of range lines, from one correction line to another, as shown by the surveys in Michigan, Wisconsin and Iowa.

By Captain Lee's tables† of the length of a degree of longitude, in statute miles for different latitudes, between 39° and 47° north, we can compare the field results with those theoretically obtained.

North latitude.	Length of a degree of longitude in miles.	Convergence for a deg. of lat. in miles.	Convergence for a range or township of 6 miles.	
			Ch.	Lks.
41°	52.274	0.790	7	24
42	51.476	0.798	7	44
43	50.662	0.814	7	71
44	49.833	0.829	8	09
45	48.988	0.845	8	27
46	48.128	0.860	8	59
47	47.254	0.874	8	87

The distance in latitude from one correction to another of sixty miles, or ten townships, being less than a degree, or about 52′, the convergence for that distance is proportionably less.

On the Fourth correction line in Michigan, about latitude 45° 50′ N., the average convergence of range lines for twenty-nine townships west of the meridian, is, by field measurements, 6 chains 65.5 links; in theory, 7 chains 45 links; but this correction line having been taken across and around Lake Michigan, is hardly a fair example for comparison. The townships on the correction line below, as well as all those in the upper peninsula, are made, on the correction line, two chains under six miles, in order to throw part of the irregularity upon the lower or southern townships. This excess of two chains is not enough for that latitude to equalize the townships between correction lines, as will appear by results. On the fifth correction line, about latitude 46° 45′ N., the width of the tier of townships

* The observations at Crow-wing were taken, first by Nicollet, and afterwards by Lieut. Derby of the Topographical Corps, who differ only in seconds. Those of the Montreal river were by Captain Cram, also of the Topographical Corps.

† A Collection of Tables and Formulæ, by Capt. T. J. Lee, of the Topographical Eng'rs.

next below it, or the ranges numbered T. 50 N., is, for thirteen of the westerly townships, 5 miles, 74 chains, 74 links; and the width of the same ranges on the fourth correction line is 6 miles, 2 chains — making a difference of 7 chains 26 links upon the ground. For twenty-six ranges next west of the Michigan meridian, and next south of the fifth correction line, the actual average convergence is 7 chains 50 links per range and township. In theory, as deduced from the above tables, it is 7 chains 60 links.

For the surveys in Wisconsin, I will give some of the data in detail.

	Ch.	Lks.
R. 1 E., meridian IV, T. 10 n. correction line I, - -	8	73
15 - - - - - - - -	50	00
19 - - - - - - - -	83	49
21 - - - - - - 1 m.	22	09

Along the meridian line betwen ranges twenty-one and twenty-two east of the fourth meridian,

	M.	Ch.	Lks.
At correction I, or T. 10 n. - - - - -	1	2	2.09
" " II, " 20 n. - - -	1	60	70
" " III, " 30 n. - - -	2	66	09

Here, the convergence is quite irregular, and the average is too small for these latitudes, not exceeding five chains to a township — in sixty miles nothing; but it should be stated, that much of the work in eastern Wisconsin was done before the introduction of the Solar compass; and from the intervention of unceded Indian lands, the correction lines were necessarily carried around.

On the fourth correction line in Wisconsin, west of the meridian, the townships on the north and south of the line differ in their corner posts as follows, beginning at range 17 west, in latitude say 45° 55′ north:

	M.	Ch.	Lks.
R. 17 W., T. 41 N. 4th meridian - - - -	1	30	43
18 - - - - - - -	1	30	10
19 - - - - - - -	1	35	63
20 - - - - - - -	1	42	24
21 - - - - - - -	1	53	91
22 - - - - -	1	67	20
23 - - - - - - -	1	77	00
24 - - - - - - -	2	06	00
25 - - - - - - -	1	75	79
26 - - - - - - -	2	05	00
27 - - - - - -	1	77	90
28 - - - - - - -	2	10	05
29 - - - - - - -	2	29	42
30 - - - - - - -	2	43	65
31 To the Mississippi river, - - - -	2	42	04

As before stated and as here verified, there are in the amount of convergence, as shown from range to range, irregularities that result from the different degrees of accuracy attained by different surveyors. The lower part of this column shows imperfect work, and, therefore, will not give a good general average.

For thirty-one ranges, or 187 miles 13 chains, it is 202 chains, or 6 chains 51.5 links per range. Taking it on range twenty-four west, up to which there appears to be more uniformity, the average is 6 chains 91.5 links. The width of the upper row of townships, or township forty north, on their northern boundary, should be, therefore, 5 miles 76 chains 9 links; their width in township thirty-one north, being, as is the case in northern Wisconsin, 6 miles and 3 chains. The convergence which I deduce from the tables, between these correction lines, is for a township or range, 7 chains and 42½ links. In order, therefore, that they equalize the breadth of the lower tier of townships, they should be 6 miles 3 chains and 71 links.

Convergence on the first correction line of Iowa, west of meridian V, or township 79 north; latitude about 41° 36′ north.

Ranges West.	Difference of Meridians. M.	Ch.	Lks.	Difference from range line to range line. Ch.	Lks.
7	0	17	98		
8	0	24	90		
15	0	29	35		
20	0	62	10		
21	0	73	21	11	11
22	1	05	21	12	00
33	1	09	29	4	05
24	1	14	13	4	84
25	1	16	73	2	60
26	1	17	94	1	21
27	1	61	19	43	25*
28	1	64	34	3	15
29	1	73	32	8	98
30	2	01	00	7	68
31	2	03	35	2	35
187 m. 11 ch. westerly.	Av. of 31 R's; 5 ch. 27 l. In theory, 6 ch. 27.5 l.			Av. of 11 T's; 9 ch. 21 l.	

Second correction line in Iowa, latitude about 42° 30′ north, township 89, north of meridian V.

Ranges West.	Difference of range lines on the ground. M.	Ch.	Lks.	Difference from range to range of 6 m. 3 ch. wide. Ch.	Lks.
5	0	37	63		
6	0	27	53		
7	0	51	34		
10	0	60	15		
11	0	70	43		
12	0	76	58		
13	1	03	77		
14	0	72	22		
15	1	03	88		
16	1	02	51		

* Previous errors corrected here.

Ranges West.	Difference of range lines on the ground.			Difference from range to range of 6 m. 3 ch. wide.	
	M.	Ch.	Lks.	Ch.	Lks.
17	1	09	20		
18	1	10	84		
19	1	18	10	7	36
20	1	20	25	6	15
21	1	40	20	15	95
22	1	60	04	19	84
23	1	69	64	9	60
25	1	08	25	0	39
26	1	73	05	4	70
27	2	03	40	10	35
28	2	09	42	6	02
148 m. length of meridian.	Av. of each R. of 6 m. 3 ch. is 6 ch. 5 l. In theory, 6ch. $54\frac{1}{2}$ l.			Av. of 10 tsp.; 8 ch. 88 l.	

It thus appears, from a general average in the lower part of Iowa, that, where the ranges are made 6 miles and 3 chains on the correction lines, they do not vary materially from equalizing the convergence; so that the upper townships fall as much short of six miles in breadth as the lower ones exceed it; but further north, in Iowa and Minnesota, a greater breadth than 6 miles and 3 chains is necessary on the correction lines; and as the surveys proceed northward, the excess should be greater. The great inequalities in consequence of this, as shown by the difference from range to range, below the second correction, is probably owing to the use of the magnetic compass.

CHAPTER XXI.

BOTANY.

BY W. D. WHITNEY.

Remarks on the Flora of this Region.—Predominance of Northern Types.—Effect of the Lakes in equalizing the Temperature.—The Character of the Vegetation little influenced by the geological Formations.—List of Plants, with Remarks on some of the more important Trees and Shrubs.

The following list comprises all the plants noticed by members of the Corps, between the 1st of July and the 1st of October, 1849, in the territory included within the limits of the survey. The parts of the territory visited, and more or less carefully examined, were Mackinac, the Saut, the southern shore of the lake from the latter place to Carp river, the north-eastern extremity of Keweenaw point, the Ontonagon valley as far up as the metalliferous range, and Isle Royale. It was intended to make the search after species as thorough as circumstances would allow, but they were so often and so variously unfavorable, and the region explored bears so small a proportion to that left unvisited, that the list cannot be otherwise than very incomplete.

A few observations on the frequency, mode of occurrence, &c., are appended to the names of many of the species, especially of the forest trees and shrubs, and these perhaps include all that it is necessary to say on the subject of the like vegetation in general. The following remarks, however, may be added by way of introduction.

The whole face of the lake country is covered with a dense forest, unbroken, save by the clearings of the settlers and the few natural meadows and open marshes which are scattered here and there along the rivers, especially near their mouths. The constitution of this forest is such as is characteristic of so high a northern latitude. The peculiarities consist, not as much in the introduction of new and exclusively northern species—for there is hardly one of any importance that does not occur also on the highlands of the middle states—as in the increased frequency and predominance of certain northern types, and the total absence or great rarity of many which are the most familiar to the eye of the dweller farther south. Thus, all the trees that have esculent fruit, the oak, walnut, chestnut, beech, &c., are either quite wanting, or of very unfrequent occurrence; while the spruces, the fir, the cedar, the red pine, the birches, the aspen, poplar, &c., are the prevailing growth. With the lesser herbaceous species it is somewhat different, and a much larger proportion of them are solely northern. The general distribution of the more important species through the country is very uniform. This would, for a variety of reasons, be naturally expected. The region explored extends through no great reach of latitude, and the influence of the great body of water about which it lies, is, of course, like that of the ocean, equalizing. Even Isle Royale hardly exhibits any difference in the character of its vegetation from the southern shores of the lake. Nor, in that part of the region visited by us, were there highlands of sufficient elevation and extent to impress a peculiar character upon the growth covering them. The two highest and most extensive mountain ranges — those of the Porcupine and Huron mountains — were not ascended this year; upon them it is probable that some modification of the Flora might be noticed. Nor could it be seen that the geological formations, underlying the soil, exercised any modifying influence upon the forests above them. They are too limited in their extent, and too frequently interchanged to exert any such influence; and, moreover, comparatively little of the soil upon them is of local origin, resulting from their decomposition; but the northern drift occupies most of the surface. It is in the distribution of this drift, and the consequent clayey, or gravelly, or sandy nature of the soil, that the law of distribution of the native plants also is, in great measure, to be sought. But most of all is it the presence of a greater or less quantity of moisture, that determines with what growth a tract of country shall be clothed, and the most important variations are those dependent upon this cause.

LIST OF PLANTS.

RANUNCULACEÆ.

Clematis, *L.*
- virginiana, *L.* (Virgin's Bower.)

Anemone, *L.*
- nemorosa, *L.* (Wind-flower.)
- multifida, *DC.* Mackinaw.
- pennsylvanica, *L.* Very common and showy, in thick beds.

Hepatica, *Dill.*
- triloba, *Chaix.* (Liver-leaf.)

Thalictrum, *L.*
- cornuti, *L.* (Meadow Rue.)

Ranunculus, *L.*
- abortivus, *L.*
- recurvatus, *Poir.*
- fascicularis, *Muhl.*
- repens, *L.*
- acris, *L.* (Buttercups.)

Caltha, *L.*
- palustris, *L.* (Cowslips.)

Coptis, *Salisb.*
- trifolia, *Salisb.* (Goldthread.)

Aquilegia, *L.*
- canadensis, *L.* (Wild Columbine.) Abundant and beautiful.

Actæa, *L.*
- rubra, *Willd.* (Baneberry.)
- alba, *Big.* (Baneberry.)

NYMPHÆACEÆ.

Nymphæa, *Tourn*
  odorata, *Ait.* (Water Lily.)
Nuphar, *Smith.*
  advena, *Ait.* (Yelllow Pond Lily.) Common.

SARRACENIACEÆ.

Sarracenia, *L.*
  purpurea, *L.* (Pitcher-plant.) Abundant in the open marshes.

PAPAVERACEÆ.

Sanguinaria, *Dill.*
  canadensis, *L.* (Blood Root.) Mackinac.

FUMARIACEÆ.

Corydalis, *L.*
  aurea, *Willd.*
  glauca, *Pursh.* Both common.

CRUCIFERÆ.

Cardamine, *L.*
  hirsuta, *L.* (Bitter-cress.)
Dentaria, *L.*
  diphylla, *L.*
Arabis, *L.*
  lyrata, *L.*
  lævigata, *D. C.*
Capsella, *Vent.*
  bursa-pastoris, *Mœnch.* (Shepherd's Purse.)
Cakile, *Tourn.*
  americana, *Nutt.* (Sea Rocket.) Abundant on the sandy south shore.

VIOLACEÆ.

Viola, *L.*
  lanceolata, *L.* (Violet.)
  cucullata, *Ait.*
  canadensis, *L.* Still in flower at Mackinac in October.
  muhlenbergii, *Torr.*
  pubescens, *Ait.*

DROSERACEÆ.

Drosera, *L*
  rotundifolia, *L.* (Sun-dew.) Isle Royale.
Parnassia, *Tourn.*
  caroliniana, *Michx.* (Grass of Parnassus.) Pictured Rocks.

HYPERICACEÆ.

HYPERICUM, *L.*
pyramidatum, *Ait.* (Giant Hypericum.) Ontonagon river.
ellipticum, *Hook.*

CARYOPHYLLACEÆ.

STELLARIA, *L.*
media, *Smith.* (Chickweed.)
longifolia, *Muhl.*
CERASTIUM, *L.*
vulgatum, *L.* (Mouse-ear Chickweed.)
viscosum, *L.*
SAGINA, *L.*
nodosa, *L.* Isle Royale, rocky water's edge.

PORTULACACEÆ.

CLAYTONIA, *L.*
virginica, *L.* (Spring-beauty.) Mackinac.

TILIACEÆ.

TILIA, *L.*
americana, *L.* (Basswood, Linden, Lynn.) The latter is the name by which it is generally known to the surveyors and settlers. It is of frequent occurrence, particularly in the Ontonagon valley, and attains a large size, becoming a stately and handsome tree, and capable of affording pretty large timber. Its wood is valuable for its toughness and pliability, combined with softness and ease of working.

GERANIACEÆ.

GERANIUM, *L.*
carolinianum, *L.*
robertianum, *L.*

OXALIDACEÆ.

OXALIS, *L.*
acetosella, *L.* (Sorrel.) Ontonagon river.

BALSAMINACEÆ.

IMPATIENS, *L.*
fulva, *Nutt.* (Jewel-weed.) Carp river.

ANACARDIACEÆ.

RHUS, *L.*
typhina, *L.* (Stag-horn Sumach.)
glabra, *L.*
toxicodendron, *L.* (Ivy.) The sumachs are nowhere common.

ACERACEÆ.

ACER, *L.*

pennsylvanicum, *L.* (Striped Maple. Moose-wood.)
spicatum, *Lam.* (Mountain Maple.)
saccharinum, *Wang.* (Sugar Maple. Sugar.)
rubrum, *L.* (Red Maple. Maple.)
dasycarpum, *Ehrhart.* (White Maple.) Noticed, as was believed, on the bank of the Ontonagon. The first four maples are very generally distributed throughout the lake country, and may often be found within the space of a few square rods. Yet in some quarters the sugar maple is altogether wanting, and its place is supplied by an abundant growth of the red. It is thus at Mackinac, and in the vicinity of Copper Harbor. Of the four, the sugar maple, or "sugar," as it is commonly styled by the settlers, is by far the most useful and important. In the almost total absence of oaks and hickories, it is the sole dependence of the settlers for hard wood fuel, and for charcoal. As furnishing the latter article, and of the first quality, it is especially indispensable in the iron region; and, fortunately, it is nowhere found more abundantly, or of larger and finer growth. Considerable sugar is made from it, both by the Indians and whites; but the resources of the country in this line are far from being so fully developed as the great distance from the seaboard, and comparative infrequency of communication, render expedient. As furnishing ornamental woods to the cabinet-maker, also, the Lake Superior maples, both sugar and red, are of considerable economical value. It is a remarkable fact, that nearly every maple trunk in these forests affords one or other of those beautiful and highly-prized varieties of structure, known as "birds-eye" and "curled" maple. A saw-mill has recently been erected on the main shore, opposite Grand Island, for the purpose, mainly, of furnishing these ornamental woods for exportation below; and it would seem that the enterprise can hardly fail to prove a profitable one. The *A. spicatum*, which generally occurs only as a bush, here attains, in many instances, the dignity of an undersized tree. One specimen at Mackinac measured thirty feet in height, with a trunk seven inches in diameter; and several others were noticed at various points, hardly, if at all, inferior in size.

RHAMNACEÆ.

CEANOTHUS, *L.*

americanus, *L.* (Jersey Tea.)

POLYGALACEÆ.

POLYGALA, *Tourn.*

paucifolia, *Willd.* (Flowering Wintergreen.)

LEGUMINOSÆ.

VICIA, *Tourn.*

americana, *Muhl.*

Lathyrus, *L.*

maritimus, *Big.* (Beach Pea.) Common on sandy shores
ochroleucus, *Hook.* Keweenaw Point.

Trifolium, *L.*

pratense, *L.* (Red Clover.)
repens, *L.* (White Clover.

ROSACEÆ.

Cerasus, *Juss.*

pumila, *Michx.* (Sand Cherry.)
pennsylvanica, *Loisel.*
serotina, *D. C.* (Wild Cherry.) Of these three cherries, the two latter, the red and the black, are about equally frequent; the latter, in this high latitude, so reduced as not to exceed the other in size. The first, the Sand Cherry, abounds on the light sands of the southern shore—a mere bush, two or three feet high, heavily loaded in September with dark fruit, nearly as large and rich-looking as that of the garden cherry, but unfortunately, quite tasteless and insipid.

Spiræa, *L.*

opulifolia, *L.* (Nine-bark.)
salicifolia, *L.* (Meadow Sweet.) Carp river.

Agrimonia, *Tourn.*

eupatoria, *L.* (Agrimony.)

Geum, *L.*

vernum, *Torr & Gray.*
rivale, *L.* (Avens.)

Wal teinia, *Willd.*

fragaroides, *Tratt.*

Potentilla, *L.*

norvegica, *L.* Native and common.
arguta, *Pursh.* Isle Royale.
fruticosa, *L.* Common on bare, rocky shores.
tridentata, *Ait.* As the last, and yet more abundant.

Comarum, *L.*

palustre, *L.*

Fragaria, *Tourn.*

virginica, *Ehrh.* (Strawberry.)

Rubus, *L.*

nutkanus, *Mocino.*
triflorus, *Richards.*
strigosus, *Michx.* (Wild Raspberry.)
villosus, *Ait.* (Blackberry.)

Of these species of Rubus, the *R. nutkanus* is the commonest, occuring abundantly as underbrush, in the shade of almost every piece of woods on dry soil, and in July prettily ornamenting the surface with its showy white blossoms, which are nearly as large as those of the wild rose. Its fruit is ripened in the latter part of August, and has a peculiar acid flavor, which is, at first, quite pleasant and piquant. It is excellent for preserving. The common red raspberry is also exceedingly abundant, the blackberry comparatively quite rare.

Rosa, *Tourn.*
stricta, *L.* The common wild rose of the region.
carolina, *L.* Mackinac.
Cratægus, *L.*
coccinea, (Scarlet Thorn.)
tomentosa, *L.* (Black Thorn.)
Pyrus, *L.*
arbutifolia, *L.* (Choke Berry.) Saut Ste. Marie.
americana, *D. C.* (Mountain Ash.) The Mountain Ash was in full blossom on Isle Royale in August, and was a conspicuous object amid the forest growth of the island. The trees were all of small size and much scattered, which was also the case on the southern shore.
Amelanchier, *Med.*
canadensis, *Torr. & Gray.*

ONAGRACEÆ.

Epilobium, *L.*
angustifolium, *L.* (Fire Weed.) Very common.
coloratum, *Muhl.*
palustre, *L.*
Oenothera, *L.*
biennis, *L.* (Evening Primrose.)
chrysantha, *Michx.* Ontonagon Falls.
Circæa, *Tourn.*
lutetiana, *L.* (Enchanter's Nightshade.)
alpina, *L.* (Alpine Enchanter's Nightshade.)

GROSSULACEÆ.

Ribes, *L.*
cynosbati, *L.* (Common Wild Gooseberry.)
lacustre, *Poir.*
prostratum, *L'Her.*
floridum, *L.* (Wild Black Currant.)

SAXIFRAGACEÆ.

Saxifraga, *L.*
virginiensis, *Michx.*
aizoon, *Jacq.* Shores of Isle Royale.
tricuspidata. Scovill's Point, Isle Royale.
Mitella, *Tourn.*
diphylla, *L.* (Mitre-wort.)
nuda, *L.* Both abundant; the latter the more common.
Tiarella, *L.*
cordifolia, *L.*

UMBELLIFERÆ.

Sanicula, *Tourn.*
marilandica, *L.* (Sanicle.)

HERACLEUM, *L.*
lanatum, *Michx.* (Cow Parsnip.) Abundant everywhere, and monstrous.

ZIZIA, *Koch.*
integerrima, *DC.* (Alexanders.)

CICUTA, *L.*
maculata, *L.* (Cowbane.)
bulbifera, *L.*

SIUM, *L.*
lineare, *Michx.* (Water Parsnip.)

OSMORRHIZA, *Raf.*
brevistylis, *DC.* (Sweet Cicely.)

CONIUM, *L.*
maculatum, *L.* (Poison Hemlock.) Mackinac.

ARALIACEÆ.

ARALIA, *L.*
racemosa, *L.* (Spikenard.) On dry heights.
nudicaulis, *L.* (Wild Sarsaparilla.)
hispida, *Michx.*

PANAX, *L.*
quinquefolium, *L.* (Ginseng.) Ontonagon river.

CORNACEÆ.

CORNUS, *Tourn.*
circinata, *L'Her.*
canadensis, *L.*
stolonifera, *Michx.* From the inner bark of this species, which is abundant, the Indians prepare a "kinnekinik," for smoking.

CAPRIFOLIACEÆ.

LINNÆA, *Gronov.*
borealis, *Gronov.* (Twin-flower.) exceedingly abundant: tracts of dry, level forest are everywhere almost carpeted with it. Flowers large, generally brightly tinged with rose, and emitting a delightful fragrance. It was in blossom on the island of Mackinac late in June, and on the 27th of September it was still found blooming at Grand Marais.

LONICERA, *L.*
parviflora, *Lam.* (Wild Honeysuckle.)
ciliata, *Muhl.* (Twin Honeysuckle.)
oblongifolia, *Muhl.*

DIERVILLA, *Tourn.*
trifida, *Mœnch.* Abundant.

SAMBUCUS, *L.*
pubens, *Michx.* (Red-berried Elder.)

VIBURNUM, *L.*
nudum, *L.*
opulus, *L.* (Bush Cranberry.)
lantanoides, *Michx.* (Hobble-bush.) None of the species abundant in the region visited.

RUBIACEÆ.

Galium, *L.*
aparine, *L.*
asprellum, *Michx.*
triflorum, *Michx.*
lanceolatum, *Torr.*
boreale, *L.*

Mitchella, *L.*
repens, *L.* (Partridge Berry.)

COMPOSITÆ.

Eupatorium, *Tourn.*
purpureum, *L.* (Joe-Pye-weed.)
ageratoides, *L.*

Tussilago, *Tourn.*
farfara, *L.* (Colt's-foot.) Saut Ste. Marie.

Adenocaulon, *Hook.*
bicolor, *Hook.* Common in moist situations up the Ontonagon river.

Aster, *L.*
macrophyllus, *L.* Abundant.
puniceus, *L.*
longifolius, *Lam.* South shore.
acuminatus, *Michx.*
ptarmicoides, *Torr. and Gray.* Isle Royale.

Solidago, *L.*
bicolor, *L.* var. concolor. South shore, commonest species.
humilis, *Pursh.*
arguta, *Ait.*
lanceolata, *L.* Goldenrods and asters are nowhere common in the lake region.

Erigeron, *L.*
canadense, *L.* Eagle river.
philadelphicum, *L.*

Rudbeckia, *L.*
laciniata, *L.* Carp river.

Bidens, *L.*
cernua, *L.* (Beggarticks.)
chrysanthemoides, *Michx.*

Achillea, *L.*
millefolia, *L.*

Leucanthemum, *Tourn.*
vulgare, *L.* (Ox-eye Daisy.)

Tanacetum, *L.*
huronense, *Nutt.* Grand Marais.

Antennaria, *Gært.*
plantaginifolia, *Hook.* (Everlasting.)

Artemisia, *L.*
canadensis, *Michx.*

Gnaphalium, *L.*
decurrens, *Ives.*
polycephalum, *Michx.*

SENECIO, *L.*
aureus, *L.*
ARNICA, *L.*
mollis, *Hook.* Copper Harbor
CIRSIUM, *Tourn.*
lanceolatum, *Scop.* (Common Thistle.)
pitcheri, *Torr. and Gray.* Grand Sable.
LAPPA, *Tourn.*
major, *Gært.* (Burdock.)
HIERACIUM, *Tourn.*
canadense, *Michx.*
scabrum, *Michx.*
NABALUS, *Cass.*
albus, *Hook.*
TARAXACUM, *Haller.*
dens-leonis. *Desf.*

LOBELIACEÆ.

LOBELIA, *L.*
kalmii, *L.* Abundant on the bare trap shores of Isle Royale.

CAMPANULACEÆ.

CAMPANULA, *Tourn*
rotundifolia, *L.* (Harebell.) Very common.
rotundifolia, var. linifolia. Isle Royale.
aparinoides, *Pursh.*

ERICACEÆ.

GAYLUSSACIA, *H. B. and K.*
resinosa, *Torr. and Gray.* (Huckleberry.)
VACCINIUM, *L.*
oxycoccum, *L.* (Cranberry.)
macrocarpum, *Ait.* (Cranberry.)
canadense, *Kalm.* (Blueberry.)
vacillans, *Sol.* (Blueberry.)
corymbosum, *L.* The huckleberries and blueberries especially abound along the south shore of the lake, on the sandy soil, under the shade of the red pines. Their fruit is much larger and sweeter, and borne in greater profusion than we had ever seen it elsewhere. It is greedily eaten by pigeons, robins, golden-winged woodpeckers, &c., as well as by chance travellers along the shore.
ARCTOSTAPHYLUS, *Adans.*
uva-ursi, *Spreng.* (Bear-berry.) Very common, sharing with the Linnæa the office of carpeting the forest. Its leaves are dried by the Indians and mixed with their tobacco for smoking. They call it "kinnekinik."
GAULTHERIA, *Kalm.*
procumbens, *L.* (Wintergreen.)
EPIGÆA, *L.*
repens, *L.* (Trailing arbutus. May-flower.)

ANDROMEDA, *L.*
polifolia, *L.*
calyculata, *L.*
LEDUM, *L.*
latifolium, *Ait.* (Labrador Tea.) Abounding in the swamps of Isle Royale.
PYROLA, *L.*
rotundifolia, *L.*
asarifolia, *Michx.* (Shin-leaf.)
elliptica, *Nutt.*
chlorantha, *Swartz.*
secunda, *L.*
MONESES, *Salisb.*
uniflora, *L.*
CHIMAPHILA, *Pursh.*
umbellata, *Nutt.* (Prince's Pine.)
PTEROSPORA, *Nutt.*
andromedea, *Nutt.* Carp river.
HYPOPITYS, *Dill.*
lanuginosa, *Nutt.* Ontonagon river.
MONOTROPA, *Gronov.*
uniflora, *L.* (Indian-pipe.)

PRIMULACEÆ.

PRIMULA, *L.*
farinosa, *L.*
mistassinica, *Michx.*
TRIENTALIS, *L.*
americana, *Pursh.*
LYSIMACHIA, *L.*
ciliata, *L.* (Loose-strife.)
NAUMBURGIA, *Mœnch.*
thyrsiflora, *Reicheub.*

LENTIBULACEÆ.

UTRICULARIA, *L.*
vulgaris, *L.*
intermedia, *Hayne.* Copper Harbor.
PINGUICULA, *Tourn.*
vulgaris, *L.*

OROBANCHACEÆ.

APHYLLON, *Mitchell.*
uniflorum, *Torr. & Gr.*

SCROPHULARIACEÆ.

CHELONE, *Tourn.*
glabra, *L.*
MIMULUS, *L.*
ringens, *L.* (Monkey-flower.)

VERONICA, *L.*
americana, *Schw.* (Speed-well.)
GERARDIA, *L.*
purpurea, *L.* Mackinac.
CASTILLEJA, *Mutis.*
coccinea, *Spreng.* Mackinac.
septentrionalis, *Lindl.* Common.
EUPHRASIA, *Tourn.*
officinalis, *L.* Isle Royale.
PEDICULARIS, *Tourn.*
canadensis, *L.* (Louse-wort.)
MELAMPYRUM, *Tourn.*
pratense, *L.* (Cow-wheat.) Abundant everywhere.

VERBENACEÆ.

VERBENA, *L.*
hastata, *L.* (Vervain.
urticifolia, *L.* (Vervain.)

LABIATÆ.

MENTHA, *L.*
canadensis, *L.* (Wild mint.)
LYCOPUS, *L.*
virginicus, *L.*
sinuatus, *Ell.*
CLINOPODIUM, *L.*
vulgare, *L.*
PRUNELLA, *L.*
vulgaris, *L.* (Heal-all.) Common.
SCUTELLARIA, *L.*
galericulata, *L.* (Scull-cap.)
lateriflora, *L.*
STACHYS, *L.*
aspera, *Michx.* (Hedge-nettle.)

BORAGINACEÆ.

MERTENSIA, *Roth.*
pilosa. Elm river.
LITHOSPERMUM, *Tourn.*
officinale, *L.* (Hound's-tongue.)
virginicum, *L.*

SOLANACEÆ.

PHYSALIS, *L.*
viscosa, *L.*

GENTIANACEÆ

GENTIANA, *L.*
quinqueflora, *Lam.*
detonsa, *Fries.* Mackinac.
frœlichii, *Torr. & Gr.*
alba, *Muhl.*
HALENIA, *Borkh.*
deflexa, *Griseb.*
MENYANTHES, *Tourn.*
trifoliata, *L.*

APOCYNACEÆ.

APOCYNUM, *Tourn.*
androsæmifolium, *L.*
cannabinum, *L.* (Indian Hemp.)

ASCLEPIADACEÆ.

ASCLEPIAS, *L.*
incarnata, *L.* Ontonagon.

OLEACEÆ.

FRAXINUS, *Tourn.*
americana, *L.* (White Ash.)
sambucifolia, *Lam.* (Black Ash.) Of these two ashes the latter is by far the most common, being very generally met with on low lands. It is much less valuable than the other species. It was only in the Ontonagon valley that we met with the white ash, and even there we saw of it only a few trees; which were, however, very tall, shapely and handsome.

ARISTOLOCHIACEÆ.

ASARUM, *Tourn.*
canadense, *L.* (Wild Ginger.)

CHENOPODIACEÆ.

CHENOPODIUM, *L.*
hybridum, *L.* Mackinac.

POLYGONACEÆ.

POLYGONUM, *L.*
viviparum, *L.* Isle Royale; common.
amphibium, *L.* Teal Lake.
aviculare, *L.*
articulatum, *L.* Common on the sand-beaches of the south shore.
cilinode, *Michx.* Frequent.

RUMEX, *L.*
crispus, *L.* (Dock.)
acetosella, *L.* (Sorrel.)

THYMELACEÆ.

DIRCA, *L.*
palustris, *L.*

ELEAGNACEÆ.

SHEPHERDIA, *Nutt.*
canadensis, *Nutt.* A common short shrub, on dry shores.

SANTALACEÆ.

COMANDRA, *Nutt.*
umbellata, *Nutt.*
livida. Isle Royale; common.

ULMACEÆ

ULMUS, *L.*
americana, *L.* (Elm.)
fulva, *Michx.* (Slippery Elm.). The elm is especially abundant and flourishing in the Ontonagon valley.

EMPETRACEÆ.

EMPETRUM, *Tourn.*
nigrum, *L.* (Crowberry.)

CUPULIFERÆ.

QUERCUS, *L.*
rubra, *L.* (Black Oak.) The great family of oaks is represented in the vicinity of the lake by this single species only; and even this is of rather rare occurrence, and attains no great size, appearing generally as a high bush, or a low scraggy tree. It was only in the Ontonagon valley that we found it rising to anything like the proper height and majestic appearance of the oak. It is of little or no value as timber.

FAGUS, *Tourn.*
ferruginea, *Ait.* (Beech.) The beech forms a considerable share of the growth on the island of Mackinac, but from thence northward and westward, we saw no more of it, excepting at one point. This was at the Pictured Rocks, on a tract stretching back from the edge of those precipices, the soil of which was a fine light drift-sand. It was thriving admirably then, much excelling in size and appearance the rather dwarfish growth at Mackinac.

Corylus, *Tourn.*

rostrata, *Ait.* (Beaked Hazel.)

americana, *Walt.* (Hazel.) The hazels are very common as underbrush, in almost every dry forest. No appearance of fruit was at any time noticed upon them; and indeed, by the absence of some species, and the rarity or sterility of others, the lake region seems almost entirely deprived of nuts of native growth. With the nuts, of course, are also found wanting the squirrels, except the red and ground squirrels.

Ostrya, *Micheli.*

virginica, (*Willd.*) (Hop Hornbeam.) On the trap ridges, the hop hornbeam, or iron-wood, as it is generally called, is not unfrequently found sparingly scattered through the forest. Its exceeding hardness and toughness render it valuable where strength, and no great size of material, is required.

MYRICACEÆ.

Myrica, *L.*

gale, *L.* (Sweet Gale.)

BETULACEÆ.

Betula, *Tourn.*

lenta, *L.* (Black Birch.)

excelsa, *Ait.* (Yellow Birch.)

papyracea, *Ait.* (White Birch.) One or two of the dwarf Alpine species undoubtedly also occur on the ridges, but they were not noticed. The last of the three mentioned—the canoe, or paper, or white birch—is the most abundant, occurring almost everywhere, interspersed among the other species of the deciduous forests. It is valuable for the almost infinite variety of uses to which its bark can be turned—from the manufacture of canoes down to the preparation of little specimen boxes and water cups, and the kindling of camp fires. It arrives at considerable size in the lake forests; but we nowhere meet with trees capable of furnishing bark in sheets large enough for the uses of the canoe builder. For fuel it is much inferior to the black birch, which ranks second only to the sugar maple. The black birch is also plentiful, although more nice in the selection of its soil than the other; it is rather confined to high or rocky ground. It attains a most majestic size. Its wood is valuable, not only for burning, but also for the various uses of the cabinet maker.

Alnus, *Tourn.*

incana, *Willd.*

viridis, *D. C.* Both these alders are abundant in the lake country, but they occur in quite different situations. The former prefers a wet soil, and forms here and there compact and tangled "alder swamps" on flooded land; or, especially and frequently, long strips of almost impenetrable thicket, a few rods in width on either side the river that cuts and pretends to drain an extensive cedar-swamp. The other is generally scattered along the shore, on dry and rocky lands.

SALICACEÆ.

Populus, *Tourn.*

tremuloides, *Michx.* (Aspen.)

grandidentata, *Michx.* (Great Poplar.)

balsamifera, *L.* Of these three poplars the first is so much the most abundant, that the others are hardly worth mentioning; and indeed the latter are quite rare, and only individual specimens were found by us occurring here and there. The former, on the contrary, is one of the commonest species about the lake. It is the tree that seems to spring up most readily and abundantly, where the ancient forest has been prostrated by fire or tempest, although nowhere excluding all intermixture of other species, as the birches, maples, and lesser evergreens. It is of little or no economical value, and indeed seldom attains a size sufficient to furnish any considerable timber. Yet it excels the southern growth of the same species; and on the northern ridge of Isle Royale there are trees of it which tower conspicuously above the mass of the forest about them. The willows which, as at the East, are found more or less abundantly everywhere in moist grounds, it was not found convenient to analyze and identify.

URTICACEÆ.

Urtica, *Tourn.*

canadensis, *L.* (Nettle.) Ontonagon river.

CONIFERÆ.

Pinus, *Tourn.*

banksiana, *Lamb.*

resinosa, *Ait.* (Red or Norway Pine.)

strobus, *L.* (White Pine.) The white pine is to be found in all parts of the lake country; yet nowhere did we find it growing in great abundance, nowhere forming what could properly be called a fine forest. It rather appears in single trees, standing amid the mass of deciduous forest, and far overtopping it, or in little clumps of a dozen or two, on the crest of a ridge. In many quarters, as for example, in the vicinity of Copper Harbor, the white pines have all fallen with the ancient forest, struck down by fire or by tornado, and only their huge trunks are left decaying on the earth, under the shade of the young growth that has sprung up to cover the surface anew. It is not at all stunted in its growth by the severity of the northern climate, but attains a diameter and height nearly as great as in its most noted localities. It is unfortunate for the interests of the Territory that so little of its soil is heavily timbered with this pine; yet its deficiency is in some measure made up by the abundance and excellence of the red or Norway pine, which, though by no means as valuable, yet forms a tolerable substitute for the other, when that cannot be provided in abundance. The red pine occurs not only scattered through the mixed forests, but occupying alone tracts of considerable extent, and on low sandy plains generally forming "pine plains," in which the trees stand, orchard-like, singly, not far enough apart to prevent their boughs from interlacing at the top, yet leaving free communication among their trunks at the base; the ground under them being quite bare of underbrush, and at most only covered with the low trailing bushes of the whortleberries. The trees on these plains are from seventy to a hundred feet high, with straight, shapely trunks, which are free of branches nearly to the summit, and of size sufficient to furnish very good timber.

The other species, Banks's pine, is a rough and scrubby little tree, of no economical value, growing stragglingly on the roughest and barrenest coasts, or more rarely attempting to shoot up after a comelier fashion, on better soil and in good company.

ABIES, *Tourn.*

balsamea, *Marsh.* (Balsam Fir.)
canadensis, *Michx.* (Hemlock.)
alba, *Michx.* (White Spruce.)
nigra, *Poir.* (Black Spruce.) The balsam fir is everywhere disseminated, forming a greater or less share of nearly every forest, so that it is rarely that the traveller or even explorer pitches his tent at night in a neighborhood where its branches are not to be procured to serve as his mattress. The balsams are conspicuous objects in the forest landscape, their slender-pointed tops being distinctly defined by their darker shade of green amid the brighter foliage about them. The hemlock and spruces are likewise frequent, the former choosing the ridges and rocky soil, the latter associated in the swamps with the cedar, or more rarely forming "spruce plains" in moist and level grounds, to the exclusion of other species. Of the trio, the white is much the more common.

LARIX, *Tourn.*

americana, *Michx.* (Larch, Hacmetack, Tamarack.) The larch is another tree often found in the swamps with the cedar, nowhere, as far as we noticed, attaining a very considerable size.

THUJA, *Tourn.*

occidentalis, *L.* (Arbor Vitæ. White Cedar.) The white cedar, or cedar, as it is generally styled, is perhaps the most abundant and widely and universally diffused of all the trees of the district. It grows in every situation; on the rough summits of the trap ridges, along the hill sides, on the plains, by the shores, but most especially in the extensive "cedar swamps" which cover so considerable a portion of the face of the country, filling the low grounds everywhere. Wherever there is a tract of plain land of so little inclination as not to be readily and thoroughly drained, there is a cedar-swamp. Nothing is more characteristic of the country, and nothing more troublesome and vexatious to those who journey about it, for the disagreeableness and difficulty of making one's way through such a swamp are extreme. The tangled, crowded mass of cedars, interlacing from the very bottom with their dead, stiff, incorruptible lower limbs, rises up out of a bed of mud and water, varying, according to the situation and the season, between ankle-deep and waist-deep, filled with fallen logs and rugged roots, that furnish a deceitful semblance of secure foot. The cedar of the swamps is a low, scraggy, ugly tree; in more favorable situations it sometimes attains the height of eighty feet or more, with a diameter at the base of two or three feet. Its wood and bark hold the very first rank for durability; yet so rough, irregular, and rapidly tapering are its trunks generally, that it is very difficult to procure from them any valuable timber. Its bark, peeled off in squares, is made much use of for thatching the whole outer surface of cabins.

Juniperus, *L.*
communis, *L.* (Juniper.)
virginiana, *L.* var. humilis. (Red Cedar.) The latter of the two junipers is found in the vicinity of the lakes only, as a low, prostrate, creeping shrub; a variety characteristic of this tree in high latitudes.

Taxus, *Tourn.*
canadensis, *Willd.* (Yew. Ground Hemlock.) The yew is very common, bedding the surface under the shade of the higher forest. It much impedes the progress of the traveller, and is of no value in any way.

ARACEÆ.

Arum, *L.*
triphyllum, *L.* (Jack-in-the-Pulpit.)

Calla, *L.*
palustris, *L.* Not common.

Symplocarpus, *Salisb.*
fœtidus, *Salisb.* (Skunk Cabbage.)

TYPHACEÆ.

Typha, *Tourn.*
latifolia, *L.* (Cat-tail.)

Sparganium, *Tourn.*
natans, *L.* Isle Royale.

ORCHIDACEÆ.

Corallorhiza, *Haller.*
multiflora, *Nutt.*
innata, *R. Brown.* Not rare.
macræi, *Gray.* Abundant at Mackinac, and said by the surveyors to be met with also up the lake.

Calypso, *Salisb.*
borealis, *Salisb.* Mackinac.

Gymnadenia, *R. Brown.*
tridentata, *Lindl.*

Platanthera, *Richards.*
obtusata, *Lindl.* Very common
orbiculata, *Lindl.* Not rare.
hookeri, *Lindl.*
bracteata, *Torr.*

hyperborea, *Lindl.*
dilatata, *Lindl.*
psycodes, *Gray.*
Arethusa, *Gronov.*
bulbosa, *L.*
Pogonia, *Juss.*
ophioglossoides, *Nutt.*
Calopogon, *R. Brown.*
pulchellum, *R. Brown.*
Spiranthes, *Richards.*
cernua, *Richards.*
Goodyera, *R. Brown.*
repens, *R. Brown.*
pubescens, *R. Brown.* (Rattlesnake-leaf.)
Listera, *R. Brown.*
cordata, *R. Brown.*
convallarioides, *Hook.* Not common.
Cypripedium, *L.*
parviflorum, *Salisb.* (Yellow Lady's Slipper.)
acaule, *Ait.* (Lady's Slipper.)

IRIDACEÆ.

Iris, *L.*
versicolor, *L.* (Wild Flower-de-Luce.)
lacustris, *Nutt.* Mackinac.
Sisyrinchium, *L.*
bermudianum, *L.* (Blue-eyed Grass.)

SMILACEÆ.

Smilax, *Tourn.*
herbacea, *L.*
Trillium, *L.*
grandiflorum, *Salisb.*

LILIACEÆ.

Polygonatum, *Tourn.*
pubescens, *Pursh.*
Smilacina, *Desf.*
racemosa, *Desf.*
stellata, *Desf.*
trifolia, *Desf.*
bifolia, *Ker.*
Clintonia, *Raf.*
borealis, *Raf.* Very abundant in cold woods, growing with sphagnous moss, and almost covering the surface.
Allium, *L.*
tricoccum, *Ait.* (Wild Onion.)
Lilium, *L.*
philadelphicum, *L*
canadense, *L.*

Erythronium, *L.*
americanum, *Smith.* (Adder-tongue.)

MELANTHACEÆ.

Streptopus, *Michx.*
amplexifolius, *DC.* Rare.
roseus, *Michx.* Very common.
Tofieldia, *Hudson.*
glutinosa, *Willd.*
palustris. Isle Royale.

CYPERACEÆ.

Dulichium, *Richards.*
spathaceum, *Pers.*
Eriophorum, *L.*
alpinum, *L.*
virginicum, *L.*
gracile, *Koch.*
Carex, *L.*
polytrichoides, *Muhl.*
backii, *Boott.* Ontonagon river.
stipata, *Muhl.*
trisperma, *Dew.*
tenuiflora, *Wahl.*
canescens, *L.*
deweyana, *Schw.*
scoparia, *Schk.*
stricta, *Lam.*
crinita, *Lam.*
irrigua, *Smith.*
buxbaumii, *Wahl.*
aurea, *Nutt.*
granularis, *Muhl.*
grisea, *Wahl.*
gracillima, *Schw.*
varia, *Muhl.*
scabrata, *Schw.*
flexilis, *Rudge.*
flava, *L.*
intumescens, *Rudge.*
retrorsa, *Schwein.*
vahlii. Isle Royale.

GRAMINEÆ

Alopecurus, *L.*
pratensis, *L.*
Phleum, *L.*
alpinum, *L.*

Agrostis, *L.*
scabra, *Willd.*
alba, *L.*
Cinna, *L.*
pendula, *Trin.*
Brachelytrum, *Beauv.*
aristatum, *Beauv.*
Calamagrostis, *Adans.*
arenaria, *Trin.* A sea-side species, common on the southern beaches.
canadensis, *Beauv.* (Blue Joint.) The C. canadensis is a very valuable grass to the lake settlers, rarely of many acres in extent. A luxuriant growth covers the meadows occurring here and there along the rivers, which are carefully sought out and appropriated by the dwellers in the vicinity. They are mowed in August, and the grass dried and stacked upon the spot. Then, in winter, when the deep snow has completely covered up the under-brush in the forests, and made them everywhere passible, the hay is dragged home by sled or dog-train. It is said to be greedily eaten by the cattle, and to be as nourishing as herds-grass. It grows shoulder-high, so that even a small meadow furnishes a great store of hay.
Oryzopsis, *Michx.*
asperifolia, *Michx.*
Glyceria, *R. Brown.*
nervata, *Trin.*
aquatica, *Smith.*
fluitans, *R. Brown.*
Poa, *L.*
annua, *L.* Mackinac.
serotina, *Ehrh.*
pratensis, *L.*
compressa, *L.*
Bromus, *L.*
ciliatus, *L.*
secalinus, *L.* (Chess.) Native?
Triticum, *L.*
repens, *L.*
Elymus, *L.*
virginicus, *L.*
canadensis, *L.*
var. glaucifolius.
striatus, *Willd.*
hystrix, *L.*
Aira, *L.*
cæspitosa, *L.*
Trisetum, *Kunth.*
molle, *Kunth.*
Danthonia, *D. C.*
spicata, *Beauv.*
Phalaris, *L.*
arundinacea, *L.*
Milium, *L.*
effusum, *L.*

PANICUM, *L.*
dichotomum, *L.*
depauperatum, *Muhl.*

EQUISETACEÆ.

EQUISETUM, *L.*
arvense, *L.*
sylvaticum, *L.*
hyemale, *L.*
scirpoides, *Michx.*

FILICES.

POLYPODIUM, *L.*
vulgare, *L.*
phegopteris, *L.*
dryopteris, *L.* All abundant, especially the last.
STRUTHIOPTERIS, *Willd.*
germanica, *Willd.*
ALLOSORUS, *Presl.*
acrostichoides. Middle Finger, Isle Royale
PTERIS, *L.*
aquilina, *L.* Everywhere.
ADIANTUM, *L.*
pedatum, *L.* In patches; common.
ASPLENIUM, *L.*
trichomanes, *L.*
felix femina, *R. Brown.*
CYSTOPTERUS, *Bernh.*
bulbifera, *Bernh.*
fragilis, *Bernh.*
WOODSIA, *R. Brown.*
ilvensis, *R. Brown.*
DRYOPTERIS, *Adans.*
intermedia, *Muhl.*
POLYSTICHUM, *Roth.*
aculeatum, *Roth.* Brook sides, in high lands.
lonchitis, *Roth.* Not rare, on ridges.
ONOCLEA, *L.*
sensibilis, *L.*
OSMUNDA, *L.*
spectabilis, *Willd.*
claytoniana, *L.*
cinnamomea, *L.*
BOTRYCHIUM, *Swartz.*
virginicum, *Swartz.*

LYCOPODIACEÆ.

LYCOPODIUM, *L.*
lucidulum, *Michx.*

Lycopodium.
selago, *L.*
annotinum, *Micnx.*
dendroideum, *Michx.*
clavatum, *L.*
complanatum, *L.*
Selaginella, *Beauv.*
selaginoides.

APPENDIX.

ANNOTATIONS AND ADDITIONS.

NOTE A. — Part I, p. 5.

" *The first steps towards the exploration of the country bordering on the great chain of North American lakes were taken by the Jesuits of Canada.*"

Three Jesuits and two lay brothers arrived in Canada as early as 1625. The order in Canada as in other countries, had for its head a Superior to whom the missionaries at out-posts regularly reported. The Superior reported annually to his Provincial, and these reports constitute the Jesuit Relations. These are printed in forty duodecimo volumes under the title of "*Relation de ce qui s'est passé en la Nouvelle France ès années.*" Sometimes the title runs:—" Relation de ce qui s'est passé de plus remarquable aux Missions des Pères de la Compagnie de Jesus en la Nouvelle France, ès années." They extend from 1632 to 1672. Of their merit, Charlevoix pronounces the following opinion: — " As those fathers were scattered among all the nations with which the French were in relation; and as their mission obliged them to enter into the affairs of the colony, their memoirs may be said to embrace an elaborate history thereof. There is no other source to which we can apply for instruction as to the progress of religion among the savages, or for a knowledge of these people, all of whose languages they spoke. The style of these Relations is exceedingly simple; but this simplicity itself has not contributed less to give them a great celebrity, than the curious and edifying matter they contain."* No historian can enter fully into an investigation of the circumstances attendant on the first settlement of this country, without being conversant with them, and those who pretend to acquit themselves of such a task without previously studying these works, afford only a proof of their unfitness for the duty.

In proportion to their great value is, at the same time, their great scarcity. A complete set is not now to be found even in the Royal Library at Paris. Southey, at his death, owned twenty-three volumes (1637 to 1671), excepting volume eleven. Bohn purchased this lot for seven pounds, seven shillings, and sixpence sterling.

In this country, the completest set is owned by Mr. J. C. Brown of Providence, Rhode Island, the volumes for the years 1654–5, 1658–9, and 1671–2 only being wanting. The next in order is that of Harvard College library, there being five volumes wanting. The collection of Mr. J. C. Murphy of Brooklyn is the next in point of completeness, there being eleven volumes wanting. The Relations for the years 1654–5, and 1658–9 are not to be found in any collection, public or private; in this country.

* Historie de la Nov. France, II. XI. VIII.

The following persons filled the office of Superior from 1626 to 1673:

Father	PHILIBERT NOYROT, - -	1626 to 1629.
"	PAUL LE JENNE, - -	1633 to 1639.
"	BARTHELEMY VIMONT, - -	1639 to 1645.
"	JEROME LALLEMANT, - -	1645 to 1650.
"	PAUL RAGUENEAU, - -	1650 to 1653.
"	JOSEPH LE MERCIER, - -	1653 to 1656.
"	JEAN DE QUIEN, - -	1656 to 1659.
"	JEROME LALLEMANT, - -	1659 to ——.
"	JOSEPH LE MERCIER, - -	1664 to 1670.
"	J. CLAUDE DABLON, - -	1670 to 1673.*

NOTE A 1. — Part I, p. 9.

"*The Relation of the voyage of Marquette was not published until some time after his death, and, by some, is regarded as fabulous.*"

We learn from a Chicago paper that the original MS. has been saved from the pillage of the Jesuits' college in Quebec. "It is well known by those familiar with the resources of early American history that the publication of the Jesuit Relations, which furnish so much interest in regard to the discovery and exploration of the region bordering on our northern lakes, was discontinued after the year 1672. Some were known to have been written, but the manuscripts were supposed to be lost. The Relations from 1672 to 1679, inclusive, have lately been discovered, and, among them, a manuscript containing a full account of the voyages of Father Marquette, and of the discovery by him of the Mississippi river. It was undoubtedly this manuscript which furnished Thevenot the text of his publication, in 1687, of 'The Voyages and Discoveries of Father Marquette and Sieur Joylet.' The latter kept a journal and drew a map of their route, but his canoe was upset in the falls of St. Louis, as he was descending the St. Lawrence, in sight of Montreal, and he lost them with the rest of his effects. What increases the value of the present discovery is, that the original narrative goes much more into detail than the one published by Thevenot. The motive which prompted the preparations which were made for the expedition are fully described, and no difficulty is found in tracing the route. There is, also, among the papers, an autograph journal by Marquette, of his last voyage, from the 25th of October, 1674, to the 6th of April, 1675, a month before his singular death, which occurred on the eastern shore of Lake Michigan. Also, a chart of the Mississippi, drawn by himself, illustrating his travels. The one annexed to Thevenot's account, above referred to, is manifestly incorrect, and there is a variance between the route of the Jesuit, as traced on his map, and that detailed in the text. The manuscript chart now rescued from oblivion, reconciles all discrepancies and constitutes a most interesting historical relic."

* Vide a paper on the Jesuit Relations by E. B. O'Callaghan, M. D. — *Proceedings of the New York Historical Society, November* 1847 — from which the above facts are derived.

Note B. — Part I, p. 47.

"Phenomena of the Waters."

We copy the following from the Lake Superior Journal of July 23, 1851. The editor remarks:

"While at Grand island, a few days since, Mr. Williams gave us an account of a remarkable instance of the sudden rise and fall of water, at that place, in 1845. On a certain day, without any appearance of wind on the lake, the water rose and fell several times during the day, from four to five feet above high water mark. The weather was calm before and after the occurrence, and this was the case for a hundred miles, at least, to the north-west of the island; for Captain Smithwick, of the schooner Algonquin, was that day off Copper Harbor, and nearly becalmed."

Note B 1. — Part II, p. 80.

Strength of Wrought Iron.

Experimenters.	Whence derived.	lbs. per sq. in
J. & R.*	Missouri bar iron	47,909
Martin	Fourchambauldt, (France,)	47,964
Martin	Ste. Chambaud, (France,)	49,000
Martin	English best cable	49,251
Brown	Swedish	49,796
J. & R.	Tennessee	50,000
Martin	Superior English	52,823
Rennie	English iron	55,843
Brown	Welsh iron	57,975
J. & R.	Salisbury, (Conn.,)	58,009
J. & R.	Swedish bar	58,185
J. & R.	Centre co., (Pa.,)	58,400
J. & R.	Lancaster co., (Pa.,)	58,661
Johnson	McIntyre, (Essex co., N. Y.,)	58,912
J. & R.	English cable	59,105
Brown	Russia	59,472
Tilford	Staffordshire iron, (England,)	60,928
Tilford	Swedish	64,960
Tilford	Welsh	65,520
Brunel	Best English	68,544
J. & R.	English cable, hammered	71,000
Brunel	Best English	72,352
J. & R.	Russia bar	76,069
J. & R.	Phillipsburg wire-drawn .333 in. diam.	84,186
J. & R.	Phillipsburg wire-drawn .190 " "	73,888
J. & R.	Phillipsburg wire-drawn .156 " "	89,162
Wade	Carp river iron, Lake Superior	89,582
J. & R.	Cast steel	130,681

* Johnson and Reeves' Report on the Examination of the Strength of Materials.

Note C.—Part II., p. 15.

Barometrical Observations, by S. W. Hill.

Date.	Station.	T.	R.	Ther.	Barom'r.	Height above L. Superior.	Remarks.
1849.							
Aug. 15	10 ft. above lake 7h 25′ P. M.	49	26	14	292·00		Cloudy, wind light, rain fell at 10 evening.
16	Last night's station 7h. 20′ A. M.	....	....	19½	291·90		Cloudy, wind light, S. W.
	Summit of knob on south side, section 32 east of ¼ post 10h 35′, A. M.	50	....	22	735·80	248	Cloudy, wind S. W.
	A few yards to the west of corner of sections 31 and 32 south line 1h. 15′, P. M.	....	....	20	735·80	188	Flying clouds.
	Half a mile east of corner of townships 49 and 50, range 26 and 27 on south side of section 31, granite knob	....	....	20	730·70	398	2h. 15′ p. m.
	On summit of ridge, section 1, east side, ¼ of a mile south of township corner	49	27	21½	729·20	472·5	2h. 50′ p. m.
	On same line south of ¼ post	....	27	20	732·40	343	3h. 40′
	On same line stream	....	....	19½	734·50	274·5	3h. 55′
	Summit of ridge, section 12, east line, north of ¼ post	....	....	20	729·25	492	4h. 30′
	At camp south of ¼ post, same line	....	....	19	731·65	399	5h. 15′
	The above observations must be calculated with reference to the stationary barometer						
17	8 A. M. last night's station	....	....	16½	733·60	394	Clear, some flying clouds, weather good.
	A few yards south of ¼ post on east side 13	....	....	18½	733·10	423	9h. a. m.
	40 rods south of corner sections 13 and 24	....	....	22	724·80	771	9h. 50′
	Summit of ridge south of ¼ post, section 24	....	....	21	722·45	867	10h. 30′
	Few yards north of ¼ post, section 25	....	....	21½	719·70	980·8	11h. 40′
	¼ post section 25	....	....	22½	721·20	933·5	1h. p. m.
	At meadow, section 36, ⅓ of a mile north of township corner	....	....	22	721·05	943·1	1h. 45′
	At township corner 48 and 49	....	....	23	719·50	1004·1	2h. 20′
	Brow of bank of Dead river, section 1, ¼ of a mile south ¼ post, east side of section	48	27	23	720·60	964·5	Clear, weather good, 3h. 30′ p. m.
	At Dead river, section 12, ¼ of a mile south of corner of 1 and 12 section, east side	....	....	23	727·40	694	4h.
	A few yards north of corner of 12 and 13 sec., at camp in 12	....	....	20	726·00	746·2	6h.

18	Last night's station 8 A. M.	....	....	18	726.06	751.0	Clear, wind south-west, light.
	A few yards to the north of corner of sections 24 and 25	....	....	....	....	....	9h. 35′ a. m.
	Corner of section 36 and 25 east line	....	....	....	....	474	These heights were copied from the diagrams made in the Land Office at Detroit, and were determined by Houghton.
	do 25 and 24 do	....	....	....	....	991	
	do 24 and 13 do	....	....	....	....	894	
	do 12 and 13 do	....	....	....	....	836	
21	Barometer 35 feet above Teal lake	48	26	20	725.50	....	Flying clouds, m.
	West side, section 10, on trail, iron knob	47	27	18	723.55	868.6	Clear, 3h. 40′ p. m.
	Small stream, middle section 9, on trail	....	....	18	725.35	805	4h. 10′
	Middle section 18, on trail	47	27	14½	724.43	827	5h. 3′
22	Last night's station	....	....	9½	723.85	804.6	Cloudy or foggy, 7h. a. m.
	At corner of sections 17, 18, 19, 20	....	....	14½	721.45	927.3	8h. 40′
	Line between ranges 27 and 28, a few yards south of the corner of sections 18 and 19	....	....	14½	723.15	853.6	Breaks away, 9h. 10′
	Small stream, south-west section 30, west side	....	....	15	724.60	778.3	10h.
	Branch Escanāba river, section 31	....	....	16½	725.70	753	Cloudy by spells, 11h.
	Corner of sections 46 and 47, ranges 27 and 28	....	....	17	724.00	811.5	11h. 30′
	Section 1, north-east; ¼ pine lands	46	28	19½	724.50	792.5	12h. 30′ p. m.
	South-west ¼ section 1, granite knob	....	....	23	723.20	824	2h.
	Escanāba river, section 11, east side	....	....	22	724.50	767	3h.
	Small lake, section 15	....	....	24	722.80	832.5	Pine plains, 15 ft. above lake, 3h. 45′ p. m.
	Section 30, north side, stream	....	....	21	722.60	815.8	Clear, 6h. p. m.
24	Last night's station	....	....	21	724.45	803.4	8h. a. m.
	Corner of townships 45 and 46, ranges 28 and 29	....	....	24	723.10	882	9h. 40′
	Next line, section 11, ¼ post	45	29	24	723.50	887.9	11h.
	Corner of section 10, 11, 14, and 15	....	....	24	723.00	906.2	1h. p. m.
	In section 22	....	....	22	723.85	866.7	3h. 40′
	Same place	....	....	21	723.85	....	6h.
	Last night's station	....	....	15	725.30	821	6h. a. m.
	Small stream in section 21	....	....	15	726.10	769.4	6h. 30′
	Machi-gāmig river, section 2, near foot of Long Portage	44	30	18½	727.05	759.7	8h. 20′
	North part of section 15, marsh	45	29	26	726.00	816.5	11h.
	Small lake, south of ¼ post, east line of section 1	....	....	27	4.30	850.8	4h. p. m.
	Same place	....	....	25½	724.30	846.5	Wind northwest, light 5h.

Barometrical Observations, by S. W. Hill—Continued.

Date.	Station.	T.	R.	Ther.	Barom'r.	Height above L. Superior.	Remarks.	
1849.								
Aug. 25	Last night's station	....	....	20	724.80	883.5	Clear,	7h. a. m.
	Corner of sections 1 and 12, range line	....	....	21	724 20	863.8		7h. 80′
	Small lake in section 12, east line of	45	29	21	724.84	840.7		7h. 80′
	Corner of section 12 and 13	....	....	22	723.20	908.3		8h.
	¼ section, corner east line of section 13	....	....	22	723.30	880.6		8h. 25′
	Swamp in section 13, east line of	....	....	22½	726.00	783		8h. 50′
	Small lake in section 25, east line of	....	....	24	724.70	847.2		10h.
	Corner of sections 44 and 45, ranges 28 and 29	....	....	24	725.18	821.7		10h. 55′
	¼ post, east line section 1	44	29	25½	727.20	753.4		m.
	Stream in north part of section 12,	44	29	26½	729.30	658		1h. 80′ p. m.
	¼ post, east line section 13, 25 feet above line of swamp	....	....	25	728.50	652		2h. 50′
	A few yards north of ¼ post in east line of section 24	....	....	23½	725.70	760.6		3h. 20f
	A few yards north of ¼ post east line of section 25	....	....	22½	725.35	743.5	Flying clouds,	5h.
26	Last night's station	....	....	17	725.20	....		7h. 30f a. m.
	On low granite ridge, south of ¼ post, east line section 25	....	....	18	724.00	....		7h. 30f
	In section 12, a few yards west of range line, granite knob	43	29	21	729.20	567		10h. 20f
	Corner of sections 43 and 44, ranges 29 and 28	....	....	23	728.30	598.3	Cloudy, wind south	11h. 45f a. m.
27	East line section 25, 20 feet above Lake Superior	44	29	16½	728.85	777.5	Clear, wind north-west,	noon.
29	Northwest ¼ of section 27	46	28	6	724.70	785		6h. 40f
	Corner of section 15, 10, 21, and 22	....	....	13	724.40	834	Clear, wind west,	6h. 8f
	Branch of Escanāba river, west line section 15	....	....	14	724.80	824.5		8h. 40f
	Corner of section 34, 9, and 10	46	28	18	724.50	859		9h. 45f
	Township line, corner of sections 3 and 4	....	....	15	724.00	864.3	Flying clouds,	10h. 25f
	Escanāba river, section 3, north line of	46	28	......	724.60	....		
	Section 1, north line of township	46	28	18	724.50	....		
Sept. 1	Barometer 30 feet above Teal lake	....	....	4½	729.00	....	Clear, wind light.	
	Section 1, summit of iron ridge	47	27	11	724.20	....		7h. 50f a. m.
	Summit of ridge in section 12, north line	47	27	11½	722.40	93.75		9h. 15f
	Third ridge, section 12, near the centre of said section 12, township 47, range 27	....	....	11½	722.20	....		
	Stream in deep ravine, section 12, township 47, range 27, between the fourth and fifth ridge, 10h. 20m. a. m.	....	14	13	727.40	0.905		

Note D.—p. 15.

Additional elevations in the iron region.

Township.	Range.	Section.	Fraction.	Station.	Height.
47	29	12	North-west course	One-eighth of a mile from corner	716
47	29	13	North line	Ten rods west	1,067
47	29	18		Surface of a small lake	918
47	28	18	North line	Five rods south of quarter post	1,029
47	28	18	North line	Twenty rods east	1,022
47	28	11	South-west corner		942
47	28	12	South-west corner		981
48	27				738
47	26	1	Summit on town line, one mile south.		1,100
47	26	18	South-west corner		915
47	26	31	North-east quarter		664
47	27			Corner five miles south of Teal Lake, between sections 25 and 36.	846
47	26	30		Iron cascade	724
*47	24	6	South-west corner		65
*47	24	19	North-west corner		99
*47	24	30	Southwest corner		347
*47	25	1	North-east corner	Quartz ridge	175
*47	25	1	Southwest quarter	do	220
*47	25	6	North-east quarter	do	592
*47	25			On line between sections 8 and 17	513
*47	25	7	Near centre		671
*47	25	18	South-west corner		671
*47	25	30	North-west corner		556
*47	26	12	South-west corner		780
*47	26	15	South-east corner		747
*47	26	22	South-west quarter	Horneblende ridge	923
*47	25	34	North-east quarter	Quartz ridge	587

* The heights marked with a star, were determined by Dr. Houghton. For additional heights, barometrically determined, the reader is referred to our former report, Part I., p. 36.

NOTE E.—p. 000.

IRON MANUFACTURES OF THE UNITED STATES FROM THE CENSUS RETURNS OF 1850.

STATES.	Capital invested.	Pig metal—tons.	Blooms used—tons.	Ore used—tons.	Mineral coal—tons.	Coke and charcoal—bushels.	Value raw material, fuel, &c.	Number of hands employed.	Average wages per month.	Wrought iron made—tons.	Value of other products.	Value of entire products.
Massachusetts........	$110,800	1,030	....	....	22	78,500	40,694	60	$28 35	720	....	68,320
Connecticut..........	529,500	7,031	1,640	....	5,062	783,600	358,780	370	31 59	6,325	$5,000	667,560
New York...........	1,131,500	8,530	....	44,642	13,908	5,454,150	838,314	1,037	26 16	13,633	195,000	1,432,968
Delaware............	15,000	510	160	....	....	228,000	19,500	50	24 19	550	....	35,000
Maryland............	780,650	10,172	3,389	....	10,455	246,000	439,511	563	23 33	10,000	....	771,431
Virginia.............	791,211	17,296	2,500	....	66,515	103,000	591,448	1,295	23 62	15,328	....	1,254,995
Georgia.............	9,200	100	....	....	....	76,600	5,986	26	11 35	90	....	15,384
Tennessee...........	755,050	11,696	325	9,151	62,038	....	385,616	734	15 20	10,348	38,800	670,618
Kentucky............	176,000	2,000	1,600	....	....	280,000	180,805	188	32 06	3,070	....	299,700
Ohio...............	620,800	13,675	2,900	....	22,755	466,900	604,493	708	33 61	14,416	....	1,076,192
Missouri............	42,100	1,204	....	....	9,834	....	24,509	101	30 00	963	....	68,700
Rhode Island.........	208,000	3,000	....	....	6,000	....	111,750	220	26 00	2,650	....	222,400
Pennsylvania.........	7,620,066	168,702	20,405	....	325,967	3,989,998	3,483,391	6,764	27 68	182,506	219,500	8,902,607
New Jersey..........	1,016,843	10,430	....	14,459	4,507	1,994,180	820,950	593	27 78	8,162	....	629,273
New Hampshire.......	4,000	145	....	....	....	50,000	5,600	6	32 00	110	....	10,400
Alabama............	2,500	120	....	....	....	80,000	3,000	14	20 00	100	....	7,500
North Carolina.......	108,000	....	....	1,650	....	357,000	28,143	173	10 37	....	....	....
Vermont............	62,700	750	525	2,625	....	337,000	66,194	57	31 95	2,048	....	663,986
Indiana.............	17,000	50	....	3,159	....	85,000	4,425	22	27 45	175	....	11,760
Total............	$13,995,220	251,491	33,344	78,767	527,063	14,510,838	9,518,109	12,978		272,044	$458,300	16,387,074

AGGREGATE OF MANUFACTURES.

Capital invested in manufactures June 1, 1850..	$530,000,000
Raw material consumed..	550,000,000
Amount paid for labor..	240,000,000
Value of manufactured articles..	020,000,000
Number of persons employed..	1,050,000

NOTE F., p. 273.

Artesian wells in the red clay of Green Bay, from Mr. Whittlesey's MS.

In my report made to Dr. Owen in 1849, for that part of Wisconsin east of the Wisconsin river, will be found a statement of the Artesian wells bored by Mr. Alonzo Curtis and others, in the red clay at Fond du Lac, Lake Winnebago.

Mr. Curtis has lately furnished me with the results of his borings in the same clay, but at a lower level, near the surface of Lake Michigan.

Well of Mr. Edwin Hall, commenced seven feet above the lake surface:

1. Sand - - - - - - -	8 feet.	
2. Red clay - - - - - - -	22 "	
3. Blue clay - - - -	42 "	
	—	72 feet.

4. Quicksand with water, rising within 3 or 4 feet of the surface.

Well of Mr. Edward Wisewell, five feet above the lake:

1. Sandy soil.		
2. Red clay - - - - - - -	30 feet.	
3. Dun-colored clay - - - - -	6 "	
4. Very red clay - - - - - -	1 "	
5. Blue clay - - - - - - -	38 "	
	—	75 feet.

6. Quicksand aud water, rising to within 2 feet of surface.

Well of Mr. H. S. Beard, four feet above the lake:

1. Soil.		
2. Red clay - - - - - -	30 to 35 feet.	
3. Dun-colored clay - - - - -	6 "	
4. Blue clay - - - - -	4 "	
5. Very red clay - - - - - -	1 to 2 "	
6. Blue clay - - - - - - -	43 "	
	—	90 feet.

7. Quicksand and water rising to within 1½ feet of surface.

Four other wells belonging to D. M. Whitney and others, near Mr. Beard's, show the same section; and all, thus far, give a good supply of water.

Well of Mr. M. L. Martin, one mile south of the last, surface thirty-five feet above the lake, gave, after boring through red clay one hundred and fifteen feet, a supply of water from the quicksand, rising to within seven feet of the surface.

Well of Mr. Daniel Whitney, near Manitou river, three feet above the lake:

1: Soil.	
2. Red clay - - - - - - - -	44 feet.

3. Quicksand and water rising above the surface.

Well of D. C. Robinson, at Astor, half a mile north of the last, about six feet above the lake:

1. Confused mass of sand and gravel - - -	34 feet.
2. Red clay—water rises to lake level.	

Well of Jeremiah Porter, five feet above the lake:

1. Sand - - - - - - - -	14 feet.	
2. Red clay - - - - - - -	94 "	
	—	108 feet.

3. Limestone, probably Trenton—no water.

Well of Mr. Daniel Whitney, four feet above the lake:

1. Sand - - - - - - - -	4 feet.	
2. Red clay - - - - - - -	50 "	
3. Blue sand, with leaves and sticks. A specimen of cedar was given me from a piece eight inches thick -	3 "	
4. Red clay - - - - - - -	40 "	
5. Blue clay - - - - - - -	11 "	
	—	108 feet.

6. Trenton limestone—no water.

Another well sunk by Mr. Whitney to the depth of one hundred and six feet, in red and blue clay, struck the rock at that point, but gave no water.

Four other wells, on a line of half a mile north and south, and about on the same level, gave a depth of one hundred and eight feet before striking the rock.

In all the cases where no quicksand was met with below the clay, no water was obtained. Mr. Robinson's well is not Artesian, but one of the ordinary kind, in which water filters through the gravel, and fluctuates with the level of the water in the bay.

The stratification is evidently very irregular; for, although the extreme wells are not more than a mile and three-quarters apart, yet the sections vary much, even in the distance of a few rods. In one of the borings, at the depth of forty-three feet, a bed, two feet thick, of rotten wood and leaves, was intersected between strata of red and blue clay. It also contained the remains of the bones of fishes.

The wood was submitted by me to M. Lesquereux, for examination, and pronounced by him to be cedar, and transported by fresh water. Several pieces of the same wood were given me at Appleton, which were also taken from the red clay, but at a height of one hundred to one hundred and fifty feet above the lake. The one above mentioned, however, was found fifty feet below the level of the lake.

The alternations of red and blue clay much resemble those of the west side of Lake Michigan, as, for instance, at Racine and Milwaukee; and it is evident that they both belong to one formation. Since, therefore, the great clay deposits of Lake Michigan graduate, on the south, into the blue marly sand and clay of Lake Erie, and on the north into the red marly clays of Lake Superior, it follows that they ought to be considered to be of the same age.

Those on Lake Erie and the streams flowing into it, contain the same wood as those of Lake Michigan, and also a few fresh-water and land shells. It follows, therefore, that the Lake Superior clays are also of fresh water and not of marine origin.

In the vicinity of Green Bay, the red clay may be seen at a height of one hundred and fifty feet above the lake; but, on ascending Fox river, its surface rises, and on the hills south-east of Lake Winnebago, it attains a height of four hundred feet. On the waters of Fox river, the bricks made from it are of a cream-color, like those of Milwaukee, when hard-burnt, otherwise they are red. The color of these red and blue clays is due to iron in different stages of oxidation. They all contain more or less carbonate of lime and magnesia. Pebbles of the sedimentary rocks are also sparsely distributed through them, as well as some fragments of the northern igneous and azoic rocks.

The principle upon which water rises in the wells of Green Bay and Fond du Lac, is very simple: A bed of quicksand, or some other material into which water can penetrate, is confined between impervious strata above and below; wherever the edges of the first mentioned stratum come to the surface, they are penetrated by the water, which gradually fills the whole of the permeable mass in which it is confined, as a reservoir. Of course, if the superior bed is bored through, the water will rise nearly as high as the edge of the bed which is filled with water, according to the well-known laws of hydrostatics.

At Appleton, on the Fox river, wells are bored, which either give no water, or it only rises in them a part of the distance to the surface. But then the river is near, and has cut through the clay to the underlying sandstone, so that the water finds, in part, a natural outlet from the beds of quicksand.

A few observations have been made on the temperature of these wells. At Oshkosh we found, in September, 1849, that the water of a well thirty feet deep was at 48°, Fahrenheit. In July, according to Mr. M. Williams, a well ninety feet deep gave the same temperature, and in the January following, 51°, F.

Note G.

"Fisheries of Lakes Michigan and Superior."

The number of persons engaged in this business is very variable, as well as the quantity of fish caught. Fishermen say that the same ground is much better one year than another, so that they are obliged to shift their quarters. We saw at Pointe au Cheñe, Biddle river, Payment Point, Point Patterson, at the harbor west of Bark Point and many other places, abandoned fishing stations; but these may all be resumed during the present year. There were fishermen at the island of St. Helena, Gull island, and others in the lake, not within our course, whose number we cannot state. They had thus far been unsuccessful, the fish having retired far out into the deep and cool water.

At Seul Choix, there was a greater assemblage of men and boats than at any other point in our route.

From the best estimates, there were at

Seul Choix, - - -	90 boats and	200 men.
Point Barbeau, - - -	30 "	75 "
Summer Islands, - - -	5 "	18 "
Rock Island, - - -	10 "	30 "
Washington Island, - -	14 "	50 "
Pilot Island, - - -	6 "	20 "
	155	393

Many of the fishermen had their families with them, who assisted in the curing and packing of the fish.

On the west shore of Green Bay and the west shore of the lake, south of Death's Door, there are also fishing stations.

Altogether there must be nearly a thousand persons engaged in this pursuit. The fish here taken are the white-fish and Mackinac trout. (*Mr. Whittlesey's MS.*)

On Lake Superior there are fisheries at White-fish Point, Grand island, La Pointe, and Isle Royale, where considerable quantities are taken and exported; but we have no statistics as to the number of men employed, or the number of barrels exported. Between the head of Keweenaw Point and the mouth of the Ontonagon river, considerable quantities of fish are taken, for which there is a ready market at the mining stations. In addition to the white-fish and Mackinac trout, the siskawit is occasionally taken. Its favorite resort, however, is the deep water in the vicinity of Isle Royale.

Note H.

Statistics of Lumber.

There are eight saw-mills in operation along the southern coast of the Upper peninsula, viz:

One at the mouth of the Manistee, running - -	2 saws.
One at Sturgeon river, (Bay des Noquets,) running -	1 saw.
One at Escanaba river, running - - -	4 saws
One at White-fish river, running - - -	2 "
One at Fort river, running - - - -	2 "
One at Cedar river, running - - - -	3 "
Two at Menomonee river, running - - -	7 "
	21

At Cedar river and the Menomonee, there are lathe machines, and probably at others. The best saws cut from 4000 to 6000 feet of lumber in twenty-four hours, while running; but the mills generally lie still during winter, and from breakages and other causes are not in operation at all times during the remainder of the season.

There is an excellent belt of pine lands, extending from the Manistee to the Menomonee and thence to the Wisconsin and even the Mississippi, but towards the sources of these streams the timber is less abundant and valuable.—(*Mr. Whittlesey's MS.*)

Note I.

Origin and Orthography if some of the proper Names in the Lake Superior District.

Hardly anything has more perplexed us than the difficulty of ascertaining the correct names of the prominent natural features of our district, and of writing them as they are pronounced, so as, at the same time, to preserve the original meaning. While very few of the small lakes, rivers, or hills, in the interior, have as yet received any names; almost all the streams, points, and bays, along the coast of the great lakes, are known by some name, generally either of Indian or French derivation. Many of these are now so corrupted from their original designation, that it is impossible ever to restore the correct spelling, or to bring again into use the original name.

As the race, by which most of the conspicuous points and rivers were named, is rapidly disappearing, we deem it worth while to place on record such information as we have been able to obtain, either from the natives (Chippeways or Ojibwas), or from our *voyageurs* (Canadian French, or French and Indian), or from the published works of the old explorers of this region, and especially of the Jesuit fathers. How many of the great topographical features of this country retain their aboriginal names, while the meaning of those names has become irrevocably lost!

In Part I. of this report we have given a fac-simile of the map of this region, made by the Jesuit missionaries, probably about the years 1670 and 1671, and published in Paris in 1672. The astonishing amount of geographical knowledge of the borders of these lakes, obtained by the earliest explorers, speaks volumes for their skill and perseverance. Some of the maps published in this country and in England, within the last ten years, do not exhibit the main features of Lake Superior as correctly as they are shown on the old Jesuit map.

From these old Jesuit authorities, especially the "Lettres edifiantes," and from Charlevoix, "Journal d'un Voyage," &c., we have gleaned what information we could, with regard to the original designation and meaning of the names.

In giving the abstract, we will begin at Saut Ste Marie, and, following the northern shore of Lake Superior toward the west, make the circuit of that lake, and then follow the northern shores of Huron and Michigan, towards the west, along the southern borders of our district, to Green Bay.

Lake Superior (*Lac Supérieur*, Fr., *Kitchi-gummi*, Ch.).—The name upon the Jesuit map is "Lac Tracy ov Svperievr." *Lac Supérieur* means simply, *Upper Lake*. *Lac Tracy* seems to indicate a desire on the part of the Jesuits to perpetuate the name of M. de Tracy, by giving it to the largest sheet of fresh water on the globe. We need hardly add, that the name of Lake Tracy was never adopted, and is quite unknown. *Kitchi-gummi* signifies *Great water* or *Great lake*, *gummi* being, in general, a collection of water, or lake.

Saut Ste. Marie (*Le Sault, Mission de Ste. Marie du Sault*, Jesuit map).—Sault is the old French orthography. The French name seems now finally adopted by the inhabitants at the Saut, or *Soo*, as it is frequently pronounced. The river, on the other hand, is known by the English name—St. Mary's river. The Indians at the Saut are called *Les Sauteurs*.

Gros Cap.—A name given by the voyageurs to innumerable projecting headlands; but in this case appropriately, since it is the conspicuous feature at the entrance of the lake.

Goulais Bay.—Derivation doubtful; perhaps *goulet*, the funnel-shaped opening of a net, from some fancied resemblance in its form.

Batcheewauaung Bay.—Derivation unknown.

Mamainse (Indian).—Little sturgeon.

MICHIPICOTEN (*Great sand*) BAY.—Not descriptive of the island, but of the river.

NEEPIGON BAY.—*Neepi* or *nipi* is water; *neepigon*, dirty water.

KAMANISTIQUIA.—"River that goes far about." Serpentine.

LE PATE.—*Pie island*, or *Pastry island*, from its fancied resemblance to a French pie. The island rises from the water to the height of eight hundred feet, with regular and slightly sloping sides, like a hat; and the term, "Hat island," would convey a better idea to the American reader, of its outline, than that now in use.

ISLE ROYALE.—Isle *Minong* on Jesuit map. *Minong* is said to mean Great island. Another explanation is, that it means an island which is intersected in passing from one point to another. Thus one in voyaging down the north shore might pass from Pigeon river to Washington harbor, and, following along the shore of this island to its eastern extremity, make the traverse to Point Porphyry. It is very curious to observe that, on the map of the great lakes published in Charlevoix's Journal (1744) another large island of nearly the same size and shape as Isle Royale is inserted about half way between Keweenaw Point and Isle Royale. To this island, which is not on the Jesuit map, published sixty years before, the name of *Isle Philippeaux* is given, and it figures to this day on some of the European maps. This same error, if we recollect aright, is perpetuated in Henry's work, published in 1822.

MONTREAL R.—The name Montreal is one which is most frequently given by the voyageurs, in memory of their home, and the head-quarters of the Hudson's Bay Company. Indian *Ka-wa-si-gi-nong sipi*, or *River of the White Falls*, alluding to the fine fall near the mouth of the river and visible from the lake.

CHAQUAMEGON (*Cha-ga-wa-mi-kong*).—Narrow pointed bay.

KARGWAJIWING.—Porcupine mountains. *Karg* is the Chippeway for porcupine, probably given from the great abundance of these animals in the region, and deservedly.

AGOGEBIC (*Little fish*) LAKE.

ONTONAGON, R.—*Nagon* or *nogon*, signifies cup or dish, but whence the origin or what the meaning of the whole word, we have never been able satisfactorily to learn. Spelled on the Jesuit map *Nantounagan*.

KEWEENAW POINT.—On many maps Keweewaiwona. Kioüchounaning, Jesuit map. Pronounced by our Indians, *Ki-wi-wai-non-ing*, now written and pronounced as above; meaning a portage, or a place where a portage is made. The whole distance of some eighty or ninety miles around the point, being saved by entering Portage lake and following up a small stream, leaving a portage of only about a half a mile to Lake Superior on the other side.

EAGLE RIVER.—The name given by the voyageurs is *La rivière nid d'aigle*, Eagle's-nest river.

MANITOU ISLAND, supposed to be one of the residences of the Indian goblin.

AGATE HARBOR.—Indian name, *Na-jo-wi-kue-do-wang*, or Double bay.

KEWAINOQUOT HARBOR, generally called Horse-shoe harbor, a few miles east of Copper harbor, a beautiful little boat harbor. Indian name explained to us as signifying Flying clouds.

BETE GRISE BAY.—Hardly any name on Lake Superior is written in so many different ways, but never as actually pronounced. The invariable pronunciation in the Lake Superior region is as if written "Bay Degree." The name is said to have been given from some gray animal seen in that vicinity, and to be written correctly must be "Baie de la Bête grise," or "Bête grise bay." The Indian name is *Ba-ghi-dq-wi-i-ning*, a bay where nets are set; there being here excellent fishing ground.

TORCH LAKE, *Ba-ki-ga-mang*, in allusion to spearing fishes by torch-light

STURGEON RIVER, *Namê Sepi.*

TOBACCO RIVER.—*Wa-sa-ko-di-na-bi-kon*, or Burnt-stone river, from the red sandstone at its mouth; the former given in allusion to the dark brown color of its swampy water.

FALL RIVER. *Me-ta-bi-ki-ti-goei-ang Sepi*, or *Shallow river*.

L'ANSE.—Anse is bay,—"une très petite baie qui s'enforce peu dans les terres." *Dict. Fr. Accd.* It is applied to many indentations of the coast, but for the most part, it has reference to the settlements at the head of Keweenaw bay.

POINT ABBAYE.—A corruption of Point aux Baies, a name very commonly given by the voyageurs to a point, on each side of which there is a bay. Indian name *Kitchi-ni-ia-sing*. Big Point.

LAKE MICHIGAN (*Lac de Ilinois*, Jesuit map).—Probably the signification is the same as that of Lake Superior—*michi*, vast; *gummi*, water.

MANISTEE RIVER AND LAKE.—This name has been generally spelt on the map, *Monistique*. The name is pronounced by those residing at the mouth of the river, *Manistee*. It is written also by Charlevoix, *la Manistie*. This we think sufficient authority for changing it. The name, as explained to us by ourIndians, means, "A river at whose mouth are islands." There is, at least, one other river of this name emptying into Lake Michigan.

SEUL CHOIX POINT.—The only choice; in allusion to the few spots along the coast suitable for landing. Properly written, *Seule Choix*.

BARK POINT, near Point Detour. Not *Pointe aux Barques*, but *Pointe aux Ecorces*, in French.

Bay des Noquets.—This is the proper name of this bay, but it is universally pronounced in that region as it is written, *Bay de Noque*, or *Nock* in English. The following quotation from Charlevoix shows that this is a very ancient name:—"Nous nous embarquâmes le deux de Juillet après midi, nous cotoyâmes pendant trente lieues une Langue de terre qui separe le Lac Michigan du Lac Supérieur, elle n'a en bien des endroïts que quelques lieues de large, et il n'est quéres possible de voir un plus mauvais Pays; mais il est terminè par une jolie rivière nommè *la Manistie*, fort poissonneuse, et qui abonde sur tout en Esturgeons. Un peu plus loin, en tirant au Sud-Ouest, en entre dans un grand Golphe, dont l'Entreè est bordeè d'Isles, on le nomme le Golphe, ou la *Baye des Noquets*. C'est une très petite nation, venue des bords du Lac Supérieur, et dont il ne reste plus que quelques Familles disperseès ça et là, sans avoir de demeuse fine. La Baye des Noquets n'est separeè de la Grande Baye, que par les Isles des Pouteouatamis."—*P. de Charlevoix, "Journal d'un Voyagè," &c., vol. 5, p.* 429.

TRAINE RIVER (*Rivière la Traine*).—Traine is the old French term for sleigh or sledge—*traineau.*

NEKOMENON, OR DEAD RIVER (*Rivière du Mort*).—Probably named from some tradition of a dead man found near its mouth.

LAUGHING-FISH RIVER (*Rivière du Poisson qui rit*).—The origin of this singular name we are at a loss to understand.

Tequamenon.—On Jesuit map, *Outakoniman;* meaning unknown.

Green Bay.—The name of this bay on the Jesuit map is "*Baye des Puans*," the "*Puans*" being the not over-cleanly Indians who inhabited its borders.

Menomonee River—Indian—equivalent to Wild-rice river. On Jesuit map, "*Rivière des Oumalouminee, ou de la folle avoine.*"

Escanaba River.—Flat-rock, or Smooth-stone river. Name given in allusion to the geological peculiarities of the river, as described in the preceding pages of this report.

Machigamig River.—A river flowing from a great lake. Spelt on various maps, *Michigamig* and *Peshekemme.*

Machigummi, or *Michigummi.*—Great lake.

Night-watching (*Nibe-go-mi-nini*) River.—A branch of the Machigămig, so called because the Indians were wont to watch for game on its banks by moonlight.

Fence River (Indian, *Mitchikau*).—A branch of the Machi-gămig. The name, Fence river, alludes to the manner of catching the deer, by building a long line of fence diagonally to the river, and abutting against it, so that the deer are concentrated at one point.

Pemenee (*Elbow*).—Falls of the Menomonee river, where the river bends like an elbow.

Bekuenesec (*Smoky*).—Name given to a waterfall on the Menomonee, in allusion to the spray rising like smoke.

Swampy River (*Wabashkiki*).

Jack-fish (*Ki-no-je-si-kauing*) Lake.—So called from a species of Esox (pickerel) inhabiting it in great abundance.

Note J.

ERRATA—PART I.

Page 64, line 24; ninety-seven, read sixty-seven.
" 66, line 27; section 16, read section 10.
" 67, line 23; town 56, read town 36.
" 73, Minnesota Company, section 15, read section 16.
" 129, line 5; 100 read 50.
" 135, line 33; read, the vein from 8 to 10 inches.
" 140, line 9; read S. W. qr. of section 33.
" 140, line 37; read section 30, township 50, range 39.
" 147; North American Mine, 1700, read 700.
" 156; Product of gold in the United States, 100,000, read 200,000.
" 160, bottom line; southern slope, read northern.
" 179, line 6; aqua regia, read aqua reginæ.
" 181, line 40; three-fourths, read one-fourth.

INDEX.

As many of the streams and bays connected with the two lakes bear the same name, in such cases L. S. is appended to those connected with Lake Superior, and L. M. to those with Lake Michigan.


SECTION
AND
DIAGRAM
Illustrating the Geology
OF THE REGION BETWEEN
THE NORTHERN SHORES
OF
LAKES SUPERIOR AND MICHIGAN.
SCALE.
AZOIC SYSTEM
THUNDER CAPE
THUNDER BAY
ISLE ROYALE
LEVEL OF LAKE SUPERIOR
OCEAN LEVEL
PROTOZOIC OR SILURIAN SYSTEM
KEWEENAW POINT
CLIFF MINE
TORCH L.
MOUTH OF PORTAGE L.
IRON KNOB
PORTAGE No. 2
BRULE RIVER
TWIN FALLS
STURGEON FALLS
QUIVER FALLS
CHIPPEWA ISLAND
WHITE RAPIDS
GRAND RAPIDS
SAW MILL
MENOMONEE CITY
GREEN BAY
AZOIC SYSTEM
SILURIAN SYSTEM
THUNDER BAY
ISLE ROYALE
LAKE SUPERIOR
KEWEENAW BAY
PORTAGE LAKE
SECTION LINE
MICHI-GAMIG RIVER
MENOMONEE RIVER
MICHIGAN
WISCONSIN
GREEN BAY