C.D. WALCOTT.

THE TRENTON LIMESTONE

AS A SOURCE OF

PETROLEUM AND INFLAMMABLE GAS

IN

OHIO AND INDIANA.

BY

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INTRODUCTION.

The discovery and exploitation of petroleum on a large scale constitutes the most important addition that has been made to the economic geology of the United States for the third quarter of the present century, and the utilization of natural gas in a large way is by far the most striking and important economic fact in the geological history of the country for the last few years.

The use of petroleum has been extended very widely throughout the civilized world, and it is manifest that its discovery is a contribution of great value to the well-being of mankind. The use of natural gas has been thus far sharply limited and circumscribed, so far as territory is concerned; but within its own fields the new fuel has been found to possess extraordinary value and to awaken extraordinary business activity. Its influence extends far beyond its territorial boundaries, and it is already effecting or threatening changes of a revolutionary character in varied and important industries and in widely separated centers of production.

While all the facts in the recent developments of these remarkable products have been altogether new and unexpected, the last chapter proves to be more surprising and anomalous than any that has preceded it. Those who have made themselves familiar with the earliest stages of the history of petroleum in this country and with the geological conditions under which the great stocks have been found are scarcely better prepared on this account for the new development. The oil and gas derived from the Trenton limestone in certain portions of Ohio and Indiana differ from the oil and gas of the Pennsylvania wells in chemical composition and in physical properties, in the horizons from which they are obtained, in the structural features of the rocks that are associated with their production, and most of all in the kind of rock which produces them. No facts more unexpected have ever been brought to light in connection with the geology of this country than those with which we are now becoming acquainted. That a well beginning in Upper Silurian limestone, drilled a thousand to fifteen hundred feet deep, and terminating in the uppermost beds of the Trenton limestone should produce from the last-named stratum 1,000 and even 5,000 barrels of oil in twenty-four hours, and should maintain this flow day after day and month after month until 100,000 barrels monthly are already credited in some instances to single wells; or that inflammable gas, amounting to twelve to fifteen million cubic feet a day, should flow forth from like openings under a pressure of three or four hundred pounds to the square inch and continue so to flow with little diminution of volume or pressure for two or three years—all this it is extremely hard for those who know most in regard to the subjects involved to adjust to their previous knowledge and belief as to this geologic series, even when the facts are displayed before their eyes.

It is the purpose of the present paper (1) to sketch the history of this remarkable discovery up to July, 1887, (2) to point out what is known in regard to the geological scale and the geological structure of the regions within which the new fields are embraced and to trace the chief factors that influence or control the productiveness of the oil rock, and (3) to describe the special features and boundaries of the several fields and to set forth the leading facts in the present development and utilization of these lately found sources of power.

Before taking up the subdivisions of the subject proper, a brief statement will be made of the chief theories in regard to the origin and accumulation of petroleum and natural gas.

The several subjects to be discussed will therefore be treated under the following divisions: (1) Origin of petroleum and natural gas; (2) modes of accumulation of petroleum and gas; (3) discovery of petroleum and gas in northwestern Ohio; (4) geological scale and structure of the new fields; and (5) description of the several gas and oil fields.

CHAPTER I.

THEORIES RESPECTING THE ORIGIN OF PETROLEUM AND NATURAL GAS.

Natural gas and petroleum are embraced among the products of the crust of the earth known as bitumens; other bodies in the same list are the semi-fluid maltha and the solid asphaltum. All of these substances unquestionably have a similar general history. They are found under the same conditions, and the transitions from one to another, as of petroleum to asphalt, can be often noted. They are technically known as hydrocarbons, since carbon and hydrogen constitute almost their entire substance, the former making about 85 per cent. and the latter about 15 per cent. of them.

They have long been known to man, and their use antedates history, but the importance which they now possess in the civilized world is of quite recent date. The discovery and use of petroleum on a large scale fall within the last twenty-five years, and all of the really important applications of natural gas belong to our own day and are now in their initial stages.

Within the last fifty years, and particularly within the last twenty-five years, much has been written by geologists and chemists upon the origin and the modes of accumulation of petroleum and gas. Our knowledge respecting the conditions of their occurrence in the rocks has been increased and various theories have been advanced to account for the facts brought to light, but there is no one theory that commands universal acceptance; and here, as elsewhere, it is no doubt true that theorists are sometimes opposed to one another because they respectively regard but one side of a subject which has more than one side.

Brief statements of the more commonly received views as to the origin and accumulation of these bituminous compounds will here be given. An elaborate compilation of these views has been made by Prof. S. F. Peckham, in his excellent work on petroleum and its products.[1] This compilation has been freely used in the present chapter and acknowledgment for the service rendered by it is hereby made.

The theories as to the origin of petroleum and natural gas, including the derivatives of petroleum, asphaltum, and maltha, can be divided into two main groups, viz, (1) those which refer these bodies

[1] Report on the Production, Technology, and Uses of Petroleum and its Products: Tenth Census U. S., vol. 10. 1884.

to inorganic sources, or, in other words, which make them the result of chemical affinity acting on mineral matter, and (2) those that regard them as the result of a partial decomposition of vegetable or animal substances that have been stored up in the rocks.

These two classes of theories will be briefly considered.

STATEMENT AND DISCUSSION OF THEORIES OF CHEMICAL ORIGIN.

It has been claimed by a number of chemists, some of whom stand high in the scientific world, that the several members of the series now under consideration can be referred to a purely mineral origin. In 1866, the distinguished French chemist Berthelot propounded a theory that would in his view account for all of the natural hydrocarbons in this way.[1] He supposed the alkaline metals, viz, potassium and sodium, to exist in the interior of the earth in a free or uncombined state and, necessarily, at a high temperature. If, now, water carrying in solution carbonic acid—and the crust of the earth abounds in both—should find access to these metals, he pointed out the steps of the chemical action that must take place and that would result in the formation of a series of hydrocarbon compounds. In this case, the process of oil and gas formation would be deep-seated and continuous, the reactions that give birth to them being constantly renewed in the recesses of the earth.

Another theory that invokes chemical force only for the origin of these bodies was advanced by the eminent Russian chemist Mendeljeff, in 1877.[2] It attracted a large measure of attention and interest throughout the scientific world. He supposed the interior of the earth to contain large masses of metallic iron and also metallic carbides (compounds of carbon and metals), all at a high temperature. The contact of water under these conditions with these bodies would, in his view, generate metallic oxides and hydrocarbons. Mendeljeff accordingly holds that petroleum is never of organic origin, but is as purely a product of chemical affinity as a vein stone or an ore. It would follow from this theory, also, that the process of oil and gas formation is continuous.

There are several other theories of the same general character, but none that have been supported by as great authority or that have attracted as wide attention as the two named.

In regard to this class of theories, it is to be observed that they are the work of chemists and not of geologists, and, as might be expected, they accord better with the chemical than with the geologic facts involved. They especially fail to account for the different sorts of oil and gas that characterize different rocks, as limestone and sandstone, for example; and, more important still, they fail to account for the distribution of petroleum and gas.

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[1] Ann. de Chém. et de Phys., Dec., 1866.

[2] Bull. Soc. Chém., de Paris, 1877.

It is further to be observed that the hypotheses on which they depend and which are indispensable to the theories are of the sort that are doomed forever to remain hypotheses. They are, in their nature, incapable of verification. They can not advance beyond their present stage, that of chemical and geological possibilities. There are fields of scientific speculation in which, from the nature of the case, we can have only such materials; but this is not true of the theories now under consideration. In the fact that all these theories "require the assumption of operations nowhere witnessed in nature or known in technology,"[1] we find enough to condemn them or, at least, enough to forbid any large measure of confidence in them.

STATEMENT OF THEORIES OF ORGANIC ORIGIN.

Theories of this class stand on a very different footing from those already named; for, according to them, petroleum and natural gas are derived from vegetable and animal matter contained in the rocks in which they are found or in associated strata. The argument for this view is simple and direct. Compounds similar to petroleum or natural gas, or identical with them, are easily derived by the process of destructive distillation from both vegetable and animal substances, as from wood, peat, bones, oil, etc. The manufacture of artificial gas from bituminous coal is also a familiar illustration of the possibilities in this direction. Bituminous shale may be substituted for coal in the manufacture and may be made to yield a series of these bituminous products, including both petroleum and gas. Further than this, the decay of vegetation at ordinary temperatures gives rise to light carbureted hydrogen or marsh gas, if the air be excluded from the decaying substance. These conditions are met when vegetable matter, as wood and leaves, is buried at the bottoms of ponds and lakes or, on a larger scale, in the beds of glacial drift. As is well known, large accumulations of ancient vegetation are buried in or beneath the bowlder clay in many parts of the country; and these masses sometimes yield gas in large enough amount to be of economic value. Peat bogs not only yield inflammable gas, but sometimes produce other members of the bitumen series, nearly allied to petroleum and asphaltum, as has been shown by many competent observers, among whom E. W. Binney, the veteran English geologist, may be named. In a word, it is scarcely too much to say that during the natural or artificial decomposition of organic substances in the absence of air, both petroleum and gas are naturally produced. If this be so, and if in the rocks both material and force are found that would produce those substances in the ordinary course of nature, why invent far-fetched and unverifiable theories to account for their presence?

[1] Peckham, op. cit., p. 61.

But while the derivation of petroleum and gas from vegetable or animal substances is at present accepted by almost every one whose opinions on the subject are entitled to consideration, there is still a good deal of diversity of view as to the manner in which the work has gone forward. In fact, the inquirer soon learns that beyond the general conclusion already noted there is little agreement among our best authorities as to the particular mode of origin of the substances under discussion. There is not only a want of positive knowledge of the facts, but there is also a lack of self-consistent and comprehensive theory. Two views have become especially prominent in this country in the discussions of the last twenty years, and the one or the other of these is accepted by most of those who seek for well-balanced and presentable opinions on these questions.

THEORY OF ORIGIN FROM PRIMARY DECOMPOSITION OF ORGANIC MATTER.

The first view is that petroleum is in large part derived from the primary decomposition of organic matter that was stored in or associated with the strata which now contain it. According to this view, the decomposition was mainly effected in situ, and the product resulting is therefore mainly indigenous to the rock in which it is found. The last feature is seized upon in most popular statements, and a theory of indigenous origin is made to include most beliefs of this class. It must be borne in mind, however, that while no author is to be found who holds strictly and consistently to such indigenous origin, the name may safely be used as a general designation.

The second view is that petroleum is derived from the secondary decomposition of organic matter stored in the rocks. It assumes that the original vegetable and animal matter has suffered a partial transformation and is now held in the rocks as hydrocarbon compounds, from which, by a process of distillation, oil and gas are derived. The so-called bituminous shales are counted the chief sources of these products. After distillation it is held that the gas and oil are mainly carried upward by hydrostatic pressure to some overlying porous stratum that serves as a reservoir. This class of views may be conveniently grouped under the name of the distillation theory.

A few words will be devoted to each of these theories.

Statement of Hunt's theory.—The most elaborate and effective exposition of the theory that petroleum is derived from the primary decomposition of organic tissue is that of Dr. T. Sterry Hunt. He urges with great force the view that petroleum originates in and is mainly derived from limestones. When found in limestones, he counts the oil indigenous, but when found elsewhere, as in sandstones and conglomerates, he counts it adventitious and he then refers it to underlying limestones. In regard to this latter point, however, he makes concessions, as will be seen further on.

The following extracts from various articles that he has published contain a clear statement of his views upon this subject.

In speaking of the oil fields of Canada, he says:[1]

The facts observed at this locality appear to show that the petroleum, or the substance which has given rise to it, was deposited in the beds in which it is now found, at the formation of the rock. We may suppose in these oil-bearing beds an accumulation of organic matters, whose decomposition in the midst of a marine calcareous deposit has resulted in their complete transformation into petroleum, which has found a lodgment in the cavities of the shells and corals immediately near. Its absence from the unfilled cells of corals in the adjacent and interstratified beds forbids the idea of the introduction of the oil into these strata, either by distillation or by infiltration. The same observations apply to the petroleum of the Trenton limestone, and if it shall be hereafter shown that the source of petroleum (as distinguished from asphalt) in other regions is to be found in marine fossiliferous limestones, a step will have been made toward a knowledge of the chemical conditions necessary to its formation.

Again he says:[2]

In opposition to the generally received view, which supposes the oil to originate from a slow destructive distillation of the black pyroschists belonging to the middle and upper divisions of the Devonian, I have maintained that it exists ready formed in the limestones below.

This statement seems to recognize the possibility of the transfer of petroleum from its sources to reservoirs in associated strata.

Finally, in referring to the bitumen-bearing dolomite in the Niagara series near Chicago, he says:[3]

With such sources ready formed in the earth's crust, it seems to me, to say the least, unphilosophical to search elsewhere for the origin of petroleum and to imagine it to be derived by some unexplained process from rocks which are destitute of the substance.

In this passage, also, a possible transfer of petroleum seems to be recognized.

These statements leave nothing to be desired as to clearness and explicitness. The author's view could not well be put into more concise terms than he has used. It must be added, however, that he has sometimes described the oil of Pennsylvania and Ohio as indigenous to the Devonian and Carboniferous sandstones which contain it.[4]

Statement of theories of indigenous origin.—Prof. J. P. Lesley has also urged the view that petroleum is derived, at least in some conspicuous instances, from vegetable remains that are still found associated with it in the rocks, but he does not theorize as to whether it results from primary or secondary decomposition. In speaking of the petroleum of the eastern coal-fields of Kentucky he refers this

[1] Am. Jour. Sci., 2d series, vol. 35, 1863, pp. 168, 169.
[2] Ibid., vol. 46, 1868, p. 360.
[3] Chem. and Geol. Essays by T. Sterry Hunt, 1875, p. 174.
[4] Ibid., pp. 171, 172.

petroleum to the great conglomerate at the base of the Coal Measures He says.[1]

> A conglomerate age or horizon of petroleum exists; this is the main point to be stated. It must be kept in view apart from all other ages or horizons of oil, whether later or earlier in order of geological time. . . . The rock itself is full of the remains of plants, from the decomposition of which the oil seems to have been made. . . . For hundreds of square miles this vast stratum of ancient sea-sand is a thick-packed herbarium of coal-measure plants. . . . We can easily conceive of the wide, flat, sandy shores of the coal islands of the ancient archipelago of the coal era becoming completely charged with the decomposed and decomposable reliquiæ of both the plants of the land and the animals of the sea.

Professor Lesley has also advocated the indigenous origin of the Pennsylvania petroleums in many of his discussions of the subject, but some of his latest statements seem to show that he also considers petroleum and gas to have been gathered in the sandstones that now contain them from some lower source.

Prof. I. C. White has also supported the view that the petroleum of the third oil sand of Venango County, Pa., is indigenous to this rock, basing his belief on the abundance of vegetable remains that he finds in the outcrop of this sandstone in Erie County, Pa.[2]

Prof. J. D. Whitney has expressed the belief that all of the bituminous minerals of California, including asphalt and petroleum, are derived from the remains of infusoria in marine limestones, but he has not expanded this view into any formal statement.[3]

The opinions of several eminent American geologists have now been quoted in support of the general view that petroleum and gas originate in the strata in which they are found, and by the primary decomposition of organic matter, so far, at least, as the most extended statement is concerned.

The testimony of geologists from other parts of the world could also be adduced to support the above-named view, if it were counted necessary at this point. It is enough to say that the opinions of a number are on record which express in the clearest manner a belief in the primary derivation, and thus in the indigenous origin, of petroleum. One of the most striking testimonies is that of G. P. Wall, relating to the origin of Trinidad asphalt.[4]

THEORY OF ORIGIN FROM DISTILLATION OF ORGANIC MATTER.

The second of the main theories noted—that petroleum and gas are the product of the secondary rather than of the primary decomposition of organic substances, or, in other words, that they are derived from the hydrocarbons of the rocks by a process of distillation—is accepted far more widely than the opinion just considered.

[1]Proc. Am Philos. Soc., vol. 10, 1865–1868, pp. 43, 44.

[2]See the Geology of Erie and Crawford Counties, 2d Geol. Survey Pa., Report of Progress QQQQ, 1881, p. 239.

[3]Bull. Acad. Sci., San Francisco, vol. 3, 1868, p. 324, quoted by Peckham, p. 65.

[4]Quart. Jour. Geol. Soc. London, vol. 16, 1860, p. 467.

In connection with this theory it has always been held that these products of distillation are carried upwards by hydrostatic pressure, to be stored in porous reservoirs or to escape at the surface. This doctrine has without doubt aided in giving currency to the distillation theory with which it has always been associated, but it must be observed that it is not incompatible with the first-named theory of the origin of petroleum, and that it has been of necessity recognized, at least by implication, by the advocates of the first theory. Whatever the origin of petroleum, it is certain that it has been accumulated, at least in many instances, by the method here indicated. The distillation theory must therefore be considered by itself.

That petroleum and gas can be artificially produced from coal, bituminous shales, and other rocks by the process of destructive distillation is well known. We should have a right to expect the same products if similar rocks should be subjected to volcanic heat while buried deep below the surface. When, therefore, we find these or other members of the bitumen group present in the rocks of volcanic districts or in the neighborhood of hot springs—in a word, in regions where elevated rock temperatures prevail or have recently prevailed—we refer them without hesitation to a process of distillation from the strata which the heat has traversed. Conditions are seen to be at hand similar to those which we establish in the artificial production of these substances. It may be added, in passing, that petroleum and asphalt are frequently found under the circumstances named above.

Such an origin, however, can not be made out for the great supplies of petroleum and gas in the Eastern United States. These, without exception, are drawn from regions which have never been invaded by igneous rocks and which have been but little disturbed by geological accidents, the uniform and monotonous dip of their formations being only occasionally interrupted by the low arches that traverse them.

Statement of Newberry's distillation theory.—The theory that has been the most elaborately stated and most widely accepted of all advanced to account for the oil and gas of the Allegheny field is that of Prof. J. S. Newberry, who refers the origin of these substances to the extensive deposits of Devonian and Subcarboniferous shales and, particularly, black shales that underlie the productive districts. He considers petroleum and gas the products of a slow, spontaneous distillation of the organic matter of the shales, and he regards the process of their formation a continuous one.

In his noted paper on the rock oils of Ohio[1] he says:

> The precise process by which petroleum is evolved from the carbonaceous matter contained in the rocks which furnish it is not yet fully known, because we can not in ordinary circumstances inspect it. We may fairly infer, however, that it is a distillation, though generally performed at a low temperature.

[1] Ohio Agr. Rept., 1859.

Again he says:[1]

The origin of the two hydrocarbons [petroleum and gas] is the same, and they are evolved simultaneously by the spontaneous distillation of carbonaceous rocks.

In another place he says:[2]

I have already referred to the Huron shale as a probable source of the greater part of the petroleum obtained in this country. . . . The considerations which have led me to adopt this view are briefly these:

First. We have in the Huron shale a vast repository of solid hydrocarbonaceous matter which may be made to yield from ten to twenty gallons of oil to the ton by artificial distillation. Like all other organic matter this is constantly undergoing spontaneous distillation, except where hermetically sealed deep under rock and water. This results in the formation of oil and gas, closely resembling those which we make artificially from the same substance; the manufactured differing from the natural products only because we can not imitate accurately the processes of nature.

Second. A line of oil and gas springs marks the outcrop of the Huron shale from New York to Tennessee. The rock itself is frequently found saturated with petroleum, and the overlying strata, if porous, are sure to be more or less impregnated with it. . . . Again, the emanations of oil and gas from the Lower Silurian rocks at Collingwood, Canada, and on the upper Cumberland River, Kentucky, are associated with similar deposits of black shale which represent the Utica slate of New York.

Third. The wells on Oil Creek penetrate the strata immediately overlying the Huron shale and the oil is obtained from the fissured and porous sheets of sandstone of the Portage and Chemung groups, which lie just above the Huron and offer convenient reservoirs for the oil it furnishes.

So far, at least, as pointing out the sources of Pennsylvania oil and gas this statement has met with wide acceptance among geologists.

For example, S. F. Peckham says[3] of the oils of Pennsylvania and adjacent territory:

These oils are undoubtedly distillates, and of vegetable origin. The proof of this statement seems overwhelming. Pennsylvania petroleum was examined in 1865 by Warren and Storer in this country, and in 1863 by Pelouze and Cahours in France, who found the lighter portion to consist of a certain series of hydrocarbons, identical with those obtained in the destructive distillation of coal, bituminous shales, and wood when the operation was conducted at low temperatures.

To most of those who have studied the subject with care, a statement even as positive and emphatic as this will seem in its main claim scarcely too strong. The vegetable matter to which Peckham refers the origin of Pennsylvania petroleum must be mainly the organic matter contained in the Devonian shales which underlie the productive regions, and which is presumably of vegetable origin.

Statement of Peckham's distillation theory.—There is, however, another statement of the distillation theory that must be concisely presented. It is that of S. F. Peckham. It is clear and self-consistent, recognizing all the necessary factors and conditions. He refers the oil and gas of Pennsylvania and adjacent territory to a dis-

[1] Rept. Geol. Survey Ohio, vol. 1, 1873, p. 192. [2] Ibid., p. 158. [3] Op. cit., p. 69.

tillation effected by the heat that accompanied the elevation of the Appalachian Mountain system. He says:[1]

Bitumens are not the product of the high temperatures and violent action of volcanoes, but of the slow and gentle changes at low temperature due to metamorphic action upon strata buried at immense depths. . . .

It is not necessary here to discuss the nature or origin of metamorphic action. It is sufficient for our purpose to know that from the Upper Silurian to the close of the Carboniferous periods the currents of the primeval ocean were transporting sediments from northeast to southwest, sorting them into gravel, sand, and clay, forming gravel bars and great sand-beds beneath the riffles and clay banks in still water, burying vast accumulations of sea weeds and sea animals far beneath the surface. The alteration, due to the combined action of heat, steam, and pressure, that involved the formations of the Appalachian system from Point Gaspé, in Canada, to Lookout Mountain in Tennessee, involving the Carboniferous and earlier strata, distorting and folding them, and converting the coal into anthracite and the clays into crystalline schists along their eastern border, could not have ceased to act westward along an arbitrary line, but must have gradually died out farther and farther from the surface.

The great beds of shale and limestone containing fucoids, animal remains, and even indigenous petroleum must have been invaded by this heat action to a greater or a less degree. . . .

Too little is known about petroleum at this time to enable any one to explain all the phenomena attending the occurrence of petroleum on any hypothesis; but it seems to me that the different varieties of petroleum . . . are the products of fractional distillation, and one of the strongest proofs of this hypothesis is found in the large content of paraffine in the Bradford oil under the enormous pressure to which it is subjected. . . .

If this hypothesis . . . really represents the operations of nature, then we must seek the evidences of heat action at a depth far below the unaltered rocks in which the petroleum is now stored.

DISCUSSION OF THE SEVERAL THEORIES OF ORGANIC ORIGIN.

The statements now presented, inadequate and incomplete as they appear, are probably the most careful and extended that have been made upon the subject. They bring before us the main views as to the origin of petroleum, viz:

1. Petroleum is produced by the primary decomposition of organic matter and mainly in the rocks that contained the organic matter. Of this view, Hunt is one of the chief advocates.

2. Petroleum results from the distillation of organic hydrocarbons contained in the rocks and has generally been transferred to strata higher than those in which it was formed. Newberry and Peckham have been quoted at length in support of this general theory. Newberry holds that a slow and constant distillation is in progress at low temperatures. Peckham refers the distillation of the petroleum of the great American fields to the heat connected with the elevation and metamorphism of the Appalachian Mountain system.

These views as to the date of the origin of petroleum and gas are seen to cover almost all of the possibilities in regard to the subject.

[1] Tenth Census Repts. U. S., vol. 10, p. 70.

Hunt believes petroleum to have been produced at the time that the rocks that contain it were formed, once for all. Newberry believes it to have been in process of formation, slowly and constantly, since the strata were deposited. Peckham refers it to a definite and distant time in the past, but long subsequent to the formation of the petroliferous strata. He supposes it to have been stored in its subterranean reservoirs from that time to the present.

In these several statements as to origin, two questions are seen to be especially prominent, viz, What particular kinds or classes of rocks are the sources of petroleum? and What is the nature of the chemical processes involved in its production?

In answering the first question, we find the views of Hunt and Newberry distinctly opposed to each other. Hunt counts limestones the principal source of petroleum and denies that it has been produced by distillation from bituminous shales; while Newberry finds in these shales the main source of both oil and gas and vigorously opposes the view that limestones are ever an important source of either.[1]

It is not necesssary to follow the discussion in relation to these points further. It is enough to say that in the light of present knowledge each statement is sustained as to its particular affirmations and inconclusive as to its general denials. Petroleum is undoubtedly indigenous to and derived from certain limestones, as Hunt has so strongly asserted. On the other hand, Newberry's doctrine that the great supplies of the Pennsylvania field are derived from Devonian shales is becoming more firmly established and widely accepted every year, though it seems likely that he has laid too much stress on bituminous shales.

In other words, the theories are not incompatible with each other. Different fields have different sources. We can accept without inconsistency the adventitious origin of the oil in Pennsylvania sandstones and its indigenous origin in the shales of California or in the limetones of Canada, Kentucky, or Ohio.

The double origin of petroleum from both limestones and shales—and it is not necessary to exclude sandstones from the list of possible sources—deserves to be universally accepted. In confirmation of this double origin, it is coming to be recognized that the gas and oil derived from these two sources—limestones and shales—generally differ from each other in noticeable respects. The oil and gas derived from limestones contain larger proportions of sulphur and nitrogen than are found in the oil and gas of the shales. Nitrogen renders the oils unstable, and sulphur compounds impart to them a rank and persistent odor from which they can be freed only with great difficulty. In the case of the oil-bearing shales of California, the petroleum is evidently derived from the animal remains with which the formation was originally filled. In composition this oil agrees with

[1]Rept. Geol. Survey Ohio, vol. 1, p. 159.

the limestone oils already described. It contains more than four times as much nitrogen as the Mecca oil of northeastern Ohio and its percentage of sulphur is very high. Peckham says of these California oils:[1]

> The exceedingly unstable character of these petroleums, considered in connection with the amount of nitrogen that they contain and the vast accumulation of animal remains in the strata from which they issue, together with the fact that the fresh oils soon become filled with the larvæ of insects to such an extent that pools of petroleum become pools of maggots, all lend support to the theory that the oils are of animal origin.

He speaks again of this class of petroleums as formed of animal matter that has not been subjected to destructive distillation.[2]

It now appears as if oil and gas derived from animal remains can be distinguished from those of the bituminous shales by the characters above described. Certain it is that the "limestone oils" differ in physical characteristics from the Pennsylvania oils, for example, in a marked degree. They are dark in color; they are heavy oils, their gravity generally ranging from 34° to 36° Beaumé, though sometimes falling to 40° or even 42°; they have a rank odor, arising from the sulphurous compounds which they contain. The oils of Canada, Kentucky, Tennessee, and of the new fields in northwestern Ohio all agree in these respects, and the oil and gas of the Utica shale and Hudson River group of the State fall into the same category.

In the preceding statements the organic matter of the bituminous shales has not been positively referred to a vegetable source. Such a source is highly probable, but it can not be said to be fully demonstrated until the origin of the so-called *Sporangites* of the shales is finally determined. There are a few geologists who are inclined to refer these forms to hydroid zoöphytes (animal) rather than, with Dawson, to marine rhizocarps (vegetable). Whatever their origin, they give rise to petroleum and oil of a definite character, which is in marked contrast to that of the limestone oils.

Which of these theories as to the mode and time of origin of petroleum has the most to commend it?

DISCUSSION OF PECKHAM'S THEORY.

The statements under the previous section which refer the petroleum of western Pennsylvania to the destructive distillation of carbonaceous matter in the underlying shales by the heat involved in the elevation of the Appalachian Mountain system will be first considered.

Peckham's theory demands the agency of unusual temperature and directs us "to seek the source of heat action far below the unaltered rocks in which the petroleum is now found."[3]

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[1] Op. cit., p. 69. [2] Ibid., p. 71. [3] Ibid., p. 71.

How far below? If we descend 2,000 or 2,500 feet below the Berea Grit, which is the great repository of oil and gas in eastern Ohio, we reach, on an average, the bottom of the Ohio shale, and this is the only source that we know in our series of oil and gas of the Pennsylvania type. But the drill has repeatedly gone down 2,000 or 2,500 feet below the Berea Grit and not a trace or a hint of metamorphic action is found in the drillings that are brought up. In such drillings from the deep well at Canal Dover, 2,700 feet below the surface and 1,850 feet below the Berea Grit, the microscopic spores that make so characteristic a feature of the black shales were found in normal condition. All observations attest not only the general uniformity of the shale formation throughout the State and at all depths, but also the entire absence of any appearance of metamorphic action.

The same line of facts obtains in regard to the limestones underneath the shales. They have been penetrated to a great depth. The drill in the well of the Cleveland Rolling Mill rested at 3,200 feet below the surface, but the limestones at the bottom of the hole showed no signs whatever of metamorphism. The same is true of all the deep borings of northwestern Ohio. Nearly the whole of the Lower Silurian system has been penetrated there, and new supplies of oil and gas are found in these rocks, but they obviously come from the limestones themselves and differ in a marked degree from the oil and gas of the shales. In Canada, the Trenton limestone bears oil where it is separated by only a stratum of sandstone from the old granitic floor of the continent.

But, in the second place, Peckham demands for oil-production "slow and gentle changes at low temperature."[1] We must again ask for a limit. How low a temperature? Must it not be high enough to agree with the facts of observation and experiment as to the production of gas and oil by the destructive distillation of bituminous shales? The temperature at which such changes are effected in the laboratory will scarcely be placed below 400° Fahr. But the shales could not be brought to this degree without suffering metamorphic change. They contain alkaline solutions in greater or less amount, and both Bischof and Hunt have shown that when such compounds are present they become powerful solvents of silica and silicates at as low a temperature as 212° Fahr. If, then, the temperature had been raised to even 212° Fahr., unmistakable evidences of the fact would have been left in the constitution of the rocks.

But if a lower temperature is proposed than that which we are obliged to use in effecting destructive distillation in the laboratory, we are compelled to ask, on what authority? It is useless to answer that we do not know at how low temperatures this distillation can be effected in nature. This is true, but it is none the less true that if we reason upon the subject at all we must be governed by the

[1] Ibid., p. 70.

facts that our experience affords. Any other way of reaching an answer is assumption, pure and simple.

In the third place, this theory would seem to necessitate a coke or carbonized residue in the rocks which give rise to the petroleum. Inability to point out such a residue seems to have been one of the reasons that led our author to locate the source of the oil-distilling heat at such great depth. He counts a carbon residue a necessity, but he buries the rock from which the petroleum is derived so deep that we can not expect to obtain any direct knowledge of it. As has already been shown, in doing this he drops below the only known source of oil and gas of the Pennsylvania type.

The absence of these residual products constitutes a real difficulty in the way of any distillation theory.

On the whole, then, we are obliged to conclude that Peckham's theory does not harmonize with the facts of geology as found in the great fields of oil and gas, and that it can not be used to explain the origin of the substances whose history we are seeking to trace.

DISCUSSION OF NEWBERRY'S THEORY.

The remaining exposition of the distillation theory must be briefly considered.

Precisely what is meant by the term "spontaneous distillation," as used by Professor Newberry, it is not possible to determine, since his statements are not explicit in relation to all the points respecting which questions would arise. He does not seem to require for oil production any unusual temperature. He speaks of the distillation as "constant" and as going on "at a low temperature." He never uses in these discussions the term "destructive distillation," but those who have criticised his theory have in all instances counted destructive distillation as involved. He sometimes compares the production of natural gas with processes included under the head of destructive distillation, but there are other passages in which he seems to make the term "distillation" cover the ordinary decomposition of organic matter in situations from which the air is mainly excluded.

The latter use of the word is not, however, authorized. Distillation as distinguished from decomposition requires the action of temperatures decidedly above the normal; in fact, there is no process known under the name of distillation by which the substances under consideration can be produced from organic matter in rocks except destructive distillation.

If Professor Newberry's theory involves destructive distillation, the facts and arguments brought forward in the discussion of Professor Peckham's theory will apply to it also without change. If it does not involve destructive distillation, then it requires to be restated and defined anew.

To these statements but one qualification is needed. If it could be shown that under the pressure of great depths and with the normal increase of temperature due to descent the transformation in question could go on, then a basis would be supplied for this phase of the distillation theory; but, so far as known, there are no facts whatever to warrant the belief that such a state of things exists. If instead of distillation this theory should substitute decomposition of organic tissues at ordinary temperatures, without access of air, it would approach the theory of Hunt, that petroleum is due to the primary decomposition of organic matter.

DISCUSSION OF HUNT'S THEORY.

There is much to be said in favor of Hunt's theory that petroleum originates in the primary decomposition of organic substances, but his restriction of oil production to limestones must be discarded, of course, and just why the process should be made to terminate with the formation of the rock is not apparent. We know that vegetable substances may remain unchanged when buried in the earth for long periods, and so long as they are present in unchanged state they would seem to be available for the process here appealed to.

Hunt denies that the so-called bituminous shales, "except in rare instances, contain any petroleum or other form of bitumen."[1]

This statement is wide of the mark so far as the Ohio shale is concerned. It is to be regretted that quantitative examinations have not been made as to this point, but either gas or oil or both are unmistakably present throughout our great shale series, and especially in the black bands that traverse it. Whether taken from the natural outcrops or the deepest drillings, every fresh sample of the black shale attests by the characteristic odor the presence of these substances. In drilling through the shale along the shore of Lake Erie in particular the gas is generally found in some harder portion of the light-colored bands that compose so large a portion of the series, each harder cap or "shell" giving a new though short-lived supply; but the real source of the gas becomes apparent if the drill descends a little lower than the gas-producing "shell," when a darker band is almost invariably reported.

Newberry states the facts bearing upon this supply in the passage already quoted (p. 492), and Shaler sets the same line of facts in strong light in his discussion of the Ohio shale in Kentucky.[2]

But the limestone series of Ohio is in very much the same condition as the shale, so far as oil and gas are concerned. These substances are present in nearly all the limestone formations of the State, and apparently indigenous to them.

The Corniferous limestone, the first to be reached below the Ohio

[1] Chem. and Geol. Essays, p. 169.

[2] Geol. Survey Kentucky, vol. 3, new series, 1877, p. 109, bottom pagination.

shale, in some of its fields and in certain courses contains representatives of this class of substances. The Point Marblehead limestone of Ottawa County is classed[1] as "bituminous dolomite." It gives out a bituminous odor when struck with a hammer. And other portions of this limestone stratum are much more bituminous than the Point Marblehead stone.

The Waterlime or Lower Helderberg formation that comes next below is decidedly bituminous. It contains grains of asphalt in cavities in the rock and carbonaceous films that have had the same origin, distributed through its substance. When struck with a hammer it gives out the fetid odor of "limestone oil." Bowlders of it in the drift can be distinguished by this means from all associated limestones except a part of the Corniferous. In Auglaize County this stone becomes an asphaltic limestone, the bituminous element rising to a notable percentage. In other parts of the State also the amount of asphalt is so great that it is counted a decided advantage in the calcination of the stone for quicklime.

The Niagara limestone, as a whole, is less bituminous than the Helderberg, but there are parts of it, as in portions of Highland County, that contain a considerable amount of these products, mostly in the shape of asphaltic films and grains. Fossil corals are often partially occupied by this asphalt, and petroleum is sometimes found in small amount.

The Clinton limestone is decidedly petroliferous in almost all its outcrops. It yields oil in small amount at many points where quarries are opened, and springs that issue from it carry out small quantities of oil. These facts led in the oil excitement to the drilling of several deep wells along its line of outcrop. By the time the drill was buried in the rock this source of oil was passed and the remainder of the descent was marked by little encouragement.

Small deposits of asphalt have been found under convex surfaces of the Dayton limestone, just above the Clinton stratum, the asphalt being obviously derived from an inspissation of the oil of the latter formation.

The limestones of the Cincinnati group always contain bituminous matter in their outcrops, but when penetrated by the drill they have not yielded at any point large supplies of oil or gas. Short-lived flows, however, have been frequently reported from this series in northern, central, and southern Ohio.

The Trenton limestone, which has a very limited outcrop in the State, but which underlies much, and perhaps all, of its surface, by means of explorations with the drill during the last three years has been proved to be frequently a source of oil and gas. In northwestern Ohio it has given rise to an abundant supply of high-pressure gas at several localities, and also to oil wells, which have yielded in one

[1] Peckham, op. cit., p. 80.

instance 5,000 barrels of petroleum in a single day. The drill has penetrated at least 550 feet of this limestone series and all portions of it have been found petroliferous, but the only accumulations are found at the surface of the stratum.

The limestones and the shales of our geological series are thus seen to agree in these respects. Both of them carry petroleum through all of their substance, and the product of each class has its own characteristics. In other words, these supplies appear to be indigenous to the rocks of both groups.

Hunt's theory as to the petroleum in these limestones is that it was formed in them at the time the beds themselves were formed, by a peculiar transformation of vegetable matters, or in some cases of animal tissues, analogous to them in composition.[1] This is vague, it is true, and the stress probably is laid on the wrong element so far as the limestone oil is concerned; but why shall it not be extended for what it is worth to the other section of our rocks in which petroleum occurs under precisely similar conditions? If there is good reason for believing in the contemporaneous origin of oil and rock in the limestones, and if there is advantage to be derived from the doctrine as applied to them, the same reason will be found to exist in the case of the shales, and they should be allowed the same advantage.

The advantage that can perhaps be rightly claimed for this theory is that, in referring oil and gas to the primary and not to the secondary decomposition of organic matter, it rests upon processes which are known to be in present operation in the world.

Reference was made on page 490 to Wall's report on the Trinidad asphalt. A remarkable passage occurs in this report, which bears directly on the question before us. It is as follows:[2]

> When in situ, it [the asphalt] is confined to particular strata, which were originally shales containing a certain proportion of vegetable débris. The organic matter has undergone a special mineralization, producing bituminous in place of ordinary anthraciferous substances. This operation is not attributable to heat, nor of the nature of distillation, but is due to chemical reaction at the ordinary temperature and under the normal conditions of the climate. The proofs that this is the true mode of generation of the asphalt repose not only on the partial manner in which it is distributed in the strata, but also on numerous specimens of the vegetable matter in process of transformation and with the organic structure more or less obliterated. After the removal by solution of the bituminous material, under the microscope a remarkable alteration and corrosion of vegetable cells becomes apparent, which is not presented in any other form of the mineralization of wood. . . . . . .
>
> Sometimes the emission is in the form of a dense, oily liquid, from which the volatile elements gradually evaporate, leaving a solid residue.

Wall's testimony is confirmed by other authorities.[3]

Petroleum rapidly hardening into asphalt is also recorded as oc-

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[1] Canadian Nat., vol. 6, 1861, p. 241, 242.

[2] Quart. Jour. Geol. Soc. London, vol. 16, 1860, p. 467.

[3] Hunts' Chem. and Geol. Essays, p. 177.

curring in some of the small tributaries of the Coaxocoalcas River in Central America. The petroleum seems to arise from the decomposition of vegetable remains with which certain beds of shale are stored.[1]

If Wall's statements are correct—and they bear the marks of intelligent and discriminating observation—the facts are as follows: Beds of shale, formed in comparatively recent times beneath the sea, but now raised above its level, containing in abundance vegetable remains brought down by the Orinoco River, near the mouth of which Trinidad is situated, are yielding petroleum in large amount by a direct decomposition of vegetable tissues, and the petroleum rapidly passes into asphalt, inasmuch as it is exposed directly to the atmosphere. There are some recent accounts, however, of the Trinidad asphalt which speak of a temperature of several hundred degrees C., as observed in the center of the Pitch Lake.

At how great a depth in the rocks these changes are going on we have no observation to show, but no reason is apparent why these phenomena should be superficial. In subsiding areas—and almost all river deltas are such—the beds containing vegetable remains may be buried to a considerable depth before the decomposition can be fully effected, especially if the buried substances consist of the more durable vegetable products. In such a case we might expect the resulting petroleum to remain stored in the shale where it originated.

Why the phenomena of oil production have been generally reported from shales and not from sandstones has not been explained. The difference between the two formations in this respect may be in part due to the fact that the shale seals up the vegetable matter more perfectly than the sandstone. In the latter ordinary decomposition would seem to have a better chance to go on.

Another fact to be noted in this connection is the affinity of clay for oil of all sorts. Illustrations of this affinity are familiar to every one, but an observation by Prof. Joseph Leidy, made a number of years since, is especially noteworthy. He observed that on the bed of the Schuylkill River, for some distance below the Philadelphia Gas Works, a deposit of clay, impregnated with the petroleum-like oils that are produced in the manufacture of coal gas, was in process of formation. These oily substances which would otherwise be found on the surface of the river are absorbed by the particles of fine clay in the water and gradually sink to the bottom with them, thus forming a petroliferous clay on the river bed.

If petroleum arising in such springs as occur in Central America and South America had found its way by rivers to lakes or seas or had been liberated from sources beneath the sea, the same results

[1] The Isthmus of Tehuantepec; by J. J. Williams; New York, D. Appleton & Co., 1852, p. 169.

would have followed. It would have been absorbed by the fine particles of clay held in suspension in river and sea, and the combined clay and oil would have been gradually carried downwards to rest on the sea floor as an oil-bearing shale.

From the fact that all of the chief bituminous accumulations of recent age belong to the torrid zone, it seems necessary to conclude that a tropical climate or a climate of 80° Fahr. at least is most favorable, if not essential, to a large production of this class of bodies. The main asphalt deposits of commerce are found about the southern and western shores of the Gulf of Mexico.

The asphalt of Trinidad, which seems to be in constant process of formation, is derived from shales that belong to the later Tertiaries, and, though derived from the most recent of all rocks that precede the present geological age, it must still be separated from our time by a considerable interval. If, then, the formation of petroleum is made contemporaneous with the rock that contains it, it must be a geological contemporaneity that is meant, in which events that may be separated from one another by many thousands or even tens of thousands of years are counted contemporaneous.

But if petroleum is a result of the primary decomposition of vegetable tissue, what is there to hinder these processes of petroleum formation from going forward? So long as vegetable matter remains undecomposed in the rocks, and so long as the conditions as to temperature and pressure remain favorable, why limit them to the time of rock formation?

It would seem that in the vast periods that have elapsed since the Paleozoic era there would have been time enough and to spare for all of these changes to be accomplished and that the process would be necessarily arrested either for want of material or for lack of proper conditions.

The essential point in Hunt's theory of the origin of petroleum is, not that it was produced contemporaneously with the rock nor that it is especially a product of limestones, but that it results from the primary decomposition of organic substances. Discarding these incidental elements of the theory and applying its central postulate to the explanation of the origin of the petroleum of eastern Ohio and of Pennsylvania, we can see what some of the steps in the history must have been.

The shales which constitute its chief source were accumulated in a tropical sea. The Devonian limestone, which immediately preceded them in time, bears witness to most genial conditions of climate. Its massive corals required at least as high an annual temperature as is found in any part of the Gulf of Mexico to-day.

The sedimentary deposits that were laid down on the floor of this Devonian sea consisted of clay and sand with occasional gravel bars, the sources of which must be sought in the rising Atlantic border or in the Canadian highlands, as is proved by all the deposits thickening and growing coarser in those directions. To the western limit of this sea, along the shores of the emerging Cincinnati uplift, only fine clay was borne, and this fine and homogeneous material accumulated very slowly, one foot requiring as much time as ten or twelve feet of the coarser and more varied series to the eastward.

In these seas, as we know, there was a vast development of marine vegetation. Some plants of rhizocarpean affinities were especially abundant, and their resinous spores and spore cases, which constituted by far the most durable portions of the plants, were set free in enormous quantities. Even now, in some parts of the series, these spores constitute a notable percentage of the shale. In structure and composition they are but little changed from their original condition. Other portions of this and like vegetation may have been carried to the sea floor in a macerated condition and have there passed through the coaly transformation, resulting in the structureless, carbonaceous matter that constantly characterizes the black shales. This carbonaceous substance can still be made to yield the members of the bitumen series through the agency of destructive distillation, and, doubtless, so also can the spores that remain unaltered in the shales, each leaving a carbon residue.

The shales that were slowly accumulating on the floor of this tropical gulf, thus charged with vegetable remains, must have behaved as similar shales do around the borders of the present gulf. The vegetable matter was turned into petroleum as it is in Trinidad and the West Indies now. The petroleum would have been absorbed by the particles of clay in contact with which it was originated, or, if liberated in the water, it would there have been laid hold of by the like floating particles of clay to be carried with them in due time to the sea-floor, and the work would have gone on until the material was exhausted or the requisite conditions were lost.

The resulting stratum of bituminous shale would have been much more highly charged with petroleum than any portion of these shales is at the present time. Over it at last a bed of sandstone is deposited, which in turn is roofed in by another fine-grained shale. The pores of the sandstone are occupied by sea-water, but a slow system of exchanges would be established between the rocks by which at last petroleum would be gathered into its final reservoir. The presence of petroleum in considerable amount in a shale might give it a measure of permeability.

Such would appear to be some of the steps in the production of petroleum, if Hunt's view of its origin by the primary decomposition of organic tissue is adopted. The results would correspond fairly well with those of the spontaneous distillation theory already discussed. Both would find the petroleum distributed through the substance of the shales, and both would expect its constant escape from outcrops of producing shale or sandstone reservoir. Continuous origination is by no means a necessary conclusion from continuous outflow.

The advantage that Hunt's theory has over others is that it seems to find more support in the processes of nature at the present time. We find the bitumen series in actual process of formation in many parts of the world, resulting apparently from the primary decomposition of organic matter, under normal conditions. On the other hand, we do not find this series, in any cases which are open to observation and subject to measurement, resulting from secondary decomposition of carbonaceous matter contained in the rocks, unless the comparatively high temperatures of destructive distillation are reached.

The several views as to the origin of petroleum that seem most to deserve attention have now been fairly stated. Some liberty has been taken with the last named in the way of removing limitations, but no new theory has been broached and no real contribution to our knowledge of these very interesting questions is claimed. In subjects which tempt speculation as much as those which are now under discussion, it is well to know the opinions that are most entitled to respect, even where grounds of positive knowledge are wanting. How little real knowledge we have of this subject has been made to appear in this brief review, and it is safe to conclude that until the boundaries of our knowledge are considerably extended every theory in regard to the origin of petroleum should be held as provisional only.

The theoretical views that we hold as to the origin of petroleum will influence our judgment as to the duration of its supply. The question is often asked whether there is any provision in nature by which the supplies that are now drawn upon or exhausted can be renewed. It is to be observed that in the several theories passed in review only the discarded chemical hypotheses hold out any promise of a perennial supply. Of the three views from which most people will feel compelled to make their choice, two answer emphatically in the negative the question raised above and the remaining theory gives in reality no more encouragement. Newberry's theory makes the process of oil formation a continuous one, it is true, but it extends it through such vast cycles of time that one thousand years or ten thousand years would not constitute an important factor. In other words, the reservoirs that we are now piercing with the drill and that are yielding such vast and valuable stores of light and power would have yielded in all probability about the same supply one thousand or ten thousand years ago.

Practically the stock is now complete, as much so as the contents of coal mines and mineral veins. As a result of our interference with natural conditions, small local movements of oil or gas may go on in the rocks, but these would be but insignificant exceptions to a general rule that the reservoirs hold all the oil and gas that they will ever hold, and that, when once exhausted, they will never be replenished.

Gas and oil have been considered together in all the preceding discussions, as if the history of one would cover the history of the other also. There are, however, speculations which dissociate them in origin. By some, gas is counted the first and original product, and it is supposed to be converted into petroleum in the sandstone reservoirs by some unknown process of condensation.

This belief, like those that have preceded it, does not admit of final and definite confirmation at the present time, but chemical probabilities do not seem to favor it. Petroleum is more composite and unstable than gas, and in these respects it seems to stand at less remove from the organic world. A large percentage of natural gas is light carbureted hydrogen, one of the simplest and most stable products of decomposition. Petroleum readily gives rise to marsh gas, when subjected to destructive agencies, but we have no known experience in which the higher compound results from synthesis of the lower. It seems, therefore, safe to count petroleum first in the order of nature.

A few words remain to be said under this head upon another branch of the subject. In the preceding discussions shale and limestone have been considered the chief sources of petroleum, although, as is well known, sandstones are the direct source of the great supplies. There are some who hold that these supplies originate in the sandstones which now contain them. This view may be urged with plausibility, at least for such sandstones as Lesley describes in eastern Kentucky, or as I. C. White finds the Le Bœuf sandstone to be; but the Berea Grit, which is the main oil sand of Ohio, is singularly free in most of its outcrops from all traces of vegetation. The claim at the best has many weak points, as is well shown by J. F. Carll.[1] Speaking of the Venango sands, he says:

> We find that the largest wells are those which are sunk through the coarsest part of the oil-bearing sand rock. The drillings show nothing but coarse sand and pebbles. Pieces of the unpulverized rock, one or two cubic inches in bulk, are often brought up after torpedoing, but nothing can be detected in them that could possibly originate petroleum. Could a rock of this character have originally contained a quantity of organic matter sufficient to yield a cubic foot of oil to every ten or twelve cubic feet of rock and those organic remains be so completely converted into oil as to leave no residual trace of their existence?

With these questions and suggestions, and many others in the same line, he shows the difficulties of this view.

[1] 2d Geol. Survey Pa., Report of Progress, III, 1880, p. 272.

SUMMARY.

In concluding this chapter, a few of the previously stated propositions in regard to the origin of petroleum that seem best supported will be concisely summarized:

(1) Petroleum is derived from organic matter.

(2) It is much more largely derived from vegetable than from animal substances.

(3) Petroleum of the Pennsylvania type is derived from the organic matter of bituminous shales and is of vegetable origin.

(4) Petroleum of the Canada and Lima type is derived from limestones and is of animal origin.

(5) Petroleum has been produced at normal rock temperatures (in Ohio fields) and is not a product of destructive distillation of bituminous shales.

(6) The stock of petroleum in the rocks is already practically complete.

CHAPTER II.

MODES OF ACCUMULATION.

In preceding pages petroleum has been shown to be widely distributed in the rocks of Ohio. The limestones and shales of the series, in particular, everywhere contain it. Hunt has made a calculation showing the amount of petroleum which the oil-bearing dolomite of Chicago holds to the square mile for every foot in thickness of the stratum.[1] If we apply a like calculation to the rocks of the Ohio scale we shall find the total amount of oil enormously large. We may take, for example, the Waterlime stratum, which is notably and almost universally petroliferous. Estimating its petroleum contents at one-tenth of one per cent., and the thickness of the stratum at 500 feet, both of which estimates are probably within the limits, we find the petroleum contained in it to be more than 2,500,000 barrels to the square mile. The total production of the great oil field of Pennsylvania and New York to January, 1885, is 261,000,000 barrels. It would require only three ordinary townships, or a little more than one hundred square miles, to duplicate this enormous stock from the Waterlime alone. But if the rate of one-tenth of one per cent. should be maintained through a descent of 1,500 feet at any point in the State, each square mile would, in that case, yield 75,000,000 barrels, or nearly one-third of the total product of the entire Pennsylvania and New York oil fields. These figures pass at once beyond clear comprehension, but they serve to give some idea of the vast stock of petroleum contained in the earth's crust. If petroleum is generally distributed through a considerable series of rocks in any appreciable percentage it is easy to see that the aggregate amount must be immense. Even one-thousandth of one per cent. would yield 750,000 barrels to the square mile in a series of rocks 1,500 feet deep, but this amount is nearly equal to the greatest actual production per square mile of any part of the leading Pennsylvania fields. It is obvious that the total amount of petroleum in the rocks underlying the surface of Ohio is large beyond computation, but in its diffused and distributed state it is entirely without value. It must be accumulated in rocks that serve as reservoirs before it becomes of economic interest. In respect to the importance of concentration it agrees with most other forms of mineral wealth.

[1] Chem. and Geol. Essays, p. 173.

COMPOSITION AND ORDER OF SEQUENCE OF PETROLEUM-BEARING ROCKS.

SANDSTONES AS RESERVOIRS.

The drillers in Venango County, Pa., in 1859, were not long in learning the facts as to the composition and order of arrangement of the series from which petroleum was obtained. Beginning in the valley of Oil Creek, it was found that the drill first descended through several hundred feet of soft and fine-grained shales, after which a series of sandstones, imbedded in shale, was passed through. These sandstones were three in number when the series was complete, and from the upper surface of the uppermost member to the bottom of the lowest the interval was about three hundred and fifty feet. It was at once learned that the petroleum for which the drilling was undertaken was confined to these sandstones, which accordingly took the name of "oil sands," first, second, and third, named in order from above. When all three were found in the well section the oil was confined to the third or lowermost, but the gas was sometimes found in the second or even in the first. When the third oil sand was wanting the second became the receptacle of the oil and gas, and when both the second and third were wanting the stock was found in the first. The important fact thus came to light that the first sandstone to be reached in ascending order from the bottom of the series was the oil-containing stratum. The rocks below the oil sand were found at a somewhat later period to be gray or dark shales.

The Venango "oil sands" proved to be sandstones of medium or coarse grain, or even in some cases conglomerates. The third or lowermost sand in particular often assumed this phase, containing quartz pebbles in abundance. These sandstones were considered, in the course of the development of the field, to be elongated bars of sand or pebbles, their longer axes extending in a northeasterly and southwesterly direction. The productive fields were found to extend in length for a score or more of miles in some cases, while their width would be confined to one or two miles. In thickness, the oil sands ranged from a shell to one hundred feet. Some of them are described as having no outcrop, never rising to the surface in the characters which they are found to possess when deeply buried.

Under the interpretation of the oil sands given above, which is substantially that of Carll, these oil-containing reservoirs are seen to be lenticular in transverse section. It is in any case certain that the productive belts showed the relations named above, and, further, that production was related in a very definite way to the grain and thickness of the oil sands. The coarser and the more open the sand the greater the amount of oil, and, in like manner, the thicker the stratum the larger was its production likely to be, other things being equal.

It must be noted, however, that all the facts presented by such a field can be explained without supposing the oil rocks to be ancient sand bars or submarine gravel ridges. Sandstone strata, with an ordinary measure of continuity, under certain accidents of structure or arrangement, could present just such phenomena as we are called on to explain. In fact, the sand-bar theory does not apply at all to the oil production of Ohio. We find the oil and gas of eastern Ohio in a stratum of sandstone that rests on shales and that is covered by them, but the stratum, so far from being lenticular in character, is wonderfully persistent, though varying in thickness and grain from point to point, and occasionally nearly disappearing for a short space. It was also learned that the roof shales were not altogether impervious, but that oil, and especially gas, found their way upward through them, furnishing the so-called "surface indications." The thickness of the cover was found to be a factor in oil production to a certain extent, the large accumulations seldom being found under light cover.

The first drillers in Venango County took possession of the valleys, supposing the production of oil confined to them, but later comers began to try fortune on the slopes adjacent, and little by little the drilling rigs overran highlands as well as valleys. The fact was soon made apparent that the only probable advantage possessed by the valleys was the shorter distance to be drilled to reach the oil sand.

The wells drilled on the uplands revealed the presence of other sandstone strata, lying many hundred feet above the oil sands. To these new strata the name of "mountain sands" was given, and three of these also were enumerated, viz, the first, second, and third mountain sands. Petroleum and gas were sometimes found in these strata to a small extent.

The order that was thus ascertained to exist among the different strata penetrated by the drill in the valley of Oil Creek at the beginning of petroleum production on the large scale in this country has proved to be the universal order in the oil and gas fields of Pennsylvania, New York, and eastern Ohio. In all of these fields, without important exception, sandstones buried in shales have proved to be the reservoir of oil and gas when the latter are found in large quantity. The overlying shale is the cover or roof of the reservoir; the underlying shale appears to be the source from which the bituminous products are derived. We can count on this as the established and essential order for oil and gas accumulation in the territory already named. Several distinct sets of oil-producing sands have been brought to light besides the Venango, the most important of which are the Warren and the Bradford sands, both of which underlie the Venango system.

The three elements that constitute an oil-bearing group may exist by themselves, as in the Venango field, already described, or they may be buried under hundreds or even thousands of feet of superincumbent strata. In the latter case several distinct oil and gas horizons may be traversed in a single well section, but each one will consist of the three elements named—cover, reservoir, and source.

LIMESTONES AS RESERVOIRS.

In the cases less frequent where large accumulations of oil and gas are found in limestones instead of in sandstones, the conditions vary somewhat from those just described. The shale cover is still an essential element, but the reservoir and the source of oil and gas are apparently blended in one common rock. The best examples of this sort of production are derived from the fields of northwestern Ohio, where at a depth of eleven hundred to twenty-two hundred feet the Trenton limestone is struck. It is covered by four hundred to one thousand feet of shales, viz, the Utica, the Hudson River, and the Medina shales, named in ascending order. The various limestones of the underlying series have been penetrated for 1,800 feet without being exhausted. The Trenton limestone itself is several hundred feet thick. Through most if not all of its extent it is petroliferous, as is shown by the drillings, but the accumulated stocks of both oil and gas are always found in the uppermost beds of the stratum and generally not more than twenty or thirty feet below its upper surface. The fragments of the oil-bearing rock that are brought out after the use of torpedoes in the wells are found to be quite porous. The cause of this porosity is to be considered in a later chapter.

The oil rock carries, at a lower level than that in which the oil is found, but sometimes dangerously near, a brine of unusual character. It has in fact the composition of a bittern or a water left over from the concentration of ordinary brine. It contains unusual quantities of chlorides of calcium and magnesium.

The facts as to the occurrence of the oil and gas in this stratum seem reconcilable with the theory that they have risen slowly through the limestone rock until they find storage in a porous stratum. A further ascent is forbidden by the overlying shale, and their accumulation therefore takes place at this point. There is certainly nothing like the sand bars or gravel ridges that are proposed as explanations of the Pennsylvania fields in this oil-producing stratum, so far as its composition is concerned.

PERMEABILITY OF THE RESERVOIRS.

The fact that different portions of the oil sands communicate with one another with more or less freedom was early established in the history of oil production in Pennsylvania. Adjacent wells were often found to affect one another's yield, and the location of wells at once began to be governed by this fact. Wells were especially multiplied along boundary lines, with the selfish purpose of obtaining oil from the lands of others and in the attempt to protect rights of ownership against unjust invasions.

The descent of surface water into the oil sands through abandoned wells proved disastrous to entire fields and it became necessary to invoke stringent legislation to guard against this source of danger by requiring wells to be securely plugged before being abandoned. In these various ways it came to be seen that there was a fairly free communication through the oil sands, at least in some cases, for intervals of one or more miles. So, also, in thick and gently dipping strata like the Bradford oil sand the division of the rock into gas, oil, and salt-water territories, respectively—the gas holding the highest and the salt water the lowest levels—made the conclusion well nigh irresistible that the entire rock is permeable, and that in the course of ages its various contents have been differentiated, as we now find them, under the influence of gravitation.

On the other hand, it became equally clear that there was no necessary and absolute connection between different portions of an oil sand, but that in many instances this stratum exists in lenticular masses, the several divisions of which may be nearly or even entirely disconnected. This conclusion is based on the facts that contiguous wells often show no connection with each other and that in what are supposed to be exhausted oil fields small pockets of sand are sometimes subsequently discovered that furnish considerable supplies of oil. The rapid changes in thickness of the oil sands in adjacent wells furnishes conclusive proof upon this point. We can follow the stratum down to a feather edge by these records. The facts which have been collected from the Pennsylvania field by Mr. John H. Carll are conclusive as to this point.

In oil sands of moderate thickness, as the Berea Grit, which generally ranges in Ohio between five and twenty-five feet through large areas, these interruptions more frequently occur. There are no facts known in Ohio which show a continuity in this stratum that allows the differentiation of its contents after the fashion and on the scale of the Bradford oil sand. Communication through a few square miles of the rock can be occasionally inferred, but beyond this we have thus far no warrant for going.

We have fewer facts in regard to the limestone reservoirs, but it is doubtful whether the same freedom of communication obtains here as in the sandstones that we have been considering. As free communication can scarcely be expected through a porous limestone as through a sandstone of equal dimensions where the latter has the open structure so often found in the oil fields. The gas wells of Findlay, however, affect one another noticeably. The release of the gas in the famous Karg well has brought about an increase of oil production with a diminution of gas in several of the nearest wells.

RELATIVE IMPORTANCE OF THE ELEMENTS OF AN OIL SERIES.

Of the three elements already named as essential to oil production, viz, cover, reservoir, and source, it is obvious that the last is the fundamental element; but inasmuch as the sources of petroleum in our rocks are so nearly universal, less importance attaches to it than to the other two. Furthermore, as rocks of various grain can be made to receive and to retain these accumulations, more interest centers in the roof shales or cover than in any other part of the system. There can be no large accumulation without an approximately impervious roof. A considerable deposit of shale at any point in the geological series of Ohio is very likely, in fact, is almost certain, to cover an oil rock. For example, the great beds of shale just named cover the Trenton limestone, which is now proved to be at various points a source of high-pressure gas and oil. The Niagara shale is in many parts of the State a moderately heavy deposit, and the Clinton limestone directly below it is very often notably petroliferous. The Ohio shale covers the Corniferous limestone, and small deposits of oil are known in this stratum in Ohio and in adjacent States.

The Cuyahoga shale makes the cover of the Berea Grit, and this, as is well known, is the main oil and gas rock of all eastern Ohio. Whenever the Logan conglomerate is roofed with shale it also becomes petroliferous or gas-bearing. Numerous examples of oil and gas production from this horizon were furnished by the early salt wells of the Muskingum Valley. Throughout the Coal Measures there are not less than four sandstones roofed with shales that are found at times petroliferous.

From facts like these it is apparent that the composition and order of arrangement of a series of strata have a vitally important relation to the accumulation of oil and gas that may take place within it. Some geologists count the composition of the series the main element in oil production. They regard especially the grain and thickness of the oil sand or reservoir, accounting largely for the difference in production of different fields or of different parts of the same field by the character of the oil sand. As already stated, the practiced driller also makes great account of these facts. John F. Carll has discussed these questions at length in his invaluable reports on the petroleum fields of western Pennsylvania. He holds that an oil-bearing pebble rock under favorable conditions may contain one-tenth or even one-eighth of its bulk in oil, basing his belief upon the indications of experiments made upon the rock.[1] He also shows that the pores of the sandstone would serve as channels for the largest supplies of oil that have yet been found and that we are under no necessity of resorting to hypothetical "crevices" to account for any of the facts pertaining to the yield of oil wells. Mr. Carll lays special

[1] Second Geol. Survey Pa., Report of Progress, III, pp. 251, 253.

stress upon the character of the oil sand, and in this respect Professor Lesley and Mr. Ashburner seem to agree with him, while Prof. I. C. White, also of the Second Pennsylvania Survey, urges the paramount importance of another element, especially in gas accumulation. This element will be next considered.

EFFECT OF DISTURBANCES OF STRATA UPON THE ACCUMULATION OF OIL AND GAS.

This subject is one which has been discussed ever since the discovery of petroleum and gas in this country on a large scale. Definite theories as to the influence of such disturbances as have occurred in the oil-producing territory were early propounded, and some of them have been maintained to the present day. Prominent among them is the so-called anticlinal theory, which takes account of the low arches or folds that have traversed some portions of the oil-producing districts and especially of West Virginia and southern Ohio.

EARLIER STATEMENTS OF THE ANTICLINAL THEORY.

The "oil-break" of West Virginia, in the neighborhood of Burning Springs, in the early days of the search for petroleum, furnished a striking example of the effect of structural disturbance on oil production. There is an uplift there which is both considerable and conspicuous, viz, the White Oak anticline, and the productive oil wells out of the great number of wells drilled in this region were found to be strictly confined to the region of the anticline or axis. These facts were brought out in a very clear manner by the late Prof. E. B. Andrews.[1] The discovery of the axis in its relation to oil production seems to have been made by General A. J. Warner, associated with Professor Andrews in 1865. Beyond the structural disturbance shown in the anticline, Professor Andrews also counted necessary the existence of crevices or fissures on the large scale in rocks from which the oil was derived. To effect the separation of water, oil, and gas in the supposed crevices, he invoked the force of gravitation, showing that these substances would necessarily be arranged in the order of their densities in any space which they might occupy in common.

The clew that was thus given to the location of successful wells was of course promptly followed. The anticline was traced throughout its entire extent and test wells were put down at numerous points, but of these a large percentage failed. To account, if possible, for these failures, Mr. F. W. Minshall, of Parkersburgh, W. Va., undertook at a later date a careful determination of the levels of the axis. He found that, instead of either keeping a horizontal plane or of dipping regularly and uniformly, the axis advanced by a series of pro-

[1] Am. Jour. Sci., 2d series, vol. 32, 1861, p. 85.

nounced undulations, having domes or summits at some points and sinks or sags at others. All of the productive oil and gas wells had been located on the domes and the failures were to be found in the depressions.[1]

Dr. T. Sterry Hunt, in 1863, a still earlier date, maintained that the petroleum supply of western Ontario was all derived from the line of a low and broad anticline which runs through the district in a nearly east and west direction. He distinctly taught that the anticlinal structure is a necessary condition for a large production of petroleum, referring its accumulation in such portions of the series, of course, to hydrostatic laws.[2]

Dr. Newberry seems also to accept the anticlinal theory, though his statements on this point are less explicit than those already quoted. Speaking of the Canada oil field,[3] he says:

This district is in the line of the Cincinnati arch, which here, as in the islands of Lake Erie, shows evidence of disturbance long subsequent to its original upheaval.

In speaking of the Pennsylvania oil fields, he says:[4]

These strata have all felt the disturbing influence of the forces which raised the Allegheny Mountains. Here, then, we have a peculiar geological substructure, such as is especially favorable to the production and accumulation of petroleum, and such as must be more or less perfectly paralleled elsewhere to make productive, or at least flowing, wells possible. This structure consists in a great mass of carbonaceous strata below, more or less disturbed and loosened, from which the oil is supplied in a constant and relatively copious flow; above this, strata of porous, jointed sandstone, serving as reservoirs where the constant product of oil and gas may accumulate for ages; still higher, argillaceous strata, impervious in their texture and not capable of being opened by fissures, forming a tight cover which prevents their escape.

Elsewhere he says:[5]

The facts I have observed lead me to conclude that the disturbed condition of the strata in certain districts east of Ohio is the cause of the phenomena which they present. Where the oil and gas producing rocks and those overlying them are solid and compact . . . the escape of the resulting hydrocarbons is almost impossible. Where they are more or less shaken up . . . reservoirs are opened to receive the oil and gas, and fissures are produced which serve for their escape to the surface. Near the Alleghanies all the rocky strata are more or less disturbed, and here along certain lines the liquid and gaseous hydrocarbons are evolved in enormous quantities. As we come westward, however, we find the rocks more undisturbed and the escape of oil and gas, through natural or artificial orifices, gradually diminished.

This reasoning, as will be seen, is in harmony with the anticlinal theory. From the statements already quoted it is shown that distinct theories and claims have been advanced during the last twenty years connecting the accumulation of oil and gas with anticlinal structure.

[1] Peckham, op. cit., pp. 49–52.
[2] Am. Jour. Sci., 2d series, vol. 35, 1863, pp. 157–171.
[3] Geol. Survey Ohio, Geology, vol. 1, p. 159.
[4] Ibid., p. 160.
[5] Ibid. p. 193.

THE ANTICLINAL THEORY AS SPECIALLY APPLIED TO GAS WELLS.

Within the last two years, since natural gas has attained such prominence in Pittsburgh, its sources and the conditions of its occurrence have been studied anew with sharpened inspection by both geologists and practical men, and some real advance seems to have been made in our search. The anticlinal theory has been revived and extended, and has been used successfully in the location of many productive wells. For the new statement we are indebted to Prof. I. C. White, of the University of West Virginia, recently of the Pennsylvania Geological Survey but now connected with the U. S. Geological Survey. Professor White, in turn, was aided by a suggestion from Mr. William A. Earsenian, an oil operator of many years' experience, who had noticed that the principal gas wells then [1883] known in western Pennsylvania were situated close to where anticlinal axes were drawn on the geological maps. From this he inferred there must be some connection between the gas wells and the anticlines. Professor White goes on to say :[1]

After visiting all the great gas wells that had been struck in western Pennsylvania and West Virginia, and carefully examining the geological surroundings of each, I found that every one of them was situated either directly on, or near, the crown of an anticlinal axis, while wells that had been bored in the synclines on either side furnished little or no gas, but in many cases large quantities of salt water. Further observation showed that the gas wells were confined to a narrow belt only one-fourth to one mile wide, along the crests of the anticlinal folds. These facts seem to connect gas territory unmistakably with the disturbance in the rocks caused by their upheaval into arches, but the crucial test was yet to be made in the actual location of good gas territory on this theory. During the last two years I have submitted it to all manner of tests, both in locating and condemning gas territory, and the general result has been to confirm the anticlinal theory beyond a reasonable doubt.

But while we can state with confidence that all great gas wells are found on the anticlinal axes, the converse of this is not true, viz, that great gas wells may be found on all anticlinals. In a theory of this kind the limitations become quite as important as, or even more so than, the theory itself; and hence I have given considerable thought to this side of the question, having formulated them into three or four general rules (which include practically all the limitations known to me up to the present time that should be placed on the statement that large gas wells may be obtained on anticlinal folds) as follows:

(*a*) The arch in the rocks must be one of considerable magnitude; (*b*) a coarse or porous sandstone of considerable thickness, or, if a fine-grained rock, one that would have extensive fissures, and thus in either case rendered capable of acting as a reservoir for the gas, must underlie the surface at a depth of several hundred feet (five hundred to two thousand five hundred); (*c*) probably very few or none of the grand arches along mountain ranges will be found holding gas in large quantity, since in such cases the disturbance of the stratification has been so profound that all the natural gas generated in the past would long ago have escaped into the air through fissures that traverse all the beds. Another limitation might possibly be added which would confine the area where great gas flows may be obtained to those underlaid by a considerable thickness of bituminous shale.

[1] Science, vol. 5, pp. 521, 522.

Very fair gas wells may also be obtained for a considerable distance down the slope from the crest of the anticlinals, provided the dip be sufficiently rapid, and especially if it be irregular or interrupted with slight crumples. And even in regions where there are no well-marked anticlinals, if the dip be somewhat rapid and irregular, rather large gas wells may occasionally be found, if all other conditions are favorable.

To some of these statements Mr. C. A. Ashburner takes exception.[1] He says:

Professor White's theory that "all great gas wells are found on the anticlinal axes" can not be accepted until he shall limit, by definition, all great gas wells to exclude all gas wells, both large and small, comparatively, which produce gas from strata not found either on anticlinal axes or in close proximity to such structural lines. The Kane gas wells, the Ridgeway well, the "Old Mullin Snorter," and several Bolivar wells are notable instances among many which might be mentioned where large gas wells have been drilled in or near the center of synclines.

Although it is a fact that many of our largest Pennsylvania gas wells are located near anticlinal axes, yet the position in which gas may be found and the amount to be obtained depend upon (*a*) the porosity and homogeneousness of the sandstone which serves as a reservoir to hold the gas; (*b*) the extent to which the strata above or below the gas sand are cracked; (*c*) the dip of the gas sand and the position of the anticlines and synclines; (*d*) the relative positions of water, oil, and gas contained in the sand; and (*e*) the pressure under which the gas exists before being tapped by wells.

To these criticisms Professor White rejoins that subordinate anticlines often run along the central line of synclines, and that when gas is found in synclines it is at these points, and that when found here it is seldom free from salt water, by which it is likely to be soon overpowered. He further urges that all the successful gas companies of western Pennsylvania and West Virginia are getting their gas from the crests of anticlinal axes, while those that have confined their operations to synclines have met with uniform financial disaster. He points to the brilliant lights along the summits of the eight axes nearest to Pittsburgh, and he has since added a ninth, and also to the darkness that envelops the intervening synclines, in which hundreds of thousands of dollars have been invested without developing a single profitable gas well.

To the qualifications already made Professor White would probably add at this time one to the effect that gas wells shall be located on the domes of the axis, rather than in its depressions, recognizing the same line of facts in regard to them that Minshall had already established in the case of the White Oak anticline of Ohio and West Virginia, to which reference has been made.

The facts cited by Professor White as to the gas supply of Pittsburgh seem conclusive. Every foot of it comes from anticlines, not because it has been sought nowhere else, but because when found in other stations it is speedily overrun and extinguished by salt water. Where anticlines of the type here referred to traverse an

[1] Letter in Science, vol. 6, 1885, p. 43.

oil-bearing series, it may be considered to be demonstrated that they exert a decided effect on the accumulations of oil and gas in this series. So rational is such a conclusion, so directly does it result from the facts already stated, that it is difficult to see on what grounds it can be called in question.

While there is no element of the theory as stated by Professor White that differs from the theory stated before, his applications of it are bold and, best of all, successful, marking a new period in our study of the geology of oil and gas.

But, as has been already shown, pronounced anticlines are of infrequent occurrence in Ohio. A few of the low arches of western Pennsylvania extend across the border, but they soon flatten out and disappear. There are also a few low folds that originate and run their entire course within Ohio. In Indiana no movement of the crust that deserves to be called an anticline has yet been shown to exist. Even if the anticlines are held to account for the facts of oil and gas accumulation, the theory would have but limited application to Ohio and Indiana geology.

ARRESTED ANTICLINES.

Though distinct arches are for the most part wanting in Ohio geology, there is another sort of structural deformation found here which is connected in a direct way with the oil and gas of eastern Ohio. The structure referred to is associated with the arrest or suppression of the prevailing dip of the rocks for a given space and the establishment of a terrace or level bench in its place. If the series had lain level instead of being inclined at the slight angle which marks most of eastern Ohio, the movement to which the present terrace is due would have resulted in a low arch, but the uplifting force was too feeble to do more than counteract for a short space the normal dip by which the entire series is affected.

The structure referred to comes to view in the Macksburgh oil field of southern Ohio.

The entire series that is found to be connected here with oil production is at least one thousand five hundred feet thick. It enters the field dipping gently to the southeast, at the rate of twenty to thirty feet to the mile, but it suddenly ceases its descent and for about three miles there is no appreciable fall. In other words, a normal descent of sixty to seventy-five feet is neutralized. The amount of territory included in the terrace appears to be fifteen to twenty square miles. Beyond this, the regular dip is resumed.

In the 1,500 feet of rock which composes the section that the wells here penetrate there are not less than five distinct oil sands, or, in other words, five horizons at which oil and gas are sometimes found. Each one of these is productive of oil to a greater or less degree upon the terrace, and of gas upon the upper margin of the terrace. The development of the field began with the discovery of oil in the shallowest sand. Step by step the lower horizons were reached. The productive areas of each have the same surface boundaries. The petroleum contained in the different sandstones has different characters, varying in gravity, in color, in chemical properties, from sand to sand. Wells are in operation in most if not in all of these horizons in the Macksburgh field at the present time.

How are these facts to be explained? If there were an anticlinal fold here, it could be urged that the gas had found its way through the fractures and fissures of the arch from the bottom upward, so that one supply could account for charging all of the rocks. This explanation would leave the differences in quality of the oils found in the several rocks unexplained, it is true, but it might still be maintained. There is, however, neither arch nor fold of any sort. That five sand rocks, distributed through 1,500 feet of stratified deposits, should each happen to secure the right grain and composition to make them repositories of oil within exactly the same geographical limits is, of course, incredible.

There is but one explanation of the facts here given. The accumulation of oil and gas is due to the structure, or, in other words, to the arrangement of the rocks concerned. It thus appears that structure is a vital element in the accumulation of oil and gas. The facts in eastern Ohio point to the conclusion that all other conditions for oil production are met much more frequently than the structural conditions required. The source of gas on the large scale is found in the universal sheet of shale that underlies this portion of the State. A reservoir is furnished by the Berea Grit almost as wide as this universal source of gas. The Cuyahoga shale has everywhere the essential conditions for roof or cover of the oil sand. But all of these are powerless to produce an oil field until the right inclination is given to the series. This condition is met in but few instances, so far as our present knowledge reveals.

The Wellsburgh gas field in the Ohio Valley below Steubenville has a structure similar to the Macksburgh field. There is a similar arrest of normal dip and a consequent terrace-like bench upon the summit of which the gas is found. Oil has not yet been reported from this field, but if explorations are continued it will undoubtedly be found.

So far as examination has gone, every one of the few oil and gas fields of eastern Ohio betrays structural irregularity, and most of them point to the terrace-like structure already described.

STRUCTURAL IRREGULARITIES IN NORTHWESTERN OHIO.

The occurrence of petroleum and gas, but especially of the latter, in northwestern Ohio has been found to be associated with greater irregularities of structure than are known elsewhere in the State, except in a single locality. The drift deposits of this region are so thick and so continuous that there are no adequate opportunities to determine the horizons or dip of the underlying rocks by natural outcrops, and inasmuch as the surface does not betray any notable irregularity it has been a great surprise to find from the well records that the strata are dipping at some points at the rate of six hundred feet to the mile. It is in Findlay that the most marked disturbance occurs and the great supplies of gas that are found there appear to be closely connected with this disturbance. The largest gas wells are located near the edge of the steep descent, while others that are situated on the slopes yield both gas and oil. The wells at the bottom of the slope have yielded thus far oil alone or oil and salt water. The facts connected with this irregularity of structure will be more fully stated in Chapter V.

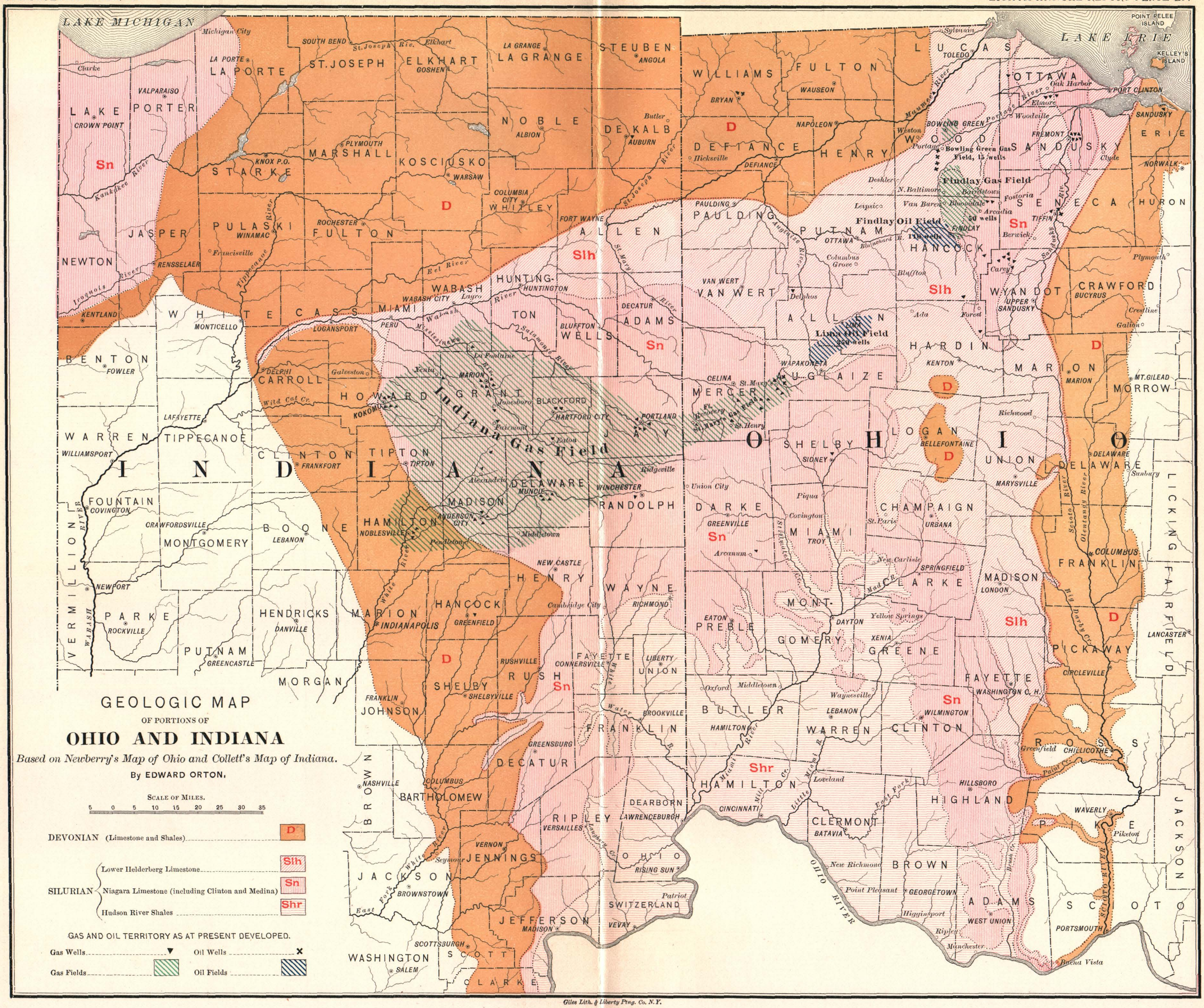
It is only necessary to say at this point that the gas of western Ohio, like that of the eastern half of the State, seems to depend upon unusual facts of structure for all of its important accumulations. The Indiana gas field has a remarkably regular and uniform structure, but still it will be shown in the account of this field that its gas production is entirely controlled by its structure.

CHAPTER III.

THE DISCOVERY OF OIL AND HIGH-PRESSURE GAS IN THE TRENTON LIMESTONE OF OHIO.

THE BLACK SWAMP.

The surface of northwestern Ohio is quite flat and monotonous. There are many single tracts of fifty or a hundred square miles in which the extremes of elevation will not exceed twenty-five feet. The dividing ridge between the waters of the Gulf of St. Lawrence and those of the Gulf of Mexico extends in a westerly and southwesterly direction across the State, making in part the southern boundary of the region which is here designated northwestern Ohio. The maximum elevation of this water-shed is about one thousand feet above tide, while the lands that immediately border on Lake Erie have a general elevation of six hundred to seven hundred feet above tide. The difference of three hundred to four hundred feet between these extremes is distributed through sixty to eighty miles of equable descent to the northward. The surface is, as a rule, quite deeply covered with drift deposits, the maximum thickness of which is four hundred feet. But low ridges and level areas of Upper Silurian limestone, thinly covered with soil, occasionally constitute the surface for a few square miles at a time. In numerous instances the streams have worn their way to the bed rock, and the only stone quarries possible in many districts are situated at or below the low-water mark of these streams. Though the valleys, without exception, are shallow, they afford nearly all the relief that the surface enjoys. The additional features of relief are the low rocky ridges already named, the geological origin of which is not always apparent, and certain long lines of sand and gravel deposits, which are rightly known as lake ridges. The latter were undoubtedly formed by the action of Lake Erie at its higher levels in the closing stages of post-Tertiary time. They are often continuous for scores of miles upon the surface, running in a general way parallel to the present shores of Lake Erie. There are several of these ridges at different distances from the lake shore. The early roads of the country followed them and the most desirable building sites in early times were found upon them. The elevation of the ridges, both stone and gravel, is small, rarely exceeding fifteen or twenty feet above the general level.



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From the description here given it will be seen that the drainage system of this portion of the State must in the main be sluggish, and that large areas in a state of nature are certain to be found as swamps and marshes. A wealth of decaying vegetation under the conditions named is also sure to be incorporated with the forming soil, giving to it all the elements of fertility.

In view of these facts it is not surprising that much of northwestern Ohio was known in early time as the Black Swamp. Of late years its drainage has been greatly improved by deep ditches drawn in long lines across the country. But, though the name is no longer suggested by its condition, it still remains in common use. The Black Swamp is rapidly becoming one of the most fertile and valuable agricultural districts of the State, and it is destined for centuries to come to give a generous support to a dense population.

To whatever else the region is adapted it would certainly seem an unpromising field for geological exploration, inasmuch as natural rock sections of a dozen feet are rare within it, and sections of twice this height are impossible; but it is out of this Black Swamp that there has been derived the most important and surprising discovery ever made in the economic geology of Ohio. The discovery is not one of merely local importance. It extends the boundaries of geological knowledge, and makes an addition of immense importance to the stocks of power which the crust of the earth was previously known to hold. It carries at a single step the prolific horizons of petroleum and gas from the sandstones and conglomerates of the middle Devonian to the lowest main division of the Lower Silurian. The descent is accomplished in a single step, as already stated, but it measures a full half mile in the vertical column.

SURFACE INDICATIONS.

The discovery of valuable stocks of oil and gas, derived from the Trenton limestone, was first made in Findlay, Hancock County, Ohio, in November, 1884. Hancock County is the third county south of the lake shore. Findlay, the county seat, is forty-five miles due south of Toledo. The surface of the country at and around Findlay has an elevation of about seven hundred and eighty-five feet above tide. The town is traversed by Blanchard's Fork of the Auglaize River, a stream that has in the main a sluggish flow. Its direction is to the northwest. The level of low water in the stream is about fifteen feet below the general level of the country. In Findlay and in its immediate vicinity the drift deposits are quite shallow. All of the streams have rocky floors to a greater or less extent, and along their banks limestone quarries have for many years been worked for the supply of building stone, lime, and road material. In the town proper the drift is seldom more than fifteen feet thick, and for much of the area it is less than ten feet thick.

The wells that are dug in and around the town usually pass entirely through the drift, and their supply of water is derived either from the surface of the underlying limestone or from comparatively shallow depths in it.

The first discovery on record of inflammable gas in the Findlay field was made while digging a well, three and a half miles south of the court-house, in October, 1836. But from the known facts as to its occurrence it is scarcely possible that its presence should not have been known to the earliest occupants of the country.

The discovery was made under the following circumstances: A well was being dug on a farm in the northwestern quarter of section 5, Jackson Township, which was at the time owned by one Aaron Williamson. The diggers had reached a depth of ten and a half feet in the drift and water began to appear. They were just then called to supper, but fearing that the well would fill with water and that the banks would cave in if left, they returned in the early evening with lighted torches to complete their work by laying the wall, the stone for which had already been drawn to the spot. Lowering a lighted torch into the excavation to ascertain its condition, they were startled by a violent explosion, and a flame of considerable volume was afterwards found burning from the surface of the water below. The labor spent in the excavation was counted lost and a supply of water was sought at another point. The burning well attracted a good deal of attention in the neighborhood. The flame lasted for several months, but was at last extinguished by the rains and snows of early winter and the well was afterwards filled up. Similar experiences soon followed in other wells and in like excavations, and these were especially common within the village limits of Findlay. From this time it was known that inflammable gas, explosive also when mixed in certain proportions with air, was likely to be found whenever the limestone floor of the country was approached. The cases in which this oftenest occurred were in the digging of wells, cisterns, and sewers in the town of Findlay.

There were other surface indications at hand that were equally significant. From the springs that issued from the limestone rocks in the valleys gas was constantly escaping in considerable quantities. It was known that this gas could be lighted at any time and that it would often continue to burn for hours without interruption. Experiments in lighting it were constantly repeated, and not a child grew up in the neighborhood without becoming acquainted with its manifestations.

The gas was offensive in odor on account of the presence in it of sulphureted hydrogen, This substance was dissolved in the water through which the gas found its way to the surface, and as a consequence most of the well and spring water of Findlay was so strongly impregnated with it as to be disagreeable and unwholesome. By reason of the wide diffusion of this sulphurous gas a satisfactory supply of drinking water has been hard to secure in Findlay. The abundant presence of natural gas in the neighborhood was, in fact, more obviously attested by the contaminated water supply than by any or all other indications.

From the statements now made, it is clear that the presence of inflammable gas has been known in Findlay and its vicinity since the country was first occupied. There have always been surface indications here of pronounced character, the most conspicuous of which are the sulphureted water of wells and springs, the escape of gas from springs and rock crevices, and its presence in numerous excavations that were carried down to the limestone rock. While the presence of gas was universally known, from the facts already stated, it was likewise universally deplored as a nuisance that must be endured because it could not be abated.

The utilization of gas was begun in Findlay on a small scale at an early date. In 1838 Mr. Daniel Foster, residing at the corner of Main and Hardin streets, dug a well on his premises, with the usual experience for this part of the town. The water was too sulphurous for use, and, moreover, gas bubbled through it continually in considerable volume. Failing to find a supply of potable water, he determined to utilize his labor, nevertheless, in securing a supply of heat. He accordingly arranged an inverted sugar kettle in the well in such a way as to accumulate the gas, which was then conveyed by a wooden pipe laid from the well to the sitting-room of his house, where it was burned in an old gun-barrel adapted to the purpose. The fire that was thus lighted in 1838 has been continued practically ever since. A number of years afterward the house was bought by Dr. Jacob Carr, a dentist of Findlay, and ex-mayor of the town. Dr. Carr dug several other wells and cisterns on the premises to obtain water, if possible, for household use, but all proved, like the first, sources of gas rather than of water. Obtaining an additional supply of gas from these several excavations, Dr. Carr was able to make a somewhat larger use of it for light and fuel than had been possible before this time.

It is to Dr. Carr also that we owe the first scientific examination of Findlay gas. In the oil excitement of 1865, in connection with the well drilling that was undertaken at this time and which will be presently referred to, Dr. Carr bottled a sample of the gas and placed it in the hands of an eminent chemist, Dr. Chilton, of New York, for chemical determination. Dr. Chilton pronounced the gas light carbureted hydrogen derived from petroleum. The first statement was the result of an approximate analysis and the second must have been a sagacious inference.

The first person who is known to have recognized the larger possible value of Findlay gas and to have set about devising schemes for developing and utilizing it on any considerable scale is Dr. Charles Oesterlin, an old and highly respected physician of the town. As early as 1862, Dr. Oesterlin made repeated efforts to interest his fellow-citizens in some means for accumulating the escaping gas in quantity enough to light the village streets at night. He experimented upon the gas springs and gathered all the facts as to the presence of gas in the wells and other excavations of the neighborhood. There was no one, however, to second his sagacious plans, and nothing came from this discussion. In 1865, while the first petroleum excitement was sweeping through the country, a deep well was undertaken by prospectors for oil upon the land of Dr. Carr in Findlay. The drill became fast in solid limestone rock at a depth of 135 feet, and the undertaking was abandoned without result.

In 1869 the geological survey of the State was undertaken. Dr. Oesterlin was the representative of Hancock County in the State legislature at this time. He took pains to bring the facts pertaining to Findlay gas to the attention of a member of the geological corps, the late Hon. J. H. Klippart, of Columbus, and urged a scientific investigation of the questions involved. But the time had not fully come for the recognition of the new fuel. The geological range of Findlay seemed in the highest degree unpromising as a source of natural gas, and the real significance of its surface indications of gas was not even suspected.

In 1871, however, the geology of Hancock County was worked out in its due order by Prof. N. H. Winchell, to whom Dr. Newberry had assigned most of the northwestern counties of the State. Professor Winchell called attention to the occurrence of inflammable gas in Findlay in his report on the county. He published a letter from Dr. Carr, in which the facts already given as to the utilization of the gas were briefly stated.[1]

The Survey failed to recognize the immense significance of the Findlay facts, because the time for such recognition had not yet come in either the scientific or the practical world. But in the study of this and adjoining counties a good deal of faithful and accurate work was done, particularly in mapping the different formations as they appeared on the surface, and this work is proved to be connected in a very interesting and important way with the development of the oil and gas territory. Attention will be called to these points on a later page. Though Findlay gas was distinctly recognized in the reports of the Survey, as already shown, no emphasis was given to the statements concerning it, and probably the attention of few readers was definitely directed to the subject by reason of the mention thus made of it.

For the next ten years no progress whatever is to be reported. Dr. Oesterlin was the only man in the community who believed in

[1] Report Geol. Survey Ohio, vol. 2, p. 366.

Findlay gas, and he had long since abandoned all expectation of awakening interest enough among his neighbors to lead them to join him in drilling for a larger supply. But in 1882 and 1883 the new experience of Pittsburgh was beginning to affect surrounding communities. Ohio towns began to discuss projects of drilling for natural gas. Those localities in which surface indications had been already recognized were generally the first to move. Bucyrus, a town forty miles southeast of Findlay, is located upon the edge of the Ohio shale, a formation which above all others in the geological scale of the State is given to "surface indications." There is scarcely a mile of its outcrop across the breadth of the State that does not yield enough gas or oil to arouse great expectations in the mind of the unwary prospector. These expectations, it may be added, are invariably doomed to disappointment, for shale is never a prolific rock, and at best supplies only a moderate amount of low-pressure gas. Bucyrus had these surface indications, and, relying upon them, it became the first town in the central portion of the State to follow the new impulse. A shallow well was drilled here in the fall of 1883. The opportunity for Findlay was now drawing near. Dr. Oesterlin's enthusiasm was rekindled and he found it at last easy to interest his neighbors in his long-cherished beliefs in regard to a home supply of natural gas. In the winter of 1883-'84, Mr. Charles Eckels, a citizen of Findlay, made a visit of a few weeks to Westmoreland County, Pa., and saw something of the new development of natural gas that was in progress there. He returned to Findlay, ready and even eager to take his full share of responsibility in testing the territory at home. Thus re-enforced, Dr. Oesterlin was able to organize the Findlay Natural Gas Company in March, 1883. The capital stock of the company was $5,000 and there were nine corporate members. Correspondence was forthwith opened with contractors, but it was September before a derrick was erected and the drill began its descent. The well was located on land belonging to Dr. Oesterlin, on the east side of the corporation, and in the vicinity of some of the gas springs already referred to. Brownyar & Martin, experienced drillers from the Bradford field, took the contract to sink the well.

THE PIONEER WELL.

A somewhat detailed account has now been given of the steps leading to the drilling of the Pioneer well at Findlay, as the beginning of a movement of extraordinary interest and importance in the economic geology of the country. The history of this well and of the facts that led to sinking it fully deserves all the time that has been given to it. Before following the record further, it may be well to recall the various estimates that were made upon this venture at the time of its inception. Findlay gas is now well known throughout the length and breadth of the land. But what was the state of mind of those that were cognizant of the undertaking before the first well was drilled? With the facility that people have for adjusting themselves to accomplished facts, it is difficult to find any one now in these favored communities who does not seem to himself to have always known of the presence of gas and oil in the Trenton limestone.

How did geologists look upon the venture? It may be said in reply to this that no geologist was consulted before the drilling was begun or while it was in progress. There are circumstantial accounts current in the community to the effect that geologists discouraged the experiments, and these accounts are set down to the discredit of the science. But as a matter of actual fact such reports are entirely without foundation. It must be granted, however, that they have an air of truth. They show what might easily have happened. If geologists had been consulted their judgment would probably have been unfavorable to the scheme. The search for gas or oil in this part of the geological scale would have appeared almost as barren of large possibilities as a descent into the primeval granite.

Excellent reasons could have been given for unfavorable prognostications. The drill would have begun in Upper Silurian limestone. What ground was there for expecting any valuable accumulations of oil or gas in these well-known strata? Thousands of square miles of the rocks of this age lie open to-day within the borders of the State. They are worked in quarries large and small in almost every county in northern and western Ohio. Asphalt occurs in them in considerable amount in certain localities and certain beds, and occasionally small accumulations of petroleum are found; but there is no indication whatever of large stocks.

If the Upper Silurian limestones were passed, what encouragement could be got from the formations that underlie them? The strata that are due below them are the Medina, Hudson River, and Utica formations of the general scale. All of them are known to be mainly shales in northern Ohio, close-grained and impervious; and certainly there could be no great promise in beds of this age and character for the supply of high-pressure gas. Moreover, these strata appear, one or all, in extensive outcrops to the southward and give no hint of oil or gas on the large scale. What comes next below this series of shales? The Trenton limestone, one of the firmest and most massive, as well as one of the most wide-spread strata in the foundations of the continent, and one which has as little promise of oil and gas as any other in our entire column.

Dr. T. Sterry Hunt called attention many years ago to the fact that the Trenton limestone of the Manitoulin Islands, Lake Superior, was to a small extent petroliferous (Essays, p. 170). Twenty barrels of oil were pumped from a single shallow well that was drilled into it in that region in 1865. It may be that Dr. Hunt would have seen reason to encourage the expectation of valuable results by drilling to the Trenton limestone at whatever depth it might be found in northern Ohio. But, if he had done so, he would probably have stood alone among the geologists of the country. It may be remarked, in passing, that Dr. Hunt's teachings in regard to the sources of petroleum are much more in harmony with the new experience than those of any other prominent authority. Most of the geologists who saw in current news items the account of the drilling that was begun in Findlay doubtless regarded it as a chimerical scheme. It seemed to them, and it was to a considerable extent, based upon the widespread and ineradicable fallacy that holds possession of the popular mind in regard to the search for gas, and which can be stated in this general form, viz: "Pittsburgh finds high-pressure gas in unlimited amount at fifteen hundred or two thousand feet below the surface. Why, then, should not every town find it by drilling to the same depth?"

So much for the attitude of geologists. There was no reason known why they should place confidence in the new undertaking. The point of beginning of the Findlay well was a fully half mile below the lowest fairly productive and persistent horizon of gas or oil known in the country, and of a new horizon no one even dreamed.

How did the oil-producing interest of the country regard the sinking of this "wild-cat well" in the Black Swamp of northwestern Ohio? There is no reason to believe that the venture attracted the slightest attention from the sagacious men who controlled this great interest. They were (or, if acquainted with the facts, would have been) as scornful and skeptical in regard to any important possibilities as the geologists were, and upon very much the same grounds. There were no known facts to warrant any expectation of valuable results.

How did the people of Findlay regard the undertaking? There were nine men in the town who had faith enough in the possibilities of gas production to risk their money in sinking a well to find it. But it had taken many years to get even this small number together. It must not be inferred that in intelligence or sagacity the Findlay company was in any respect superior to the companies that had before this time drilled wells elsewhere or that have drilled wells since on every side. They were simply following "surface indications" of the same sort that their neighbors had, but somewhat more pronounced, and they were following them in exactly the same way that their neighbors were. Not a single idea in regard to geological horizons or geological probabilities or possibilities found entrance to their minds, but they were dominated to the usual extent by the popular delusion that high-pressure gas was likely to be found anywhere if only the drill should go deep enough. Their advantage was that their surface indications were better than those around them, and stood for something entirely new in the history of petroleum, not only in this country, but in the world. To the number of corporate members of the Findlay Natural Gas Company a very few of the citizens can probably be added who had a measure of faith in the success of the drilling at the time it was begun; but the majority seem to have counted it an ill-judged expenditure of money, and many found in the undertaking food for merriment and ridicule at the expense of the oversanguine investors. Some of those who were foremost in ridiculing or disparaging the scheme have long since been among the most active in the development of the new interest, and so earnestly have they worked in the utilization of Findlay gas since it was discovered, that it would perhaps be difficult for them to realize that there was ever a time in which they did not believe in it. The discovery of Findlay gas is due to the company whose organization has now been described; but it is not detracting from their just credit to add that it could not have been long delayed in any case. The impulse to the new method of exploration was rapidly gathering strength, and the drill would certainly have found its way at an early day into a town with so many traditions of natural gas as Findlay possessed.

The drilling of the Pioneer well, begun in September, 1884, went forward without serious interruption to its completion. At the point selected for the well the drift was but 8 feet thick. It was followed by a series of nearly continuous solid limestone beds, that continued to a depth of 250 feet below the surface. The drill then entered a series of shales about 850 feet thick. Gas was found in considerable quantity at several horizons in the shales. The first notable flow was at 516 feet; another was struck at 618 feet; and still another at 640 feet. From these sources enough gas was obtained to run the engine through all the subsequent drilling. It was made evident thus early that the Findlay well was likely to be justified by the outcome. At 718 feet a little oil was obtained, but at 1,092 feet, which depth was reached about the middle of November, 1884, the shale gave way to a solid and highly crystalline limestone rock. This stratum proved to be a reservoir of high-pressure gas. As soon as the drill penetrated its surface gas in large volume was set free, and the flow was increased for the next ten or twelve feet of descent. The gas was lighted, and its blaze at night illuminated a circle of country 20 miles in diameter. The Pioneer well was successful. A new horizon of gas and oil, not dreamed of heretofore, was brought to light, and Findlay became the center and inspiration of a development of fossil power scarcely, if at all, inferior in value to the great petroleum reservoirs of western Pennsylvania and New York. The excitement ran high throughout the entire country. As many as 3,000 people are said to have visited the burning well in a single day.

The flow of gas obtained from the first well would not be counted large according to present standards. From the testimony of those best qualified to judge, the volume is thought to have been 250,000 or possibly 300,000 cubic feet a day.

Though abundantly justifying the drilling of the well and ample to reward the company for its outlay, the amount of gas obtained did not, after all, meet expectations, and the well was sunk deeper, in the hope of striking a larger volume. It was carried down through hard and stubborn limestone for about five hundred and fifty feet below the gas rock, or to a total depth of 1,648 feet, when a bitter brine of peculiar character was struck, which rose rapidly, and the drilling was consequently discontinued. The well was plugged near the bottom, to shut out the salt water, and preparations were forthwith begun to utilize the new supply of fuel. The gas was found to have great heat-producing properties and to answer a fair purpose as an illuminant. It contained a minute percentage of sulphureted hydrogen. Small though the amount of this substance was, it was still large enough to advertise the presence of the gas quite widely and quite distinctly and to render it somewhat offensive.

DEVELOPMENT OF THE NEW HORIZON.

This review has now brought us to the beginning of 1885. The towns of the Black Swamp in the closing months of the preceding year saw a great light, the history of which was simple and easily comprehended. Findlay had drilled a well in its rocky floor and at a depth of 1,100 feet had found a solid stratum of limestone that proved to be a reservoir of high-pressure gas. Was not the same reservoir equally available to the surrounding towns and to the entire country as well? Answers to such questions were sure to be sought in a practical way in all the centers of business enterprise throughout northwestern Ohio. Findlay herself was the first to prove the horizon she had discovered, and to demonstrate that the gas of the pioneer well was not contained in a pocket nor limited to a single fortunate locality. The Findlay Gas-light Company saw that their occupation as manufacturers of artificial light was gone. A well that could be drilled for $1,500 had been found to yield as much gas in one or two weeks as they had been accustomed to sell in a year. At the rates at which they had been accustomed to sell manufactured gas the product of the well for a single day would exceed $600. Clearly there was nothing left for the company to do but to drill, if it expected to make any further use of its mains and gas lines. A well was at once located within the inclosure of the gas works and early in 1885 the drill was started. It repeated almost identically the experience of well number one, though its flow of gas was scarcely as large. There was no further use for the fires and the retorts of the old works, and natural gas was at once turned into the channels that had been constructed for the artificial supply.

A wider extension of the field followed: Bowling Green, the county seat of Wood County, 24 miles due north of Findlay, is built on limestone rock as Findlay is, and it also had traditions of oil and gas. The inference that was sure to follow was drawn at once and the drill was set to work in Bowling Green early in the year. The section found here was similar in all respects to that of the two Findlay wells, and the gas rock was reached at almost the identical depth at which it had been found in them. Thus far the descent of the surface toward the lake proved to have exactly kept pace with the descent of the entire series to the northward. Both surface and gas rock were nearly a hundred feet lower at Bowling Green than at Findlay. The gas rock proved much less productive in Bowling Green than in the Findlay wells, but it was still a gas rock. It required a torpedo to develop the well into respectable proportions, but the final statement could be made that Bowling Green had drilled for Findlay gas and found it.

Lima, 30 miles southwest of Findlay, a rich and thriving town, a railroad center and given to manufacturing enterprise, was the next to seek and find the Findlay gas rock. The rock was found, but in the interval it had turned to an oil rock. The surface of Lima is nearly a hundred feet higher than that of Findlay and the well was 150 feet deeper than the Findlay wells. The oil produced at the Lima well was dark in color and low in gravity and the amount was quite small. It contained, moreover, a small percentage of sulphureted compounds throughout which very stubbornly resisted elimination.

It is well to note at this point the singular feature that marked the discovery and early development of the new oil and gas horizon. Drilling was begun in northwestern Ohio at almost the only point where failure would be impossible. In all the new field there is but one Findlay.

Not only was the beginning made at the best possible point but the second and third points were also located at the only other county seats in northwestern Ohio where drilling has proved reasonably successful. We have no longer the right to say that all the success in the new field has been limited to the three counties which first made trial of the drill. It is, however, true that the developments of these three counties are incomputably more important than those of any other. The Lima oil field has reached out into Auglaize County, and Auglaize County connects with the Mercer County gas territory. But when this is said practically all the additions to the present date have been made for northwestern Ohio.

The effects of this early experience can be easily understood. The experience already described furnished to every county in northwestern Ohio a good reason for expecting like results with those obtained in Findlay, Bowling Green, and Lima. Why not? Three towns had made the trial and every one had succeeded; it was but to ask and to receive. The general geologic conditions were obviously very much the same throughout this entire section of the State.

This confidence was soon clouded, however, to some extent. The doctrine of lines and belts in which gas and oil are distributed and to which they are confined was sure to come into the new field. Since all of the experience available in its development was brought in from Pennsylvania and New York, where lines and belts of oil production are unmistakable and of the highest importance, the question was soon raised, when the prospects of a town were under consideration, "Is it in the gas belt?" Until that question was answered satisfactorily there was enough uncertainty to give at least zest and excitement to the search. But what is the new gas and oil belt? In what direction does it run? What are its metes and bounds? The doctrine of belts and lines is very welcome to the common mind. It furnishes a semblance of explanation of the facts involved, and meets in a cheap and off-hand way the demand for a rational basis on which to work. There is a great deal to support it or it could never have obtained the hold it has in the practical world. It has a geological foundation, and therefore it needs to be applied and limited by an acquaintance with geological facts and geological methods of reasoning.

As to direction, which is the main factor, most of the oil experts were not left in doubt. Lima is southwest of Findlay and this was conclusive. Bowling Green was conveniently left out of the account. The line was then the famous and familiar one established in the great Pennsylvania wells, north 45 degrees east, which is considered by Pennsylvania drillers the natural and necessary direction of oil and gas accumulations the world over, and to be looked for with all confidence even in Europe or Asia, or wherever oil and gas are found. It cost but little violence to bring the Canadian oil field into line with Findlay and Lima, disregarding the fact that Canada oil is derived from an entirely distinct and widely separated horizon. But the field was not to be left with one line only. There was certainly something to be said for other directions. The north and south line that joins Findlay and Bowling Green could not escape notice, and great confidence was felt by many in territory that could be located on extensions or in the intervals of this line. Other lines were also laid down and followed in attempted development according to the fancy of the projectors. The Findlay or the Lima wells are connected on the map with some other productive territory, it may be hundreds of miles away, and great interest is taken in marking the towns that are ranged along such lines. A majority of the people had but little use for any one who was studying the field without a "line" on which to work.

The geologists made their contributions, attributing a good deal of importance in the new discovery to the famous Cincinnati axis of Newberry, assuming Findlay to be upon its crest, a location which had never been suspected theretofore. In what direction does the axis extend from Findlay? The general direction of this axis was believed to have been already defined. It bears to the northeast, and to this extent, the geologist and the oil expert were agreed, productive territory could fairly be expected to extend in a northeasterly belt from Findlay.

Some little check was thus given to the confidence that would otherwise have been for a short time universal throughout northwestern Ohio. It became a question after all whether each and every square mile of the Black Swamp contained, in addition to its inexhaustible agricultural resources, mineral wealth in the shape of oil and gas, in comparison with which the former would be counted insignificant. A town might perhaps be "outside of the belt," but the tests by the drill were multiplied quite rapidly.

Wells Nos. 3 and 4 were drilled at Findlay. The last of these, known as the Adams well, proved of unusual interest on several accounts. Its flow was more than twice that of the first two wells combined, and it served thus to show larger possibilities for the new field than could have been justly inferred from previous experience. The volume of the Adams well was measured in May, 1885, by Mr. Emerson McMillin, of Columbus, by means of the anemometer. This is the first instance on record, so far as known, of the application of this instrument to this purpose. The flow was found to be 1,296,000 cubic feet for twenty-four hours. Another fact of great geological interest and importance was brought to light by the Adams well. The gas rock was found 100 feet lower than the first well, while the surface remained at the same elevation. In wells Nos. 1 and 2 the surface of the oil rock was 312 feet below tide; in the Adams well it was 405 feet below. The distance between the wells was less than 2,000 feet, and yet within this interval the entire series had been bent downward to the amount already indicated. The fact proved to be of immense importance in connection with the Findlay field.

Still another important and significant fact was brought to light by this well. It yielded oil as well as gas. It pointed distinctly to an oil field bordering on and bounding the dry gas which had been found in the earlier wells. No well except the first has been drilled in the Findlay field which has had so many and so important offices to serve as the Adams well.

Fostoria and Fremont, enterprising towns to the northeast of Findlay, were next in order in testing the Findlay gas rock. Fostoria found the rock at 1,253 feet below the surface, or 472 feet below tide, but it was entirely unproductive. Fremont found the same rock at 1,300 feet, and it was barren here also, or so nearly barren that it would have been better for the town if there had been no encouragement to further drilling. These facts greatly impaired the confidence that had been felt in the northeast line and the Cincinnati axis as guides to the development of the new oil and gas rock. Toledo also made a test of its territory. The Findlay rock was found here during the summer of 1885 at a depth of 800 feet below tide. It was practically barren.

A YEAR'S PROGRESS.

It will be remembered that Findlay gas was discovered in the closing months of 1884. It will be instructive to gather up the results of the development for the first year thereafter throughout the new field. By the end of 1885 it had been clearly established that a gas field of considerable value was in process of development at Findlay. Eleven wells had been drilled in all, six of them yielding dry gas and three yielding more or less oil or salt water, with a preponderating volume of gas. One of them was an oil well with gas enough to deliver its product of 30 barrels a day to the surface, and one of the wells was unproductive, though it could have been made to yield a little oil by pumping. The best of the gas wells was producing about three million cubic feet a day. The second best was the Adams well, already described. The lower limit of production was 100,000 cubic feet a day. The gas was already utilized in heat, light, and power on a large scale through the town. The closed pressure of the wells was found to be about four hundred pounds to the square inch, and was the same for all of the wells, whatever the facts of their production.

Bowling Green had during this year also developed a gas field of smaller proportions and less force in every way than the Findlay field, but still of considerable value and of better promise. The gas had been already utilized in the town, but the demand exceeded the supply at the close of the year. The amount used in the town at this time was estimated at 150,000 cubic feet a day, and this was the total product of the first five wells of the field. This scanty production was to be supplemented in a very effective way by the wells that were already under contract here.

Of equal importance with the gas development at Findlay, and perhaps of even greater importance in the long run, was the work of exploration going forward at and around Lima during the same year. An oil field was in process of development there which has proven itself, in extent of territory, in the percentage of successful drilling, and in the volume and the steadiness of the wells that are obtained, to be second to but one field yet discovered in the country, and it is a question whether Bradford ever covered a larger stock of power. It cost the severest and most persistent repression to keep the production of Lima oil, in 1887, down to 15,000 barrels of oil a day. With a price equal to one-half of what the Pennsylvania oil brings in the market, the production inside of sixty days would rise to 25,000 barrels of oil a day, and 50 cents a barrel would in another sixty days double the last-named figure.

During 1885 twenty-two wells were begun at Lima or in the country around by companies operating from Lima. About one-half of them were completed during this year. The history of the first well has already been given in brief. It produced a small amount, never more than twenty or thirty barrels a day, of what has become so widely known as Lima oil. It is surprising that so insignificant a beginning should have led to such large results. It could not have happened at any other point in the field but Lima. A few barrels of oil have been obtained from the Findlay rock at a score of towns in northwestern Ohio during the last two years, but this is the only locality where so small a promise has led to any important outcome.

The first well left everything uncertain as to the quantity and quality of oil to be obtained. The second venture, which had the important office of authenticating the field, is known as the Citizens' well, from the fact that it was controlled by a company of public-spirited gentlemen who determined to find out in the common interest what the real facts were as to this possible source of a fortune for their community. This well was located not far from the center of the town. It was drilled in the summer of 1885, and its production was much in advance of well No. 1, starting with a daily yield of 50 barrels. The oil rock showed good staying qualities, as is evident from the fact that 1,200 barrels were credited to the well in December of the same year. The character of petroleum was also first determined from the yield of this well. A car-load was sent to Pittsburgh for treatment, and the possibility of making from it an excellent grade of illuminating oil, free from the offensive odor that belonged to the crude product, was here measurably established. The effect of torpedoes on the oil rock was also first determined in this well. On account of the experimental character of the work it proved expensive, and it has never repaid the company for the investment.

The first two wells, with others that followed them closely, have since proved to be located on the very edge of the productive territory. They were in such close proximity to salt water that constant attention was required to maintain them in operation. Following the Citizens' well a dozen others were drilled, most of them on town lots, in the general neighborhood of the former. But the history of one is substantially the history of all. They were crowded together in some instances at the rate of two or three to an acre. Not one of them has paid for itself. But they served their purpose in the development of the new oil field. The work could go forward only by much wasteful and ill-judged expenditure.

The most important exploration in the field at large during the present year was conducted by a company that was organized as soon as Lima oil was discovered, viz, the Trenton Rock Oil Company. In this company were represented the local interests of Lima and the successful experience of oil production in the Bradford field. It was managed with sagacity and energy, and to its early work we owe much of our knowledge of the limits and characteristics of the Lima field. Following the 45° line of the oil expert, already referred to, a large amount of territory was located for the company between Lima and Findlay, and a half dozen wells were started at different points in this interval. All these outlying wells, without exception, proved failures, more or less complete; and the worthlessness of lines or belts as guides to location was again emphasized. But the Trenton company carried forward its work systematically. Levels were run to every well, and the facts obtained were communicated freely to the Ohio Geological Survey. By means of figures derived from this source the secret of success or failure in drilling presently came to view. It was made apparent that the level of the oil rock with reference to adjacent territory was the feature that more than any other determined what it should produce, whether gas, oil, or salt water. These levels, as is obvious, could best be seen by referring all to an absolute base, as tide-water. This was the most fruitful and important discovery of 1885 pertaining to the Lima oil field.

The year closed without any great increase of production in the Lima field. But practical and sagacious men who had watched the history of other fields saw signs of promise here that led them to stake their money and their time on the results of drilling. It thus became certain early in 1886 that more complete knowledge of the capabilities of the Lima oil rock would be obtained.

The facts pertaining to the first three centers of oil and gas production from the new horizon for 1885 have now been given. But many other towns in northwestern Ohio undertook to prove themselves oil and gas territory during the same period. What were the results of these explorations? The story is short and monotonous. The list of wells is essentially a list of failures. In a few instances the fall was broken by some small return in the shape of gas or oil from the Findlay rock when it was reached. But such experiments are generally to be counted even more unfortunate than those which failed outright, as proprietors were lured on by these weak returns to new but still unremunerative expenditures. Among towns that drilled in 1885 to the Findlay rock, some of which have been already named, the following are the chief: Marion, Kenton, Mount Blanchard, Fostoria, Fremont, Toledo, Ottawa, Columbus Grove, Sidney, and Springfield. The outlines of the productive territory are beginning already to appear, and the key to the production, as already stated, had been found to be the level of the oil or gas rock with respect to adjacent territory.

MAGNITUDE AND IMPORTANCE OF THE NEW FIELD.

It was reserved for the year 1886 to demonstrate the large proportions and immense importance of the new field. An entirely new face was put upon it by the facts brought to light during the progress of this year. All that had been discovered up to this time belongs to the day of small things. The real character and possibilities of the reservoir of stored power now for the first time came into view.

Findlay still kept the lead in development and kept it by a long interval between herself and her nearest competitor. On January 20, 1886, the Karg well was completed. It was located on the bank of the river, within the limits of the town. It found the Findlay gas rock at a depth of 347 feet below tide, and, as subsequent explorations have proved, it was located on the very edge of the steep westward descent that is found in the strata here. In a thousand feet to the westward, it has since been learned that the strata descend 120 feet, and the gas rock has changed in the interval to an oil rock. This descent, it will be observed, is at the rate of 650 feet to the mile.

The Karg well gave to the people of Findlay their first example of a great gas well. To those unacquainted with eastern wells each vigorous well at Findlay had seemed to exhaust the possibilities of production. But here at last was a flow that fairly deserved to be called great. The well was not measured when the gas was escaping from the casing, but, after it had been tubed with 4-inch pipe, its daily volume was found to be about 12,000,000 cubic feet. The open pressure in the 4-inch pipe was found to be 15 pounds. The closed pressure, or rock pressure, was nearly 400 pounds, as in all the other wells of the field. The velocity of the escaping gas was 1,513 feet a second. But when compared with the great Pennsylvania wells, both the open and the closed pressure of the Karg well are moderate. The Andrews well of Beaver County, Pa., for example, has an open pressure in a 4-inch tube of 45 pounds against 15 pounds in the Karg well, while the closed pressure of this field is 675 pounds to the square inch. But this volume increases very slowly beyond the volume which the Karg well attains, no matter how rapidly or how high the pressure rises. The volume of the Andrews well, counted as Findlay gas, would be 16,500,000 cubic feet a day The lower specific gravity of Pennsylvania gas would increase these figures to about 18,000,000 cubic feet a day. It is often said, though it does not appear on what authority, that some of the Murrysville gas wells yield 30,000,000 cubic feet a day. Until such a claim is substantiated by published data, showing the system on which the measurement is made, it may well be called in question. To say the least, it seems very doubtful whether 30,000,000 cubic feet of gas have ever escaped from a 4-inch pipe in twenty-four hours. The velocity of such a flow would be prodigious. The gas of the Andrews well, above named, had a velocity of 1,700 feet per second, but such a volume as is claimed above would require a far greater rate. If the statement were that the Murrysville wells produced 30,000,000 from the casing (5⅝ inches in diameter) there would be no reason to call it in question.

The Karg well, aside from its economic interest and value, deserves to be remembered, because of the fact that the problem of measuring the flow of great gas wells was first worked out upon it. The Robinson method, which is the only published method of solving this difficult problem on scientific principles, was devised for this well and first applied to it. Attention will be called to this subject on a later page.

From the casing the flow of the Karg well must have been little, if any, short of 14,000,000 cubic feet a day. This mighty volume blazed forth into the air unrestrained for three or four months. Its light could be seen 40 miles away. The figures of this fearful waste of power are easily enough computed, but it is impossible for the mind to attach any clear conception to them.

This well could not but make a profound impression on the entire community. It gave an altogether unexpected revelation as to the capabilities of the limestone reservoir of the new field, and showed that all the conditions for a great production of oil as well as of gas must certainly be looked for here. In a word, it raised the new field at a single step from third or fourth rate obscurity into first-class prominence and importance.

The recognition of the Findlay field as a source of gas, adequate not only for the largest manufacturing supplies, but also for pipe-lines leading out to surrounding cities, dates back to the origin of the Karg well. This event constitutes, in fact, the real opening of the Findlay field, as the field is now understood.

During the summer of 1886 there was a great extension of gas territory developed to the north and northeast of Findlay. A number of wells of high value and promise were brought in along the line of the Baltimore and Ohio Railroad, between North Baltimore and Fostoria. The south line of townships of Wood County and the north line of Hancock County proved as prolific as Findlay itself. Of the numerous wells drilled here two belonged to the same class with the Karg well. These are the Simons well, of Bloom Township, Wood County, and the Van Buren well, of Allen Township, Hancock County. The first was found to produce 12,482,000 cubic feet of gas a day through the casing. The second delivered through the casing

15,000,000 cubic feet a day. Through a 4-inch tube, the Van Buren well yielded 12,614,000 cubic feet, which showed it to be somewhat larger than even the great well of Findlay. Thus far the Van Buren well stands at the head of the list of the wells of the new field. The Simons well, if measured through a 4-inch pipe, would have yielded ten to eleven million cubic feet of gas a day, but its absolute production is from one to two million feet less than that of the Karg well.

Facts like these were sure to attract the attention of capitalists and corporations that had already learned the enormous value of the great stocks of petroleum and gas wherever found. The year was signalized in this extension in the Findlay field by the establishment of several companies, organized for the conveyance of the gas by pipe to neighboring cities, among which the Northwestern Ohio, the Toledo, and the Tiffin Natural Gas Companies hold the leading place. They have drilled fifty or sixty wells already and have obtained control of a large part of the most desirable gas territory outside of Findlay; and they have already reached with their pipe-lines Fostoria, Fremont, Tiffin, and Toledo.

During 1886 Findlay oil made but little progress. The belt was found to extend due west of the town and to be quite narrow. The wells mainly showed small production, and the proportion of failures was discouragingly large.

Early in 1886 Bowling Green drilled a well, a mile to the south of the town, that was worth many times more than its first five wells combined. The supply was now ample, not only for all domestic use in the town, but also for steam-production and for lime-burning on a large scale. Other similar wells were added, so that the town is now attractive to manufacturers who make the largest use of power.

Of equal importance to the new field with the great gas wells of Hancock and Wood Counties was the extension of oil territory in the Lima field, and especially the revelation of the productive power of the Lima oil rock. It was in this year that the field took shape and made itself known in the oil production of the country at large as a factor that could no longer be disregarded.

The state of things at the close of the previous year will be recalled. A dozen wells, more or less, had been drilled in the Lima field or in the Lima interest, the greater part of them being failures. Within the corporation of Lima, however, oil had been found in what was then considered paying quantities. The Citizens' well, with its 1,200 barrels production in December, seemed to the oil producers to warrant extensive operations. Early in the new year the results of this activity began to appear, and it was soon made apparent that the first developments, favorable though they were counted, had not done justice to the Lima field. A well located in the vicinity of the

Citizens' well reached the oil rock February 2, 1886, and revealed new possibilities. It proved to be a flowing well. On the third day after its completion it produced 70 barrels of oil. During the remainder of the month it yielded 1,000 barrels, and in the succeeding month 700 barrels. It was, of course, seen at once that flowing wells immensely improved the value of the field.

It was also learned about this time that by the use of torpedoes pumping wells could be converted, for a time at least, into flowing wells. The Citizens' well and the McHenry well were the first to establish this fact.

On April 20 another well, located also within the town limits, but south of those previously named, was brought in. It marked another advance in the field. Gas was found with the oil, possessing volume and energy enough to throw a column of it 80 feet into the air. This well filled a 250-barrel tank in the first twenty-four hours; a production far in advance of anything previously known. A number of wells located a mile or more south of the first that were drilled, and just outside of the city limits, proved flowing wells of increased production and of good staying quality. The field of development was forthwith transferred from within the town limits, where all the early drilling was done, to territory south and east, and a marked increase of the production resulted. Predictions began to be made by experienced oil producers that greater wells would now be found. Some went even so far as to suggest the possibility of a 1,000-barrel well, but such figures generally appeared extravagant and improbable to a high degree. The importance of the field, however, was recognized and attested by the entrance into it at this time of the Standard Oil Company. A corporation under the control of this company and bearing the name of the Buckeye Pipe Line Company began the construction of a comprehensive system of tankage and transportation adequate to the new developments. The facts of 1887 show, as the earlier experience did, that the levels of the oil rock were still a controlling factor in its production. Nature evidently counted every foot and made the most of it in this connection. A well in which the oil rock was found six feet higher than in adjacent wells produced dry gas for a while. As the records multiplied, they continued to show the line of 400 feet below tide to be the dead line for oil production, and this was not passed in a single instance.

As the summer of 1886 advanced, continually larger wells were reported. A well three miles southeast of Lima produced 500 barrels for its first day's flow. A tract three miles east of the town was also found to be prolific oil territory. The first well located here started with a daily production of 300 barrels, but a well drilled on an adjoining farm more than doubled this output, and during its first three months it had flowed 14,000 barrels. At the end of this time it still maintained a daily rate of more than one hundred barrels, and a third well in the same neighborhood probably equaled it in production.

The next addition of productive territory was made upon the southwest of the town. Here a number of great wells were drilled during the summer and fall of 1886. A production of 500 barrels a day was no longer a surprise, and at last a well was drilled in this vicinity that struck a thousand-barrel rate. In its first hour it flowed 65 barrels, and its first day's work was little, if any, short of 1,000 barrels. Even this production, incredible as it would have seemed a few months before, has been already nearly doubled, a sober estimate crediting the Ridenour well with 1,700 barrels for its first day, and with a total flow of 60,000 barrels for the first six months.

The fairly productive portion of the Lima oil field, at the close of 1886, was eight or ten miles long by two or three miles wide. The direction of its axis was northeast, and the bulk of the field lay to the south and east of Lima. The percentage of dry holes within this territory was extremely small.

It has thus been shown that during the progress of 1886 a gas field of first-class proportions, in respect to territory, to rock pressure, and to productiveness, had been developed in Findlay and adjacent townships; and, further, that an oil field of magnificent promise in every respect, except, possibly, in the character of its oil, was rapidly being developed in Allen and Auglaize Counties. In other words, the deep-lying limestone of Findlay and Lima had during this year accredited itself as a reservoir of stored power scarcely inferior to the great oil rocks of Pennsylvania and New York.

The development of the new industry has now been set forth. What progress was to be reported for the next year for outlying territory? The experience of the year sets in strong light the exceptional fortune of the small districts that had been successful hitherto. The increased importance of Findlay gas and Lima oil and the prosperity that was plainly coming to these towns by reason of their discoveries made the search for like sources of wealth more resolute and persistent than ever throughout the entire western half of Ohio. Tests of the underlying rocks to the horizon of the Findlay gas rock, and oftentimes hundreds of feet below this limit, were made and often repeated more than once throughout this portion of the State, and even hamlets that had got along thus far without sidewalks or street lamps or graveled roadways, to say nothing of sewerage and water supply, suddenly awoke to the consciousness that life was scarcely worth living unless they could strike Findlay gas.

Drilling, directly inspired by the successful experience of Findlay and Lima, was carried on at nearly a hundred different points in the State during this year. There is but one county-seat in the western half of Ohio whose people failed to drill during this year, except where they had previously drilled. The question recurs, what increase of oil and gas territory resulted from all this tremendous activity and this large expenditure? The Lima field was extended by excursions into Auglaize County, and at Saint Mary wells were drilled that obtained questionable success as oil wells; but this was a normal extension of an established field, rather than the discovery of a new one.

At Oak Harbor, in Ottawa County, and in its vicinity, a distinct gas field was developed. It depended upon the same gas rock as Findlay, but the production was found associated with some new conditions. The territory, however, is small, and its yield is thus far of only local importance.

In a word, established fields were considerably extended, but mainly within limits that had already been approximately recognized. Not an addition of any large importance was made to the regions already known to be productive; and the thorough tests that were multiplied on every hand rendered it more and more probable that the real boundaries of the oil and gas territory had been fairly defined. Four counties contained practically all the gas and oil that had been found in the new horizon, viz, Hancock, Wood, Allen, and Auglaize. A single well, finished in Mercer County at the very close of the year, indicated that Mercer was soon to be added to the list.

THE FINDLAY GAS ROCK IN INDIANA.

A history of the discovery and an outline of the development of the new oil and gas horizon up to the close of 1886 has now been briefly recorded. A final section remains to be added to this division of the subject, and though it covers a short time, the facts that belong to it are second in importance only to the original discovery at Findlay. Indeed, it may well be questioned whether in prospective economic value the district now to be described is not the most important in the entire field. The scene is no longer laid in Ohio, or, at least, the division to which we have now come includes but a small area in that State. The Findlay gas rock has been traced from county to county until the State borders are reached and passed, and it is found to become the source of the remarkable production of natural gas that is now going forward in central Indiana. A gas field is in process of development there which, in the apparent magnitude and disposition of its area and in the reliability of its gas rock, so far as tested, is without a parallel in all known gas fields. It now appears to be a field without lines or belts. The most thorough belt and line expert would be puzzled to draw a line in the new territory for which even a plausible claim of superior advantage could be made. The field is spread out as if it were a receptacle of one of the fixed forms of stored power, like coal or black shale, rather than one of the ordinary reservoirs of the mobile forms of power, such as petroleum and gas. Oil and gas, being free to move, have been forced by the accidents of their history to seek the summits of the folds of the strata that contain them; and these summits or anticlines are generally arranged in more or less continuous lines, which are fairly persistent in direction. The Indiana field is probably to be referred, like the Findlay field, to terrace structure, but its scope is so much larger than the latter that comparison is difficult. The Findlay gas terrace, all told, does not probably contain more than 250 square miles of productive territory. The productive portions of the Indiana field, according to present indications, can not be comprehended within 1,500 square miles, and may very likely be found to occupy 2,000 square miles. Such an area of productive territory, it must be repeated, is altogether without a parallel in the history of gas fields. It is, however, to be borne in mind that the brevity of the history of the field does not justify us in laying down its boundaries with hard and fast lines.

The discovery of the Indiana field grew naturally and necessarily out of the extension of the new Findlay horizon in Ohio. It began in the latter part of 1886, but a more important development was included within the first half of 1887.

Reference was made at the close of the preceding chapter to the discovery of gas in Mercer County. On the edge of the Cranberry Marsh, Granville Township, late in December, 1886, a vigorous gas well was brought in. The rock was found at a high level for Ohio, viz, at about two hundred and thirty-five feet below tide. Several wells have since been drilled in this vicinity, all of them successful. In production they range each from a half million to four and a half million cubic feet a day. The usual volume is about two million feet. They are located in the southern half of the county. There is no reason for believing that the gas belt is strictly continuous, but up to the present time the failures have been few. The westernmost of the Ohio wells is located at Fort Recovery, near the Indiana line. The well drilled here in April, 1887, was altogether anomalous in character. It yielded nearly two million cubic feet of gas a day, but the gas was derived from the shallow depth of 525 feet and its horizon was in the Hudson River shales. The flow was so vigorous as to forbid or at least to hinder the further descent of the drill. The Findlay rock when reached was found at a high level but entirely unproductive. It is this Mercer County gas field that appears to extend bodily into Indiana. There seems good reason for holding to an apparent continuity of productive territory from one State to the other. Jay County, Ind., borders Mercer County, Ohio. The people of Portland, its thriving county seat, have made repeated trials of fortune in the Findlay rock. Seven or eight wells have been drilled for gas and several of them have proved moderately productive. The town has at once utilized it to the full extent.

Chas. D. Walcott.

Blackford County lies west of Jay. At Hartford, its county seat, a deep well was drilled, in the spring of 1887, which found a fair supply of gas in the Findlay rock.

Grant County is next west of Blackford. The gas developments in this county are the most important in the State thus far. Marion has four or more vigorous wells. Jonesborough has a well with a capacity of six or seven million cubic feet a day. Fairmount brought in, during May, the largest well in Indiana, one which is fairly comparable with the first-class wells of the Findlay field. Its daily volume is 11,500,000 cubic feet.

Still west of Grant County lies Howard. At Kokomo, its county seat, an enterprising and ambitious town, wells were drilled late in 1886 and found gas in the new horizon. Drilling has been since continued with only a fair measure of success so long as it confined its search to its immediate limits. Its experience here plainly indicates that it is located on the very edge of the productive field, but its last well, No. 5, drilled a mile and a half southeast of the town, has proved extraordinarily vigorous.

The story that has now been recorded is certainly a remarkable one. Wells have been drilled at the county seats of four consecutive counties and all have found gas in large and very profitable quantities. These counties lie in an east and west line, and the towns at the ends of the line are nearly seventy miles apart. Throughout this territory the gas rock is practically level. It is about seventy feet below tide at Portland and about ninety feet at Kokomo; and its range for the entire district does not probably exceed fifty feet. It is slightly higher in the middle of the line than at either extremity, and the greatest production appears to correspond with the greatest elevation. Another line about fifty miles long, drawn at right angles to the first, from La Fontaine on the north to Anderson on the south, and passing through Marion, Jonesborough, Fairmount, and Alexandria, at each of which towns very successful wells have been drilled, displays, even more strikingly than the first, the persistence and steadiness of the gas supply of this unique region. The range of elevation of the gas rock along this line is even less than on the east and west line already reported.

At many other localities great gas flows have been obtained. Anderson, Noblesville, and Muncie deserve special mention in connection with the productive towns already named. This, in brief, is the Indiana gas field, the greatest contribution of 1887 to the remarkable history that we are now tracing. Eight counties in this State, lying in a solid block, have obtained wells of large volume at twenty or more localities—the wells ranging from tens of thousands of feet to eleven and a half million feet a day. Several other counties have found in this rock smaller supplies of the same gas that are still counted valuable.

A connected chronicle has now been given of the results of the search for natural gas begun in Findlay in the fall of 1884, which since that time has swept like a prairie fire over a full half of the counties of Ohio and Indiana. On the part of many communities the interest in the search has been very great. It has led to a considerable increase of scientific knowledge, and, therefore, to a considerable increase in the popular respect for such knowledge, and from this point of view it marks a real advance for multitudes of people.

In this search there has been an immense expenditure of money. Drilling alone has absorbed a very large amount. But where the drill has been successful it has in many instances laid the foundation for a wonderful increase in the volume of business and an equally remarkable enhancement of the price of real estate. The investments following the discovery of natural gas in Ohio and Indiana towns for the last two years will aggregate tens and possibly scores of millions of dollars.

CHAPTER IV.

THE GEOLOGY OF THE NEW GAS AND OIL FIELDS.

THE GEOLOGICAL SCALE.

The geological scale of western Ohio and eastern Indiana is quite simple and easily apprehended in its general features, and yet there are many unsettled questions pertaining to it. Important additions have been made to our knowledge of the subject through the drilling which has been going forward during the last three years.

The order of the strata as determined both by their outcrops and by the sections found in wells may here be briefly given. The lowest rocks of the two States in geological order are found in southwestern Ohio and southeastern Indiana. All of the strata here exposed dip gently to the northward, but an east or west element is generally to be added to the northerly descent. It is obvious, therefore, that to find the strata underlying this region we must look to the southward. These buried rocks of Ohio and Indiana rise to the surface in Kentucky and are well shown in the northern central counties of that State. As distinguished and divided by the present geological survey of Kentucky[1] they are as follows, the strata being named in descending order, viz: Trenton beds, 175 feet thick; Birdseye beds, 130 feet thick; Chazy Limestone, 350 feet thick. It is these lower limestones, and especially the one first named, the Trenton, that give rise by disintegration and decay to the wonderfully fertile soils of central Kentucky. The Blue Grass region owes its agricultural excellence to this source. The several divisions are described by Mr. Linney in the paper already referred to. The Trenton is said to be composed of a heavy-bedded, semi-crystalline, gray limestone, followed by brecciated limestone, black limestone, black shale, and bituminous limestone, which in turn is succeeded by shaly layers and finally by heavy-bedded limestone at the bottom of the series. Certain dove-colored beds are found at the top of the Trenton in some instances in the southern counties. It is thus seen that the series is composite.

The Birdseye is described as a pure, compact limestone, brittle and breaking with a conchoidal fracture and with crystalline portions scattered throughout, which represent the former places of fossils.

[1] Rocks of Central Kentucky, W. M. Linney, Geol. Survey Kentucky, 1882.

The Chazy beds are described as heavy-bedded, strong, tough limestones, full of the impressions of sea weeds and having *Murchisonia magna* as the most characteristic fossil.

With all these beds the people of Ohio and Indiana are becoming acquainted, as specimens are represented in drillings brought up from deep wells sunk on every side.

It seems probable that the Trenton lime stoneeven enters Ohio in outcrop, shown in a single line of quarries, viz, those located at Point Pleasant, Clermont County, 15 miles above Cincinnati. These quarries have long been known to be the deepest-lying beds of the State.[1] The identity of these beds with the Trenton limestone of the Kentucky scale was asserted a number of years ago by some geologists. Mr. S. A. Miller, of Cincinnati, made this reference in 1873.[2] But taking the Trenton limestone as the base of the Ohio and Indiana sections, so far as these sections are involved in the present discussion, and counting the Ohio black shale of Devonian age as the summit of these sections, what formations of the general scale are due in the interval? Dana's classification of this part of the column of the United States is essentially as follows (see Manual, 3d edit., pp. 142, 163, 236):

Ages.	Periods.	Epochs.
	Chemung	Chemung group. Portage shale.
DEVONIAN	Hamilton	Genesee slate. Hamilton group. Marcellus shale.
	Corniferous	Corniferous limestone. Schoharie grit. Cauda Galli grit.
	Oriskany	Oriskany sandstone.
	Lower Helderberg	Lower Helderberg: Pentamerus limestone, etc.; Waterlime.
UPPER SILURIAN	Salina	Salina shales.
	Niagara	Niagara: Limestone; Shale. Clinton group. Medina sandstone and shale.
LOWER SILURIAN	Trenton	Hudson River group. Utica shale. Trenton limestone: Trenton; Black River; Birdseye.

The divisions named above cover the geological history of the entire country for the vast periods represented. They are found in their fullest display on the eastern border of the continent, and especially in the States of New York and Pennslyvania. How many

[1] Rept. Geol. Survey Ohio, vol. 1, pp. 120, 370.

[2] Jour. Nat. Hist. Soc. Cincinnati.

of them are to be recognized in the geological scale of these interior regions?

Beginning with the Trenton limestone as the unmistakable base of the section with which we have to deal, we find above it in outcrop the following formations, the identification of which is not likely to be called in question, viz: The Hudson River group, which is known in the geological reports of Ohio as the Cincinnati group; the Medina shale, the Clinton limestone, the Niagara shale and the Niagara limestone, the Lower Helderberg limestone in one well-characterized division and perhaps in more than one, the Corniferous or Upper Helderberg limestone, the Marcellus shale, the Hamilton limestone and shale, and the Genesee shale. The Portage shale would also be recognized with but little question. It is held by several geologists that the Salina group has outcrops in northern Ohio and that the Oriskany is represented in both Ohio and Indiana. To this list we can add the Utica shale, the presence of which in characteristic and unmistakable form has been made known to us through the drilling carried on of late in the State. This well-defined stratum is found under deep cover in full force in northern Ohio. It is reduced in thickness as it is followed to the southward and appears to be lost by or before the time the Ohio Valley is reached in the southwestern corner of Ohio. No trace of it, at least in its *normal form*, viz, a brownish-black shale with few but characteristic fossils, has been reported in the outcrops of its possible horizon in Kentucky. As to the separation of the Marcellus, Hamilton, and Genesee divisions in the States now under consideration, some question may be raised. Prof. R. P. Whitfield positively identifies the Marcellus shale in a band of shaly limestone that is interpolated in the upper portion of the Devonian limestone of central Ohio and is generally counted with the latter formation. It follows from this identification that the limestone beds intervening between the Marcellus shale and the Genesee shale is Hamilton in age. Dr. Newberry identifies the Hamilton in one or two exposures of fossiliferous shale in Erie County, Ohio; Prof. James Hall is counted authority for recognizing the Genesee slate in the basal portion of the Ohio black shale. The section as thus reduced is represented in Plate LIV.

A brief account will be given of the several elements of the scale.

THE TRENTON LIMESTONE.

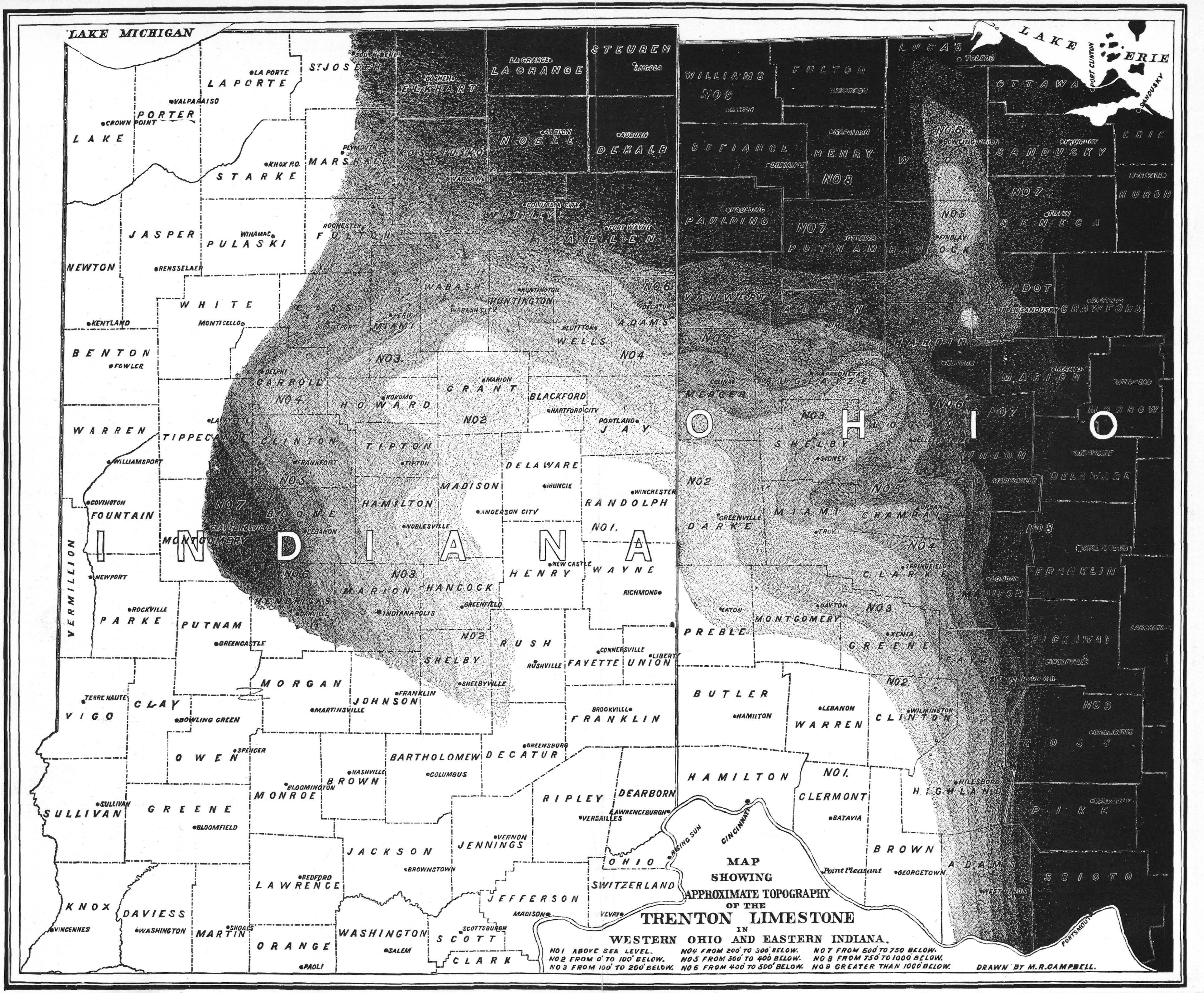
The Trenton limestone has suddenly become invested with great economic importance. The geological questions connected with it are of greater interest, in fact, for very many towns of Ohio and Indiana to-day than any other geological question or than all other geological questions combined, such interest embracing the questions, How deep beneath them it lies; in what direction and at what rate it slopes; what its grain and composition are; and, above all, whether it is porous, and if so, what it holds—whether gas, oil, or salt water, and what amount. The cause of this new-born interest in the Trenton limestone lies in the fact that the recently discovered gas and oil rock of northwestern Ohio and of Indiana, the history of which has been traced in the preceding chapter, has been identified with it. How the gas rock of Findlay was proved to be the Trenton limestone can be told in a few words.

From the Pioneer well at Findlay the following section was reported by the driller, viz:

	Feet.		Feet.
Drift	8	Red slate	33
Limestone, gray and blue	160	Gray shale	400
Thin slate	2	Brown shale	352
Limestone	75	Solid limestone struck at	1092
Blue shale	38	Main gas from	1092–1108

The limestone series extended with slight changes of grain and color to 1,648 feet, where salt water was reached and the drilling was suspended. The solid limestone, when first struck, was mistaken by local geologists for the Cincinnati limestone. Mr. Charles Eckels, one of the nine members of the original Natural Gas Company, devoted the most of his time while the drilling was going forward to keeping a record of the well. He saved with great care well washed samples of the drillings that marked all changes of importance in the rocks. These drillings he kindly turned over to the Ohio Geological Survey, and the samples proved invaluable in determining the stratigraphical order of the well section. Few subsequent records have been as thoroughly supported by the drillings as was the first.

The limestone which was first struck in the well is worked in adjacent quarries and is unmistakably Niagara limestone. Of these beds there were 160 feet. The two feet of slate reported by the driller as coming next below were found to be an exceedingly fine-grained and bluish-white clay which is a very characteristic formation. It marks the boundary between the Clinton limestone and the Niagara limestone in their outcrops to the southward. By its fossils it is held to belong to the Clinton series, but in ordinary sections it is generally counted in with the Niagara shale, with which it has a closer physical agreement. This last-named element was not reported in this well, but in most that have been drilled here since it is unmistakable. Its ordinary thickness is from ten to twenty-five feet. Its place would be directly above the clay already described. The limestone beds next below were also thoroughly characteristic. They were marked by high colors, white, gray, and blue. They were also highly crystalline, and in every way they corresponded well to the Clinton formation as seen in its southern outcrops. To this formation they belonged. The thickness reported by the driller, viz, 75 feet, is a little less than the usual measure. Whether the 38 feet of blue shale reported next below is to be referred to the Clinton or to be counted with the stratum that underlies it can not be positively


MAP
SHOWING
APPROXIMATE TOPOGRAPHY
OF THE
TRENTON LIMESTONE
IN
WESTERN OHIO AND EASTERN INDIANA.
NO 1 ABOVE SEA LEVEL.
NO 2 FROM 0' TO 100' BELOW.
NO 3 FROM 100' TO 200' BELOW.
NO 4 FROM 200' TO 300' BELOW.
NO 5 FROM 300' TO 400' BELOW.
NO 6 FROM 400' TO 500' BELOW.
NO 7 FROM 500' TO 750 BELOW.
NO 8 FROM 750 TO 1000 BELOW.
NO 9 GREATER THAN 1000' BELOW.
DRAWN BY M.R.CAMPBELL.
INDIANA
OHIO
LAKE MICHIGAN
LAKE ERIE

determined, but in reference to this underlying stratum, viz, the 33 feet of red rock that follows in the record, no question can be raised. Its color and its grain, taken in connection with its stratigraphical order, make it certain that it is the Medina shale of the New York column. The red band often carries streaks of sand and small pebbles. The thickness of this division is probably given too low in the driller's report. At least, in all adjacent wells, larger measures have been found.

Not more difficult was the positive identification of the 400 feet of gray shale that came next in order as the Hudson River shale of the New York series. This division might as well have been counted a little thicker and the next below a little less. Between these two beds of shale the boundary is not sharp and distinct, but the gray shale gradually grows darker and it is always a question as to just where the dividing line shall be drawn. In this series were many thin sheets of limestone carrying the usual fossils of this formation, fragments of which were frequently brought up large enough to admit of identification.

After the preceding statements, the name and place in the geological scale of the three hundred or the three hundred and fifty feet of the brown shale of the driller require no discussion. This division, in its nearest exposures in New York and Canada, coincides in order, in lithological characteristics, and in volume with the Utica shale. The final demonstration of its geological age, of course, would depend on the identification of the characteristic fossils of the Utica shale in these deep-lying beds. But to find in the chips brought up by a sand pump from a thousand or twelve hundred feet below the surface the characteristic fossils of a formation in which such fossils are as a rule of small size and sparingly distributed would seem to be asking too much of fortune. Yet in the case before us even this final evidence was not wanting. Excellent specimens of the almost microscopic shell *Leptobolus insignis* Hall were found on many chips from the bottom of the black shale. Other fragmentary fossils which are common in the Utica shale of New York were also found here. The specimens were submitted to Prof. R. P. Whitfield, of the American Museum, New York City, and he reported the formation to be, without question, the Utica shale.

The determinations that have now been given make the identification of the firm but porous light-colored limestone, fossiliferous in many of its layers, which lay next below the black shale but separated from it by an abrupt boundary, and which was the main source of the gas in the well, an easy task, and one in regard to which differences of opinion can scarcely arise. The Findlay gas rock is the Trenton limestone, one of the best known and the best characterized as well as one of the most widely distributed strata in the older portions of the geological scale of the continent. Its economic services hitherto have been confined to every-day and commonplace uses. It has furnished building stone of excellent quality and road material on a large scale. At many places it has been burned into lime of approved quality, and it is sometimes pure enough for furnace flux. Years ago Dr. Hunt called attention to its petroliferous contents, shown in a preceding section, but no facts were added to those given by him until the discovery at Findlay in 1884. What was known in regard to its value in this respect before gas was found at Findlay was of the smallest value. The Trenton limestone could not be said, in fact, to have the slightest importance or significance as a source of petroleum or gas. What has been learned since makes it one of the greatest reservoirs of stored power of the entire geological scale of the country, comparable on nearly or quite equal terms with the famous Devonian oil sands of Pennsylvania, or even with the coal seams of Carboniferous or Lignitic age in important coal fields.

The identity of the Findlay gas rock and the Trenton limestone has now been shown and the limestone has been traced, by the driller's sections, through all portions of northwestern Ohio and the adjacent parts of Indiana, and no question can exist as to the bodily extension in all directions from Findlay of the series that was first found and identified there.

Returning from this digression, which was made necessary by the introduction of the Trenton limestone and the Utica shale into the geological scale of Ohio and Indiana, the character of these two last-named formations, as found in the two States, will be briefly given. It must be premised that as to the Trenton limestone no single statement will suffice. The formation varies in character at different localities. It has three well-marked and distinct phases, but these graduate into each other imperceptibly, giving rise to rocks that differ widely among themselves in character. For purposes of comparison, it may be borne in mind that the Trenton limestone of New York and New Jersey consists of about 80 to 90 per cent. of carbonate of lime and 2 to 10 per cent. of carbonate of magnesia.

The Point Pleasant beds, which, as has been stated, are probably the bodily continuation of the Trenton limestone of Kentucky, consist of heavy-bedded, light blue or gray limestone, somewhat slaty, and sometimes rudely concretionary in structure. The analysis of a single specimen of the quarry stone (1) and two analyses of the concretionary beds (2) and (3) (Wormley) show their composition to be as follows:

	(1)	(2)	(3)
Siliceous matter	12.00	18.00	12.40
Alumina and iron	7.00	2.60	3.00
Carbonate of lime	79.13	76.40	73.20
Carbonate of magnesia	0.91	2.77	10.44

How much of the rock is represented in these analyses has not been ascertained, but appearances would indicate that nearly similar results would be obtained from the remaining portions of the beds exposed. An analysis of the uppermost beds that are counted Trenton at Cincinnati is significant. The sample that was analyzed was obtained from a well of one of the gas companies, at a depth of two hundred and eighty to three hundred feet below the surface, or about one hundred and ninety feet above tide, from a stratum believed to be of the same age with the Point Pleasant beds; and the results of the analysis show a close agreement between the two rocks. The analysis (Lord) is as follows:

Siliceous matter	12.95
Iron and alumina	5.04
Carbonate of lime	78.70
Carbonate of magnesia	1.93

The result of a single analysis of Trenton limestone from Kentucky are also added. The figures are published by the Kentucky Geological Survey:

Carbonate of lime	70.00
Carbonate of magnesia	7.00

The Trenton limestone struck at Hamilton, at about two hundred and fifteen feet above tide, has the following composition:

Siliceous and insoluble matter	12.00
Carbonate of lime	84.75
Carbonate of magnesia	3.25

At Hillsborough, 70 miles east of Cincinnati (depth, 1,200 feet; below tide, 125 feet), the proportions are:

Siliceous and insoluble matter	11.80
Carbonate of lime	85.00
Carbonate of magnesia	2.20

At New Vienna, Clinton County (depth, 1,226 feet; below tide, 96 feet):

Siliceous and insoluble matter	21.10
Carbonate of lime	74.00
Carbonate of magnesia	4.90

At Osborn, Greene County (depth, 990 feet; below tide, 168 feet):

Siliceous and insoluble matter	14.50
Carbonate of lime	81.80
Carbonate of magnesia	2.70

At Springfield (depth, 1,150 feet; below tide, 210 feet):

Siliceous and insoluble matter	9.63
Carbonate of lime	81.00
Carbonate of magnesia	6.00

At Springfield a second analysis was made, showing the limestone at 1,200 feet, or 50 feet below, to consist of:

Siliceous and insoluble matter	12.19
Carbonate of lime	84.01
Carbonate of magnesia	1.88

At Piqua, Miami County (depth, 1,208 feet; below tide, 307 feet):

Siliceous and insoluble matter	17.70
Carbonate of lime	78.70
Carbonate of magnesia	2.60

At Columbus, 1886 (depth, 1,915 feet; below tide, 1,188 feet):

Siliceous and insoluble matter	23.60
Carbonate of lime	69.30
Carbonate of magnesia	6.10

The drillings were mixed with Utica shale, and the figures in the first line are too high. Reducing to the normal proportion we find carbonates of lime and magnesia to be, respectively, 76 and 7 per cent.

At Columbus, State-House well (depth, 2,115 feet):

Siliceous and insoluble matter	9.84
Carbonate of lime	84.16
Carbonate of magnesia	2.96

At Columbus, State-House well (depth, 2,340 feet):

Siliceous and insoluble matter	12.19
Carbonate of lime	84.01
Carbonate of magnesia	1.88

In most if not in all of these cases the limestone appears as a nearly white and flaky rock, the drillings coming up in thin chips. Throughout southern Ohio this phase is universal, and as far as the drillings derived from southern Indiana have been examined they prove to be of the same character.

The analyses thus far show that the rock in southern Ohio agrees fairly well with the eastern type of the Trenton, in which the carbonate of lime ranges between 80 and 90 per cent. and the carbonate of magnesia between 2 and 10 per cent. It will be borne in mind that the analyses already reported have been in all cases confined to the uppermost beds of the Trenton unless otherwise specified. In none of the localities represented has it been proved an oil or gas rock of any importance whatever. It is, of course, impossible to verify details of physical structure in drillings, but so far as can be judged the Trenton limestone in southern Ohio is fairly well represented in the Point Pleasant type, already described. The drillings are mainly light-colored and often almost white, and are flaky in structure.

Passing northward from the parallel of Piqua and Columbus, we soon discover a marked change in the composition of the uppermost beds of this formation. They are now found through a number of counties to be magnesian limestones and nearly true dolomites in composition, and of a fair degree of purity. Several analyses are subjoined which will serve to show the facts pertaining to the limestone in this portion of the State. The thickness of the magnesian beds has not been definitely determined, but it is probably less than one hundred feet in all and less than fifty feet in most cases.

The first intimation of change is to be noted in the results of analysis of the gas rock at Sidney (depth, 1,226 feet; below tide, 267 feet), the proportions here being as follows:

Siliceous and insoluble matter	4.40
Carbonate of lime	62.30
Carbonate of magnesia	32.30

The Trenton limestone is seen to have become a highly magnesian limestone in this short interval, though still falling short of true dolomitic proportions. It is altogether probable that the Sidney rock consists of dolomite intermixed with calcite.

This last-named or dolomitic character is reached in the next stage to the northward. In the Lima oil field the Trenton limestone has become essentially a dolomite. Its composition is shown in the following analyses, the first being of the Paper Mill well, depth of surface of limestone, 1,247 feet; below tide, 297 feet; the second that of the Woolsey well:

	1.	2.
Carbonate of lime	55.90	52.66
Carbonate of magnesia	38.85	37.53
Alumina and iron	2.94	.....
Silica	0.75	.....

A single discordant analysis must be added. The Trenton limestone in the Hume well is found to consist of:

Carbonate of lime	63.46
Carbonate of magnesia	24.20
Iron and alumina	2.75
Siliceous matter	5.10
Organic matter and loss	4.49

It is sometimes found that the uppermost beds of the Trenton consist for a few feet of a true limestone overlying the dolomite. This cap is recognized by the driller by its hardness. A little of this intermixed with the oil rock would explain the analysis given above.

Passing to Findlay, we find the gas rock of the Pioneer well to yield the following results to analysis:

Carbonate of lime	47.05
Carbonate of magnesia	33.38
Insoluble residue	11.73

The drillings that were analyzed came from the cap of the Trenton limestone and carried many particles of the overlying Utica shale. The limestone proper was doubtless a dolomite. Reducing the figures above given to the common basis by rejecting a part of the insoluble residue, we find the proportions of the carbonates of lime and magnesia to be, respectively, 54.41 and 35.69 per cent.

The composition of the surface of the Trenton limestone (1) at Bowling Green, Wood County (depth of surface of limestone, 1,096 feet; below tide, 387 feet), is given below, and also the composition of the limestone 94 feet below the surface (2):

	1.	2.
Insoluble residue	4.89	2.15
Carbonate of lime	51.78	88.64
Carbonate of magnesia	36.80	6.77

Following this great sheet to the eastward we obtain the following results at Fostoria, the surface of the Trenton being reported from this point (1) (depth, 1,264 feet; below tide, 472 feet), and also the composition of the limestone 146 feet below its top (2):

	1.	2.
Insoluble residue	5.82	13.48
Carbonate of lime	61.50	63.13
Carbonate of magnesia	27.30	21.05

The return of the rock towards the constitution first indicated is to be observed. A still further change is found in the composition of the cap of the Trenton limestone at Fremont, 20 miles northeast of Fostoria, which is as follows:

Insoluble residue	6.53
Carbonate of lime	75.74
Carbonate of magnesia	13.37

The farthest point eastward to which the Trenton limestone has been followed in the deep wells of Ohio is Plymouth, Richland County. The Trenton was struck here at a depth of 2,900 feet, or about 1,900 feet below tide. Its composition as found here is as follows:

Insoluble residue	16.6
Carbonate of lime	67.5
Carbonate of magnesia	14.9

Rejecting the excess of shaly matter that resulted from the intermingling of the overlying shale, we should probably find the carbonate of lime to reach at least 70 per cent. The change here seen to be in progress gives small promise of success to the towns of the eastern part of the State that are spending so much money to reach the Trenton limestone.

A third distinct type of the Trenton limestone remains to be mentioned, viz, a nearly pure carbonate of lime, light gray in color, crystalline in composition and distinctly fossiliferous, the fossils occurring in identifiable condition. It constitutes the cap or cover of the gas rock proper in many portions of the Ohio field and notably in Mercer County. It has been found also within the limits of Findlay and at other points, as Carey and Dunkirk. In thickness it does not, so far as observed, exceed eight or ten feet. The driller always recognizes it when present by reason of its hardness. When the well is torpedoed this cap-rock is almost certain to furnish a considerable part of the larger fragments that are thrown out, and thus it comes to be considered by many as the true source of the gas. This reference is, however, inadmissible. It contains little or no gas, and in all productive wells is underlaid by the dolomite already described.

This type of the Trenton limestone is supported by a single analysis only, but the appearance of the rock is so characteristic that it can easily be identified.

The analysis in question is derived from fragments of the rock thrown by the torpedo from the second well at Saint Henry's, Mercer County, and is as follows:

Siliceous residue	1.27
Carbonate of lime	93.64
Carbonate of magnesia	3.87

The composition of the Trenton limestone has not been determined at many points in Indiana, but it is certain that the same lines of facts now shown to exist in Ohio are essentially duplicated there. The southern or normal type of the rock (80 per cent. carbonate of lime) enters the State from Ohio in Union, Wayne, and Randolph Counties, and extends westerly or southwesterly from this region. It probably occupies Henry and Hancock Counties in large part. It is certainly found in Rush and Shelby Counties.

The Findlay or dolomitic type enters from Ohio in Jay County and spreads out through Delaware, Madison, and Hamilton to the southwestward, and through Blackford, Grant, Howard, and Miami to the west and northwest. It appears probable that this phase of the limestone underlies all northwestern Indiana.

Several analyses of the Indiana gas rock will be found in the final chapter of this report. Two will be introduced here to illustrate the uniformity of composition that prevails in the productive phase of the Trenton limestone wherever found. The examples are taken from Muncie on the south and Kokomo on the west. The results are as follows:

	1.	2.
Carbonate of lime	51.96	52.80
Carbonate of magnesia	38.11	39.50
Alumina and oxide of iron	3.72	2.40
Insoluble residue	3.30	4.60

Both examples are seen to represent the highest type of the Findlay gas rock.

THE UTICA SHALE.

The formation which has been described under the last heading has not more than a single outcrop in the State, and yet it is more studied and discussed than any other stratum in our entire geological column. The formation next to be considered occurs even less frequently than the Trenton limestone, and there is no undisputed outcrop of it within the State limits.

The conditions under which it was first unmistakably recognized in Ohio geology will now be recalled, viz, as 300 feet of brown shale in the Findlay wells, which became darker as they were followed downward, until at their basal portion they could properly be called black shales. It must be acknowledged that the upper boundary is not sharp, as the blue shales of the Hudson River division gradually change into the brown shales of the Utica division. This great shale formation has been followed in all directions from Findlay with proportions that alter but slowly. It is expanded somewhat to the eastward and it is reduced to the westward, but through several counties south of Findlay it seems to retain the volume and the character first found. When traced farther southward it becomes more calcareous and its shaly beds are sometimes altogether interrupted by limestone seams of ten to fifteen feet thick. It seems to have its original thickness in sections obtained at Springfield and at Piqua, and its color is scarcely broken there, but its composition is somewhat changed in this locality, the transformation already noted becoming more and more manifest as it is followed to the southward. A few approximate analyses show its general constitution:

	Bowling Green.	Fostoria.	Springfield.
Siliceous residue	68.32	71.68	50.33
Carbonate of lime	11.87	9.86	36.82
Carbonate of magnesia	6.88	4.95	3.86

In all these cases the samples were taken from the lower half of the formation and represent its darker portions. A great variety in composition could doubtless be made out by the analysis of the different beds of the formation. An average composition can scarcely be found.

To the westward, and especially in portions of the Indiana field, the shales that make so prominent a part in the Ohio records, viz, the Medina, the Hudson River, and the Utica, are much reduced. Whether the Medina appears at all is a question. The division between the Hudson River and Utica shales is also much less distinct than in Ohio, and it is quite likely to be found that one or the other fails altogether in different parts of the field. If the Utica is found at all in the central part of the gas field it is somewhat lighter colored than in Ohio. The evidence of fossils bearing on its presence or absence has not yet been found.

In the Ohio Valley it is still a question whether the Utica is represented or not in open section. Its presence has been positively asserted by several geologists, among whom may be named Messrs. S. A. Miller, C. D Walcott, and E. O. Ulrich. The argument for its presence has been based on paleontological grounds mainly. In the lower beds exposed at Cincinnati there are found various fossils that are counted diagnostic of the Utica shale; but the fact that fossils beginning in the Trenton limestone of New York and characteristic of it there are found in the beds here counted Utica, and even in far higher beds in this region, would suggest a possibility of a like ascent of the ancient life of the Utica shale of New York to the Hudson River beds of Ohio It may be added that some of the fossils which are named in the lists as characteristic of the Utica are not strictly so, since they are found even at the east in both the higher and the lower formations, as, for example, *Triarthrus Becki*. Though considerable deep drilling has been done about Cincinnati, few records have been obtained that throw much light upon the series until quite recently. A careful register of a well now being drilled in Cincinnati has been kept by Dr. W. A. Dun, the section of which to date, kindly furnished by him, is as follows, viz:

	Feet
1. Drift	48
2. Blue limestone and shale	54
3. Bluish limestone	20
4 Blue limestone and shale	50
5. Black, brown, and calcareous shale	47
6 Limestone, crystalline, hard, white, some beds dark	73
7 Black-brown shale	15
8. White, compact limestone, with greenish tint	110

Mr. E. O. Ulrich identifies No. 2 of this series as the sole representative of the Utica shale, and makes the Trenton begin at a depth of 102 feet in the well. This determination assumes that 300 feet of black shale which can be found for more than a thousand miles as such, and which is traced to within 75 miles of Cincinnati, has been entirely replaced in this interval by 54 feet of blue limestone and shale, indistinguishable in physical characteristics from the normal Hudson River shale. A more probable reference, on stratigraphical grounds, would be to make the compact limestone, No. 8, the top of the Trenton, and to count Nos. 5, 6, and 7 as Utica.

The new opportunity to study the extensions and the equivalents of this wide-spread stratum will doubtless lead to a clearing up of our knowledge in regard to questions like these. A few carefully kept sections in the interval between central Ohio and the Ohio River will do a great deal towards removing the present uncertainty. Until they are secured, any prolonged discussion over the several possible constructions of the facts in hand would seem to be a waste of time.

THE MEDINA SHALE.

A bed of red shale, ten to thirty feet thick, marks the boundary between Lower and Upper Silurian time in several counties of southwestern Ohio. It is especially well marked in Greene, Clark, Montgomery, and Preble Counties. It was identified in Newberry's survey of Ohio, on purely stratigraphical grounds, as the equivalent of the Medina formation of the East.[1]

A heavy bed of red rock two to three hundred feet thick which was reported in the State-House well, and a like thickness which seemed to be shown in drillings on the lake shore many years ago had previously been recognized by Newberry as probably the equivalent of the Medina formation.[2] But it was reserved for the driller's records of the last few years to complete the demonstration of this claim and to fully establish and confirm the halting reference which was made in 1869 of the red shale of southern Ohio to the Medina epoch. There is now a connected series of well records from the lake shore southward in which the Medina occurs as a red shale from one hundred and fifty to thirty feet in thickness. The shale is sometimes interrupted with streaks of sand or of small pebbles of quartz and other rocks. These sand streaks are sometimes greenish in color and become oil or gas reservoirs on the small scale. A good example of this phase was found at Bluffton, Ohio, and in many other sets of drillings the same line of facts has been noted. Generally the material of the stratum is a soft shale, much of it bright red in color, but frequently interrupted with beds of blue shale. No fossils have been reported in it thus far in drilling. In outcrop the formation is also devoid of traces of life except rude casts of sea weeds.

The Medina shale, so far as it is represented by red beds, fails entirely in the extreme northwestern counties of Ohio, and no trace of it is reported from Indiana. No red rock is found in the Lima field,

[1] See Report for 1869, p. 148; Report for 1870, p. 268.
[2] Rept. Geol. Survey Ohio, vol. 1, p. 126.

nor in the Auglaize or Mercer County wells. Of the few exceptions to the general statement given above one comes from Van Wert County, where in the first deep well drilled last year there were a few feet, not to exceed five or six, of red rock at the place where the Medina is due. The record of well No. 4, Bryan, also indicates the presence of a few feet of red rock at this part of the scale. So far as known this marks the farthest advance of this phase of the Medina to the westward. Whether the top of the great shale series in this region belongs to the Medina age can not be determined. At the present time it seems quite possible that the Medina "wedges out" to the westward.

THE CLINTON GROUP.

In the Findlay field, and throughout much of northern Ohio, a blue shale, thirty or forty feet thick, always covers the red shale just described. Whether the blue shale should be referred to the Medina or to the Clinton is an open question. It is certain that in some parts of the State the Clinton incloses beds of shale, interstratified with the limestones that constitute the bulk of the formation.

In its outcrops, all of which are confined to southern Ohio and southern Indiana, the Clinton beds are definitely marked. They consist, in their best phases, of highly crystalline, crinoidal limestones, very uneven in bedding and marked by high colors, as pink, red, white, and yellow, along with the common shades of brown, blue, and gray. Besides the crinoidal remains, which often make the substance of the rock, other fossils of the usual types abound in these beds. The most unequivocal mark of the Clinton is the iron ore that it contains. There is not in the geological scale of the country a more entirely unique or distinctive formation than this Clinton ore. Nothing like it is known in any other part of the scale. This ore is found in good condition and in fair thickness at several points in southern Ohio. A small furnace was built fifty years ago in Clinton County to work it. The ore is also found in unmistakable character in deep wells at Lancaster and at Newark. Red rock, indeed, is one of the distinguishing marks of the Clinton throughout all central Ohio. The first red rock struck in the State-House well is Clinton limestone. In the deep well at Sandusky, also, there is a large amount of red rock to be referred to this age.

The chemical composition of the Clinton limestone in its outcrops in Ohio and Indiana is nearly uniform. It ranges between 75 and 85 per cent. of carbonate of lime, with 10 to 15 per cent. of carbonate of magnesia. Under cover in northern Ohio it does not show the same composition, but approaches more nearly to the dolomitic composition of the Niagara series.

The question that has been raised by some geologists as to the separate place of the Clinton in the geological scales of the States now under consideration could scarcely have been raised if all the facts of its outcrop had been known, and especially the facts that pertain to the occurrence of its peculiar ore. But, now that the records of the deep wells are in hand, giving a continuous section from the lake shore to the Ohio valley, there is no ground whatever for the doubt that has been expressed. The New York section can be followed into northern Ohio with its elements and its proportions almost unchanged, and it can even be followed across Ohio with only minor changes in the thickness of the several groups.

The Clinton limestone is as well characterized in its outcrops in southern Indiana as in southern Ohio, with the exception of the fossil ore which has not been reported in the former State. In the well records it often figures as blue limestone.

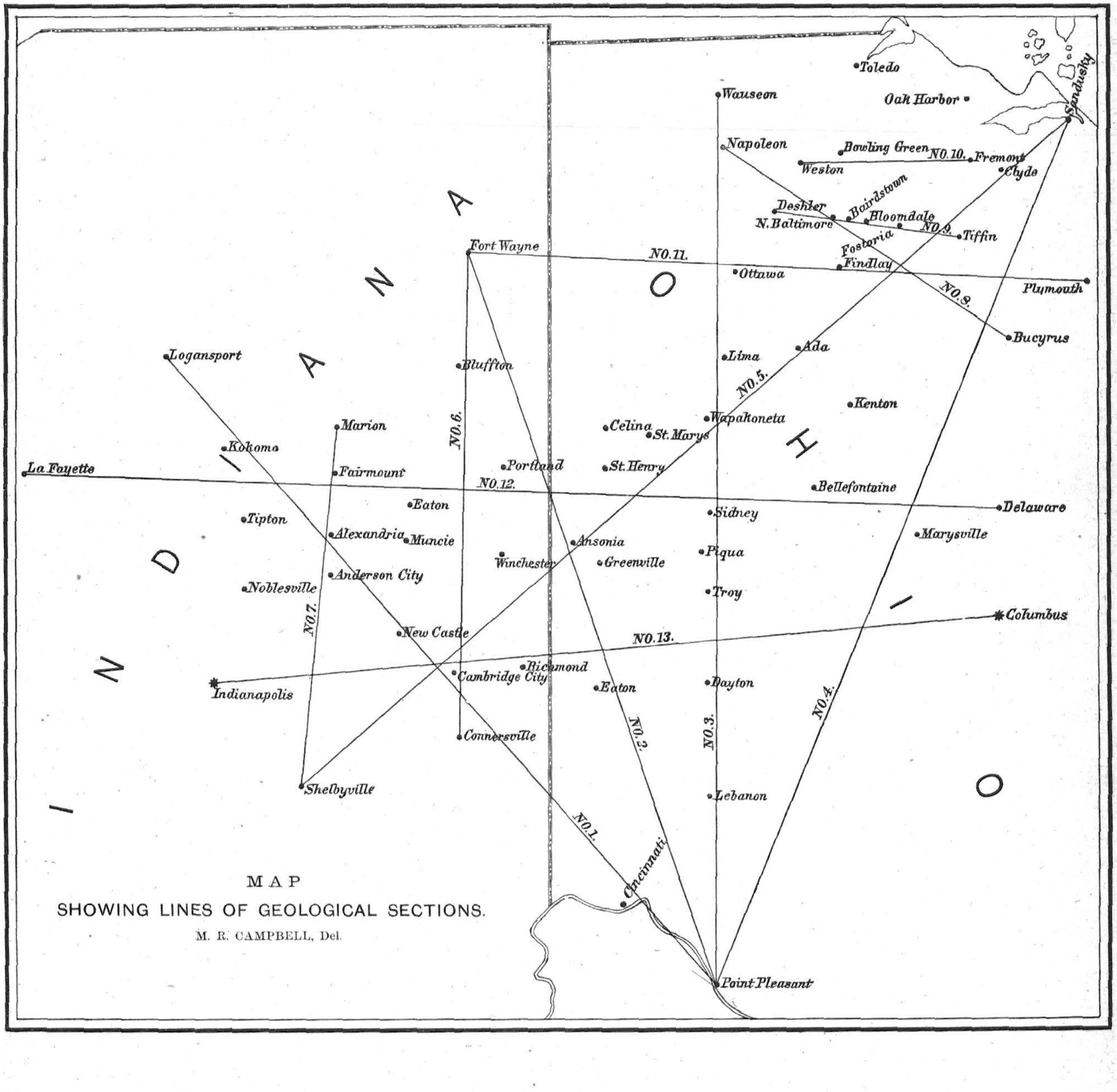
The thickness of the Clinton varies considerably in different portions of the territory now under consideration. In its outcrops it ranges from fifteen to sixty feet. Under cover in northern Ohio it is about seventy-five to ninety feet; but in the central parts of Ohio the deep wells show one hundred to one hundred and fifty feet in this series.

The Clinton limestone in southern Ohio is overlaid by a bed of very fine-grained, bluish-white clay that carries a number of characteristic fossils. This clay is generally counted in with the Niagara shale, which is found next above it, rather than with the solid limestone that it covers, but its relations are undoubtedly with the latter.

Special interest attaches to the Clinton formation in Ohio on account of its petroliferous character. The presence of petroleum in this limestone was first noted by Dr. Locke in his notes upon the geology of southwestern Ohio, in the first geological survey of the State.[1] Outcrops and especially quarries of the Clinton limestone in Preble, Montgomery, Miami, Clarke, and Greene Counties frequently show small quantities of petroleum, generally in connection with springs that issue from the rock. Sometimes a pint or two of oil can be obtained from the surface of the water, and in breaking the limestone oil is found in cavities within it. These "surface indications" have led to a great deal of unprofitable exploration in the way of deep drilling. All that they stand for is a small amount of indigenous oil, and the deeper the drill descends the farther it is from the source of the oil.

Under cover, however, the formation has recently developed a more valuable stock of oil and gas. Throughout the new field of northern Ohio, at many points, gas and oil have been found in valuable quantities in this formation. Quite large flows of gas were derived from it in several of the Findlay wells. In Portage Township, Wood County, it has proved in a single well a somewhat prolific oil rock. A well drilled during the present year has produced as high

[1] Facts more fully given in Newberry's Survey, vol 3, p. 407.



MAP

SHOWING LINES OF GEOLOGICAL SECTIONS.

M. R. CAMPBELL, Del.

as forty barrels a day of Clinton limestone oil. No long life is expected for the well. At Fremont, the Clinton has proved a valuable source of low-pressure gas for domestic use. The stratum is reached at about six hundred feet below the surface, and wells drilled to it yield from two to twenty thousand feet of gas a day. The supply has proved fairly persistent for the two years since the first wells were drilled.

Still more interesting is the experience of Lancaster. A deep well drilled here in 1886–'87 reached the Clinton group at about nineteen hundred feet. At 1,962 feet, in a hard limestone, between two layers of red rock, one of them being well-marked fossil ore, a considerable vein of gas was struck. Five wells have since been drilled to the same depth and all produce gas or oil, one of the gas wells yielding 1,000,000 cubic feet a day. The same horizon appears to be found at Newark, Ohio, at a depth of about twenty two hundred feet. The Clinton limestone has not been separated from the Niagara in many of the Indiana wells; but it can be distinguished clearly in a part of the new field.

THE NIAGARA GROUP.

The Niagara group consists of two elements, viz, the Niagara shale and the Niagara limestone, named in ascending order. Both are well shown in the new oil and gas fields.

The Niagara shale.—In outcrop the Niagara shale ranges in thickness from five or ten feet in Clarke County, Ohio, to one hundred feet in Adams County. There may be sections in which it does not appear at all, but usually the Clinton limestone is separated from the overlying Niagara limestone by a few feet of white or yellowish, impure, calcareous shale. Under cover in northern Ohio the shale makes a constant element in the Findlay field. It ranges from five to thirty feet in thickness. In central Ohio it seems to be thicker. At Columbus about seventy feet were referred to this formation, and at Newark still more. The Niagara shale is a much less prominent element in Indiana than in Ohio, but it is recognizable there in numerous sections. It is frequently found as a yellowish or greenish, impure, calcareous shale.

The Niagara limestone.—The Niagara limestone is one of the main elements in the sections of the new gas fields. The gas wells of both Ohio and Indiana, with but very few exceptions, are begun where the Niagara limestone makes the surface rock, or at least where it is due as surface rock. All the limestones that are found at or near the surface, whatever their geological ages may be, are carelessly classed by the driller as Niagara limestone, and thus the term has become a very familiar one. But, even when strictly used, the name stands for a very important element in the geology of the new fields as regards both its thickness in separate sections and the areas which it covers.

The Niagara limestone consists of several divisions which have more or less local importance, but only two need to be named here, a lower and an upper division. The lower is the Niagara limestone proper, and the upper is the Guelph or Cedarville division. The former occurs in fairly even beds of varying thickness, which furnish most of the building stone and flagging of the formation in Ohio. The latter is found in either massive sheets with infrequent divisional planes or in thin and "shelly" courses. It is a great source of lime for the country at large, but it has no other valuable uses.

In composition, the Guelph beds of Ohio are true dolomites. They are wonderfully uniform over wide areas, and their total impurities in northern Ohio often range below 1 per cent. The lower beds are magnesian also, but they contain much more foreign matter, especially alumina and iron. The upper beds are prevailingly light-colored. They are sometimes as white as marble, but generally a creamy or yellowish tint prevails, or they are light gray or drab in color. The lower beds are darker and are frequently blue-gray.

The Guelph division is generally and often exclusively made up of fossils, which have been to a greater or less degree dissolved, leaving the rock carious or porous to a considerable extent. Consequently its specific gravity is low, and it has but little strength to resist pressure. The lower portion contains fossils much more sparingly and has a good degree of solidity and strength.

The entire series has a maximum thickness of about four hundred feet, three-fourths of which belongs to the Guelph beds. A common thickness of the entire series in northern Ohio is two hundred to two hundred and fifty feet. In southwestern Ohio one-half of this measure is seldom attained. In Indiana the thickness of this series seems to vary between similarly wide limits. In the northern counties of the productive gas territory the series has the greatest volume.

One element must be added to the Niagara limestone series, viz, the Hillsborough sandstone. Intercalated with the Guelph beds of Highland County is a peculiar deposit of sharp and pure sandstone, the grains of which are nearly uniform in size, and many are perfect or nearly perfect crystals. The sandstone has a maximum thickness of about thirty feet. The sand has no exact and constant place in the series, but is either at or near the summit of the Guelph beds. It is the first of three sandstone deposits of the same general character that are found in the upper Silurian and Devonian limestones of Ohio.

The Niagara limestone makes the surface rock over large areas in both Ohio and Indiana, and these areas, as already stated, constitute almost the entire high-pressure gas territory of both States. In Ohio the limit is passed in but very few instances, so far as known.

The areas occupied are indicated on the geological map accompanying the chapter. For reasons presently to appear, no separate place will be given to the Salina group in this review.

THE LOWER HELDERBERG SERIES.

The series next to be described, so far as area and thickness are concerned, is the most important of the limestones of the Ohio scale. In Indiana it has not heretofore been recognized as distinct from the Niagara limestone, but, though it lacks here the importance that it has in Ohio, it certainly exists in considerable force and covers an extended but at present undefined belt of country. It has proved to be a complex series in Ohio and much remains to be learned concerning it in both States. Even the name by which the series should be known is not entirely agreed upon. By some geologists the entire formation in Ohio is credited to the Waterlime division, and this stratum is altogether separated by Hall from the Lower Helderberg. This paper, however, will follow the more common practice of referring the Waterlime to the Lower Helderberg series, of which it is counted as the basal member. This name, Waterlime, is a most unfortunate and misleading one. For a few square miles in the State of New York this formation yields waterlime or hydraulic cement, but through the hundreds and thousands of square miles over which its remaining outcrops extend it is generally destitute of it.

The Waterlime was first recognized as an element of the Ohio scale by Newberry, in the limestones of Put-in Bay Island. They had been generally counted non-fossiliferous theretofore, but as the results of the search undertaken for the purpose of determining their age fossils in sufficient numbers were found. The most abundant were *Leperditia alta*, *Eurypterus Eriensis* Whitf., and *Spirifera sulcata*. These are the characteristic fossils of the Waterlime of New York. The beds which contain these fossils are well marked in lithological features. They consist of a light brown or drab dolomitic limestone, deposited in thin and even beds and sparingly supplied with fossils. What fossils there are are mainly found upon the surface of the layers. The rock is petroliferous throughout, and freshly broken surfaces always give the odor of oil. Oil can also be dissolved out of the limestone by proper agencies, and the amount obtained is often considerable. This fact, however, is not strictly characteristic of this formation. At some points asphalt is accumulated in the limestone in large quantity. In northern Ohio, beds have been found with five to ten per cent. of asphalt in their composition, but the extent of such deposits is not known to have been proved.

This formation, first recognized in 1869, by Newberry, as a separate division of the Cliff limestone of Ohio, was easily followed to the south and west from the original locality. The marks by which it was characterized were so distinct that no trouble was experienced in tracing it, and it soon appeared that the Lower Helderberg limestone covered a larger area than any other limestone formation in Ohio. It makes the surface rock, in whole or in part, in seventeen counties of the western half of Ohio.

The original characters are found to be maintained, with minor exceptions, throughout its whole extent. The prevailing color is brown or drab, but in large areas in western Ohio the stone is dark blue. It gives proofs of origin in shallow water through much of its extent, by surfaces covered with sun-cracks. These marks are repeated in many successive beds. In Lima, Bluffton, Dunkirk, Urbana, and Washington Court House they are specially noticeable. The bearings of these facts on the geological history of this part of the State are easily seen to be of great importance.

The formation is also frequently characterized by a rude concretionary structure in its upper beds. This mark is mainly confined to central Ohio. It destroys the even bedding of the limestone where it occurs, and gives rise to a rolling and unsteady appearance of the beds.

Two important facts remain to be added to the account of the Lower Helderberg limestone. In its upper beds it frequently is found distinctly brecciated, while through a considerable area in northern Ohio it is a coarse limestone conglomerate.

The brecciated structure is often associated with the concretionary character already described. The layers of limestone appear to have been traversed by joints dividing them into cubical blocks of two to ten inches in diameter, and the separate blocks have been recemented by material of the same sort that composes the substance of the rock. Sometimes, indeed, the rock is found weathering into these blocks which have either lost the cement bond or never had it. Particular layers are characterized by this brecciated structure, while beds both below and above them are free from it. The cause is not obvious, but the phenomenon is certainly not referable to uplift and disturbance. The subterranean force that would shatter one bed would not leave another in contact with it undisturbed. It seems more probable that if we were able to trace out the history we should find some modification of the force that produces joints, whatever it may be, as the cause of the phenomena which we are considering.

The conglomerate of the Lower Helderberg, previously referred to, makes a striking feature in the upper portion of this great series through parts of several counties of northern Ohio. It is most frequently met in Ottawa and Lucas Counties.

The pebbles that compose it range from an inch to a foot in diameter. They are in all cases limestone, and in fact are indigenous to the formation that contains them. They represent different beds of the series, as is evident from their variation in grain and in color.

They are fairly well rounded and thus indicate considerable exposure and wear before being deposited where they now occur. The cement that unites them is limestone mud, less pure than the pebbles themselves.

Sheets of rock six to eight feet in thickness are found that consist entirely of these pebbly masses.

This line of facts evidently corresponds well with the shore-marks already pointed out in the sun-cracked surfaces of the beds of the formation in various portions of the State.

The middle and upper portions of the series where it is thickest contain fossils distinct from those already named. In Fayette and Highland Counties large chambered shells are occasionally found in the thin-bedded limestones that occur here. In the same vicinity a number of new species of brachiopods have been found. Among those recently described from this locality are *Streptorhynchus hydraulicum* Whitf., *Nuclospira rotundata* Whitf., *Rhynchonella hydraulica* Whitf., *Pentamerus pes-ovis* Whitf., *Leperditia angulifera* Whitf. In Allen County, also, beds of the same age are found with fossils different from any thus far named. It must be added, however, that the formation is often barren of all distinct signs of life for large areas and through many successive beds.

As the result of recent investigations, a complex constitution, not suspected heretofore, has been demonstrated for the series now under consideration. The plaster beds of Ottawa County were originally referred by Newberry to the Salina group of the New York shale, and the place assigned to them was immediately below the beds recognized by him as the Waterlime. This order of arrangement does not prove to be the true one. The plaster beds are buried in this Waterlime or Lower Helderberg series rather than beneath it. They hold a place near or below the middle of the great series. The characteristic fossils of the Waterlime appear to be found both below and above them; at least, the lowest beds of the Waterlime in Ottawa County, for example, contain such fossils where these beds rest upon the Guelph division of the Niagara. With this new place for the plaster beds of Ottawa County, the Salina group drops out from the catalogue of surface rocks of Ohio. It may be represented in the salt deposits of the deep well at Newburgh, Ohio.

Another surprising addition remains to be made to the Lower Helderberg group in northern Ohio. The Sylvania sandstone, which consists of a lenticular deposit of glass sand of remarkable purity, has been heretofore assigned to the Oriskany horizon. Its real place is 150 feet below the summit of the Lower Helderberg series, as is shown by a nearly continuous series of exposures recently opened between the sand and the Devonian limestone, which crops out a short distance to the westward. This interval is occupied by Lower Helderberg rocks, that are identified as such beyond any chance for question by their composition, their lithology, and their fossils. The Monclova sandstone is of the same age, and it seems altogether probable that the entire number of the lenticular and sporadic beds of this sort of sandstone that have been found in Monroe County, Mich., and Lucas County, Ohio, belong to the same place in the scale.

It remains to be added that there are no known exposures of sandstone in Ohio at the place where the Oriskany is due. In the Corniferous limestone and near its base there are several pockets of the same sort of sand that has now been described in both the Niagara and the Lower Helderberg series. But the deposits referred to are not at the very base of the Corniferous limestone, but from ten to twenty feet above, the interval being filled with the highly fossiliferous beds of Devonian age.

The thickness of the Lower Helderberg system of Ohio remains to be given. All of the earlier estimates have proved far too low and it is now found to have a volume that is proportioned to its broad outcrops in the State and adequate to account for them. In northern Ohio its total thickness exceeds five hundred feet. In central Ohio, at Columbus, for example, it is about four hundred feet thick. In Fayette and Highland Counties it ranges from fifteen to one hundred feet in included sections. It wedges out to the westward very rapidly in this part of the State by overlap of the Devonian shales.

The formation reaches its highest economic value at Greenfield, Highland County, Ohio, where a peculiarity that characterizes it throughout its whole extent culminates in 40 feet of the most even-bedded limestone of the Ohio scale. The courses range from two to twelve inches in thickness, and they are taken from the quarry with faces as true as if they had been sawed.

The Lower Helderberg formation in Indiana can not be described in as definite terms as have been applied to it in Ohio; it is certain, however, that it constitutes an important member of the geological scale of this State. It enters Indiana from Ohio in Adams and Allen Counties with a probable breadth of outcrop of eighteen miles, but it is heavily covered with drift from the start, and comparatively few opportunities are found to examine it. At Decatur it is worked in several quite large quarries, in the valley of the St. Mary's and below the level of the river. The junction of the Niagara and Lower Helderberg limestones occurs at this point, the upper quarries of the town being in Niagara. The precise line of junction is not, however, exposed. The contrast between the two formations is very marked. The Lower Helderberg, as here developed, carries the unmistakable lithological characteristics of the formation as already described. It is a brown limestone, even and regular in its bedding, sparingly fossiliferous, but containing some fossils that have not been reported in the formation elsewhere, and that appear to have come up from the Niagara. Among them may be mentioned *Strophomena* *subplana* and the large chain coral *Halysites labyrinthica.* Both of these are also found in the underlying Niagara. It contains *Leperditia alta* and a *Meristella,* probably *levis,* which are quite characteristic of the formation in Ohio.

The remaining statements pertaining to this formation traverse to some extent the views heretofore presented as to the geological age of the portion of the State here considered. The need of more careful study of the facts is recognized, and some of the conclusions here expressed are held open to revision in the light of larger knowledge.

The Lower Helderberg is also clearly shown at various points in the Wabash Valley. At Huntington it contains a considerable quantity of flint, and it is for the most part destitute of fossils, but the peculiarities of bedding and color are unmistakable. In the abandoned quarries below the town the Lower Helderberg, as identified by the characters above named, is seen to rest unconformably upon the fossiliferous Niagara.

Further down the valley it is composed of the same thin and even beds that characterize the formation through all its eastward extension. The well-known Wabash flaggings are here counted of Lower Helderberg age. Large chambered shells, both straight and coiled, are very conspicuously shown upon the surfaces of the layers. The flinty beds of Huntington are also found here. At Logansport and in its vicinity a section is obtained, of which the Devonian limestone makes the summit. The section is as follows:

		Feet.
DEVONIAN	Yellow and blue limestone in three or four strata, Lux's quarry	40
UPPER SILURIAN (LOWER HELDERBERG)	Brecciated bed	15
	Buff limestone, magnesian, with *Pentamerus Knighti*	15
	Thin-bedded stone, with *Leperditia alta*	11
	Thick-bedded stone (Simon's quarry)	15
	Thin beds to river	10
		106

This is an interesting and important section. The several members must be briefly described. Nos. 1, 2, and 3 are in all their lithological features representative Lower Helderberg limestone. No. 4 is a brownish, highly fossiliferous magnesian limestone, the most characteristic forms of which are *Pentamerus Knighti* and *Halysites labyrinthica.* This fixes the place of these well-known Delphi fossils in the Lower Helderberg division rather than in the Niagara, to which they have been previously referred. This bed is overlaid by No. 5, the most remarkable of the series. It is a brecciated limestone, the separate fragments of which are fine-grained, very pure, and break with a conchoidal fracture; in fact, they resemble lithographic stone. The cementing matter is limestone, but is less pure.

This stratum is highly fossiliferous; in particular it contains multitudes of a small shell that sometimes almost makes up its substance. This shell is *Cœlospira disparilis.* It also contains in abundance *Pentamerus galeatus* and other pentameroid shells. Professor Whitfield recognizes the type of this shell, as found here, as closely agreeing with that found in the combined Niagara and Lower Helderberg formation of Tennessee. This brecciated structure is sometimes misunderstood as indicating upheaval and violent disturbance of the strata. Such an explanation is unnecessary and untenable.

The Devonian limestones come into the section at Logansport in four distinct divisions, with a total thickness of 40 feet. They will be briefly described on a subsequent page.

The Lower Helderberg limestone has been followed to the westward in the several beds already described as far as Delphi, where the Pentamerus bed reaches a wonderful development. The Wabash Valley, in the interval between Logansport and Delphi, is occupied in part by the Waterlime and the Devonian limestone and shale and in part by the Devonian series alone.

Passing to the southward from Logansport, the Lower Helderberg limestone is shown in a thoroughly characteristic and unmistakable phase in the quarries of Kokomo and the Wild Cat Valley, and it undoubtedly occupies considerable additional territory in the State.

In the geological map that accompanies this paper (Pl. LIV) the outlines of the formation as indicated on Collett's map of 1881 are modified to a small extent to give a hint of the facts herewith presented, rather than to represent them, but no complete or symmetrical statement with reference to the separation of the Lower Helderberg from the Niagara in Indiana has yet been given. The outcrops of the Niagara limestone in the northwestern corner of Indiana are not considered here at all. The Lower Helderberg is supposed from the facts that have been observed to narrow towards the westward, but the exact boundaries under the drift-covered regions of northern Indiana can not be even guessed at.

THE UPPER HELDERBERG LIMESTONE.

The necessity of dropping the Oriskany sandstone from the Ohio scale has already been shown. There is no sandstone deposit between the Upper and the Lower Helderberg limestones in the State. If it should happen that in any locality a few feet of the peculiar sand deposits, already described, should occur at just this point in the series, the occurrence would not constitute a good reason for naming the sandstone Oriskany, because the bed would be found to agree exactly with other sandstone beds above and below in the scale that can not possibly be Oriskany or have any distinct relation to it. The Pendleton sandstone of Indiana has been generally referred to the Oriskany horizon; but it is quite possible that when its place is definitely settled it will be found correlated with the sandstone deposits already described. In the Delphi quarries considerable deposits of this peculiar sandstone are found.

The Upper Helderberg limestone is commonly called the Corniferous limestone in Ohio. In this State it has a maximum thickness of 75 feet and is separable into several tolerably well-marked divisions, two of which, a lower and an upper, are all that need to be considered here. Both of these divisions are highly fossiliferous, some of the fossils being common to the entire formation, but more being confined to particular horizons. The lower division, which is about forty feet thick, consists of rather heavy and fairly even-bedded limestones, that grow progressively richer in lime and poorer in magnesia from the bottom upward. The higher beds of this division generally contain 90 to 95 per cent. of carbonate of lime, while the bottom courses do not carry more than 60 to 70 per cent. The beds are light in color, gray being the prevailing tint, though occasional courses are blue or drab.

The upper division consists of blue, thin-bedded stone, inclining to a shaly character, and much less pure in composition than the lower division.

The limits of the Corniferous formation can be determined in deep wells by chemical analysis of the drillings. The Upper Silurian limestones are mainly dolomites and are thus readily separated from the calcareous beds of Devonian age.

The statements above given apply to Ohio. The section in Indiana does not altogether agree with the preceding account.

A section of the Devonian limestone as seen at Logansport, to which reference has already been made, contains the following elements, viz:

	Feet.
Yellow siliceous limestone	15
Blue limestone	8
Firestone, coralline limestone	20

The lowest division is a true coral reef, crowded with the characteristic forms of Devonian time. In composition it is quite high in lime, but the percentage can not be given. Toward the upper portion it passes into thin courses, which abound in crinoidal remains. This phase is locally known as firestone and the rock has been used in chimney backs and furnace arches on the small scale for a long time. The division next above consists of a blue limestone of peculiar tint and grain, and this is overlaid by a so-called sandstone, the siliceous yellow limestone of the section above. In default of better building stone this is used to some extent.

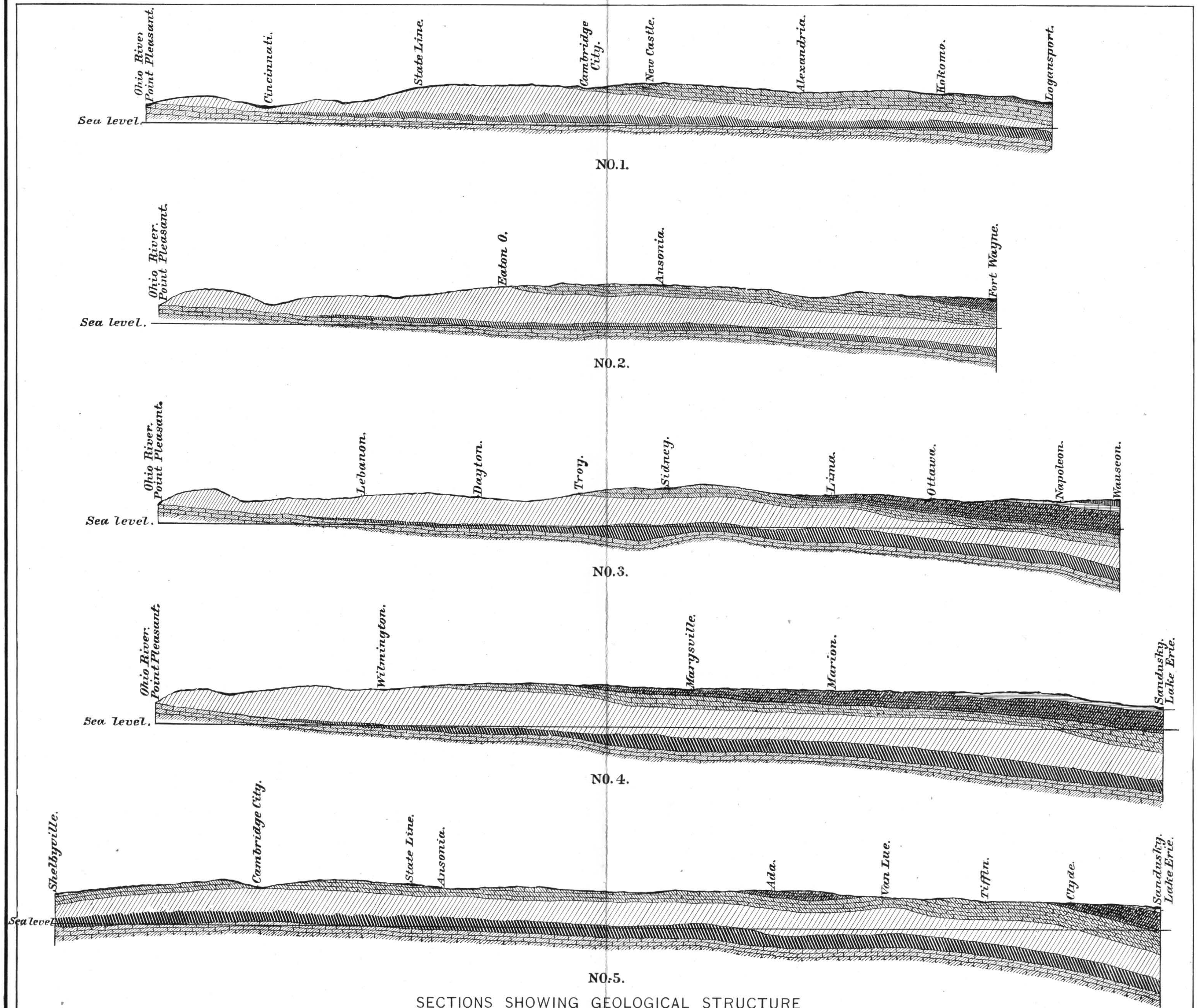
The Devonian limestone has much less volume and economic importance in Indiana than in Ohio. It is so thin that it occupies very small areas of the surface in connected beds. Wherever exposed to erosion of the ordinary type it has been worn through and removed to a greater or less extent, bringing to light the lower beds. Most of the Upper Helderberg areas are on this account areas of Lower Helderberg rock in part also.

THE DEVONIAN SHALE.

One other division of the geological scale of the two States must be included in this brief review, viz, the Devonian shale. No extended account of it will be undertaken here; it is enough to say that, by a very marked change in the physical geography of the district involved, the limestone growths of the Upper Helderberg age were brought to an abrupt termination. With them was also brought to an end the formation of limestones on a large scale in Ohio. The great sheets of Lower Silurian, Upper Silurian, and Devonian time had been slowly built up on this part of the sea floor through long-continued periods and no one of them shows more genial conditions or more varied and abundant life than the last. Its last layer was crowded with fossils, but upon it there was laid down abruptly a mass of what are ordinarily counted non-fossiliferous shales, hundreds or even thousands of feet in thickness, and limestone making on the large scale was never resumed in Ohio.

The thickness of this series of shales can not be given in any general statement, for the reason that it depends upon the point where the measure is taken. In Highland County, Ohio, the entire interval between the upper and the lower boundaries of this stratum is but 250 feet. In eastern Ohio the same interval exceeds 2,500 feet.

There is a small bed of shale of rather uncertain occurrence at the bottom of the series, that has been separated by Newberry under the name of the Hamilton shale. But very few outcrops of this division are known. The type locality is at Prout's, a station six miles south of Sandusky, Ohio. The shale is light-blue in color, calcareous in composition, and abounds in fossils which, according to Newberry, are exclusively of Hamilton age. This division is perhaps continued to the southward under the name of the Olentangy shale of Winchell. Under cover to the northward there are indications of a greater measure of this light-colored shale, immediately above the Upper Helderberg limestone. The remainder of the series, which in reality is almost the entire mass of the shales, is known by various names. Those most prominently applied to it are names that mark Newberry's threefold classification, viz, the Cleveland shale, the Erie shale, the Huron shale, which are given in descending order. These several divisions were thus described by their author, viz, the Cleveland shale, Sub-carboniferous in age, 50 to 75 feet in thickness, black in color, and containing fossils, the most characteristic of which are fish remains; the Erie shale, greenish-blue in color, 0 to 1,500 feet thick, and containing Devonian fos-



SECTIONS SHOWING GEOLOGICAL STRUCTURE
OF
WESTERN OHIO AND EASTERN INDIANA.

HORIZONTAL SCALE OF MILES.
10 MI. 20 30 40 50

M. R. CAMPBELL, Del.

VERTICAL SCALE OF FEET.
1000 2000 3000 4000 5000 6000

TRENTON LIMESTONE. UTICA SHALE. MEDINA SHALE. HUDSON RIVER SHALE. NIAGARA LIMESTONE. NIAGARA SHALE. CLINTON LIMESTONE. LOWER HELDERBERG LIMESTONE. UPPER HELDERBERG LIMESTONE. OHIO SHALE.

sils of Chemung age, and the Huron shale, 100 to 300 feet in thickness, black in color, and constituting the best known and most important part of the entire series. It was considered by Newberry as certainly including beds of Portage age. It contains a varying percentage of bituminous matter, which sometimes rises to 10 or 12 per cent. This proportion is large enough to continue combustion in the shales when once fairly begun. The bituminous matter can be expelled by raising the shale to a high temperature, or it can be distilled into coal oil and similar products by appropriate means.

The belief that the great shale system would everywhere admit of the convenient and easily applied system of division above stated has not proved well founded. It is impossible to establish divisions in the formation that are founded on color, for the reason that the colors of the beds are not constant. It is true, however, that in the lower portion the black beds predominate and that the central portion, especially where the measures are the longest, are prevailingly light in color, though even here dark bands are common. The higher portions of the shale are either blue or black, or both in rapid alternation. Taken as a whole, the shale consists of dark or black shales, often called slates, interstratified with blue or gray shales, often called soapstones, without regularity of division or interval. No exact equivalence is to be found in the sections taken from different portions of the field. The threefold name may be profitably replaced by a shorter one, viz, the Ohio shale, which can be counted as covering the interval between the Bedford shale above and the underlying limestones of whatever age they may be. The shale system has for its normal floor the Upper Helderberg limestone, but by overlaps extending to the southward it comes successively down upon the Lower Helderberg, Niagara, and finally upon the Hudson River group.

As a rule the shales are very poor in fossils, except in those of microscopic size. Though the conspicuous fossils of the formation are rare, as has been said, some of them have proved as remarkable as any of the entire geological scale of the country. The gigantic Placoderms brought to light by Newberry are not only the largest of fossil fishes, but they are at the same time the most important remains of all Devonian life. They combine types of structure that are widely separated now, and thus throw much light on the history of vertebrate life on the globe. The vegetable fossils of the shale are far more abundant than the animal fossils. Silicified wood is often found and may be counted characteristic of the lower portion of the shales in both Ohio and Indiana. This wood is found by microscopic section to have been derived from the ancient pines which occupied the land at this time. Strap-shaped leaves of sea weeds also infrequently occur. When all has been said, however, macroscopic fossils from both kingdoms must be confessed to be rare in the shales; but the very substance in some beds is composed in large part of microscopic vegetable fossils in an exquisite state of preservation. The most abundant of these forms are those known as *Sporangites*.

A number of years since, under the name *Sporangites Huronensis*, Sir William Dawson described an excellent representative of these fossils from the basal beds of this same shale series, as it occurs at Kettle Point, Canada. These fossils occur as flat disks, one fiftieth to one two-hundredth of an inch in diameter, often completely covering the surface of the shale layers, and making, indeed, a conspicuous percentage of the rock itself. They are undoubtedly derived from marine vegetation, representing the reproductive vessels, which are the more durable portions of the production of a Sargasso sea. The vegetation that is thus attested is an altogether adequate source for the bituminous matter that abounds in the shales. The microscopic fossils are the only ones that can be relied upon for the identification of the formation, and for this purpose they are invaluable. They are found in all parts of the formation in both Ohio and Indiana.

This great shale series covers a number of counties in northwestern Ohio and in northeastern Indiana. Not more than two hundred feet of it are shown in any section in this part of Ohio, but at Elkhart and at Goshen, Ind., drilled wells have proved this series to be more than five hundred feet in thickness and about evenly divided between the blue shales above and the black shales below. In western and southern Indiana, and also in the adjacent portions of Kentucky and Illinois, the same formation is found in reduced thickness. An excellent section of the lower beds is found at Delphi. On the eastern border of the Silurian and Devonian limestone, in the central regions of Ohio, the outcrops of the shale are also found in a broad band that extends from the valley of the Ohio River to the shore of Lake Erie. There are but few sandy seams scattered through this series in Ohio. Aside from the organic matter that it contains, it is fairly homogeneous in character. It is in this formation to the eastward that the great oil sands of Pennsylvania and New York are buried. But these are wanting for the most part in Ohio, and altogether wanting in the western half of the State.

The petroleum of the formation remains to be mentioned. Throughout its whole extent the Ohio shale contains a determinable percentage of free petroleum, which can be extracted by the action of proper solvents on the comminuted rock. The amount obtained will depend necessarily on the fineness of the division of the shales. Prof. N. W. Lord, chemist of the Ohio Geological Survey, has found in the ordinary samples of the black beds of the Ohio shale .002 of free petroleum, recognizing at the same time the limitation as to quantity involved in the process. The petroleum is not confined to the darker beds of the shale, but is nearly if not quite as abundant in some of the lighter-colored beds. The Ohio shale is undoubtedly the main source of the great stocks of petroleum and gas of eastern Ohio and of western Pennsylvania, but with this factor we have no present concern. It is found to a small extent as a surface formation in what is sometimes improperly counted a part of the Trenton limestone field, but the outcrops of the shale are in reality always beyond the line of valuable production from this new-found source of power.

This completes the brief review of the geological scale of the two States so far as we need to know it in studying the development of the new gas and oil fields. Only the most general statements pertaining to the subject have been attempted, and in regard to them many gaps have been indicated which present knowledge does not enable us to fill.

GEOLOGICAL STRUCTURE.

The structure of the gas and oil fields now under consideration involves the structure of the western half of Ohio and the eastern half of Indiana, and it can not be clearly understood except when studied in connection with the larger areas of which these fields form a part. The subject, in fact, includes a review of the geological history of these large tracts of country. Only the leading facts pertaining to it can be considered here.

THE CINCINNATI UPLIFT.

All of the earlier geological history of these two States, as far back as it can be followed, is connected with an elevatory movement that, advancing from the southward, extended itself through most of the territory now under consideration. This great uplift is most widely known in geology under the name of the Cincinnati axis or Cincinnati anticline, a designation to which Newberry gave wide currency in his admirable account of the geological structure of Ohio.[1] The views that he sets forth as to the character of this uplift have been invalidated to some extent by the surprising discoveries of the last three years, but the account given by him still remains by far the best that has been published of the earlier stages of this important movement. He has shown beyond question its early origin in Tennessee and Kentucky and its gradual advance through these States. The term "axis" or "anticline" as applied to a structural feature of this character is in some respects misleading. It is hard to qualify it so that it will not at once suggest to the ordinary reader a line or ridge, but this feature has been expressly excluded from all the statements that have been made in regard to it. Its extreme flatness and its great breadth have been insisted upon by all

[1] Report of Geol. Survey Ohio, vol 1, p. 93.

who have studied it. In the discussion of the physical geology of the Cincinnati group of southern Ohio it was shown that for 30 miles in an east and west direction there is scarcely any appreciable fall in the strata that compose the axis, and that all the determinable dip is a very slight and equable fall to the northward.[1] The term "axis" might well be replaced by a less confusing term, viz, the term "uplift."

More recently the late W. M. Linney, of the Kentucky Geological Survey, has proposed to account for the structural features of northern Kentucky, involving also those of southern Ohio and Indiana, by an altogether different line of explanation. (See Rocks of Central Kentucky, Ky. Geol. Survey.) Mr. Linney denies the existence of a line of elevation through the State in the direction assigned to the Cincinnati axis, and substitutes for it what he denominates the "Kentucky axis," which extends, as he defines it, from the mouth of the Little Sandy River in the Ohio Valley to Clarksville, Tenn. Its direction, as thus shown, is about north sixty degrees east. The steepest slopes of parts of northern Kentucky, and by implication of the States adjoining Kentucky, he found to be approximately at right angles to this line, or, in other words, a few degrees west of north. Due credit is to be given Mr. Linney for the recognition of this important series of facts, but the broad conclusion that he draws from it is altogether unwarranted so far as Ohio and Indiana are concerned. He refuses to recognize the east and west slopes involved in the old doctrine of the Cincinnati axis, but these slopes are beyond question present as controlling factors in the geology of both States, and to the extent that they occur they justify and necessitate the recognition of the great structural feature that deserves the name given to it.

Newberry traced the uplift by the only means available at the time his work was done, viz, by the disposition of surface rocks. From the data at his command he deduced a direction for the uplift to the northeast. According to his view the axis extended from Point Pleasant, a few miles above Cincinnati, to the islands of Lake Erie. As will presently be seen, there is a large element of truth in this claim, but the facts are not nearly so simple as the earlier statements would lead us to believe.

The uplift entered Ohio as dry land at the close of the Lower Silurian time, as is proved by the Clinton conglomerate of Adams County.[2] The various stages of advance and retreat of this early land are most clearly shown in the subsequent geological history of the State.

By the remarkable disclosures of the drill in Ohio and Indiana during the last three years it has been possible to obtain data as to the growth of the Cincinnati uplift that enable us to trace its history

[1] Rept. Geol. Survey Ohio, vol. 1, p. 411. [2] Ibid. p. 103.

with much more clearness and certainty than ever before. The Trenton limestone has been the goal of the driller in many hundreds of deep wells that have been sunk in these two States, and by means of the facts established in this way, we are able to determine the approximate topography of this great formation for more than thirty thousand square miles of territory. It need hardly be added that the facts of the uplift will all be found recorded in the history of this great basement sheet of our geological column.

The facts pertaining to the topography of the Trenton limestone are indicated in the accompanying map (Pl. LV), in which the varying elevations of its surface are roughly indicated by shadings of varying intensity. The representation is confined to the western half of Ohio and the northeastern quarter of Indiana. Facts are not now at hand that enable us to complete the contours for western Indiana. It is known, furthermore, that in the northwestern corner of the State the Trenton rises to sea level, or possibly higher, through several counties, and there is reason to believe that the lines marking the present westernmost boundary in Indiana could be extended towards the Ohio Valley with a decided easterly trend.

The area in which the Trenton limestone lies above sea level is left without shading.[1] On the southern border of the two States the elevation of the surface of the Trenton is nearly five hundred feet above tide. It will soon become possible to extend the bands laid down upon the map to the Ohio Valley, and, indeed, throughout all the area of the State. The line in which it falls below tide is seen to extend through the following counties of Indiana, viz: Rush, Henry, Madison, Delaware, Blackford, Randolph, and Wayne; and in Ohio, through Preble, Montgomery, Greene, Clinton, Highland, and Adams Counties. Points at which the sections are established are often quite distant from each other, and the true boundary must be much more sinuous than is here represented. In many cases lines have been continued considerably beyond the limits of exploration in directions in which they were running; but there is no reason to doubt that the general conformation of this portion of this deeply buried stratum is in substance as indicated on the map. The same qualification must be made for all the other boundaries that are laid down, and for most of them a like claim as to substantial accuracy can be made. Drilling has been carried much farther in Ohio than in Indiana, and more data have been collected here, but the facts revealed in central Indiana are as instructive as any that appear in the Ohio field. The bearing of these facts on the production of gas and oil will be presently discussed.

Attention will be called to a few of the most obvious facts that are indicated by this map.

[1] The uncolored areas of western and southwestern Indiana must not be confounded with the area now described. The former are simply undetermined.

(1) The main axis of the Cincinnati uplift extends to the northwest and not to the northeast. In the light of all that we have been accustomed to hold in regard to this great structural feature the statement here made is a surprising one, but no other interpretation of the facts is possible. The high levels of the Trenton limestone all advance to the west of north, and for this we ought to have been partially prepared by facts already in hand. The geological map of the United States has long shown a distinct westerly trend for the joint Silurian formations of the two States, Ohio and Indiana.

(2) From Wayne and Randolph Counties, Indiana, a northeasterly prolongation of high-lying Trenton rock extends through Darke, Mercer, Shelby, Auglaize, Allen, and Hardin Counties, to the central part of Hancock County. This prolongation may be named the Lima axis. From Hancock County an important spur of high-lying Trenton extends northerly, with a very slight westerly element in its direction. On the western side this spur is bounded by one of the most marked disturbances yet discovered in Ohio geology, viz, a monoclinal fold, or perhaps a series of connected folds of this character. The downthrow is to the west, and its total amount is not less than two hundred feet. The most of the descent is accomplished within a half or a quarter of a mile, and in some cases at the rate of one foot in eight. This field may be appropriately styled the Findlay Monocline, the Findlay Break, or the Findlay Arch. It can be followed northward to the Michigan border, which it reaches near Sylvania. It can also be traced to the south and east of Findlay, though in somewhat reduced proportions.

(3) On the eastern margin of this high-lying Trenton in Ohio the line of 750 feet below tide agrees fairly well with the theory of the Cincinnati axis that has been previously taught. This line bears a few degrees east of north entirely across the State; and it agrees measurably with the direction of the outcrop of the Devonian limestones and shales in this portion of the State. In the later stages of this series of movements, therefore, the claim of a northeasterly axis finds somewhat more support in the facts of Ohio geology than would at first sight seem possible.

(4) In northern central Indiana the Trenton seems very loth to descend from its elevated terrace, and it is altogether probable that the depression which it at last undergoes in this region is but temporary, and that in the northwestern counties of this State its surface is again brought up to or above sea level. This last uplift would scarcely be counted as a part of the Cincinnati uplift in any case. It would rather be referred to a movement originating elsewhere and advancing in a different direction from that which we have now been tracing.

(5) The order of elevation disclosed is of the continental and not of the mountain-making type. This view was long ago urged by

Prof. E. T. Cox, former State geologist of Indiana. He denied that the doctrine of the Cincinnati axis as expounded for Ohio would furnish an adequate explanation of the facts of structure of Indiana. He had the sagacity to recognize the true character of the uplifting agencies far in advance of recent explorations but in essential harmony with them.

(6) Within the areas now described, and especially in the great prolongation of the high-lying Trenton limestone in Indiana, there are no other axes or anticlines that deserve the name, but the rock lies nearly as regular as any stratum of the earth's crust. It has its normal rate and direction of descent, and variations of a few feet or a few scores of feet may occur in any field, but nothing of the character of persistent folds or arches has thus far been apparent.

The disturbance of the rocks along the Wabash Valley will be alluded to on a subsequent page.

The structure of the region covered by the map (Pls. LVI–LVIII) is illustrated by diagrammatic sections which are carried across it in various directions. The sections must be acknowledged to be ideal for ninety-nine hundredths of the regions which they traverse. They are based upon records of wells that have been drilled at the several stations named along the line. These stations are separated by long intervals, and there is always a possibility that in this unknown intervening territory a considerable divergence from what is found in the records of the wells may occur. To this extent the sections are ideal, but if irregularities occur in these intervals the recovery from them is very rapid, and the sections of the different wells are remarkably uniform. The impression made upon the mind by the facts as they appear is that of wonderful steadiness and constancy for the entire series. Few portions of the earth's crust have had a more equable and regular mode and rate of growth than this part of the Mississippi Valley.

The different formations are indicated by symbols as far as they can be definitely distinguished from one another. Certain boundaries are left indistinct; for example, between the Hudson River and the Utica shales in a large part of the territory involved. The Utica shale is represented as thinning out in southern Ohio and disappearing altogether. Another version of the facts is possible, as has been already stated. No line is drawn between the Medina and the Hudson River shales, though in much of the productive territory in northern Ohio a fairly sharp boundary may be laid down for the Medina.

Several of these sections, radiating from Point Pleasant, Ohio, the only locality in either State in which the Trenton limestone becomes the surface rock, embrace between their extremes the whole of the new gas and oil fields. The sections referred to are Nos. 1 to 4, inclusive.

Section No. 1 extends from Point Pleasant to Logansport, Ind. Its direction is about forty degrees west of north.

Section No. 2 extends from Point Pleasant to Fort Wayne, Ind., and its direction is 20 degrees west of north.

Section No. 3 extends in a due northerly direction from Point Pleasant to Wauseon, Ohio.

Section No. 4 extends in a direction 20 degrees east of north to Sandusky, Ohio. The length of each of these several lines is about two hundred miles.

These sections indicate the surprising steadiness of the region which they traverse as a whole, and at the same time the important features can all be recognized in them.

In section No. 1 there is nothing specially noteworthy. It marks the extreme western boundary of the Indiana gas field. At its northern termination, it reaches the disturbed stratification of the Wabash Valley, but this is not yet proved to be a fact of great importance in the general section. The Trenton is found at Logansport about where the normal descent that begins at Anderson would carry it, viz, at 340 feet below tide. The last-named town is near the southern margin of the gas field, so far as its boundary now appears, and Kokomo is on the extreme western margin. This section is seen to traverse for a long distance a high level of Trenton limestone, thus showing an unusually slow descent for the strata. The total fall of the Trenton on this line is 840 feet.

Section No. 2 extends from Point Pleasant to Fort Wayne, and indicates a series of facts quite similar to those shown along the line previously described, except that there is a steeper descent to the northward. At Fort Wayne the surface of the Trenton is 666 feet below tide, against 340 at Logansport. This section traverses but little productive gas territory. The monotony of the structure that appears in it results in part from our lack of knowledge of the long intervals. The total fall of the Trenton in this section is 1,166 feet.

Section No. 3 is more varied and instructive than either of the others, because more work in drilling has been done along its line. Its direction is due north, and it traverses the most important oil field yet found in the Trenton limestone, viz, the Lima oil field. The total descent of the Trenton on this line is more than one thousand eight hundred and fifty feet, the fall at the northern end of the section being quite precipitous as the rocks sink to form the southern rim of the Michigan coal basin. The low arch shown between Sidney and Lima is the uplift referred to under the name of the Lima axis.

In section No. 4 the eastern margin of the Ohio gas and oil field is defined, and but very little productive territory is traversed by the line. The total descent of the Trenton on this line is 1,200 feet. A section drawn on a northeast line from Shelbyville, Ind., to Sandusky, Ohio, and marked No. 5, indicates quite a similar line of facts.

Sections 6 and 7 are north and south sections drawn across the productive gas field of Indiana, the former on the eastern margin of large production, and the latter through the very heart of the field. The remarkably uniform surface of the Trenton limestone as shown in section 7 is to be particularly noted. The extreme range, so far as present data go, does not exceed one hundred feet. Few beds of rock anywhere approach as near a horizontal surface as the Trenton limestone in this field.

Sections 8 to 11, inclusive, pertain mainly to the Findlay field, and they vie with each other in displaying in the most conspicuous way the Findlay monocline or arch.

Section 8 extends from Napoleon to Bucyrus, in a direction 30° south of east. The Trenton limestone rises from 1,100 feet below tide at Napoleon to 300 below on the Findlay arch at North Baltimore, and descends again to 1,350 feet below tide at Bucyrus.

Section 9 represents the short but interesting section that is furnished by the Deshler and the Tiffin wells, and by the numerous wells drilled in the interval.

In Section 10 the Findlay break as shown at Bowling Green, 24 miles due north of the point where the feature was first recognized and identified, again appears with great distinctness. At no locality along the line of the disturbance is the effect more conspicuously seen. A similar section will be found at Sylvania when further data are accumulated in the vicinity by the drilling that has already been entered upon. Section 11 is taken along an east and west line from Fort Wayne through Findlay to Plymouth, Ohio. The last-named town is thus far the Ultima Thule of the Trenton limestone on the eastward slope of the Findlay arch. The new gas rock has been sought in many other towns in this region of the State, but hitherto without success. In most of them the search has been abandoned after reaching a depth of two thousand to three thousand feet, on account of floods of salt water that could not be exhausted, and that it was difficult and expensive to exclude. The remarkable steadiness of the Trenton limestone on this line from Fort Wayne to Findlay will not escape notice. It illustrates the continental character of the uplifting force, by which the entire region was converted into dry land.

Two other sections remain to be briefly noticed, viz, 12 and 13. Both are constructed on east and west lines, one joining Lafayette, Ind., and Delaware, Ohio, and the other joining Indianapolis and Columbus. They agree with all the other sections through the region in showing wonderful steadiness. Section 12 traverses the Indiana gas field which is found in and adjacent to the low arch that is seen to underlie Eaton. This east and west section of the gas field will be referred to on a subsequent page. In section No. 13 the most noteworthy point is the steep descent of the rock from a few miles east of Springfield to Columbus. The descent in this line is continued at the same rate as far east as Newark. The dip reaches a maximum of 30 feet to a mile in this portion of the State. The possible error that would result in averaging dip over long distances is well shown by this section.

It will be found that much information as to the composition of the series in different parts of the districts under discussion is conveyed by these several sections. The proportions of the several strata are not, however, as well supported by detailed sections in Indiana as in Ohio, but it is believed that enough similar sections from Indiana are included to make the representation reasonably accurate.

DISTURBED STRATIFICATION IN THE WABASH VALLEY.

Special attention has been called by the present geological survey of Indiana to a series of marked irregularities of structure that occur in the Wabash Valley between Huntington and Delphi, and also in other parts of western Indiana. These have been particularly described by Prof. S. S. Gorby, assistant State geologist, in a valuable paper entitled The Wabash Arch.[1] Professor Gorby has also discussed the subject in several newspaper articles.

The facts are of unusual interest, and, for the Mississippi Valley, of unusual complexity, and they deserve to be carefully studied and analyzed. They include unequivocal examples of uplift and also unmistakable cases of false bedding on a large scale. The latter is a rare but not unknown phenomenon in calcareous rocks of organic origin. No clearer case of this peculiar form of structure is anywhere to be found. An excellent example occurs in quarries of the Niagara limestone on the south side of the river at Wabash City.

No discussion of this important line of facts can be undertaken here. It does not seem to have any recognizable connection with the gas production of the Indiana field; neither does the disturbance seem to have been of great magnitude at great depths. If the entire series has been raised or depressed on a large scale, Nature seems to have been very careful to restore all things approximately to their original condition. On all the lines of section traced the Trenton limestone is found at an apparently normal level compared with areas to the south of the valley. A difference of but ten feet was found in the elevation of the surface of the Trenton limestone in two wells at Huntington, a mile apart, and separated by a striking example of the disturbed structure here referred to. There is a well-marked case of uplift at Delphi, where the Pentamerus beds of the Lower Helderberg are lifted to a higher elevation than the Devonian shales which surround them, but the amount of the elevation is small. All

[1] Indiana, Dept. Geol. and Nat. Hist., 15th Ann. Report, 1886, pp. 228–241.

the facts found here could apparently be explained by a rise of fifty or seventy-five feet.

The geological composition and structure of the new fields, together with that of the territory that incloses them, have now been briefly stated. Certain important applications of the facts remain to be made.

GEOLOGICAL FACTORS IN GAS AND OIL PRODUCTION.

Upon what depends the productive character of certain comparatively small portions of the Trenton limestone within the wide areas that have now been passed in review? Why is one square mile of this formation the source of incredible wealth, while ten or a hundred square miles adjacent to or inclosing it contain only hints or traces of the newly discovered stocks of power?

It is not the general geological series that is at fault so far as this inequality is concerned. This is essentially the same for tens of thousands of square miles of the country within the limits that have been considered in this review, and for still wider areas outside of these limits. Three conditions for petroleum accumulation have been pointed out in Chapter II of this paper. They are as follows: Source, reservoir, cover. Within the territory now described sources of petroleum are never wanting in the great limestones that make so prominent a part of it, and particularly in the Trenton limestone that constitutes the base of the geological scale of both States. Again, the shales that cover the Trenton limestone with five hundred to one thousand feet of their close and impervious beds furnish an adequate cover or roof for all petroleum accumulation that may be found in the limestone. It is thus seen that two of the necessary conditions are universal throughout this territory. What is to be said of the third factor, the reservoir? The answer is that the Trenton limestone is the reservoir as well as the source, and the Trenton limestone, as has been already shown, is universal. While these latter statements are true, there is still a possible fallacy lurking in them which will presently come to light. There are, however, considerable areas where all of these claims seem to have been met, and yet the limestone contains no petroliferous value. Can the condition or conditions that are still lacking be pointed out?

The structure or arrangement of the oil or gas rock, involving the level of the stratum in contiguous territory, has been proved to be a potent factor in petroleum accumulation. A glance at the sections that have now been described is enough to show that marked structural disturbances occur in at least some of the gas and oil fields; and disturbances of exactly the sort that we should naturally connect with the desired accumulations. For all territory in which these peculiar structural features occur, and, on the other hand, for all the adjacent territory in which they are wanting, we should be able to give a reason for the facts of production or of failure. Well-marked and natural boundaries are found between the two phases of the oil rock.

But there are other productive wells in which no sharp structural boundaries are apparent; in other words, substantially the same features that characterize highly productive territory as to elevation and relative situation characterize other large areas from which nothing is derived. In such cases we can fall back upon the character of the reservoir, ascribing the failure to want of porosity in the barren portions of the field. These two lines of explanation are open to us, and they will be found to yield excellent results when applied to the facts with which we have to deal; but still they do not, by any means, cover all the ground. There are important divisions of the new field for the productiveness of which, in the present state of our knowledge, we can give no good or even plausible reason.

The two lines of explanation already suggested will be considered in connection with the several fields. The order in which they are named will be reversed in the discussion, and the porosity of the Trenton limestone will be first taken up.

POROSITY OF THE TRENTON LIMESTONE.

That the Trenton limestone is the reservoir of Findlay gas and Lima oil was established almost as soon as these substances were discovered. That it contains them as the oil sands of Pennsylvania contain their stocks of gas and oil, viz, in the pores or interstitial spaces of the rock, seems altogether probable. The Findlay gas rock is visibly and noticeably porous, especially that obtained from the wells of largest production. In fact, the best of it is much more conspicuously porous than the coarsest oil sands of Pennsylvania.

It has been urged by Dr. Lesley[1] that the Trenton limestone of the new oil field must be cavernous. He counts the presence of caves in it a necessity from the geological elements involved; and he denies in advance the sufficiency of any argument against the existence of caves which is based on the failure to find any up to this time. Caverns and communicating fissures he considers the receptacles of oil and gas as they occur in this rock. Prof. E. T. Cox has also, in recently published letters, expressed the opinion that the gas and oil of the Trenton limestone must be contained in pre-existing caves and fissures.

The argument for this cavernous condition of the limestone, it will be observed, is wholly an a priori argument. No observed facts whatever have been brought forward indicating the existence of these caverns except the facts of gas and oil production. A large number of wells had been drilled when Dr. Lesley wrote, and the number has been several times multiplied within the last year, but it is not known that a single hint or suggestion of any cavity or open

[1] Science, September 10, 1886.

fissure in this deep-lying rock has been reported by the driller. Upon this a priori assumption a good deal might be said. The effect of atmospheric water falling as rain on limestone rock that lies above the drainage system of the region to which it belongs is to produce subterranean caves and fissures, it is true. But is it probable that the saturated brines of the lower limestone that have no direct connection with surface water, and no opportunity for the renewal of their stock of carbonic acid, the great agent of corrosion, would produce such results 1,000 or 2,000 feet below the surface?

But, leaving these questions, it may be asked, if the Trenton limestone of Ohio can be shown to be as porous as the oil sands of Pennsylvania, what more need is there of caverns and fissures in it than in them? It is confessed that it is hard to form a picture of the state of things in a high-pressure oil or gas rock in any case, but just what is gained or lost by making the containing walls of the gas or oil reservoirs dolomite crystals rather than grains or pebbles of silica does not appear.

That the limestone is thus porous is well shown in the representation of thin sections of the gas and oil rock on Pl. LX.

The porosity of the Trenton limestone in the new fields is connected with its chemical constitution. For the facts pertaining to this last-named subject, the analyses given on a previous page will be recalled.[1] Wherever the Trenton limestone is an oil or a gas rock of pronounced character, it is a dolomite more or less pure. It is a dolomite also in other large areas, especially in those in which salt water promptly rises when the oil horizon is reached. The composition of the Findlay gas rock was determined by the Ohio Geological Survey very soon after this rock was struck in the Pioneer well, and the fact that it is a dolomite was made known at once. The significance and relations of the discovery were, however, not apprehended until later.

The dolomitic character of the Trenton limestone is by no means universal; in fact, it is rather the exception. The bulk of the formation, and apparently the whole of it, for 10.000 square miles in a body is best represented by figures like those given for the Point Pleasant rock, viz, carbonate of lime, 75 to 85 per cent.; carbonate of magnesia, 2 to 10 per cent. The composition of the rock seems to be gradually or rapidly changed from one character to the other in the same horizon. A question of great interest and importance may be raised as to whether the oil rock is an addition to the scale, superposed upon the normal Trenton limestone, or whether it is the modified Trenton limestone itself. The problem is not necessarily an insoluble one, but we have not data at present for working out a final answer.

A good deal can be said in favor of the first-mentioned view.

[1] Page 551–554.

The oil rock may be considered the equivalent of the Galena limestone of Illinois and Wisconsin, which in its lead-producing phases is a true dolomite. By the uplift of the Trenton limestone proceeding from the southward, the Utica shale has already been seen to be excluded from the series in Kentucky and southern Ohio. By a further elevation of the sea floor from the same direction the Galena limestone might have been limited in original deposition in Ohio and Indiana to those areas in which we now find the kindred dolomite which supplies the productiveness of the Findlay oil and gas rock. Viewed in this light, the oil rock is the Galena limestone.

According to the second view the Trenton limestone might have been in its earlier stages approximately uniform in composition through the entire territory which we are considering: the original composition being represented by the southern phases of the stone, which contain about 80 per cent. of carbonate of lime. In the oil and gas fields, and beyond them to a certain extent, the limestone was, subsequent to its deposition, transformed in its upper beds, its calcite being replaced by dolomite. It is this substituted rock which constitutes the main oil and gas reservoir.

It is hoped that these interesting questions, the solution of which involves a large amount of microscopic and chemical as well as purely geological work, will be taken up at an early day and followed through to a clear and well-settled conclusion.

The fact remains in either case that the oil rock is a dolomite, and that its porosity results from its highly crystalline character. Interlocking crystalline growths have empty spaces between them, and thus furnish adequate storage, as the result has proved, for high-pressure gas and great stocks of oil. The character of the rock can be approximately determined by inspection. The drillers judge this limestone "oil sand," so-called, by its grain, that is, by its crystalline character. A rock that breaks into small and fairly coarse cubical masses is "good sand," while fine-grained, and especially a white and flaky form of the rock, is counted unpromising. The last-mentioned form is characteristic of the Trenton limestone in southern Ohio. The driller is thus seen to be right in the declaration that he frequently makes that he has struck Trenton rock but finds no "oil sand." The porous dolomite is wanting. Trouble often arises from cases of this sort between the driller and the companies or individuals that order the drilling, the contract requiring that a certain depth in the Trenton limestone be reached. The question therefore becomes an important one as to what the proper boundaries of the Trenton limestone are. The prospecting companies are disposed to claim if they do not strike gas or oil in quantity that they have not reached the Trenton limestone.

The thickness of the dolomite in the fields where it occurs has not been found to exceed fifty or one hundred feet in any cases yet examined. It would perhaps be safer to say that dolomite has not been found at a greater depth than fifty to one hundred feet. The driller may be right in counting five or ten feet as the usual thickness of the porous bed that constitutes the reservoir. More facts are needed, however, in regard to this point. The two analyses from Bowling Green already given have a bearing on this limit, though they do not settle it. At 1,096 feet the top of the oil rock occurs, and its composition from that depth is found to be carbonate of lime, 51.78; carbonate of magnesia, 36.80; while from a depth of 1,100 feet the composition of the Trenton limestone is carbonate of lime, 88.64; carbonate of magnesia, 6.77. The southern or normal type of the formation is shown in these figures. The deepest large production in the Findlay field is reported from 93 feet below the surface of the Trenton limestone, but important production from below 50 feet is quite unusual. In the Lima field no value has been obtained by going more than 30 feet below the surface of the Trenton limestone. The fact that the rock which underlies the oil-bearing dolomite has the composition of the ordinary type of Trenton limestone can be made to agree with either of the theories of the origin of the dolomite.

The question as to the extent or limitation of the porous dolomite is seen to be a very important one. In general terms it can be said that this character of rock in the upper beds of the Trenton limestone apparently extends to the north and northwest of the present fields in a widespread area. If the Trenton limestone is unproductive of gas or oil in these directions, the fact results from some other cause than the lack of a porous rock to serve as reservoir. The dolomite appears in excellent character in the Bryan well in the extreme northwest corner of Ohio.

To the northeastward a limit appears to be sooner reached; at least, the few analyses that have been taken from the rock in this direction seemed to require such a conclusion. Single analyses at Fostoria, the top of the Trenton limestone, and at Fremont, 20 miles northeast, show the following constitution:

	Fostoria.	Fremont.
Siliceous residue	5.82	6.53
Carbonate of lime	61.50	75.79
Carbonate of magnesia	27.30	13.37

The best-marked boundary, however, is found to the southward. The dolomitic character of the limestone disappears entirely when followed a little to the south of the present limits of oil and gas production. It is replaced by the normal type of the Trenton limestone.

This fact is brought out clearly in several ways—by the results of chemical analysis, by the character of the rock as shown in drillings, and by its unproductive or feebly productive character as a source of gas and oil within these limits. The analyses that illustrate this point are grouped in the following table. There is no exception whatever to be noted in this list to the general statement, made above.

The analyses are repeated from a preceding page, but the series will be followed in a reverse order from that before adopted so far as direction is concerned. The top of the Trenton limestone or the gas horizon proper will only be considered in this list, and the carbonates of lime and magnesia are the only elements that will be here reported. The figures in the appended couplets represent these carbonates respectively. Gas and oil are produced by the limestone as shown in Nos. 1, 2, and 3, and sparingly in 4. A trifle is found in No. 5 also, but without value. In the remainder the rock carries no stock of oil or gas:

1. Bowling Green	51.78 36.80	5. Piqua	78.70 2.60
2. Findlay	[1]50.41 [1]35.69	6. Osborn	81.80 2.70
3. Lima	52.66 37.53	7. Hamilton	84.75 3.25
4. Sidney	62.30 32.30	8. Point Pleasant	79.30 0.91

[1] Corrected.

From the Findlay field to the eastward a similar line of facts is obtained as already shown.

The results are as follows. Fremont and Fostoria are northeast of Findlay; Plymouth is due east:

Findlay	50.41 35.69	Fremont	75.74 13.37
Fostoria	61.50 27.30	Plymouth	67.50 14.90

The last three are essentially or altogether unproductive.

The Galena limestone of Illinois and Wisconsin has been referred to in connection with the facts brought to light in the new oil field. The parallelism between the lead rock of Wisconsin and the oil rock of Ohio will not escape notice. Both are included in the Trenton limestone; both belong to its uppermost division; both are dolomites in chemical composition; both shade off insensibly into the common type of the Trenton limestone. To this it may be added that the mineral wealth of both formations is strictly or mainly limited to the dolomitic portion. The Trenton limestone is not a lead rock beyond the boundary of its dolomitic composition in the Galena division. The Trenton limestone is not a source of bituminous accumulation beyond similar limits in the Findlay oil rock. The Trenton limestone, aside from the composition above noted, does not seem capable of holding the largest accumulations of oil or gas. And, in fact, where it maintains its normal character, so far as present knowledge goes it is not an oil rock of any higher character than several other limestones of our scale.

The facts now stated afford a partial answer to the question with which we set out, viz, "Why is one area of Trenton limestone productive of petroleum on the large scale while an adjacent area in which the surface features and geological sections are the same is without any value whatever in this respect?" The difference is seen to result from, or at least to be accompanied by, a different chemical and mineralogical constitution of the stratum that we call the Trenton limestone.

The small prospect of success in the search for oil and gas in the regions in which the Trenton limestone holds its normal character is obvious in the light of the facts and considerations here adduced.

THE RELIEF OF THE TRENTON LIMESTONE AS CONNECTED WITH GAS AND OIL PRODUCTION.

The second geological factor to be discussed in connection with the petroliferous character of the Trenton limestone is the varying elevation of its surface. In several of the new fields this proves to be the factor that determines success or failure.

It is obvious that the character of the rock as to porosity, involving its possible adaptation as a reservoir for gas and oil, comes first in the order of important geological factors. But, given a rock of suitable quality in this regard, its productive character will be found strictly limited to certain levels. A dead line is drawn around each productive field, and very often the areas of gas and oil are sharply differentiated from each other by varying elevations of the rock that contains them both.

What are these dead lines? They are in reality the boundaries between the stocks of petroleum or gas contained in the reservoirs and the salt water that occupies the lower portions of the same porous rock and which constitutes the propelling force for both oil and gas. They mark the limits from which the energy of the imprisoned gas has expelled the salt water within the common reservoir. They will obviously be found to occupy different levels in different fields, depending upon the elevations of the reservoirs themselves. In the Findlay field the highest levels of the reservoirs are 300 feet below tide. The dead line or salt water level was originally 500 feet below tide. In the Lima field the highest level of the oil rock is a little more than 300 feet below tide. The salt water rises in the reservoir to the line of 400 feet below tide. The difference between the dead lines in the Lima and in the Findlay field is due to the lower energy and volume of gas and the greater breadth of rock in the former. In the Saint Mary's gas and oil field the lines have not been worked out with so much care as is desirable, but the probable limits of production are between two hundred feet below tide and a little more than three hundred feet below. In the Indiana fields the dead line or salt water line in the porous reservoir is a little less than one hundred feet below tide. The upper limit of the productive rock in this field is sixty to seventy feet above tide, the total range of production being included between these limits. It will be almost wholly covered by 150 feet, viz, from 90 feet below tide to 60 feet above.

The absolute elevation of the reservoir does not seem to be an important factor in productiveness. Everything turns on the relative elevation. Oil and gas will travel along any porous rock that contains them to the highest portions that are open to them. If the Trenton limestone were porous throughout its whole extent there would be no accumulations where we now find them, except as stocks of oil and gas might be trapped in the summits of folds or arches found along their way to higher ground. The outcrops of the formation would abound in surface indications.

As to the chemical composition of the Trenton limestone and thus as to its porous or non-porous character in a given territory, we can form no opinion in advance of the drill, except as may be fairly inferred from the probable constancy of chemical characteristics through large areas of rock. But in regard to the remaining factor in oil and gas production, viz, the relative elevation of the surface of the Trenton limestone, we are in altogether a different position. In a series of such steadiness as the sections already given clearly establish for the parts of Ohio and Indiana that have been passed in review, we are able to determine from the surface elevation and the surface rocks in what condition the Trenton limestone will be found so far as this factor is concerned.

The 30,000 square miles that we are considering, it will be remembered, make a very near approach to a plain. The extremes of surface elevation are confined to a few hundred feet, but the surface is occupied by formations of various geological ages. It follows, therefore, that the older the rock that makes the surface in any district, other things being equal, the higher will the Trenton limestone be found beneath. Whenever these older formations come to the surface the conditions for oil or gas accumulation must be more favorable. It so happens that two great formations of Upper Silurian time, viz, the Niagara limestone, 300 feet thick, and the Lower Helderberg limestone. 500 feet thick, occupy and divide between them a large part of the district in Ohio and Indiana which are underlaid by the dolomitic oil rock of Trenton age. When the Niagara makes the surface the Trenton limestone will be found at a higher level than when the Lower Helderberg forms the surface. The experience of the drillers up to the present time has laid a foundation for the important generalization that the Niagara limestone always makes the surface rock when the Trenton limestone occupies the proper level to constitute a reservoir of gas. In other words, the Niagara limestone is the surface gas rock. There is not a well in Ohio of large or even respectable proportions that does not begin in the Niagara limestone, or at least where this limestone is due. The limestone may have been removed by superficial erosion without vitiating the conclusion that has been drawn. The statement must not be insisted on in the strictest terms, however. There are a few instances in which a thin cap of Lower Helderberg limestone was passed through before the Niagara limestone was struck, but the outcrops of the latter were close at hand, and the territory is at least common to the two formations.

As the Niagara limestone is the gas rock, so the Lower Helderberg limestone makes the surface where all large production of oil is found. To this general statement there are no important exceptions.

These generalizations were originally drawn from the facts of Ohio experience, but the first of them proves to be almost equally applicable to the Indiana gas field. In Indiana but one form of petroliferous wealth has thus far been brought to light, viz, gas; and this keeps close within the boundaries of the Niagara formation, transgressing them at but a few points, among which may be named Kokomo and Noblesville, on the western and southwestern margins of the field. In reality, Kokomo is situated upon the boundary of the two formations and Noblesville comes within another line of similar significance.

The Niagara limestone is the surface rock for substantially all gas territory in the new fields, and the Lower Helderberg is the surface rock for all oil territory; but there is no warrant for the conclusion that gas and oil are respectively due under all the territory occupied by these formations. The latter are widespread, while the conditions for petroleum on a large scale are, it appears, difficult to meet and but rarely met. Sharp limitations are imposed by both the factors already brought forward. The Trenton limestone, to be productive, must have the right chemical composition and a proper crystalline character. Its surface at the point of production must also have some advantage in the matter of relief or elevation over surrounding areas. The localities where all things are ready are far between.

CHAPTER V.

PRACTICAL DEVELOPMENT OF THE GAS AND OIL FIELDS.

The application of the facts and principles that have been stated in the preceding section remains to be made in a condensed account of the leading geographical divisions of the new gas and oil territory. Before entering on this discussion two or three topics that have a common bearing on all the fields will be briefly discussed.

TRENTON LIMESTONE GAS—ITS COMPOSITION AND USES.

What is natural gas? The question is as hard to answer in a single statement as the question, "What is coal?" The last-named substance sweeps through a wide range of physical and chemical properties, from anthracite to lignite, and yet is coal all the time. Natural gas shows an equally wide range in composition. The deadly fire damp of the mine, the inflammable gas that arises from decaying vegetation buried in marshes and bogs, and the gases that are released by the drill from the rock reservoirs in which they have been stored are alike natural gas. In all of them the predominating element is light carbureted hydrogen. Fire damp consists very largely, sometimes almost exclusively, of this substance; rock gas has this substance for a basis, but contains varying proportions of other gaseous elements or compounds. Its composition may vary with the rock from which it is derived, and possibly with the pressure under which it exists. It is also popularly held that gas from the same well may change in composition at different dates.

But to the question "What is Findlay gas?" we have been able from the first to give an answer in the exact terms of chemical analyses. Findlay gas was approximately analyzed by Mr. Emerson McMillin, superintendent of the Columbus gas works, early in 1885. He found its percentage of light carbureted hydrogen to equal or exceed 90 per cent. Prof. C. C. Howard, of Starling Medical College, Columbus, undertook for the Ohio Geological Survey a careful and complete volumetric analysis of the gas. His examinations were repeated many times at intervals of several months, and showed the composition to be constant. The results, when interpreted according to a certain theory of combination of the elements that were found here, are as follows:

Marsh gas	92.61	Oxygen	0.34
Olefiant gas	0.30	Carbonic acid	0.26
Hydrogen	2.18	Carbonic oxide	0.50
Nitrogen	3.65	Sulphureted hydrogen	0.20

In regard to these figures it is to be observed that the determination of the hydrocarbons or marsh gas is not final. Some other members of the paraffine series may be included under this head. It would perhaps be safer to count the sum of the first two substances as the amount of the paraffines in the gas, leaving the special form in which they occur undetermined. Counting the constitution of the gas to be as given above, Professor Howard deduces for it a specific gravity of .57; but determinations by direct methods indicate a higher gravity. One method gives .6 and another gives .64.

Recent examinations made by Professor Howard show that the entire supply of Trenton limestone gas from all parts of the field and with all the varieties of depth and pressure of the wells that occur is practically one and the same thing.

Every town in Ohio and Indiana that has obtained a supply of gas since it was found at Findlay, while recognizing the fact that the supply has much in common with that of the original field, is yet sure that the production of its own wells is of a somewhat finer and purer quality than any of its neighbors have secured, and especially better than Findlay gas; and a number of observed facts can always be adduced which are thought to fully substantiate this claim. In other words, each town is sure it has discovered the best gas of the new field.

Professor Howard's figures fully confirm this claim. Each has the best, for since there is no difference whatever in quality, all are the best. The difference in purity, as popularly determined by the odor, is generally due to a difference in amount. The larger wells fill the air on all sides and oblige every one to recognize their sulphurous contributions to it; but the small wells furnish the gas in such restricted volume that it fails to make the same impression. All the claims as to a difference in the character of the supplies are set aside by the following table of analyses made in July, 1887, for the United States Geological Survey. In regard to the proportions of some of the elements reported it is to be observed that the limits of error will perhaps reach 1 per cent. Making proper allowance for this fact, it will be seen that the analyses, from Findlay and Fostoria to Anderson and Kokomo, as has been already stated, are substantially identical. The proportion of sulphureted hydrogen in each well is seen to be small, but it is also to be noted that no town has any exemption from the unwelcome element, and none has any surplus.

Composition of Trenton limestone gas. (*Howard.*)

Description.	Ohio.			Indiana.			
	Fostoria.	Findlay.	Saint Mary's.	Muncie.	Anderson.	Kokomo.	Marion.
Hydrogen	1.89	1.64	1.74	2.35	1.86	1.42	1.20
Marsh gas	92.84	93.35	93.85	92.67	93.07	94.16	93.58
Olefiant gas	.20	.35	.20	.25	.49	.30	.15
Carbon monoxide	.55	.41	.44	.45	.73	.55	.60
Carbon dioxide	.20	.25	.23	.25	.26	.29	.30
Oxygen	.35	.39	.35	.35	.42	.30	.55
Nitrogen	3.82	3.41	2.98	3.53	3.02	2.80	3.42
Hydrogen sulphide	.15	.20	.21	.15	.15	.18	.20
	100.00	100.00	100.00	100.00	100.00	100.00	100.00

NOTE.—The Fostoria gas was taken from the Watertanks wells, the Findlay gas from the six wells of the Findlay Gas-Light Company, the Saint Mary's gas from the Wilkins well, the Muncie, Ind., gas from wells Nos. 1, 2, 3, 4, and 6, the Anderson gas from the McCullough well, the Kokomo gas from wells Nos. 1 and 2, and the Marion gas from well No. 3.

The main element of value in natural gas is the heat which it contains. Its supply of light is inferior and subsidiary, but as a source of stored power it comes under the head of the most valued forms of matter. Like all other power that man is able to use, this is undoubtedly derived from the sun, through the agency of life. We know of no other source of such accumulations. As the heat-producing power of natural gas is the leading source of our interest in it, the question of how much heat it can yield is the first one to be asked. Its heat depends on its chemical composition, and varies with every change in composition.

The detailed discussion of these questions must be left to chemists. It is sufficient to say that about 31,000 feet of Findlay gas are theoretically equal to one ton of Pittsburgh coal. Practically, less than half of this amount of gas will do the work done by a ton of coal. The Trenton limestone gas is clearly one of the most valuable of natural fuels.

The only drawback is a small percentage of sulphur compounds that it contains, which renders it somewhat offensive when diffused. This is not, however, an uncompensated disadvantage. The fact that leakage, even in the smallest quantity, is immediately disclosed is to some extent a safeguard against dangerous accumulations.

The gas is perfectly adapted to domestic use in the kitchen range and the heating stove, and it also answers a fair purpose for household and street illumination; but its most important applications are in steam production and manufactures. In glass making especially it reaches its highest adaptation. In quality the manufactures made by it are superior, other things being equal, to those produced by the use of coal or coal gas.

THE ROCK PRESSURE OF TRENTON LIMESTONE GAS.

CAUSES OF ROCK PRESSURE.

What is known as rock pressure in gas wells is the maximum pressure reached when the gas is shut within the well. It is supposed to be the pressure of the gas in the rock reservoir, this pressure equalizing itself throughout the new space. It is also known as closed pressure. The open pressure of the gas, on the other hand, is the pressure registered on a gauge held in the current while the gas is escaping freely from a pipe of any size. When the gas escapes from the casing, a pipe of five and five-eighths inches diameter, it requires a vigorous well to produce any effect on an ordinary high-pressure steam gauge. The highest pressure noted in the casing (five and five-eighths inches) of any Ohio wells is six or six and one-half pounds. The open pressure increases rapidly when the opening to the well is reduced in size. A well that gives six pounds in the casing shows 20½ when the gas is made to escape through a four-inch pipe. The rock pressure or closed pressure of Trenton limestone gas varies in different fields, but is generally the same in all the wells of one immediate neighborhood in case the production of the wells is large. The usual range is between three hundred and four hundred pounds to the square inch. Higher figures than these are sometimes obtained, especially from the deeper wells. In a single instance 500 pounds is claimed for a Findlay well, and at the opening of the Findlay field 450 pounds is said to have been frequently reached. The Carey wells attain a pressure of 435 pounds. In a Tiffin well a pressure of 600 pounds is registered with probably another hundred pounds to follow. The wells of Lancaster show a maximum pressure of 700 pounds to the inch. The ordinary pressure of the Findlay field ranges from three hundred and eighty-five to four hundred pounds.

The pressure of the Bowling Green field is supposed to be the same as in the Findlay wells, viz, near four hundred pounds.

In the Saint Mary's and Saint Henry's gas wells the limit is put at 350 pounds. In the Indiana field it varies between three hundred and three hundred and thirty-five pounds to the square inch in the instances where reliable observations were obtained.

The closed pressure in the great gas wells of Pennsylvania is more than twice the highest pressure found in Trenton rock gas. Pressures of 750 pounds are reported on good authority and many facts are on record indicating a pressure of nearly or quite two hundred pounds beyond this figure. The rock pressure of the Ohio shale gas of the northern part of the State rarely exceeds 100 pounds to the square inch.

With some remarkable exceptions the rock pressure, as already stated, is generally the same for all the wells of a particular field, whatever their production may be. In other words, pressure gives in itself no indication or clew to the amount of gas a well yields. By joining to it, however, the element of time, an empirical but uncertain calculation of the volume of gas produced may be made. If a well gains a certain number of pounds pressure in a certain number of seconds or minutes, for example, the volume may be measured by one of the methods presently to be given and then used as a check on other like increase of pressure in wells of the same depth. The well that produces the largest amount of gas in the Findlay field shows the same closed pressure that the smallest well of the field shows; but in the case of the large well the entire pressure is reached in one or two minutes; in the other hours are required for it to creep slowly up to its maximum.

The phenomena connected with high rock pressure of gas and oil wells are among the most astonishing and impressive in the entire range of mining enterprise. When a reservoir of the character above named is penetrated, the gas, suddenly released from a pressure of three hundred to seven hundred and fifty pounds to the square inch, rushes forth with amazing velocity and indescribable force. It drowns like a tornado all ordinary sounds in the vicinity of the well. Unless great care be used by one engaged about the well his sense of hearing is very likely to be permanently impaired. When the gas is lighted the roar is greatly increased and can be heard for miles. The light from a great well can be seen, under favorable circumstances, forty miles away.

The cause of the rock pressure of gas and oil wells is a subject upon which our best authorities have not been in haste to commit themselves by offering definite and comprehensive theories to account for the facts. Three causes have been suggested as adequate to explain the results:

(1) The gas produces its own pressure. Solid or liquid matters in the rocks are there converted into the gaseous form and the gas thus formed requires larger space than the solid bodies from which it was derived. In seeking this larger space it exerts the pressure noted.

(2) The weight of the overlying rock produces the pressure of the gas. According to this view, the gas is in the rock and the weight of the earth above it exerts a constant pressure upon it, and forces it out with the velocity observed whenever an exit is made for it.

(3) The pressure is due to a water column that is behind the gas and oil. The porous stratum that makes the reservoir of gas and oil and salt water, and which always has an impervious roof, somewhere rises to the surface. Water entering at its outcrops will exert its pressure through all the flexures of the stratum upon the salt water that it contains, and thus upon the accumulations of oil or gas that are held within the arches and terraces of the stratum. This explanation makes the flow of gas and oil depend upon precisely the

same cause that occasions the flow of water from artesian wells, viz, a water head of greater or less elevation, at a greater or less remove.

The first theory doubtless has in it elements of truth. The beginning of gas pressure in any rock and all the pressure ever found in some formations may very well be referred to this source. For the pressure of shale gas, for example, I can see no other cause. But all the elements pertaining to this theory are vague and unverifiable. It is an explanation in name more than in reality. Moreover, the facts in regard to the great gas and oil rocks seem to require a cause at once more energetic and more variable than the expansive power of gas would furnish. If gas originates its own pressure it would be difficult to account for the extreme range of pressure that we find in the same stratum, all the gas of which has essentially the same composition. The theory certainly is weak and inadequate on this side, and we must look to either the second or the third theory for a satisfactory explanation of the remarkable facts observed.

The second explanation, viz, that which refers the pressure of reservoir gas to the weight of the superincumbent rock, appears to have found the largest measure of popular favor, but the theory is certainly unsound. It gives way when subjected to the slightest examination. Professor Lesley furnishes an excellent discussion of this theory[1] and he demonstrates its invalidity. The rock can exert no pressure on the gas, as he clearly shows, unless its particles are free to move upon one another, or, in other words, unless the rock is in a crushed state. The pebbles and grains among which the particles of gas are distributed, unless themselves actually moved, can exert no pressure on the gas, as Lesley well observes, any more than the walls of a cave can exert pressure on the river that flows through it.[2] There is nothing whatever to support the belief that the rock exists in the state which this theory demands. There are many facts that demonstrate the opposite view. No force can be found adequate to crush the rock at the depths at which the gas occurs. The slightest examination shows the weight of the overlying rocks is altogether insufficient. The Trenton limestone, in its nearest outcrops, is a firm, strong stone; and all the information we obtain as to its structure in the gas wells points to the same sort of rock there. But at its lowest measure of strength it can bear, without crushing, 720 tons to a square foot, and much of it can bear four or five times this weight. On the other hand, if the weight of the superincumbent rock that is to do the work of crushing the Trenton reservoir is one ton to the square foot for every 14 feet in height, there would be but 80 tons pressure on a foot of Trenton limestone in a Findlay well at a depth of 1,100 feet. This is but one ninth of the lowest resistance of the rock, and but an insignificant fraction of its highest resistance to crushing weight. Besides this the driller finds the rock firm and

[1] Ann. Rept. Geol. Survey Pa. 1885, pp. 657–680. [2] Ibid., p. 661.

compact to a high degree. The driller can not be deceived in this respect. It is unnecessary to follow this subject further. There is no standing ground whatever for the theory.

When we come to the third theory we see at once that it rests on a different basis from the theories previously discussed. It depends upon principles and facts of familiar experience and every-day use. Every one is acquainted with the flow of artesian wells. The present theory relegates gas wells to the same category. In fact, it makes the flow of gas from the rock reservoirs which the drill has penetrated due to the same cause that propels artificial gas through the mains of a city, viz., a water column behind and above it.

Before entering more fully upon the discussion of the question to what the rock pressure of gas wells is due, let us ask another question, the answer to which may advance us in our inquiries. The driller in the Ohio field, as well as in all other oil fields, finds gas in the higher levels of the productive rock, and, at a somewhat lower range, he finds the stocks of oil, if any, with which the reservoir is charged. If he goes below the horizon of the oil or gas, or if he goes beyond its productive limits, he reaches at once salt water, which rises in the well to a greater or less height, sometimes filling it entirely, and sometimes even flowing out of the top of the well. This experience is universal in the great fields of the United States at least. Every oil or gas field has a margin of salt water surrounding its productive portion, in whole or in part. The influx of this salt water is one of the most common evidences of total failure in wells drilled for oil or gas. The moment this fatal flood is reached all hope departs.

The question which should first be considered is this: "Why does salt water rise in wells drilled to the productive rock, but outside of the productive portion of the rock?"

Whatever explains the rise of the salt water from one portion of the oil rock will explain the flow of the gas or oil from another portion. The explanation that should reverse this order and make the rise of the salt water depend on the pressure of gas somewhere held in the rock would be ludicrously inadequate. There is an ocean of salt water; there is but a thimbleful of gas. The gas is confined to narrow streaks, it may be, on the crests of anticlines, and it occupies but a few feet at most in the upper portion of the rock, while the salt water stretches out for scores of miles on every side and through great depths in the rock. Salt water makes the normal and well-nigh universal contents of the oil sands. The rare exceptions, in locations favored by the accidents of structure, are the stocks of gas and oil, which in reality are very scanty, but which by comparison with each other we sometimes call great. Their total volume is insignificant when compared with the other elements with which they are associated. We have no reason to believe that all the accumulations of petroleum contained in the crust of the globe would exceed a few cubic miles in volume, but the salt water contained there would make a sea.

What makes salt water rise when its porous reservoirs are tapped by the drill? Let us ask one question more. What makes fresh water rise under similar circumstances? The mystery is dispelled with regard to artesian water supply. Every school-boy knows the explanation of the facts involved. If in its underground course water has dissolved from the rock more or less mineral matter the laws which governed it before such solution took place are not thereby affected. It has grown a little heavier by its mineral contents and consequently will not rise in quite as high a column as fresh water will, but this is all the difference. Salt water rises in the rocks in which it has been sealed from precisely the same cause as fresh water. It is an artesian flow or an artesian ascent, as the case may be. No other explanation of the facts involved is possible. From what source is the water head derived? The answer is the same as for all artesian flow. It is derived from water entering porous strata at their outcrops. The "requisite and qualifying conditions" for an artesian flow must all be found united in every oil or gas field.

But whatever causes the salt water to rise in wells drilled on the edge of an oil field or a gas field is beyond question the cause of the flow of oil or gas contained within the field. This is demonstrated by the close connection that exists between the salt water and the oil or gas. Working from the edge of the field towards the center, we find a progressive diminution of salt water and an increase of oil or gas in the common reservoir. With the exhaustion of a field the oil and gas are followed up and finally replaced by salt water. This is the common fate of gas and oil wells: the death to which they seem to be appointed.

The height to which salt water rises in wells drilled on the margin of a gas field gives a measure of the force of the gas within the field. This is true, at least, within the several divisions of the Trenton limestone. The height to which the gas rock rises in its nearest outcrop will in like manner determine the height to which the salt water will rise in the wells, and this factor is seen to control the rock pressure of the gas. The outcrops of porous rock, it is evident, must be followed. A stratum, though continuous in geological name, may be so changed in character that it will cease to be a factor in problems of this sort. The porous character of the Trenton limestone appears in a northerly and northwesterly direction from the new gas fields and it is, perhaps, in the outcrops of Michigan, Illinois, and Wisconsin that the water head originates which gives its spring and energy to the gas of Kokomo, Marion, and Findlay. While very many questions pertaining to the subject can be raised that can not be answered from lack of knowledge at the present time, it still appears that the only rational explanation of the rock pressure of gas is to be found in the artesian pressure of the salt water that always accompanies it.

Certain obvious inferences would follow the acceptance of this doctrine.

(1) The definite limitation of all supplies of gas and oil stored in rock reservoirs is emphasized by this view of the origin of rock pressure. If salt water is the moving force, all speculations of a constantly renewed supply of either gas or oil are vain and idle.

(2) Other things being equal, the pressure will be greatest in the deepest wells.

(3) The rock pressure of gas may perhaps be continued with little abatement of force until the end of the production of a field is near. The maintenance of pressure is no proof whatever of a maintenance of supply. The last thousand feet of gas come out from the gas holder with as much force as the first thousand feet.

(4) In a field that combines both oil and gas, but in which the reservoirs of these substances are differentiated, the first sign of approaching failure will be the invasion of either level by the contents of the division next below it.

MEASUREMENT OF GAS WELLS.

Considering the importance of the problem, it is surprising that the determination of the volume of gas escaping from high-pressure wells should have been so long neglected. Until the publication of Prof. S. W. Robinson's investigations[1] no general method had been made known by which the flow of wells could be determined. Engineers have solved the problem for themselves in many instances, no doubt, but none of them had taken the trouble to generalize a method and give it to the public. The great corporations that are distributing gas in a large way also have some formulas in use, mainly empirical, as it appears, to guide them in their estimate of the value of wells; but whatever method they have used they have kept in the nature of private information. Occasionally the formulas for artificial gas were strained to the proportions required by the new gas wells, and fair approximations were obtained from them. Generally the value of the well was estimated by the time required for the closed pressure to reach 100 pounds or some other fixed point on the gauge, the essential factor of the depth of the well being altogether disregarded.

Professor Robinson undertook his investigations for the Ohio Geological Survey and worked the problem out on the great wells of Findlay, and especially on the strongest of all, viz, the Karg well. The methods which he has devised are singularly simple and easy of application. The strongest of gas wells, provided the gas is dry,

[1] Van Nostrand's Engineering Mag., August, 1886.

can be measured by a single observation that can, if necessary, be taken in a fraction of a minute.

The appliance adopted is that known in physics as Pitot's tube. The pressure in moderate wells can be read by a mercury or water-column and the velocity of the gas in feet per second can be calculated by the formula, $v = 83.1\sqrt{h}$, where h is the height of the water column in inches. The volume per day can easily be calculated from the formula, $V = a\,v \times 86{,}400$, a being the area of the delivery pipe expressed in terms of square feet.

In the larger wells a steam gauge is used to read the pressure. Professor Robinson's discussion of the problem can not be presented at length, but in order to make clear the practical application of his method a few of his equations and tables must be here introduced. They are taken from Geology of Ohio, volume VI, 1888, p. 560:

Velocity under great pressures.—When a gas flows from a receiver into a space outside with a relatively large fall of pressure, the formulas for adiabatic flow of gas are to be employed for calculation. The correct formula for this is found in most of our best authorities, viz:

$$v^2 = \frac{2\,g\,\gamma\,p_2}{(\gamma-1)\,\delta}\left\{\left(\frac{p_1}{p_2}\right)^{\frac{\gamma-1}{\gamma}} - 1\right\}$$

in which, for the present use, p_1 = absolute pressure by Pitot's tube gauge; p_2 = absolute pressure of air = 14.6 pounds per square inch; δ = weight unit volume of flowing gas at mouth of Pitot tube = $.0807\frac{\tau_0}{\tau}\,Sg$; τ_0 and τ = absolute temperatures, as before; Sg = specific gravity of flowing gas at mouth of Pitot tube, air = 1; $\gamma = 1.408$; $\frac{\gamma}{\gamma-1} = 3.451$; $2g = 64.3$; m^2 = value in parenthesis; then, introducing the numerical values and reducing, we obtain:

$$v = 2404\frac{m}{\sqrt{Sg}} + \frac{t}{546+t}2404\frac{m}{\sqrt{Sg}},\ \text{for Cent.}^\circ\text{; and}$$

$$v = 2404\frac{m}{\sqrt{Sg}} + \frac{t-32}{954+t}2404\frac{m}{\sqrt{Sg}}\ \text{for Fahr.}^\circ$$

If the temperature of the flowing gas be taken at that for melting ice and Sg at 0.6, we obtain the approximate formula

$$v \text{ approx.} = 3103m$$

Here follows a table which explains itself:

[To facilitate calculations of velocity and temperature of flowing gas, in which $p_1 - p_2$ is the observed pressure by gauge on the Pitot's tube, and m the value of the bracketed quantity in equation (9).]

$p_1 - p_2$ or observed gauge pressure.	$\frac{p_1}{p_2}$	m	m^2
0.5	1.034	.100	.0100
0.75	1.051	.120	.0144
1.0	1.068	.138	.0189
1.5	1.103	.170	.0287
2.0	1.137	.195	.0390
2.5	1.171	.216	.0467
3.0	1.205	.236	.0555
3.5	1.240	.254	.0643
4.0	1.274	.270	.0729
4.5	1.308	.284	.0817
5.0	1.342	.299	.0894
5.5	1.377	.312	.0973
6.0	1.411	.324	.1051
6.5	1.445	.335	.1122
7.0	1.479	.346	.1197
7.5	1.514	.357	.1274
8	1.548	.368	.1351
9	1.616	.387	.1498
10	1.685	.403	.1624
12	1.822	.436	.1900
14	1.959	.461	.2126
16	2.096	.488	.2381
18	2.223	.512	.2621
20	2.370	.533	.2833
25	2.712	.578	.3341
30	3.054	.617	.3807
35	3.397	.653	.4254
40	3.740	.683	.4665
45	4.082	.709	.5027
50	4.425	.734	.5388
55	4.767	.757	.5731
60	5.110	.778	.6053

To measure the flow of a vigorous well by this method attach an open tube of convenient length, straight or bent, to a steam-gauge. Hold the open end in the current of gas at the well head and note the average pressure which the gauge shows in pounds and fractions of a pound ($p_1 - p_2$, first column of table). Add to this observed pressure 14.6 (pressure of air) and divide the sum by 14.6 $\frac{p_1}{p_2}$, (second column of table). Find the resulting number or that nearest to it in third column (m), increasing or decreasing proportionately to the difference between the number obtained by division and the number found in second column. Multiply the number thus found (m) by 3.103, and the result will be the velocity of the gas current in feet per second. To find the volume per second, multiply the velocity in feet by the area of the pipe in terms of square feet. To find the volume per day, multiply the result thus obtained by 86,400, the number of seconds in a day of twenty-four hours. The result will be the volume of gas at a temperature of 32° Fahr.

In Professor Robinson's tables the fixed multiplier, 3,103, is based upon a specific gravity of the gas of .6, approximately determined by direct measurement. Professor Howard has calculated the specific gravity from the composition of the gas as determined and construed by him and finds it to be .57. If this determination should be adopted, the fixed multiplier would become 3,184. The question in regard to the exact specific gravity of the gas is still an open one.

An example will make the mode of using the table clear. The pressure noted in the casing of a gas well is 6.3 pounds. $6.3 + 14.6 = 20.9$. $20.9 \div 14.6 = 1.431$. The number nearest this in the second column is 1.445. The difference is .014, which is seven-seventeenths of the difference between 1.445 and the next lower number in the table. In the third column, *m*, the number corresponding to 1.445 is .335. The difference between it and the next lower number is .011. $\frac{7}{17} \times .011 = .005$. Subtract this from .335 and the remainder is .330. Multiply .330 by 3,103; the product is 1,024, which is the velocity of the escaping gas in feet per second. The gas is escaping from the casing which is $5\frac{5}{8}$ inches in diameter, or, in terms of square feet, .1725. The daily yield of the well is therefore $1,024 \times .1725 \times 86,400 = 15,261,696$ cubic feet, at a temperature of 32° Fahr. and a specific gravity of the gas of .6.

For gas wells producing less than 1,000,000 cubic feet per day the anemometer is excellently adapted. So far as known, it was first used for this purpose by Mr. Emerson McMillin in determining the flow of well No. 3 (the Adams well) in Findlay.

With the Robinson method for large wells and the anemometer for small wells, we are able to determine easily and accurately the production at or near the well head of all our supplies of natural gas.

To render his method still more available, Professor Robinson has constructed the following table, which is also taken from volume VI, Geology of Ohio, 1888. The open pressure of the gas being read, and the diameter of the discharge pipe being noted, the volume of the gas can be read at once:

Cubic feet of gas, reckoned at 32° Fahr., discharged by well per day of twenty-four hours of continuous flow, by Pitot tube measurement; the specific gravity of the gas being here taken at 0.6 (air = 1), and the temperature of the flowing gas at well mouth being taken at 32° Fahr.

Observed pressure by water gauge.	Observed pressure by pressure gauge.	Diameter of orifice or of well mouth where observed in inches.					
		d_2=1 in.	d=1½.	d=2.	d=2½.	d=3.	d=3½.
Inches.	*Lbs. per sq. in.*						
.1	.0036	12,390	27,880	49,556	77,440	111,510	151,780
.2	.0073	17,560	39,510	70,260	109,750	158,040	215,110
.3	.0109	21,480	48,330	85,940	134,250	193,320	263,130
.5	.0182	27,720	62,370	110,880	173,250	249,480	339,570
.7	.0254	32,820	73,840	131,260	205,100	295,380	402,000
1.0	.0364	39,210	88,230	156,880	245,100	352,890	480,400
1.5	.0545	48,030	108,070	192,120	300,200	432,270	588,400
2.0	.0727	55,340	124,520	221,360	345,900	498,060	677,960
3.0	.109	67,910	152,800	271,630	424,500	611,190	832,020
4.0	.145	78,410	176,420	313,660	490,100	705,690	960,600
5.0	.182	87,670	197,260	350,670	548,400	789,030	1,074,860
7.0	.254	103,500	232,880	414,000	646,900	931,500	1,267,900
10.0	.3636	123,000	276,750	492,000	768,800	1,107,000	1,506,750
13.75	.50	146,220	328,990	584,880	913,880	1,316,000	1,791,200
20.62	.75	175,350	394,540	701,400	1,096,000	1,578,150	2,148,160
27.5	1.0	201,800	454,010	807,200	1,261,200	1,816,050	2,471,900
41.25	1.5	247,840	557,650	991,370	1,549,000	2,231,000	3,036,000
55.0	2.0	285,130	641,540	1,140,500	1,782,000	2,566,200	3,493,000
	2.5	316,500	712,130	1,266,000	1,978,000	2,848,500	3,877,000
	3.0	344,350	774,780	1,377,400	2,152,000	3,099,100	4,218,000
	3.5	370,000	832,500	1,480,000	2,313,000	3,330,000	4,532,500
	4.0	393,000	884,250	1,572,000	2,456,000	3,537,000	4,814,200
	4.5	415,270	934,350	1,661,100	2,595,000	3,737,400	5,087,000
	5.0	436,200	981,450	1,744,800	2,726,000	3,925,800	5,343,000
	5.5	456,200	1,026,500	1,824,800	2,851,300	4,105,900	5,589,000
	6.0	473,750	1,065,900	1,895,000	2,961,000	4,264,000	5,803,000
	6.5	489,840	1,102,100	1,959,400	3,062,000	4,409,000	6,001,000
	7.0	505,920	1,138,300	2,023,700	3,162,000	4,553,300	6,198,000
	7.5	522,010	1,174,500	2,088,0[illegible]0	3,263,000	4,6[illegible]8,000	6,395,000
	8.0	538,500	1,211,600	2,154,000	3,366,000	4,846,000	6,597,000
	9.0	565,970	1,273,200	2,2[illegible]3,000	3,537,000	5,093,000	6,932,000
	10.0	589,270	1,325,900	2,357,100	3,68[illegible],000	5,303,000	7,219,000
	12.0	633,340	1,425,000	2,533,300	3,958,000	5,700,000	7,758,000
	14.0	675,000	1,518,800	2,700,000	4,219,000	6,075,000	8,269,000
	16.0	713,550	1,605,500	2,854,200	4,459,700	6,422,000	8,741,000
	18.0	748,650	1,684,500	2,994,600	4,679,000	6,738,000	9,151,000
	20.0	779,350	1,753,500	3,117,400	4,871,000	7,0[illegible]4,000	9,546,000
	25.0	845,150	1,901,600	3,381,000	5,282,000	7,606,000	10,353,000
	30.0	902,180	2,029,900	3,609,000	5,639,000	8,120,000	11,054,000
	35.0	954,820	2,148,300	3,819,000	5,968,000	8,593,000	11,697,000
	40.0	998,680	2,247,000	3,995,000	6,242,000	8,988,000	12,234,000
	45.0	1,036,700	2,332,600	4,147,000	6,479,000	9,330,000	12,700,000
	50.0	1,072,000	2,412,000	4,288,000	6,700,000	9,648,000	13,132,000
	55.0	1,106,880	2,495,000	4,423,000	6,918,000	9,962,000	13,539,000
	60.0	1,137,600	2,559,600	4,550,000	7,110,000	10,238,000	13,935,000

Cubic feet of gas, reckoned at 32° Fahr., discharged by well per day, etc.—Continued.

Observed pressure by water gauge.	Observed pressure by pressure gauge.	Diameter of orifice or of well-mouth where observed in inches.				
		d=4.	d=4½.	d=5.	d=5⅝.	d=6 in.
Inches.	*Lbs. per sq. in.*					
.1	.0036	198,220	250,890	309,750	392,000	446,040
.2	.0073	231,040	355,590	439,000	555,910	631,160
.3	.0109	343,760	434,970	537,000	679,630	773,280
.5	.0182	443,520	561,330	693,000	877,080	997,920
.7	.0254	525,050	664,610	820,400	1,038,500	1,181,520
1.0	.0364	627,310	794,030	980,400	1,240,700	1,411,600
1.5	.0545	768,480	972,600	1,200,800	1,517,900	1,729,100
2.0	.0727	885,440	1,120,600	1,383,600	1,751,000	1,992,200
3.0	.109	1,086,510	1,375,200	1,698,000	2,148,800	2,444,800
4.0	.145	1,254,620	1,587,800	1,960,400	2,480,900	2,822,800
5.0	.182	1,402,670	1,775,310	2,193,600	2,733,900	3,1[illegible]6,100
7.0	.254	1,656,000	2,095,900	2,587,600	3,274,800	3,726,000
10.0	.3636	1,968,000	2,490,800	3,075,000	3,890,900	4,428,000
13.75	.50	2,339,500	2,760,900	3,655,500	4,626,500	5,864,000
20.62	.75	2,805,600	3,550,900	4,334,000	5,548,200	6,312,600
27.5	1.0	3,283,500	4,036,100	5,044,600	6,384,600	7,2[illegible]4,200
41.25	1.5	3,965,000	5,019,000	6,196,000	7,842,000	8,922,000
55.0	2.0	4,562,000	5,774,000	7,128,000	8,921,000	10,265,000
	2.5	5,064,000	6,409,000	7,913,000	10,014,000	11,394,000
	3.0	5,510,000	6,973,000	8,609,000	10,895,000	12,397,000
	3.5	5,920,000	7,493,000	9,250,000	11,707,000	13,320,000
	4.0	6,288,000	7,958,000	9,825,000	12,4[illegible]5,000	14,148,000
	4.5	6,644,000	8,409,000	10,382,000	13,139,000	14,950,000
	5.0	6,979,000	8,833,000	10,905,000	13,802,000	15,703,000
	5.5	7,299,000	9,238,000	11,405,000	14,435,000	16,423,000
	6.0	7,580,000	9,593,000	11,844,000	14,990,000	17,055,000
	6.5	7,837,000	9,919,000	12,246,000	15,499,000	17,634,000
	7.0	8,095,000	10,245,000	12,648,000	16,008,000	18,213,000
	7.5	8,353,000	10,571,000	13,050,000	16,517,000	8,[illegible]92,000
	8.0	8,616,000	10,905,000	13,462,000	17,038,000	19,386,000
	9.0	9,054,000	11,459,000	11,147,000	17,905,000	20,371,000
	10.0	9,428,000	11,933,000	14,372,000	18,645,000	21,214,000
	12.0	10,133,000	12,825,000	15,833,000	20,040,000	22,800,000
	14.0	10,800,000	13,669,000	16,875,000	21,357,000	24,300,000
	16.0	11,415,000	14,449,000	17,839,000	22,577,000	25,688,000
	18.0	11,978,000	15,160,000	18,716,000	23,977,000	26,951,000
	20.0	12,470,000	15,782,000	19,484,000	24,659,000	28,057,000
	25.0	13,522,000	17,114,000	21,129,000	26,741,000	30,425,000
	30.0	14,435,000	18,269,000	22,555,000	28,894,000	32,478,000
	35.0	15,277,000	19,335,000	23,870,000	30,211,000	34,373,000
	40.0	15,979,000	20,223,000	24,967,000	31,599,000	35,952,000
	45.0	16,587,000	20,993,000	25,918,000	32,802,000	37,321,000
	50.0	17,152,000	21,708,000	26,800,000	33,919,000	38,592,000
	55.0	17,710,000	22,554,000	27,672,000	35,023,000	39,848,000
	60.0	18,101,000	23,036,000	28,440,000	36,000,000	40,953,000

Tables of correction for other temperatures of flowing gas and also for other specific gravities of gas have been supplied by Professor Robinson, but it is not necessary to introduce them in this report.

CENTERS OF PRODUCTION OF GAS AND OIL.

Owing to the limitations of space in the present paper it is impossible to describe in detail the development of all the centers of production of gas and oil in Ohio and Indiana. One of the three or more gas fields of Ohio, the Findlay field, will be treated with enough detail to bring the characteristics and value and influence of the new fuel distinctly into view. The remaining fields it will be necessary to pass with the briefest mention.

In like manner, the leading one of the three important oil fields thus far developed in northwestern Ohio, the Lima field, will be described with enough detail to give the leading features of the production of Trenton limestone oil clearly. The other centers of production will be merely named. From one we can learn all.

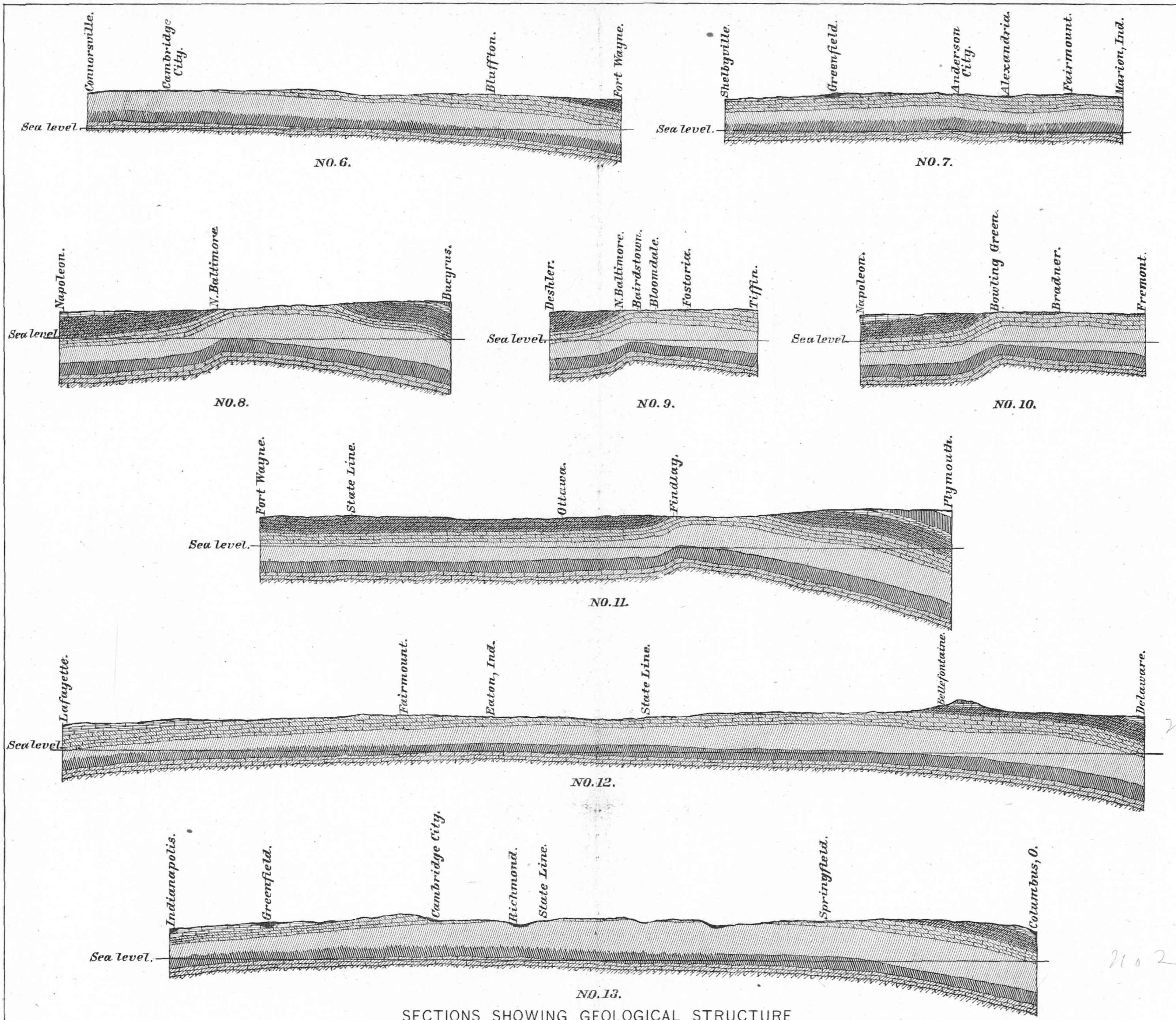
Finally, all of the gas production of Indiana will be treated under a single head. Only the more general characters of this great field will be considered.

DIVISIONS OF THE FIELDS IN OHIO.

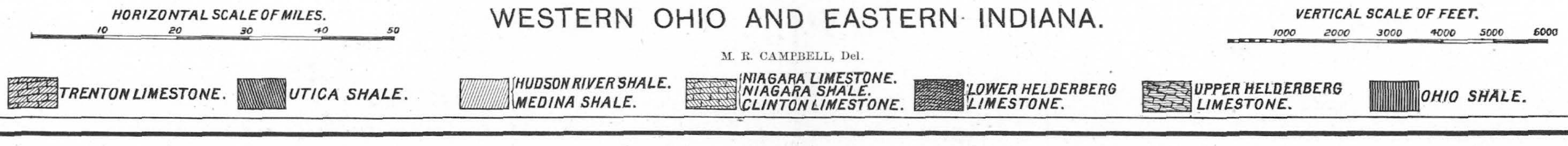
THE FINDLAY GAS FIELD.

The town of Findlay will always be associated with the gas and oil derived from the Trenton limestone. Not only were these new-found sources of wealth discovered here, but so far as gas is concerned the supplies obtained at Findlay are still unrivaled in volume and in constancy; in the use made of the gas and the commercial advantages resulting from its use, Findlay has not only more to show in the way of solid progress than any other town that has discovered and utilized Trenton limestone gas, but nearly as much as all the rest combined.

A question may be raised as to just how much shall be included in the Findlay field. By considering the geological conditions upon which the Findlay gas production depends we may be aided in establishing a proper boundary. Findlay gas is derived from areas in which the Trenton limestone is found in less than four hundred feet below sea level. Its limits in the Findlay field are 300 and 400 feet, respectively, below tide, and almost the entire supply is derived from the stratum where it lies between three hundred and three hundred and fifty feet below tide. Moreover, the surface of the productive area is entirely occupied by the Niagara limestone as the surface rock. Taking these two features as characteristic of the field, we can extend its limits as far as they are maintained. A third condition is found in the chemical composition of the rock. Where it departs from dolomite proportions it ceases to be an oil or gas rock. The western boundary which is made by the Findlay monocline is sharp and distinct. It passes through the incorporated limits of Findlay, dividing



SECTIONS SHOWING GEOLOGICAL STRUCTURE OF WESTERN OHIO AND EASTERN INDIANA.



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the village into nearly equal portions. The east side of the town is occupied by the Niagara limestone and is gas territory. The west side is occupied by the Waterlime and is oil territory. The surface elevations of the town, as already stated, are substantially one and the same thing throughout its extent, but the difference in elevation of the Trenton limestone in the two divisions ranges from one hundred and fifty to two hundred feet. These figures are well represented in the accompanying diagram (Plate LVIII). The Niagara limestone can be traced without interruption, so far as known, through three townships northward and four townships eastward. It also extends southeastward through three townships, and northeastward, according to the lines laid down on Newberry's geological map, it extends to Lake Erie. This is one of the three main characteristics already named for the Findlay field. The Niagara limestone makes the surface rock.

The other condition, viz, the depth of the Trenton limestone, must be brought in to limit and qualify this surface guide. The 400-foot line of the Trenton limestone will include, in Hancock County, the east half of Findlay Township, all of Marion, and probably all of Big Lick Township, the northeastern third of Jackson Township, all of Amanda Township, and part of Ridge Township of Wyandot County.

To the north of Findlay the whole of Allen, Cass, and Washington Townships, also in Hancock County, will probably be included, and to this must be added the southeastern third of Henry Township, the southern half of Bloom Township and the southern line of sections of Perry Township, Wood County. This entire area will aggregate about two hundred and twenty-five square miles. Gas is already produced at numerous points within this area, and a half dozen or more centers are now recognized as separate gas fields. The question as to counting the territory one field or more than one is not important, and, inasmuch as the geological conditions that are seen to be associated with the gas production of the Trenton limestone within this region are continuous, the whole of this productive territory will be counted under the Findlay field. The depths of the surfaces of the Trenton limestone below tide at various points within this area are shown in the following table, viz:

	Feet below tide.
Findlay, Pioneer well	314
Findlay, Karg well No. 1	347
Findlay, Cory well	350
Findlay, Adams well	405
Van Buren, Conroy and Johnson well	330
North Baltimore, well No. 1	360
Bairdstown, well No. 1	315
Bairdstown, Simons well	301
Bloomdale, well No. 1	360
Watertanks, Kelly wells	390

The first four wells in the list show practically the entire range of the gas horizon within the town limits of Findlay. When the surface of the Findlay rock is found lower, the rock sometimes produces gas, but oil is sure to accompany it, and generally overcomes it in a short time.

Within these limits there are doubtless considerable areas of unproductive territory, possibly due to sags or depressions in the limestone that may carry some areas of it down to oil or salt water, but such areas are more likely due to the close grain and consequent lack of porosity of the reservoir. The last-named quality, again, is dependent on chemical composition.

The essential features of the Findlay gas field have now been brought into view. It consists of a flat-lying territory of Trenton limestone, no portion of which sinks more than 400 feet below the level of the sea. This flat area of the Trenton has for its surface an equally flat territory of Niagara limestone. The depths of the wells range from 1,050 to 1,200 feet. The section of the Pioneer well, which has already been described, stands in substance for all. The cross-section between Deshler and Tiffin, Pl. LVIII, No. 9, traverses one of the most important portions of the Findlay field, and represents the facts of structure here in a significant way. The surface of the Trenton limestone appears as a low arch between the extremes, and is productive only between North Baltimore and the Watertanks. It rises from 380 feet below tide at the first station to 315 feet below tide at Bairdstown and falls again to 390 feet at the Watertanks. Similar facts are brought to light in all the other sections that have been drawn across this part of the field. Each of them shows a very flat arch of the lower limestone, appearing in the gas-producing territory. No safe generalizations can be made as to values as gas territory of the different portions of the general field further than to say that the most vigorous wells are likely to be situated on the line of the Findlay break. Examples of this sort are as follows: The Karg well, best known of the series in Findlay, is located upon the sharpest descent; the Van Buren well, north of Findlay, and the Ballard well, southeast of town, are also excellent examples of the effect of such a location. The Simons well, in Bloom Township, one of the three or four largest wells in the field, is located very near another steep descent of the Trenton limestone, the direction of which is to the north or northwest. The arrangement and extent of this structure have not come distinctly into view. The Heck well also stands very near the break; so also do the Cory and the North Findlay wells, and all of them are vigorous.

Within the corporate limits of Findlay, which have now been made co-extensive with the township, twenty or more wells have been drilled for gas since the field was opened. The number is constantly increasing. None of those in what may properly be counted gas territory, viz, the east side of Main street, have failed to produce at least a moderate supply of gas, but the range in production is considerable. The smaller wells fall below 200,000 cubic feet a day. At the other extreme is the Karg well. When measured in May, 1885, it delivered from a four-inch pipe at the well head a little more than 12,000,000 cubic feet of gas in a day, the volume being calculated for a temperature of 50° Fahr. From the casing (five and five-eighths inch pipe) the daily production would have reached 14,000,000 cubic feet. There are but few other wells in the township that produce one-half as much gas as this. Similar measurements, more or less satisfactory, have been made by the Ohio Geological Survey of several other Findlay wells. The results will be understood as representing the initial flow of the wells, taken at or near the well heads, but the figures, after all, are not fairly comparable with each other, for the reason that the measurements were made on pipes of different diameters and different temperatures of the gas are involved. The measurements are as follows:

Well.	Pipe.	Daily production.
		Cubic feet.
Jones well	2-inch	1,159,000
City well, No. 1	2-inch	1,179,000
Adams well	5⅝-inch	1,296,000
Briggs well	2-inch	2,565,000
Cory well	2-inch	3,318,000

Among the larger wells that have since been drilled in the town are the following, viz: City No. 2, Columbia, Crossley, Heck. These are variously estimated as producing from four million to eight million cubic feet each a day. The two latter, taken together, will doubtless equal the original volume of the Karg well.

The popular mode of computing the value of a gas field, which is to add the figures representing the initial flow of every well at the well head, is obviously misleading as to the available gas supply. No account is taken of the natural abatement of flow or of the losses by friction in the pipes. Several of the earlier wells at Findlay have entirely failed and the production of all has doubtless decreased, but the available supply is still vastly in excess of all demands. There are several fine wells of which no use whatever has yet been made.

The history of the utilization of natural gas in Findlay must be briefly told.

The Findlay Natural Gas Company drilled the Pioneer well in November, 1884, and made arrangements forthwith to pipe and supply the town.

The Findlay Gas Light and Coke Company, a corporation that previous to the discovery of natural gas was supplying the town with artificial gas in small amount, drilled a second well in the town, completing it in January, 1885. This company also proceeded to pipe the town and to supply fuel and light to the citizens. Two lines of pipe were thus laid in the main streets in 1885, but before the end of the year the first-named company was absorbed by the latter. The following rates were established by it:

Unit of consumption.	Monthly rate.
Cooking stove	$1.00
Heating stove	1.50
Grate	2.00 to 2.50
Light, per burner	0.15 to 0.20

Complaints began at once against this scale of prices. It cost less than $1,500 to drill and equip a well, and a single well like the Karg would supply several towns like Findlay. The agitation resulted in the city government of Findlay entering the field with authority granted by the State legislature to drill wells and to furnish light and heat to citizens.

This work was begun in October, 1886, and during the remainder of the year a third line of pipes was laid down in the principal streets. The wells drilled by the city were successful. The first two were located as near to the Karg well as they could be conveniently. Well No. 1 yielded over one million feet of gas a day, and well No. 2 five or six times as much. The city also purchased wells that had been drilled by individuals and thus began the winter with a daily production of at least ten million cubic feet, measured as indicated above.

In the competition that ensued between the city and the gas company prices were divided and reduced several times in succession, until the rates finally stood at 15 cents a month for stoves of all sorts, while lights were not counted.

The city has since purchased the entire gas property of the company, including wells, pipe lines, and distributive service, but the rates remain at the lowest point previously reached.

The use of the gas has been lavish and wasteful from the first, but the facts already recorded increased the tendency to such wastefulness.

By the end of the year 1885 all other fuel and light were well-nigh discarded in Findlay. The gas was also introduced into nearly all of the established industries of the town in which steam production was required. Two machine shops were supplied, two flouring mills, and a few other small manufacturing concerns, but at the opening of 1886 no considerable addition had been made to the business enterprises. Inquiries, however, had begun in the interests of various manufactures, and the bringing in of the Karg well stimulated and quickened all these movements.

The first important establishment to get under way in the new gas field was the Briggs Tool Works, an establishment transplanted from eastern Ohio. It brought its machinery, its workmen, and its trade with it. It employed seventy-five men at the beginning, but it is now being expanded to take in a rolling mill in which two or three hundred men will be employed. To this company belongs the credit of first welding iron and steel with Trenton limestone gas. A little doubt was felt for a time as to the practicability of this process by reason of the sulphur contained in the gas, but the gas has proved itself thoroughly adequate to the service. The work was first successfully accomplished June 9, 1886, and this date is taken as an important one in the industries of Findlay.

Glass making is an industry in which competition without natural gas seems now impossible. The adaptation of the fuel to the product is so happy and complete that a very great advantage is given to all firms who can command it. The glass manufacturers of Wheeling and Bellaire have been expending money very freely in a determined search for gas within their own boundaries, but it has come to be clearly recognized that the structure favorable to gas accumulation is lacking in their immediate vicinity. Two courses are open to them, viz, to transfer their works to locations where gas can be obtained, or to pipe gas in from the nearest productive fields. Both courses are, in fact, adopted. The first glass plant in Findlay was established by the junior members of a Bellaire company. They began to build in May, 1886; in September they were turning out an excellent article of glass, made from Sylvania sand and Findlay lime by the use of Findlay gas. The fuel bill for works on the scale with which they were operating would have been, in the old location, $300 a month; at Findlay it was $200 a year.

Three other glass factories are already in successful operation at Findlay, and three are building. Of those already established, one, at least, employs 300 workmen. Three rolling mills of large capacity are soon to be completed, and also a steel-nail mill. Lime is burned on a large scale by gas. Brick burning is also going forward, with gas as fuel. A number of other manufacturing enterprises, some of them of considerable importance, are also establishing themselves here.

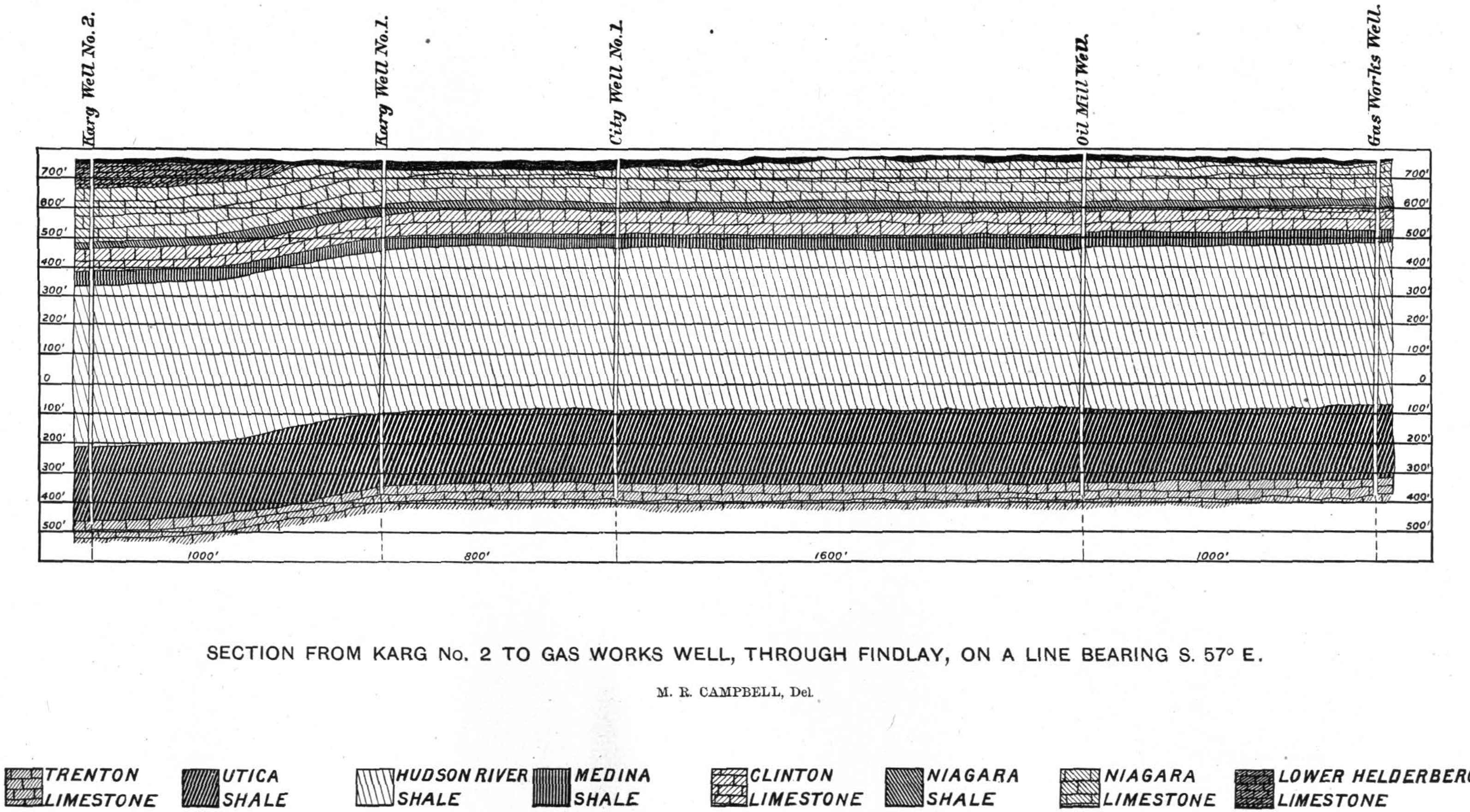
The discovery of natural gas in Findlay found a fairly prosperous county town, with a population of 5,000 people, surrounded by a rich agricultural district that was in course of successful development. Up to the beginning of 1887 the movement of growth went forward in an orderly and substantial manner. Prices for real estate were advanced gradually with the increasing demand, and many sales were made to parties for actual occupancy. The field was free from all speculative excitement. This latter element, however, entered in full force at the beginning of 1887, and the spring of that year was signalized by an extraordinary advance in prices of real property and by large investments on the part of persons who bought merely to sell again. Prices were doubled and doubled again. Additions were laid out on a magnificent scale, the entire township was taken into the corporation, and capital flowed into Findlay from all directions. Provision was made for a town of at least a hundred thousand people, and speculators reaped large rewards. But this excitement soon exhausted itself. At the extravagant prices that were reached purchasers grew scarce, and rates consequently receded once more to a point where bona fide investors could purchase with safety. The growth of the town is now proceeding rapidly and solidly.

The policy of offering inducements to manufacturing companies to locate in the towns that have secured the new fuel was begun in Findlay. Grants of land, as much as is necessary for manufacturing plants, free fuel, and sometimes liberal subscriptions to the stock of the company are all offered to companies that propose to locate.

When the Black Swamp of northwestern Ohio came to be first occupied, towns were established here and there over its surface at points suggested by apparent advantages in the way of accessibility and prospective settlement. The agricultural capabilities of the several districts were the only recognized elements of value in them, unless the supply of water or of building stone should occasionally be considered. Of mineral wealth of any kind beneath the soil no one had a thought, unless, perhaps, some ignorant and credulous dreamer, and such never stopped in their claims short of silver and gold.

The rocky floor of the country seemed to the early settlers as regular and uniform as the surface; but when it came to be mapped on a geological basis it became evident that a considerable variety of structure must underlie this monotony. But geologists, for a time, failed to apprehend the full significance of the facts. The driller has, however, brought to light beneath this flat and unbroken surface the most remarkable deep-seated movement of the strata known in the State, viz, a monoclinal fold of pronounced character, well defined, and continuous for a score or two of miles.

One of the early towns, the location of which was determined on some one of the general grounds already indicated, in addition to becoming the capital of a county of great agricultural value and promise, chanced to be located on the very line of this hidden but profoundly influential feature in the geology of northern Ohio. The main street of this town coincides for some distance with the edge of the steepest descent of the field, whose existence was not even dreamed of. This town is Findlay. No other shares its fortune in this regard. The exceptional geological structure that has been pointed out is directly connected with the wonderful resources in the way of gas and oil which have been discovered below the surface of



SECTION FROM KARG No. 2 TO GAS WORKS WELL, THROUGH FINDLAY, ON A LINE BEARING S. 57° E.

M. R. CAMPBELL, Del.

the town. The surprising progress that Findlay has made by means of the capital which this discovery has attracted, and is continuing to attract, makes it an object of envy to all the towns around, and it is easy to see that if the present rate of growth is long maintained a manufacturing center of great importance will be created here. The great advantages to such interests of having the best of fuel, either without money and without price or at a merely nominal rate, are so obvious that they can not fail to make themselves felt on all sides. New manufacturing enterprises, instead of being attached to the old ones out of which they grow, will seek a location in the natural gas belt; and when a period of business depression occurs those establishments that have power, fuel, and light free or at a nominal charge only will stand, while others in the same line of production must fail. Competition under such unequal conditions is impossible. All this turns, however, on the duration of the supply. The only consideration that now holds capital back from establishing in the new gas field duplicates of the various manufactories of the country on the largest scale is the question as to how long the supply will last.

Probable duration of the gas production.—The question is of the greatest importance, but data have not yet been accumulated in any part of the field by which even an approximation to a definite estimate as to the life of the field can be given. From Findlay we gain a few facts that bear upon the answer. The highest original level of the gas is found in the wells on the east side of the town, where the surface of the gas rock was struck at about 312 feet below tide. The deepest wells of Findlay that can with propriety be called gas wells are the Adams and the Barnd wells. In them the surface of the gas rock was found a little more than four hundred feet below tide. These wells have always produced more or less oil, and the latter also salt water, with the gas, but the oil has steadily gained on the gas, especially in the first one. The proportion of oil in the Adams well was increased at least threefold during the months in which the Karg well was suffered to blow into the air. The explanation of this is obvious. By the release of 14,000,000 cubic feet of gas per day from the common gas reservoir the oil was driven upward to a higher level. The level once gained by the oil is not again surrendered to the lighter element. It will be given up only to the great flood of salt water, whose steady artesian pressure is the propelling force of both oil and gas.

The original depth of rock occupied by gas at Findlay is seen to have been something less than one hundred feet. This space has certainly been reduced by a measurable amount since the field was open. The Karg, Cory, and North Findlay wells all occupy about one level of the limestone, viz, 350 feet below tide. Their gas was originally entirely dry. One of the first measurements bearing on the question before us will be derived from the appearance of oil or salt-water in the gas of these wells.

That the gas and the oil are stored products, accumulated in rocks of suitable structure to serve as reservoirs, or, in other words, that we are drawing upon a definite stock of this substance, is the only rational view to be taken of the facts involved. There was in the Findlay field originally a vast but still not an incalculable amount of gas, either dry or held in and permeating the oil that accompanies it. Upon this stock the wells are drawing. From it a given number of millions of cubic feet can be used for a given number of years, but when once exhausted there is no more possibility of its renewal in the reservoir than there is of the growth of coal in mines that have been worked out. It is in this light that the waste of these priceless accumulations ought to be regarded. The new gas fields of Ohio and Indiana have been depleted in a reckless and wanton way. They would seem to have fallen into the hands of grown-up children rather than sagacious business men; of ignorant vandals rather than representatives of modern civilization. Their stores, which it has cost millions of years to gather, and which if wisely husbanded might keep the wheels of industry turning for scores of years to come, have been burned as rapidly and noisily as ingenuity could devise the means for it, and largely at the dictate of real-estate speculators, whose great object was to work up that excited and irrational state of mind in regard to investments which is called a "boom."

GAS FIELDS OF NORTHWESTERN OHIO, EXCLUSIVE OF FINDLAY.

The Findlay gas field has been made to cover, as will be remembered, all the Niagara limestone area continuous with that on which the town was built that has proved productive of gas. Its most important extensions are to the north and northeast. As commonly counted there are several distinct gas fields in the northern townships of the county. To whatever divisions they may be referred, these areas rival in importance the original field. The great well of Van Buren, in Allen Township, has already been several times mentioned. It is at the present date (July, 1887) the largest gas well ever opened in Ohio. It gives good reason to expect enormous production in its vicinity. The south line of townships of Wood County, viz, Henry, Bloom, and Perry, connecting with Cass and Washington Townships of Hancock County, are proving very prolific in gas. In Bloom Township, north of Bairdstown, the Simons well is located, and ranks third in the list of great wells. Marion Township has one great well, which is known as the Thorntree well. Jackson Township also has one, the Ballard well, which produces more than 5,500,000 cubic feet daily.

This territory outside of Findlay is being developed in the main in an orderly and systematic way, under the control of three corporations that have secured a large part of the most promising territory. The foremost among these corporations is the Northwestern Ohio Natural Gas Company. In it the experience and capital of the Standard Oil Company are represented.

This company owns two of the best wells in the new field, the Van Buren and the Simons wells. They have also other very valuable wells, the entire number being twenty-four. They have introduced gas from this territory into Fostoria and Fremont, and have also reached Toledo with their pipe lines. This enterprise constitutes, in fact, one of the most important features of the new field, and involves the expenditure of a very large amount of money. The Toledo pipe line of this company is 32 miles in length, and consists entirely of 10-inch pipe. Two other pipe lines are led out from the new gas field. From the great Thorntree well, in Marion Township, gas is transported to Tiffin, and this prosperous and enterprising town is profiting greatly thereby. The company is known as the Tiffin Natural Gas Company. It controls considerable gas land in the vicinity of its first well, and has recently brought in one of the largest wells of the entire field.

The Toledo Natural Gas Company is also transporting gas from Henry and Bloom Townships, Wood County, to Toledo. The length of its pipe line is about thirty miles. The size of the pipe is 10 inches for most of the way and 12 inches near the terminus. No competition in the price of gas in Toledo is expected from the entrance of this company.

There has been a considerable and somewhat novel extension of municipal power in connection with the search for natural gas and its utilization during the last two years in Ohio. The student of political science will find the record an interesting and instructive one, and possibly will consider the policy questionable. Incorporated cities and villages in numerous cases have secured from the legislature authority to drill wells for gas, and when found to transport and supply the same for the use of citizens. The issue of bonds for that purpose must be approved by a popular vote, it is true, but thus far there has been but one result when the question has been submitted to the people. Propositions to bond the towns always carry by overwhelming majorities. The smallest taxpayers are generally the most enthusiastic supporters of the proposition.

As a consequence several towns have expended considerable amounts of money that must be raised by taxation in the search for this most uncertain form of mineral wealth. The exploration has been undertaken in some places where, so far as there are any scientific indications in the case, they were decidedly against the presence of an adequate supply of gas. One village corporation has expended $10,000 for drilling wells and has no gas to show for the expenditure. Other towns are following in the same track. Findlay led in this new policy. The company that drilled the first wells and piped the town was taxed to break down its business. All has been happily adjusted, owing to the great growth and prosperity of the town. The city has bought the entire plant of the gas company at a fair valuation, giving the company at least its money back again, but it is easy to see that the result might have been very different.

Fostoria, on the edge of the gas field, has issued bonds and drilled wells and laid a pipe line entirely around the corporation limits. It offers gas practically free of cost in unlimited amount to manufacturers who will establish themselves there. Fostoria was already reached by the pipe line of the Northwestern Ohio Company, and investments have been attracted by its vicinity to the new gas supply.

The Bowling Green gas field is the most northerly extension of the high-lying Trenton limestone that has proved productive. The second well of the new field was drilled here. This division of the gas field extends south from the village about three miles. Its extension in an east and west direction has not been proved, but it seems not likely to exceed the same distance. The gas is much the most vigorous on the southern border of this territory. There seems nothing to encourage further drilling north of the town. Of the first six wells, the last, which was located a mile south of the courthouse, yielded much more gas than all the rest combined. Its production probably exceeded one million cubic feet per day at the time the well was drilled.

Bowling Green has attracted several large manufacturing enterprises, including an extensive glass-works plant, and has shared the large investments of outside capital that have been directed to the new gas field.

A very important and promising as well as extensive gas field is now (July, 1887) in process of development in Auglaize and Mercer Counties, on the western border of the State. It may be designated by the location of the first well as the Saint Henry's field; or, from the most numerous wells, as the Saint Mary's field. The wells are not of the largest volume. Thus far they range from half a million cubic feet per day to five million cubic feet, but a considerable number of them produce between one and three million cubic feet per day. This seems to be about the normal range of this territory. The field is in general character very much like the Indiana field, which is presently to be described. Its structural features have not, in drilling, come to view with much distinctness.

Small supplies of gas are found in Carey, Fremont, Tiffin, Oak Harbor, Bryan, and other towns. Several of these towns have a measure of importance and value in this connection. Oak Harbor is the most promising at the present time. It is located on an uplift of the strata, which is indicated by the arrangement of the surface rocks as shown in the geological map of Ohio. The Niagara limestone rises here to the surface in a long tongue or prolongation which extends to the lake. A similar arrangement of the rocks is found 10 miles to the westward, and on this uplift also a little gas and oil have been found at Lindsey and Genoa. Through all of this territory the Trenton limestone lies far below the 500-foot dead-line of the Findlay field; but the influence of minor arches at a lower level proves adequate to effect some concentration. No great importance appears, however, to attach to this outlying territory so far as can now be seen.

The review of the northwestern Ohio gas fields must be concluded here. Enough has been said to show the immense economic value of the surprising discovery that was made in Findlay in November, 1884, of high-pressure gas stored in the Trenton limestone.

THE LIMA OIL FIELD.

The account to be given of Trenton limestone oil is by no means as favorable as that which has been given of the gas afforded by the same stratum. Trenton limestone gas is gold, but its oil is lead, at least under the present conditions of the market. Still, it is a fact of extraordinary scientific interest that the most prolific oil field yet found in the American continent, and second only in productive power to the great Russian field among all the oil fields of the world, is now coming to light beneath the fertile, drift-covered plains of northern Ohio.

The history of the discovery of oil at Lima has already been noticed.[1] The earlier developments of the field, by which its general proportions and areas were outlined, have also been described.

It now appears that the field was opened on its extreme northwestern boundary. If tho drill had been started a very short distance beyond the location of the first well it would have found little besides salt water. Ten or twelve of the wells next drilled were of the same character as the first, except that a number of them proved to be entirely outside of the limits of production. But by the time these were all completed the real character and promise of the field were coming into view, and the directions in which the largest production was to be looked for were approximately determined.

Structure of the field.—The Lima oil field proper, as proved up to the present time, consists of a tract eight or ten miles in length and from two to three miles in breadth. It is fairly symmetrical in outline. The axis of the field extends in a southwesterly direction from a point two or three miles due east of Lima to a point two or three miles south of Cridersville, Auglaize County. The elevation of the surface averages between eight hundred and fifty and nine hundred

[1] Pp. 530 et seq.

feet. There is a slow ascent to the southward. The tract embraces parts of Bath, Ottawa, Perry, and Shawnee Townships, of Allen County, and part of Duchouquet Township, Auglaize County. The northeastern prolongation of the oil rock is bounded on all sides by salt water. The southern central and southeastern borders find the Trenton limestone barren, apparently because of its physical character, which in turn depends upon its chemical composition. The drillings show it to be a hard and close-grained rock. The northwestern border is generally determined by the presence of salt water in the Trenton limestone.

The level of the upper surface of the Trenton limestone within and adjacent to this area proves to be a very significant and important factor in the productive character of the rock. This great stratum is found about as nearly horizontal within the productive area now described as any sheet of stratified rock ever is. On one square mile, on which more than fifty wells have been drilled, the extreme range of difference in the depths at which the Trenton was found is 16 feet, and, excluding a single well, the range is but nine feet. Two of these wells, a mile distant in an east and west line, found the Trenton at exactly the same level, and two of them in a north and south line show a difference of but three feet in the elevation of the oil rock. From a well located in section 20, Perry Township, to wells in section 5, Ottawa Township, a distance of three and a half miles in a due north direction, the descent of the Trenton is 12 feet.

An instructive section is obtained on an east and west line through the corporation of Lima. Beginning with the Ashton well on the west, we find the surface of the Trenton limestone 402 feet below tide; in the Parker well, in section 35, Bath Township, the surface is 408 feet below tide. In other wells along the line we find the surface of the Trenton below tide, respectively, at 392, 388, 381, 388, 389, 390, 402, 386, and 387 feet. Two wells near the Parker well, a little to the south, respectively show the Trenton to be at 405 and 404 feet below tide. The length of the line traversed in the entire section is four miles. There is a difference in the extremes of six feet, but one well in the middle of the line is at the exact level of the initial well. The fact of special interest is that neither of the extremes is productive of oil, nor is the well in the middle of the line, while all the rest are more or less valuable oil wells. In the productive wells the surface of the Trenton is found at the depths named above, and the extreme stations in this line are three miles apart. Further, the well in which the level of the limestone is 381 feet below tide proved to be a producer of dry gas for a number of days, the first and only well of the kind in this part of the field.

The relation between the levels at which the Trenton limestone is reached and the oil and gas production of the wells has been adverted to already in several places. The following list of wells, in which the levels of the limestone have been determined, illustrates this subject in a striking way. If all the newly ascertained facts were collated there is good reason to believe that they would confirm and extend the conclusions that have been reached. The list embraces over fifty wells that are arranged in the order of the elevation of the Trenton limestone found in them. There has been no selection of facts whatever. Every record that was readily accessible at the time the measurements were made was put in the list, and it is entirely probable that all subsequent records would fall within the same limits as those here shown. The first day's flow of every well is given in all the cases in which it could be definitely ascertained. The wells were nearly all measured by the steel tape, and the figures are as accurate as such measurements generally are. Few, if any, anomalies exist; but even these few would perhaps disappear upon a more careful examination of the records:

Name of well.	Trenton limestone below sea level.	First day's production.
	Feet.	*Barrels.*
Amos McClain	*a* 375	140
Christ. Martin	376	20
McDonel No. 1	378	70
Garvey's gas well	381	....
Bowman	382	125
Hogle	382	50
Ditzler	383	500
D. Martin	384	15
Gas Company's well	384	....
Tunget	386	700
French	387	300
Lehman	387	70
Apple	387	70
McCullough No. 1	389	20
McCullough No. 2	388	20
Steelsmith	388	....
Simons No. 1	388	10
Simons No. 2	399	(*b*)
Locke	389	10
Sarah Jacobs	389	10
Shade No. 1	390	20
Wheeler well	391	....
Reese No. 2	391	40
Reese No. 3	391	40

a Well shot. *b* Abandoned.

Name of well.	Trenton limestone below sea level.	First day's production.
	Feet.	*Barrels.*
Reese No. 4	392	30
Holmes No. 1	391	30
Holmes No. 2	396	30
Harrod	392	8
Dingledine	392	10
Hume	392	250
Paper mill No. 2	395	20
Citizens	395	35
Reichelderfer	396	10
Chicago No. 1	396	8
Fritz	397	10
Moore & Brotherton	397	12
Collins	400	(*b*)
Ashton	402	(*b*)
Faze	402	(*b*)
Ehrich	403	(*b*)
Hefner	404	(*b*)
Boose	404	(*b*)
Tapscott	405	(*b*)
Woolsey	406	(*b*)
Smith	407	(*b*)
Roberts	408	(*b*)
Parker	408	(*b*)
Woolet	410	(*b*)
Cole	416	(*b*)
May	421	(*b*)
Hadsell	432	(*b*)
Hoffman	433	(*b*)

b Abandoned.

To the southward the level of the Trenton limestone rises slowly to the extreme southern limit of what has been here described as the Lima field. The surface of the Trenton has an elevation of 360 or 370 feet above tide. The limestone continues to rise both to the southward and to the westward, interrupted occasionally by shallow troughs that break the regularity of its ascent to a slight degree.

The geological structure of the Lima pool has been brought into view more clearly by the figures that have now been given than could be done in any other way. The field is seen to consist of a very flat-lying terrace of Trenton limestone. its extremes of elevation being 400 and 360 feet, or differing only by an interval of 40 feet; in fact, an interval of 30 feet would cover almost the complete range of the field. Beyond the limits of the oil field to the north and west the rate of descent of the strata is more rapid, being sometimes 15 feet to the mile.

A dead line for oil production is shown with great distinctness in the tables above given. Not a well that has found the surface of the oil rock 400 feet or more below tide has proved productive, and the value of the productive wells is very closely connected with the level of the oil rock.

Outside of the oil field, and also upon its border, salt water rises promptly to the surface from wells whenever the rock is reached. In wells where the limestone is found only four or five feet above the dead line more or less salt water is constantly raised with the oil, and any prolonged intermission in the work of the pump is disastrous to the well. The suspension of pumping in the Citizens' well of Lima for twenty-four hours decreased the oil with a corresponding increase of salt water to such an extent that it took steady work for an entire week to regain the oil production. An interruption of a few days would obviously be fatal, where the surface of the oil rock is less than ten feet above the dead line. The wells seldom flow except when first shot. Every foot of elevation of the rock appears to be directly effective in production.

The greatest productiveness is limited to those areas in which the limestone is between three hundred and seventy and three hundred and ninety feet below tide. One main factor in the productiveness of the Lima field has now been briefly discussed. Another of coordinate importance remains.

The oil and salt-water rock.—The oil sand of the drillers, as has repeatedly been shown in the preceding pages, is a dolomite or magnesian limestone. Its value as an oil reservoir is proportioned to its purity. There is no free sand or silica in it, and the percentage of silicates is very low in the best examples of the rock. Its composition is shown in the following analysis executed for the Ohio Geological Survey by Prof. N. W. Lord:

	Paper Mill well.	Woolsey well.	Simons well.	Hume well.
Carbonate of lime........	52.66	55.90	57.40	63.46
Carbonate of magnesia ..	37.53	38.85	36.45	24.20
Insoluble residue .... } Iron and alumina....... }	4.15	00.75	1.64	5.10
		2.99	....	2.75

The results from the Hume well are anomalous. It is probable that the composition of the hard cap of the limestone that overlies the oil rock may be represented in these figures. The oil rock is divided by the driller into three portions, viz, the hard cap, three to seven feet thick; the oil rock proper, a porous dolomite, seven to fifteen feet thick; the salt rock, hard and fine-grained. The entire series is seldom penetrated more than 30 feet. No profit has been found in going deeper than this or even to this depth. A small amount of gas is generally found in the cap rock, and sometimes a little oil. The oil rock is often divided into two levels, separated by four to six feet of unproductive rock, in which a small quantity of salt water is frequently stored. The porosity of the oil rock is very marked, and is obviously due to the imperfect interlocking of the dolomitic crystals of which it consists. Few fossils are found in the oil rock proper and these are indistinct. The salt rock, so called, is merely a firm, hard phase of the same stratum. No better place will be found to describe the salt water that occupies all the lower levels of the oil rock than this.

Salt water, when struck in a well in the Lima field, is not necessarily fatal to its oil production. By vigorous and prolonged pumping, the water, in many instances, has been exhausted, and a good supply of oil has been thereafter reached. All seems to depend on the absolute level of the oil rock in this regard. The salt water reported from the Trenton limestone has a peculiar character. It agrees in general composition with all the salt water derived from the Paleozoic limestones of our scale. A distinct type of mineral waters that may be called limestone brines comes into view. Dr. T. Sterry Hunt first determined the composition of the Trenton limestone brine as he found it in a well drilled for oil on Manitoulin Island:

In 1,000 parts there were—

Chloride of sodium	4.800
Chloride of potassium	.792
Chloride of calcium	12.420
Chloride of magnesium	3.650
Total	21.662

Dr. Hunt calls attention to the unusual fact that the chloride of calcium constitutes more than one-half of the solid contents of the brine. He suggests that it is a diluted bittern of the ancient seas, the sulphates having, by evaporation, been eliminated in the form of gypsum.[1] He also gives[2] the composition of a Devonian limestone water from Bothwell, Canada, as follows:

In 1,000 parts:

Chloride of sodium	14.4460	
Chloride of potassium	0.3350	
Chloride of calcium	3.1830	
Chloride of magnesium	5.7950	
Sulphate of lime	3.0580	
Sulphide of sodium	0.8797	0.4600 HS.
Sulphureted hydrogen	0.0767	
Total	27.7734	

[1] Chem. and Geol. Essays, p. 158. [2] Ibid., p. 163.

The composition of the so-called Blue-lick water of the wells that go down into and below the Trenton limestone series in southern Ohio and Indiana is probably various. There is but a single analysis at hand. The water of the Hemingray well, Newport, Ky., as analyzed in the Ohio Geological Survey by Professor Lord,[1] has the following composition:

Parts in 1,000:	
Chloride of sodium	10.530
Chloride of magnesium	0.929
Sulphate of lime	1.818
Silica	0.007
Iron and alumina	Trace.
Sulphureted hydrogen present but undetermined.	
Total	13.284

Another limestone water obtained from the Niagara or Clinton limestone in well No. 1, at Bowling Green, was analyzed by Professor Lord with the following result:

Specific gravity, 1.1172.

Parts in 1,000:	
Chloride of sodium	83.30
Chloride of calcium	65.05
Chloride of magnesium	15.96
Sulphate of lime	1.03
Total	165.34

A mineral water of considerable interest has been recently found in the Upper Helderberg limestone of northern Ohio buried at a depth of a thousand feet. In a well drilled at Lorain, Lorain County, Ohio, a brine was obtained from the horizon named above that has the following composition, according to Professor Lord's analysis. The specific gravity of the water is 1.0837:

Parts in 1,000:	
Chloride of sodium	48.599
Chloride of calcium	37.370
Chloride of magnesium	22.430
Chloride of potassium	1.460
Bromide of sodium	0.601
Sulphate of lime	0.712
Carbonate of lime	1.210
Alumina	0.040
Silica	0.024
Total	112.446

This water is turned to account as a bathing and medicinal water under the name of the Devonian Springs. The quantity of bromide of sodium in it is notable. The use of mineral waters in this country is generally empirical as yet, and while the tests of these deep-

[1] Geol. Survey Ohio, vol. 6, 1888.

seated waters, which have now been described, are going forward on a small scale and on a purely experimental basis, it seems likely that they will be found to make valuable additions to our resources in the healing art.

Production and promise of the field.—Drilling in the Lima field was begun in the spring of 1885. It was a year, however, before the oil-producers entered vigorously upon its development. The wells on the Shade farm, south of the town, made the first significant departure from the day of small things with which the work was begun. All these were flowing wells. The early summer of 1886 marked the beginning of rapid development. The production of single wells increased from 60 and 70 barrels to 100 barrels a day; and presently, in the Hume well, to 250 barrels in a day, and a little later to 700 barrels in the Tunget well. To the southward great wells were presently found. The Ridenour farm, the Hueston, Moore, Ditzler, Ballard, Lehman, Goodenow, and Spear farms all became centers of large and certain production. By October 1 the character of the field had come into clear view as second to none yet found in the United States in volume of production. During September, 1886, 33 wells were added to the 128 previously drilled. Of these, one was dry. The total production of the new wells was 2,455 barrels daily, showing an average of 75 barrels to the well. Six of these wells were credited with an aggregate production of 1,300 barrels daily. In November a number of other great wells were brought in, and the Douglas, Crumrine, Boop, Mechling, McLain, and other farms were added to the prolific areas. A well drilled during this month on the Alonzo McLain farm, section 13, Shawnee Township, reached a production for its first day of nearly or quite 1,000 barrels. This well is still flowing at the rate of 150 barrels a day. The largest production in the Lima field for a single day is that of a well on the J. W. Ridenour farm, section 18, Perry Township. It put into tanks in the first twenty-four hours 2,760 barrels of oil. Its rate was 115 barrels per hour.

Of 20 wells completed in November, one was dry and nine produced daily 100 barrels each or more. Of 22 wells completed in December, one was dry and 11 produced daily 100 barrels each or more. The 11 of this group are credited with 2,500 barrels daily.

On January 1, 1887, according to the published accounts, there were in the Lima field 235 wells, with a daily production of 9,488 barrels. In January, 35 wells were added to the list, and in February, 34. Of the latter, 16 wells were reported as producing from 100 to 250 barrels daily. It is unnecessary to follow the development in detail further.

On the 1st of May, 1887, there were 444 wells in the Lima field. The number has been increased but slightly since this time on account of the determined effort of the Buckeye Pipe Line Company (the Standard Oil Company) to restrict production. The price of the oil was reduced in the latter part of 1886 from 40 cents to 35. Other reductions, each of 5 cents, have subsequently followed, the latest being made on July 20, when the price fell from 20 to 15 cents per barrel, at which point it rests at this writing. These successive reductions, the company insists, are justified and rendered necessary on several grounds. Prominent among these is the bringing in of the great wells of the North Baltimore field of Wood County, one of which has reached the amazing production of 5,000 barrels of oil in a single day. This is the highest mark of the Trenton limestone.

At a conference between the producers of the field and the Buckeye Pipe Line Company in July, 1887, it was agreed that drilling should be suspended for the rest of the year, or at least until some efficient means of reducing stocks should be found, and that the torpedoing of wells should be entirely abandoned. The average production for the total number of wells drilled in the Lima field does not reach a very large figure, because the early wells were mainly drilled on the edge of the field where the oil rock lies near its dead-line. In the wells drilled during the last six months nearly 50 per cent. have been of the 100-barrel rate, or even larger. The average for the new wells of several separate months has exceeded 75 barrels. The proportion of dry holes has been very small since the laws of the field have been approximately ascertained—probably not exceeding 5 per cent. The highest daily production of the Lima field proper is not far from 14,000 barrels. It must be borne in mind that this production has been reached under the most adverse circumstances. Drilling has been confined for the last few months to the holders of leases for the main part, and it is being avoided now, in many instances, by the lessors waiving the terms of the lease in this regard.

The qualities and uses of Trenton limestone oil.—The Trenton limestone oil is in all respects a typical limestone oil, dark in color, rather low in gravity, and containing a percentage of sulphureted products which, though small, make themselves offensive and resist expulsion with great stubbornness. The extremes of gravity observed in the new fields are 31 and 42 degrees, but the great bulk of the oil is included between 35 and 40 degrees.

The initial experiments with Lima oil seemed favorable. The quality of illuminating oil obtained from it was thought to be equal to any, though the percentage was smaller than of Pennsylvania petroleum. The Standard Oil Company undertook the large expenditures necessary in taking care of the oil and afterwards entered upon the work of refining it on an extensive scale. Independent refineries were established with considerable outlay at Lima and Findlay, and more recently at Bradner, and the oil has also been handled at a Toledo refinery in small quantities.

With all this expenditure and experience we are still unable to make positive and final statements as to the value and capabilities of the oil on account of the diametrically opposite testimony that is given by different parties in the field. The Standard Oil Company has planted in the new field more than $2,000,000, and it now avers through its representatives that it has made a great mistake, and declares that the numerous, extensive, and very costly experiments conducted by it in seeking to obtain from Lima crude an illuminating oil that will fairly compete with Pennsylvania oil in open market have resulted in complete and utter failure. The company declares that out of 208,000 barrels refined by them no oil that could be successfully used as an illuminant has been obtained. Representatives of the company further declare that the only use that they have been able to find for Lima oil is for fuel, and to its introduction for this purpose they are now directing all their efforts. They have more than 2,000,000 barrels already stored in the field, and the stocks are increasing at the rate of fifteen to twenty thousand barrels a day. This increase has gone forward in spite of the severest attempts at repression in the reduction of the market price of the oil. There are, however, other companies in the field engaged in refining Lima oil, and their testimony is not of the same tenor as that already quoted. They declare that they are obtaining satisfactory results in refining Trenton limestone oil. They claim that the deodorization of the oil is practicable, and that the cost of the process is not excessive. One of the companies so engaged reports as the result of its operations, when fresh oil of 40° Baumé at 60° Fahr. is treated, 50 per cent. kerosene of 150° fire test, 10 per cent. gasoline, and the same proportions and qualities of lubricating oils that are obtained from Pennsylvania crude. The quality of the illuminating oil is excellent. A larger percentage of loss than in eastern oil is admitted, but it is alleged that the loss is not excessive.

Laboratory experiments on crude petroleums can not always be trusted to indicate what their behavior will be when treated in a large way for commercial purposes, but the results of a few analyses recently made for the Ohio Geological Survey will be found instructive.

Professor Lord, chemist of the Ohio survey, adopted the comparative method in his examinations. Crude oil from the Macksburgh field, the character and yield of which are well known, and crude Trenton limestone oil from northwestern Ohio, were subjected to the same treatment, with the following results, viz:

	Macksburgh oil, 41° gravity.	Trenton limestone oil, 39° gravity.
	Per cent.	*Per cent.*
Naphtha	16	15
Kerosene, between .73 and .83	38	33
Sulphur	.025	.535

The distillation was arrested before "cracking" had begun. It is known that the Macksburgh oil can be made by the latter process to yield a total of 70 to 80 per cent. of distillates. It is probable that the limestone oil would closely follow these figures if treated in the same way.

The enormous disproportion in sulphur compounds in the two oils can not fail to attract attention. It is not certain, indeed, that all of the sulphur present in the oils is shown in the analyses, owing to possible defects in the method used.

The refiners of the Trenton limestone oil are certainly able to mask, more or less completely, the offensive sulphur compounds by their several methods of treatment, but they fail in some of the processes, at least, to remove them. This is shown in the following results from the examination of one sample of oil:

Crude Trenton limestone oil, sulphur	0.553
Crude distillate, sulphur	0.52
Refined distillate (deodorized), sulphur	0.36

The results of the chemical examination here reported seem to show that the new petroleum has about the same character as the Macksburgh oil except in its high percentage of sulphur compounds.

In considering the conflicting testimony to which attention has now been called we should not lose sight of the fact that very large interests and investments elsewhere are involved in the success or failure of Lima oil, nor of the further fact that decidedly the greatest oil field of the United States, so far as capacity of production is concerned, is coming into view in the Lima district, to the equal surprise of practical and of scientific observers. Its development on the scale that we are now compelled to recognize is nothing less than revolutionary so far as the present interests of production and refining are concerned. An output of 20,000 barrels a day, as already shown, has been forced upon the Standard Oil Company, which has undertaken the task of purchasing and storing the petroleum of the country. The company has built more than a hundred tanks in the new field, each holding 30,000 to 36,000 barrels, and at the rate which the producers were maintaining, in spite of the severe repression by the reduction of price from 40 to 15 cents a barrel, the company found itself obliged to add to its plant two or three tanks each week. In fact, it became apparent that Trenton limestone oil could be produced, at least from one section of the new field, with a profit, even at 15 cents a barrel. No fact illustrates more significantly the character and possibilities of this production. To check this marvelous yield it was at length found necessary to warn producers in substance that no further provision would be made for new wells during the year 1887. Under this compulsion the drill was finally brought to rest.

If the price of Lima oil had been mantained at 40 cents there is no question that the field would now be producing 100,000 barrels a day. If the price should be raised to 30 cents a production of 50,000 barrels a day would be reached inside of sixty days. These estimates are certainly within the limits.

It is obvious that the exploitation of the new field is premature. The markets of the country can not endure without a total collapse of prices the influx of even 20,000 barrels a day of crude oil from new sources, to say nothing of thrice or five times as much. It thus becomes a question whether the new oil shall be temporarily marked down to a price far below its first cost, its production being thereby greatly restricted, or whether by a general leveling of prices the Eastern stocks shall be ruinously depreciated. The older centers could easily be impoverished without enriching the new. With such a field at hand as that which has now been described, in which the expenses of drilling and production are reduced to their lowest terms, crude petroleum is certain to be cheap in any case.

Taking all the sources of information into account, the following statements seem warranted in regard to the new petroleum:

(1) Trenton limestone oil is inferior to oils of the Bradford fields, or, in other words, to the best oils of Pennsylvania, on the following grounds, viz, (*a*) it yields a smaller percentage of illuminating oils, unless cracking is resorted to; (*b*) it contains a vastly larger proportion of offensive sulphur compounds which must be removed before the oil is ready for market and which resist removal with great stubbornness; (*c*) it suffers a larger percentage of loss in distillation.

(2) The best of the illuminating oil produced from it is fully equal to the best oil of any field. It endures comparison with any as to the brightness, the clearness, and the duration of its flame, but a good deal of the refined oil that is in the markets from this source can not endure the test; it crusts the wick and clouds the chimney of the lamp in which it is burned.

(3) Trenton limestone oil can be deodorized with small expense, to this degree at least, that it can enter the market without serious prejudice or disadvantage arising from its odor. Complete deodorization is claimed by most of the firms that are engaged in refining it, but while the possibility of the entire removal of its sulphur compounds is beyond question, this result has not thus far been generally attained.

(4) The lubricating oils and the other accessory products of refining are of a high degree of excellence.

(5) The present price of Trenton limestone oil, viz, 15 cents a barrel, is in no way a measure of its real value as compared with the present price of Pennsylvania oil.

There is one use of Lima crude oil in regard to the success of which all are agreed, viz, its use as fuel. It is excellently adapted to the convenient and economical production of heat for almost every purpose. It has been applied to simple uses, as to cooking and heating stoves, and also to the production of power in stationary steam-boilers and to locomotives to a small extent; to the heating of gas retorts, to puddling and reheating furnaces, and to various other uses. In all these it has demonstrated its adaptability and great value.

Various processes for using it safely and conveniently have been devised, and there is probably room for important additions in this field. Four barrels of oil are counted equal to one ton of soft coal. At the present price of crude oil it could scarcely be displaced by natural gas where it is introduced. The crude oil ought to be deodorized before being applied to any of the purposes already named, but this has not yet been done where it is used for fuel, except in an experimental way. There seems to be no doubt that this result can be easily accomplished.

If all other and higher uses of petroleum are dropped entirely out of the account it is still evident that an enormous stock of fossil power, vastly greater than all that can be furnished by the newly discovered natural-gas fields of this part of the country, is made available to us in the Trenton limestone oil.

THE OIL FIELDS OF NORTHWESTERN OHIO EXCLUSIVE OF THE LIMA FIELD.

The Findlay oil field.—The presence of oil in the Trenton limestone of Findlay was discovered in the first well that was drilled there; but the amount was insignificant. In the third well an oil production of about five barrels a day was reached, in connection with a considerable volume of gas. The first well to be drilled expressly for oil was the Matthias well, on the west side of the town, and one and one-half miles distant from the court-house. It proved a flowing well, its daily yield being about thirty five barrels for the first six months after its completion. It was drilled in the fall of 1885.

Early in 1886 the development of the oil field was begun in earnest. After the fashion of oil fields, new wells were located as close as possible to the first successful one. Those that were nearest in location repeated the experience of the first well. The price of oil was 40 cents a barrel, and a daily flow of 30 barrels was therefore counted a fair return. The field, however, soon began to reveal its metes and bounds. Barren rock was found at some points and salt water at others. The territory to the southwest of the town proved unproductive, and a limit was thus laid down in this direction.

This was the direction to which all the imported traditions of the Pennsylvania field pointed as the line of promise, and it was only when the oil rock was found charged with salt water ready to fill the well as soon as its level was struck that the search along this line was reluctantly abandoned. The search northeastward was cut off by the upper terrace of the Findlay monocline, which was gas territory by way of excellence, and the territory to the southeast was known to be gas territory if anything. From three of the quadrants of the circle at the center of which he stood at Findlay, the driller was therefore cut off in his search for oil, and his only lines of advance were between west and north. Deep-set casings, Trenton below the dead-line, and consequent floods of salt water were soon reported from the northwest, and the productive field was still further narrowed down. Its boundaries have now become fairly distinct, and the Findlay oil field can be defined as consisting of a low ridge or terrace of the Trenton limestone, the upper surface of which is approximately horizontal and about 1,250 feet deep, about two miles wide in a north and south direction, and less than five miles long in an east and west line, extending west and a trifle north from the court-house in Findlay. The entire productive territory is virtually included in Liberty Township.

The dead-line of the oil field has been referred to in a preceding paragraph. It is the line which marks the descent of the limestone to 500 feet below tide. Not a well that has found the surface of the Trenton limestone 500 feet or more below tide has proved productive. It so happens that the general elevation of the surface of the country above the sea is very nearly the same as the thickness of the shale series that underlies the Upper Silurian limestones, the measure of each being about eight hundred feet; consequently the depth below tide of the Trenton limestone can be approximately determined from the thickness of these Upper Silurian limestones, and since these limestones contain salt water that requires to be cased out of the wells, the depth of the Trenton limestone below tide can be also determined by the depth at which the casing stands in the wells. Not a well that needs to be cased as much as 500 feet has thus far proved productive.

During all its earlier history the Findlay oil field was far less prolific than the Lima field. Until December, 1886, none of the wells reached a daily yield of 100 barrels. The field, however, had one decided advantage from the first, namely, its wells were mainly flowing wells and therefore required no outlay beyond the drilling. In December, 1886, better wells were brought in to the west of the town. One of these was credited with 150 barrels for the first day, and several others with 100 barrels each. The November production of 1886 was a little over seven hundred barrels a day. In December the production was brought up to 1,300 barrels a day, nine new wells adding 600 barrels to the previous figures. In January, 1887, nineteen new wells were brought in with a total daily production of 773 barrels, making the aggregate of the field 2,000 barrels a day, the production of a number of wells being held back at the same time for lack of tankage. February brought the total daily production up to 3,000 barrels. March gave the first great well to the Findlay field. On the D. J. Cory farm, Liberty Township, a well was drilled on the 1st of the month which started in with a flow of twenty-five to thirty barrels a day. On March 14 it was heavily shot, and one week from that day it had produced 5,000 barrels, though it was held back as much as possible on account of lack of tankage. Its best rate was at least 1,500 barrels a day. This well has proved a wonderfully persistent producer, holding up for at least sixty days after it was first brought in to 800 barrels a day. On August 1, 1887, it was still producing 350 barrels a day when allowed to flow. Its total production at that time was already in excess of 50,000 barrels. This is the largest well of the Findlay field proper, and ranks among a dozen of the great wells that the Trenton limestone has thus far furnished. In April the production of the Findlay field was counted 5,000 barrels a day and in May 6,000 barrels, the total number of wells being 97. Since that time, in accordance with the arrangement insisted upon by the Buckeye Pipe Line Company, no new wells have been drilled, and the production has been restricted as much as possible. From the statements already made the capabilities of the field are seen to be large, and with due encouragement of price Liberty Township could, in sixty or ninety days, be depended upon for 10,000 barrels of oil a day. This production could be maintained for at least three or four years, according to present indications. The rate of production of the prolific portions of the field to the acre or to the square mile can not yet be given, from the fact that no such areas have thus far been exhausted. The field shows good staying quality.

The North Baltimore field.—The most remarkable section of the new oil field remains to be named—the North Baltimore field. It occupies a few square miles on the eastern side of Henry Township, Wood County, and is several miles north of the village from which it takes its name. The field is quite limited in extent. It consists of a belt less than two miles in breadth, and extending five or six miles in a due north and south line, on the east side of which great accumulations of gas are found, while on the west side the drill strikes salt water as soon as the Trenton limestone is reached. In some parts of the field salt water is found in the oil sand; in all parts it comes in as the wells begin to fail.

The facts already given indicate that the North Baltimore field lies at the foot of the Findlay break, in its northern extension, and that it derives all of its value from the same remarkable geological factor that has proved so important in the oil and gas production of Hancock County. Sections 2, 11, 12, and 13 of Henry Township (T. 3 N., R. 10 E.,) are thus far the most prolific of this subdivision, and they bid fair to take rank with the most famous centers of oil production yet found in the United States.

The development of the field began with the drilling of a well on the farm of Mr. David Fulton, section 14, about the 1st of December, 1886. The Trenton limestone was reached at 1,160 feet, or approximately 430 feet below tide. Oil was found between 1,192 and 1,194 feet, and the well filled a 250-barrel tank in the first twelve hours of its flow. This at the time was the largest production that had been found outside of the Lima field, no previous well in the Findlay district having thus far yielded more than half this amount per day. The consequence was that there was a great influx of drillers to the immediate neighborhood, and the new territory was eagerly competed for. The second well to be brought in was known as the Henning well. It is situated about five hundred feet eastward from well No. 1. It was completed on February 25, 1887. The Trenton limestone was reached at a depth of 1,206 feet, and the oil at 30 to 37 feet in the limestone. At the depth of 33 feet 250 feet of oil appeared in the well. Below the first oil streak a hard crust occurred. When this was penetrated the drill seemed at first to fall as if it had reached a cavity. Presently the force of the gas accompanying the oil became so great that the weight of the tools was borne up, and the walking-beam, being thus relieved, played rapidly up and down. The oil filled a 250-barrel tank in fifty-seven minutes, and the total production of the day ranged, according to judicious estimates, between 1,500 and 2,000 barrels.

These facts put a new face on the oil production of Hancock and Wood Counties, as regards both producers and purchasers. In spite of the low and steadily-shrinking prices paid for the oil, production could be profitably maintained on wells like the last named. The possibilities of the new territory, as revealed by this well, led to an immediate reduction in the price paid for oil throughout the fields.

The record of this well prepares us for a still more remarkable production, which was obtained early in July. The Slaughterbeck well No. 3, located in the southwest quarter of section 13, Henry Township, on the first day after the oil rock was reached and without any aid from torpedoes, put 4,800 barrels into the tanks in twenty-two hours, and overflowed upon the ground for the remaining two hours of the day. It is therefore entirely within limits to say that its first day's yield was considerably in excess of 5,000 barrels. At the end of sixty days it was still producing between 2,000 and 3,000 barrels a day, when allowed to flow. Its total production to October 1, 1887, will fall little, if any, short of 100,000 barrels. This great well marks the highest point reached by the new oil rock, and would insure it a place, if any doubt still existed as to its character, among the great oil reservoirs of the world.

Throughout this field the Trenton limestone is found at a depth of about 1,150 feet, or about 440 feet below tide. It lies very nearly level throughout all the productive district. It is not necessary to follow the details of the development further. The producers of the North Baltimore field could profitably sink wells, even when the price of oil is reduced to 15 cents a barrel, and it required varied arguments, the most potent of which was the intimation that tankage would no longer be provided for the oil of new wells, to induce them to entirely suspend the work of the drill through the latter half of 1887 except as the requirements of contracts might occasionally demand. A few producers who find their own markets are still testing the territory and some great wells have recently been added to the lists already given.

Practical men, who are familiar with the history now briefly sketched, entertain great expectations of this portion of the field. The most conservative among them declare that with a price of 30 cents a barrel for oil the production of this township would within sixty days rise to 50,000 barrels a day. There are those who believe that even these figures could be doubled.

The cost of drilling is comparatively small. The casing does not exceed 400 feet, and the wells are but little more than 1,200 feet deep. Thus far but few of the wells have been shot. So long as the production exceeds 100 barrels a day they are let alone. Torpedoing restores their production for a time. No pumping has yet been done.

The character of the oil is decidedly superior to that of other fields. When fresh, it has a gravity of 42° B.; in other words, it is considerably livelier and therefore more valuable for refining than the Lima or the Findlay oil. The highest stage of Trenton limestone oil as to both quality and production is undoubtedly reached in the North Baltimore field.

DIVISIONS OF THE GAS FIELD IN INDIANA.

DISCOVERY.

A brief account of the newly discovered gas field of central Indiana will conclude this paper. Indiana was sure to repeat within a short interval the tests to which the western counties of Ohio were led by the great discovery of Findlay gas and Lima oil. Drilling directed specifically to the Trenton limestone in search of these new supplies of power was carried forward through the eastern and central counties of the State during 1886, and several valuable discoveries of gas were made in the Findlay horizon. In October of this year Kokomo reached a fair flow of gas at a few feet in the Trenton limestone. This stratum was struck at a depth of about nine hundred feet, which would make it about ninety feet below tide. Eaton, Delaware County, had previously redrilled and deepened a well in which gas had been discovered a dozen years ago. The new horizon was found productive here when it was reached. The search was greatly stimulated by these early successes, and in the course of a few months most of the county seats and many towns and villages besides along the central Ohio border and for two or three tiers of counties removed, had made a test of the possibilities of gas supply from the Trenton limestone. As one after another of these tests proved the presence of high-pressure gas in considerable or even in large volume at the points where the drilling was done, the excitement increased and extended until all sections of the State were overrun by it. As a consequence, deep wells have been drilled by the score and even by the hundred throughout Indiana, and a very large amount of new information in regard to its geological composition and structure has thereby been obtained.

Better than this, from an economic point of view, is the discovery in the eastern central portion of the State of the largest connected field of high-pressure gas that has yet been found in the world. The gas districts of western Pennsylvania show a much higher pressure and a much larger production than has yet been realized in the Indiana field, and probably a larger production than is possible there; but if these districts were all united in one they would be found decidedly inferior in area to what at the present time we are obliged to consider as one continuous gas field in central Indiana.

AREA.

From Jay County, on the Ohio border, through Blackford, Grant, and Howard Counties, a distance of more than sixty miles in a due west direction, the Trenton limestone has been tested at ten or more different localities, comprised in a belt of five to ten miles in breadth. Not a single locality has failed to show high-pressure gas in considerable quantity. The towns of this belt are Portland, Dunkirk, Redkey, Eaton, Hartford, Marion, Jonesborough, Greentown, and Kokomo. A belt of equal breadth and 40 miles long in a north and south line, and thus at right angles to the first-named belt, drawn through Grant and Madison Counties, gives similar testimony. The prominent towns in this belt are Marion, Fairmount, Alexandria, and Anderson, and to this list several smaller towns can be added. In each of them one or more wells of great value have been obtained; in several of them two to six wells have been drilled, all of them successful.

While the apparent conclusion that these dimensions, 60 by 40 miles, might be multiplied together to give the area of the field is not warranted, still the territory that is fairly included within the boundaries of production does not fall very far below what such a multiplication would give. It seems safe to say that the new gas field contains not less than 1,800 square miles. Within what are now counted its boundaries, doubtless areas of barren territory will be found as development goes forward, but these will probably be more than covered by additions from outside the limits as the latter are now understood. The counties which in whole or in part constitute the bulk of this territory are the following, namely: Jay, Blackford, Grant, Howard, Tipton, Hamilton, Madison, and Delaware. Contributions of greater or less importance are also made to the tract by the other counties, as Randolph, Hancock, Wabash, and Miami. In still other counties productive territory is likely to be found. Gas has been discovered during the recent search in other portions of the State, but in several of these cases, if not in all, the supply appears to be derived from other horizons than the Trenton limestone, and therefore need not be considered here. Among these horizons the Hudson River and Utica shales are the most conspicuous.

GEOLOGICAL SCALE.

As in Ohio, the surface rocks of the Indiana gas field are in the main Upper Silurian limestones. The Niagara limestone constitutes by far the larger part of the surface of the main productive territory, as, for example, Blackford, Grant, Howard, Madison, and Delaware Counties. The Waterlime or Lower Helderberg limestone supplements it to a small extent on the western border of the field, and the Devonian limestone in still smaller amount on the southwestern border.

The Lower Helderberg or Waterlime formation has not been distinguished as a separate member of the Upper Silurian column on the geological maps of the State now current, and the determinations of age of the surface rocks of different districts are to some extent uncertain. This formation is in some instances counted in with the Niagara on the map, but more commonly with the Devonian areas. While the gas territory is in the main confined to the regions in which the Upper Silurian limestones constitute the surface rocks it is not co-extensive with them. There is a large district to the north of the counties named in which the Niagara limestone is found in its most characteristic form, which appears entirely unproductive of gas.

A brief review of the elements of the geologic section found on the surface and in the deep wells that have been drilled in the productive belt will be given at this point. The strata will be described in descending order.

The Devonian limestone.—A good combined section of the beds of this age is found at Logansport. The elements are as follows:

	Feet.
1. Yellow limestone, siliceous (Lux's quarry)	15
2. Blue limestone, crinoidal, highly crystalline	8
3. Firestone (coralline limestone)	20
Total	43

The last stratum is by far the most characteristic. It is composed almost wholly of the representative corals of Devonian time, both massive and free; in short, it is a genuine coral reef of the Devonian sea. In composition it is a true carbonate of lime, the beds that are quarried for lime-burning yielding over 90 per cent. of this substance. Such a composition is one of the chief marks of this horizon elsewhere.

The firestone consists of the thin uppermost beds of the coral sheet. It gets its name from the fact that it bears exposure to heat fairly well, and thus serves a useful purpose in furnace walls and fire-places. The two uppermost divisions (1 and 2) contain a good deal of crinoidal waste and are quite impure in composition, apparently containing magnesia, alumina, iron, and silica in greater or less quantity.

The Lower Helderberg limestone. (*Waterlime*).—For some cause this division has not been counted in the geological scale of Indiana heretofore, but it can not be properly omitted in any review of the series of the State. It crosses the Ohio border in Adams County, where it has a breadth of outcrop of at least twenty miles. Its thickness is also considerable in this portion of the State. The maximum thickness of the formation in Ohio is 600 feet, and it may retain a considerable portion of this in the northeastern corner of Indiana, but in Adams County and to the westward through the Wabash Valley it is rapidly reduced in volume, and it is also considerably changed in character and composition as it is followed in this direction.

At Decatur, in Adams County, near the Ohio border, the Niagara limestone and the Lower Helderberg limestone are both worked in contiguous quarries of the St. Mary's Valley, but unfortunately the line of contact between them does not happen to be exposed at this point. Both formations are, however, well characterized in their respective quarries. The Lower Helderberg limestone retains the peculiarly even bedding, the chemical composition, the color that is most characteristic, and to some extent the fossils of the stratum in Ohio. It lies in strongly inclined beds, which dip northward. Among the fossils which it contains are the following: *Streptorhynchus subplana*, *Halysites labyrinthica*, *Diphyphyllum* (species ?), *Meristella bella*, *Meristella levis* (species ?), *Leperditia alta*, *Illœnus* (species). The first two are credited to the Niagara limestone elsewhere, it is true, but, as so often happens in the strata of the Mississippi Valley, the life of one series is continued without interruption into the next succeeding. The *Diphyphyllum* coral named here is also common to the Niagara and the Waterlime groups of Indiana. The remaining fossils, *Meristella* and *Leperditia*, are the characteristic and determining fossils of the formation, but even without their presence there could be no possible ground for doubt as to the place and name of the division to any one who follows the series westward from Ohio. The very fossils that are named here are the most characteristic forms in the unequivocal section of the Waterlime shown, for example, at Lima, Ohio.

Quite a change has occurred when the stratum is next seen at Huntington, in the second county west of Decatur. The Lower Helderberg limestone here consists in the main of thin, cherty, and unfossiliferous courses, ten or fifteen feet of which constitute a common section. In some places is found the light-brown magnesian limestone, with bituminous lines parallel to the bedding planes so characteristic of the formation through many thousand square miles. For example, at a point below the town, opposite the cemetery, the Lower Helderberg limestone appears, lying unconformably on the Niagara limestone. The latter is filled with the large and conspicuous coral just referred to and the Waterlime is here destitute of fossils. The contrast between the two formations is in all respects strongly marked.

The series is found throughout the valley in frequent exposures, occasionally attaining several times the thickness that is reported here, but it is always composed of extremely thin-bedded and more or less cherty limestones.

The suggestion is ventured that the well-known flag-stone quarries of Wabash, which overlie the normal Niagara limestone at this place, belong to the Lower Helderberg series. There are fifteen to twenty feet of rock in this series, lying in the thin and even courses for which this stratum is noted. The large cephalopod shells (*Lituites capax* et al.) that are found at Wabash, and which have been counted of Niagara age on account of the reference of all the rocks of the Wabash series to this group, and because they are associated with fossils found elsewhere in undoubted Niagara rocks (Guelph), may better be referred to the formation that is now under consideration.

At Logansport a longer and more complete section of the Lower Helderberg limestone is found. It embraces three or more distinct divisions, the total thickness of which is 65 feet. They are as follows, the series beginning immediately below the coralline beds of the Devonian limestone already described; the junction is beautifully shown on the grounds of the Insane Asylum:

	Feet.
1. Brecciated, with cherty layers	15
2. Even-bedded magnesian limestone, fossiliferous	15
3. Thin and impure limestone, with Waterlime bedding	10
4. Thicker courses, with Waterlime bedding	15
5. Thin beds, with Waterlime bedding	10
Total	65

The uppermost division is much the most conspicuous. It constitutes the river cliff below the city. The fragments of which the brecciated rocks consist are exceedingly fine-grained, dove-colored limestone, breaking with conchoidal fracture and resembling lithographic stone. It is quite probable, indeed, that these fragments would answer fairly for this purpose. In composition they are quite pure, but they are often bound together by cherty matter, which would make the average composition very impure. The number of species of fossils found in this limestone is not large, but in parts of the division individual fossils are quite numerous. The most characteristic among them is *Pentamerus galeatus*, but it is not the most abundant. The small shell *Cœlospira disparilis* which belongs to the Niagara limestone in New York, is very abundant here.

The second division is a brown magnesian limestone, burning into a dark and mild lime. It contains numerous ill-preserved fossils. Among the forms identified are *Halysites labyrinthica*, which is a Lower Helderberg and not a Niagara fossil in Indiana; a large *Pentamerus*, apparently the same species which characterizes the Delphi beds. This division lacks the even bedding of the strata next to be named, but occurs in thin and shelly layers.

The divisions that lie below agree in possessing the even bedding of the Waterlime, and to some extent its bituminous lines and also its fossils. They constitute the main quarry stone of the neighborhood. In the lowermost beds, or about fifty feet below the coralline limestone of the Devonian age, the characteristic fossil, *Leperditia alta*, occurs. The best points for observing these divisions and collecting the fossils of the formation are in the Simons quarry and in Fitch's Glen, on the opposite bank of the river. In the latter locality the last-named fossil belongs about fifty feet below the top of the cliff.

The Niagara limestone.—The limestone now to be described is by far the most important member of the series with which it is associated, in thickness, area, and economic value. Its thickness, however, renders full sections of it impossible in any single exposure, and a considerable difference is found in the composition and character of the several divisions, as shown in the widely separated districts in which it occurs. In general terms, the formation may be said to consist of three principal divisions, namely, a lower, a middle, and an upper division. The lowermost is the probable equivalent of the Dayton stone of Ohio. It is found only on the southern border of the formation, and outside of the gas field. The middle division is the horizon of the Springfield beds. The uppermost division is unmistakably the Guelph limestone of Ohio and the Northwestern States.

All the divisions are fossiliferous and at many points are charged with the most characteristic and best-known forms of life that belong to this period. The third division, the Guelph limestone, constitutes by far the largest portion of the entire formation. In chemical composition it is a true dolomite. as it is everywhere else. It yields a large amount of stone excellently adapted to lime production, but the building stone obtained from it is inferior in quality.

This division of the Niagara limestone is the only one that is found in the Wabash Valley, where the formation is most conspicuously shown. The Niagara shale belongs next below the Niagara limestone, but in the gas regions of Indiana it is at best but a feeble element. It is probable, however, that it still holds it place in the series here.

The Clinton limestone.—Whether this division deserves a place in the geological scale of the gas regions may be questioned. It is unmistakably present in southern Indiana. Characteristic exposures of it occur in Fayette and Franklin Counties, for example; but in the gas districts there are no natural sections that extend low enough to reach it if it were present, and in the records of the drillers these finer distinctions of the limestones are often lost. It is probable, however, that both the Niagara shale and the Clinton limestone deserve to be recognized in some of the sections reported. It has nowhere, so far as known, shown the petroliferous character in Indiana that marks it in Ohio. Still a good deal of its outcrop in the two counties above named was leased for drilling purposes in the petroleum excitement of 1865. The leasing was by Pennsylvania parties who followed the outcrop west from Preble and Montgomery Counties, Ohio, where the usual surface indications of oil in the stratum were observed.

In its outcrop to the southward its thickness is small, never exceeding fifteen to twenty feet. If present in the gas field it makes but a small addition to the column.

The entire series of limestones from the Devonian beds already described downward to the Hudson River or Cincinnati group, embracing the several divisions of the Waterlime and the Niagara limestone, and also the Clinton limestone, if present, has a considerable thickness, as is shown in the sections reported from many Indiana towns, among which Huntington, Logansport, and Delphi may be named. At Delphi, 575 feet are reported; at Logansport, 544 feet; at Huntington, 400 and 450 feet; at Decatur, about 500 feet. The thickness may be slightly exaggerated in some of these sections from a cause presently to be named. In the first two examples probably the Waterlime in part and the Niagara are both counted, but in the last two examples nothing above the Niagara is taken. This thickness seems excessive for the Niagara limestone alone, judging the section from the facts found to the eastward. In northern Ohio, at least, there seems no reason for assigning more than 300 feet to the Niagara limestone proper.

Whether the Medina formation is found in the Indiana gas wells can not be definitely settled at the present time. This formation is certainly wanting here in its most characteristic condition, namely, as a red non-fossiliferous shale. These marks are lost before the Ohio border is reached, and they are not again resumed to the westward, so far as at present noted.

The Hudson River shale (*Cincinnati group*).—This well-marked and important formation is found in strong force in the wells of the southeastern quarter of the gas field, but in the northern portion it is apparently much less fully represented, and a part of its original volume has possibly been lost here. There are many thin sheets of limestone in the southern section, as in the Ohio series, but to the northward blue or gray shales predominate. It is to be acknowledged, however, that the boundary between this and the next succeeding formation is somewhat arbitrary. The color of the Hudson River shales is generally blue or greenish blue, and sometimes gray. There is a gradual darkening in the beds as the drill descends through the series. Some drillers report the entire series as blue shale, while more will count it black shale. The line can best be drawn from 250 to 300 feet above the bottom of the shale series. The limestone beds found in the upper series are generally fossiliferous, containing a profusion of *Orthis testudinaria* and other common forms of the Hudson River series in this part of the country. Sometimes the limestone sheets are found in continuous masses, fifteen to thirty feet in thickness.

The Utica shale.—This stratum, though but recently recognized as an element in the geological scale of Ohio and Indiana, especially in its characteristic form as a black shale with a fauna of its own, has been shown by the deep drilling that is going forward to be as regular and characteristic a part of the column as any other formation that enters into it. Its upper boundary, as stated in a preceding paragraph, is somewhat uncertain, but as we descend in the series no doubt is left as to the name and place of the large body of brownish-black shale that appears in this part of the well records. To make assurance doubly sure, one of the few thoroughly characteristic fossils of the formation, namely, *Leptobolus insignis* Hall, is found to be abundant in the Ohio section in these lower beds. *Triarthrus Becki* Hall has been found in a single fragment from a deep well in Logan County. No fossils have been reported from the corresponding situation in Indiana, but they are not needed to establish the identity of the stratum, as complete continuity can be maintained in tracing the series from point to point. The Utica shale does not appear to be much shortened in the Indiana wells, but the entire series is gradually reduced at the expense of the higher shale masses, namely, the Medina and the Hudson River divisions. Eastward the Hudson River has twice the thickness of the Utica shale, but in a part of the Indiana gas field the Utica appears to constitute a full half, and sometimes more than half of the entire shale column. The shale series in the gas field and in adjacent territory ranges in thickness from 400 to 900 feet. The reduction in the volume of the shales begins, as will be remembered, in the northwestern counties of Ohio, where the series fell to a total of 600 feet. Through the Wabash Valley about the same thickness is maintained, but it is gradually reduced southwestward, where the lower limit already named is reached.

Dr. A. J. Phinney, in a series of valuable papers on the Indiana gas field published in the American Manufacturer, reports the important fact that in the Valparaiso section, in the northwestern corner of the State, the Utica series seems to be replaced by a chocolate-colored limestone 265 feet in thickness, which underlies 160 feet of the blue-green shales of the Hudson River age.

The Trenton limestone.—This great stratum, which has recently assumed such remarkable economic importance in Ohio and Indiana, comes next below the Utica shale in the northern part of the field. The boundary between the two is sharp and distinct. It is somewhat less so in the southern counties on account of a blending of black shale and limestone for fifty to seventy-five feet along the common boundary. Questions frequently arise as to the reference of this mixed series when it is found in wells. It seems safer, in view of all the facts in hand, to count this portion as of Utica age. The limestones which are actually included in the Trenton series are about five hundred feet in thickness. In Indiana as in Ohio they appear to belong to the Trenton, Birdseye, and Chazy divisions of the Kentucky column, where they occur in outcrop. At the bottom of this series a siliceous, magnesian limestone is found which is generally porous and charged with a peculiar salt water known as "Blue Lick" water. This stratum occupies the place of the Calciferous sandstone. Apparently following the determination of a like stratum in the northwest, this formation is commonly named the St. Peter's sandstone. Deep drilling in southern Ohio, however, shows so extended a series of limestones of this same sort that it is hardly safe to identify any one portion positively as the representative of the sandstone, the outcrops of which are six hundred miles or more distant.

The chemical composition of the Trenton limestone will be briefly discussed on a subsequent page.

This must conclude the review of the geological scale of the new gas field. A few statements equally brief are required to set the structure or arrangement of these strata in the proper light.

GEOLOGICAL STRUCTURE OF THE GAS FIELD.

The most important fact in the structure of the new field is plainly indicated in the map which accompanies this report and on which the topography or relief of the Trenton limestone in central Indiana is represented. It is there seen that the Cincinnati uplift is continued from southwestern Ohio in a broad and low terrace or fold into eastern and central Indiana. Its advance bears unmistakably northwestward. The uplift has nothing in it of the nature of an anticline as the term is commonly understood, but as the Trenton limestone is followed from its outcrops in northern central Kentucky it is seen to fall in all directions, but less rapidly to the north, and still less rapidly northwestward. The descents upon the east and west are much more marked than in the northwest. A high-lying area occurs in several of the eastern counties of Indiana in which the surface of the limestone lies approximately level. For 50 miles, for example, from the Wayne and Randolph County boundaries northwestward the descent is scarcely appreciable, and the stratum there continues a genuine terrace. In short, the distribution of the surface rocks with which we have been long familiar in the geological maps of the State is found to agree fairly well with the conformation of the surface of the Trenton limestone. The surface of the country is very nearly level, and thus the horizon of the outcropping rock becomes a sure guide to the level of the underlying Trenton floor.

The thinning of the shales westward, which has been already noticed, carries the high levels of the Trenton limestone a few miles outside the Upper Silurian boundaries in that direction, particularly in Hamilton County.

The gas field, the boundaries of which have been already pointed out, is limited to this area of high-lying Trenton limestone, and especially to the portions that constitute the terraces here described. The elevations of this important stratum at a number of points in the district now under consideration and in the adjacent regions are given below. The figures are mainly copied from the valuable articles of Dr. Phinney, already referred to. The highest-lying tract of the Trenton limestone is shown in the following towns, namely:

	Feet.		Feet.
Brookville	*175	Connersville	*125
New Castle	*125	Anderson	*20
Muncie	*75	Richmond	*65
Winchester	*50	Hartford	†80
Fairmount	†40	Marion	†60
Kokomo	†90		

*Above tide. †Below tide.

On the west side of this high tract the following levels of the Trenton limestone are to be noted:

	Feet below tide.		Feet below tide.
Shelbyville	65	Lebanon	300
Tipton	125	Crawfordsville	710
Indianapolis	280	Bloomington	880

On the eastern and northeastern sides we find the surface of the Trenton at Union City 70 feet below tide; at Bluffton, 215 feet below; at Decatur, 460 feet below; at Huntington, 280 feet below; at Fort Wayne, 675 feet below; and still farther northward and northeastward the descent becomes even more rapid. At South Bend the surface of the Trenton is 850 feet below tide, and at Auburn more than 1,000 feet below. Northwestward the series descends rather rapidly from Howard and Grant Counties, where it is a little less than 100 feet below tide, to 200 feet at Wabash, 220 feet at Peru, and 340 feet at Logansport. The more important facts in regard to the structure of the productive gas area can be summed up as follows, namely: The production is derived from the large terrace-like tract of Trenton limestone, which slopes gently to the northwestward, in which direction its main axis extends, and which terminates in this direction with some abruptness in Howard and Grant Counties. The productive district, it will be observed, is a high-lying area of Trenton limestone, but it is by no means the highest area of the Trenton limestone in the State. The southern and southeastern boundaries of production occur where the stratum is rising steadily towards its outcrops in Kentucky. This fact will be considered and explained under the next head.

CONDITIONS OF GAS PRODUCTION IN INDIANA.

Two conditions dominate the gas production of the Trenton limestone of Indiana as of Ohio; one chemical in its origin and nature, and one physical. The first condition is concerned with the porosity of the rock and the consequent possibility of storage of gas, oil, and salt water in it, the latter state being probably essential to all vigorous production of either oil or gas. The second condition is concerned with the relief of the surface of the gas rock, and upon this also Nature inexorably insists in all gas and oil production.

Porosity of the gas rock.—This is the first and vital condition of all production. The gas rock of Indiana as well as that of Ohio is a true and tolerably pure dolomite or magnesian limestone in the only cases in which chemical examination of it has been made. It is a matter of regret that the gas rock was obtained in time for analysis in but few of the main centers of production, but there is little or no question in regard to the representative character of these results. Anderson, Marion, Fairmount, Noblesville, Hartford, and other prolific centers will all be found to agree in this respect with Muncie and Kokomo. The results of analysis of the gas rock in the last-named places are given below:

	Muncie. (Clarke.)	Kokomo. (Lord.)
Carbonate of lime	51.96	52.80
Carbonate of magnesia	38.11	39.50
Alumina and oxide of iron	3.72	2.40
Siliceous residue	3.30	4.60
	97.09	99.30

The exact correspondence of these facts with those of the Ohio gas field will not escape notice. The figures given above might be interchanged with those derived from Findlay, Lima, or Bowling Green, without injustice to any locality.

The analyses of the Trenton limestone outside the limits of production are equally valuable and significant. They show at a glance the cause of the barrenness of the rock southward. The stratum there becomes unproductive because it loses its porosity, or, to put the facts in a more natural order, the stratum becomes productive only when the dolomitic change has been accomplished in it. The mass of the Trenton limestone throughout the country at large, ninety-nine hundredths of it, probably, is a non-porous rock. Comparatively few analyses have been made of the stratum in this barren border of the Indiana field, but every one is significant, and it happens that inspection of drillings from points to which analysis has not been applied makes it certain that the composition of the entire southeastern border of the gas field agrees with that here shown. The facts are of exactly the same character as those found in southern Ohio. To those of the Indiana wells, one or two analyses are added from the Trenton limestone of this last-named district. It is evident that the gas follows the Trenton limestone up the southward-rising slopes as far as the rock is porous enough to admit it. The boundary of the porous rock can not be laid down with any attempt at definiteness or precision from the facts that are now in hand, but it seems probable that it passes southward with a westerly trend through Jay and Randolph Counties. In Wayne, Fayette, Union, and Shelby Counties, and to the south and southeast of these counties, it appears from present developments that the Trenton limestone ceases to be an oil or gas rock in any important sense of the word. In all of this region its non-porous character constitutes an effective barrier against the ascent of the gas. The composition of the rock at a few points along this boundary and within it is shown in the following table:

	1.	2.	3.	4.	5.
Carbonate of lime	87.88	83.21	84.70	94.60	85.56
Carbonate of magnesia	7.43	12.43	1.50	.36	Trace.
Alumina and oxide of iron	1.57	1.23	1.50	.55	.60
Siliceous residue	1.89	2.14	12.00	.87	8.00
	98.77	99.06	99.70	96.38	94.16

1. Fort Recovery, Ohio (Clarke); 2. Union City, Ind. (Clarke); 3. Hamilton, Ohio (Lord); 4. Greensburgh, Ind. (Clarke); 5. Vernon, Ind. (Clarke).

The Greensburgh limestone is seen to be remarkably pure. A few instances are known in which a small production of gas has been derived from a rock of this character.

When the Trenton limestone has the composition indicated in the preceding table of analyses it is easily distinguished by its physical properties from the gas rock proper. In this condition it is a flaky and light-colored limestone, the larger pieces breaking with a semi-conchoidal fracture. It is sometimes, however, dove-colored. In almost all these cases it drills into small fragments. Its lack of porosity is indicated by its dryness. The drill must descend through it for hundreds of feet generally before the "Blue Lick water" is struck.

That the boundary of the porous rock passes through Jay and Randolph Counties is apparent from the composition of the Trenton limestone at Ridgeville, which is as follows (Lord):

Carbonate of lime	54.30
Carbonate of magnesia	33.60
Alumina and oxide of iron	3.90
Siliceous residue	6.10
	97.90

This composition is fairly favorable for a gas rock, the only drawback being found in the comparatively large percentage of siliceous matter, but so far as tested there is only a small production here. For such a failure, there are possible reasons enough that can be suggested.

Beyond the gas field in the other direction, viz, to the northward and northwestward, the limestone appears to retain the porous character that it has within the productive territory. This is shown by the fact that it is everywhere in this direction a salt-water rock, as the lower-lying portion of the gas rock should be. The few analyses (Clarke) from this part of the field also support the same conclusion. The first is 215 and the second 200 feet below tide. They are as follows:

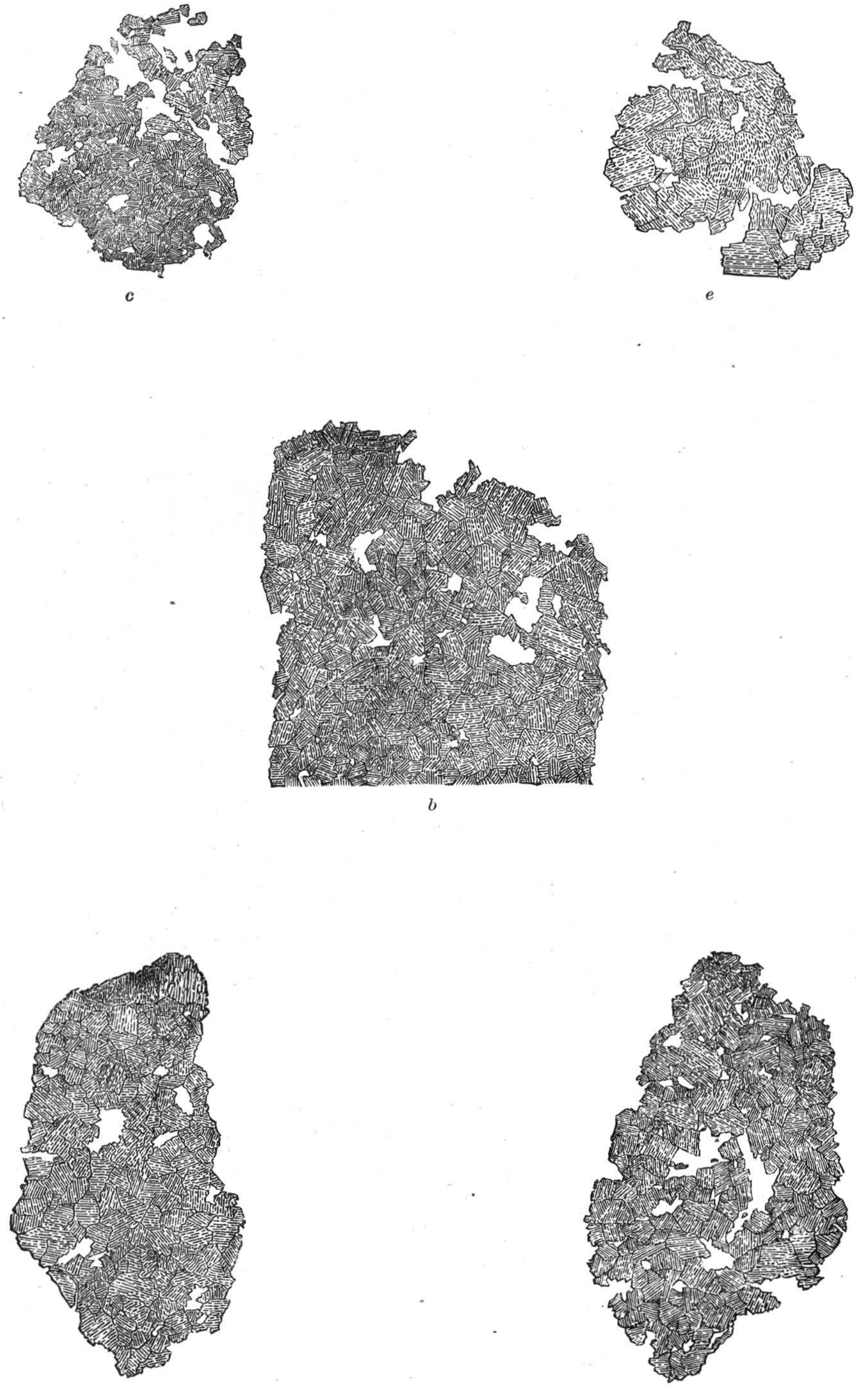
	Bluffton.	Wabash.
Carbonate of lime	53.43	53.18
Carbonate of magnesia	37.47	30.53
Alumina and oxide of iron	4.48	7.58
Siliceous residue	2.37	3.52
	97.75	94.81

Relief of the gas rock.—That the Trenton limestone must be a porous rock to be an oil or gas rock goes without saying. As just shown, the highest degree of porosity in it is associated with a dolomitic composition, but its porosity insures only the result that the rock shall be filled with one of three substances, gas, oil, or salt water, almost invariably associated in all petroleum fields. Which of the three will be found occupying any particular portion of the porous part of the rock depends altogether on the relations of this particular portion to adjacent parts of the same stratum in the matter of elevation; in other words, on the local relief of the stratum. In every field in which oil or the gas derived from it is accumulated, certain comparatively small portions of the porous rock, always distinguished from the rest by relatively higher elevation, will be found assigned, as it were, to the storage of these desired substances, while the salt water holds possession of the bulk of the stratum on all sides.

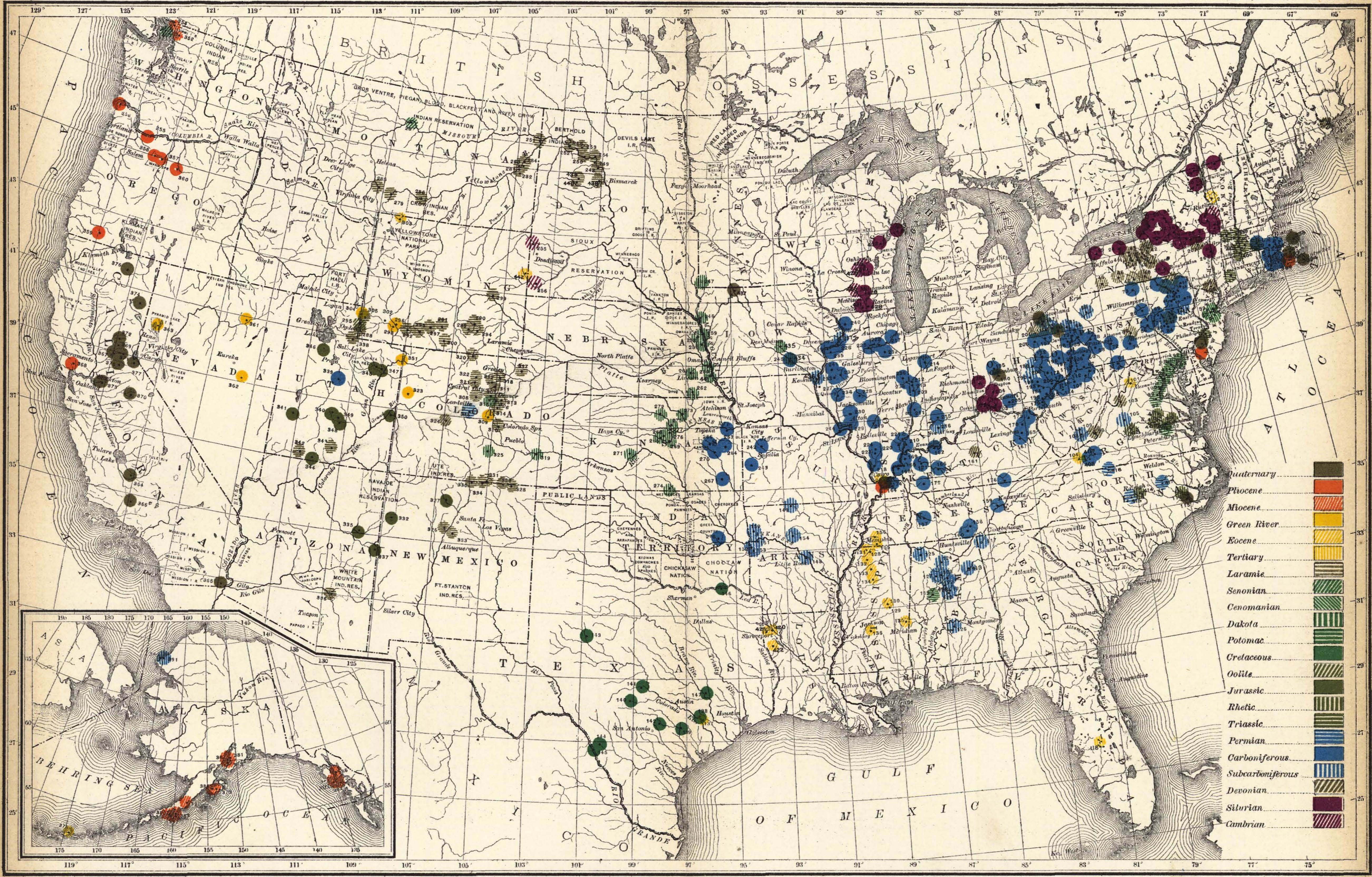
The first dozen wells in Indiana in which the search for gas in the Trenton limestone was successful brought to light the boundaries of the productive rock; in other words, a line of facts precisely similar to the facts of the Findlay field came to view, as soon as the development was fairly entered upon. So far as recorded the surface of the gas rock lies highest at Muncie and lowest at Kokomo. At Muncie it is sixty-five to seventy-five feet above tide. At Kokomo it is eighty to ninety feet below tide. The total range of the productive rock is thus seen to be one hundred and fifty to one hundred and seventy-five feet, and the dead-line is seen to be about one hundred feet below tide. Whoever drills to the Trenton limestone in Indiana where it exists in its porous state, and finds the surface of the limestone more than one hundred feet below tide, will find it occupied with salt water to the complete or almost complete exclusion of gas and oil except as small local elevations may counteract. The salt water rises promptly to the surface or nearly to the surface of the well when released by the drill. Whoever drills to this stratum where it is a little less than one hundred feet below tide is likely to find both gas and salt water from the same or nearly the same level in the rock.

In the Findlay field of Ohio the upper line of production is found on the highest level that is reached by the Trenton limestone arch or terrace, because the whole of it is dolomitic or porous, but in the Saint Mary's field of Ohio, and again in the Indiana field, the upper limit has no such physical limitation. It is there determined by the boundary of dolomitization, which is the boundary of porous rock. If the continuous porous rock rose higher than seventy feet above sea level at any point in southern Indiana, the gas would ascend into this higher portion, but there is no reason to believe that the total area of the reservoir would be increased thereby. The whole body of the gas and oil would be driven by the salt water to a higher station, and as its absolute level would be greater than before the water column which drives it would be proportionately shortened, and the rock pressure of the gas proportionally diminished. If the Trenton limestone were porous through all the interval between the present Indiana field and the outcrop of the limestone to the southward, the gas and oil would long ago have entirely disappeared from these outcrops in the form of "surface indications," except as occasional stocks might be detained in the traps formed in the strata by such arches and folds as might occur.

The productive wells of the Indiana field range in depth from about eight hundred and seventy-five feet to nine hundred and seventy-five feet, and there is a great degree of similarity in all the



MICROSCOPIC STRUCTURE OF THE TRENTON LIMESTONE.



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GEOGRAPHIC DISTRIBUTION OF FOSSIL PLANTS IN THE UNITED STATES.

BY LESTER F. WARD.

sections. So far as at present known the Trenton limestone of the gas field is traversed neither by continuous ridges of barren rock nor by troughs of salt water. Least of all does it appear to be crossed by any persistent or important lines of uplift that can fairly be called anticlines. Its surface is, however, slightly diversified, and local relief, wherever found, is likely to prove a conspicuous factor in the behavior of the rock. But it is not the departure of the surface of the Trenton limestone from a plane, either horizontal or uniformly and gently inclined, that requires to be explained so much as its close approximation to such a plane. How so widespread a sheet should have grown on the sea-floor with its surface so nearly level or how it should have passed through the mutations of the vast periods that intervene between the present and its origin with so little disturbance is the real ground of wonder.

CHARACTER OF THE PRODUCTION.

Absence of oil.—It will be noticed that this chapter has thus far been devoted to the gas production of Indiana and nothing has been said of an Indiana oil field. For this omission there is the best of reasons, namely, that so far as is known at the present time there is no Indiana oil field deserving the name. Small volumes of oil are frequently reported below the dead line of the gas field, but the amount in every case thus far reported has been insignificant. No break is known in the structure of the stratum between the Indiana gas field and the Lima and Saint Mary's oil fields. It may possibly be that in the course of ages the differentiation and separation of the oil and gas have taken place along this extensive territory, and that the Indiana gas field is the term corresponding to the Lima oil field. This is suggested, however, as possible rather than probable.

Rock pressure.—The rock pressure of the gas in Indiana wells is less than in the wells of the Findlay field. The general range is 300 to 350 pounds in Indiana against 400 to 450 pounds in the Findlay field. The shallower depth at which the Trenton limestone is found in Indiana affords sufficient explanation of the decrease in pressure in the former. To the present levels of the gas rock in each field let an addition of 600 feet be made, which is the approximate elevation above the sea of the nearest outcrops of the limestone to the northward or northwestward, and we obtain 650 feet for Indiana and 950 for the Findlay field of Ohio. These numbers bear a relation to each other that agrees fairly well with the rock pressures of the respective fields. The proportion would be as follows: 950 feet : 650 feet : : 450 pounds: 310 pounds. This last result is not far from the ordinary pressure of gas in the Indiana field. Figures are not at hand in regard to the closed pressure in all the subdivisions of the field. If the mode of reasoning in regard to this subject employed in these pages is correct there would be a lower rock pressure at Muncie, for example, other things being equal, than at Kokomo. This seems to be the fact. At the latter place the rock pressure, as observed, is 328 pounds to the square inch.

Composition of Indiana gas.—The facts pertaining to the composition of Indiana gas have been stated on a preceding page, but for the sake of convenient reference the analyses will be repeated here. They were made by Prof. C. C. Howard, of Columbus, Ohio. The qualification previously made in regard to the paraffine series in the gas will need to be borne in mind in connection with this subject. The bulk of the hydrocarbon is without doubt marsh gas, but other members of the series above named may be included under the proportions of hydrogen and carbon which are given by the chemical analysis of the gas.

	Muncie.	Anderson.	Kokomo.	Marion.
Hydrogen	2.35	1.86	1.42	1.20
Marsh gas	92.67	93.07	94.16	93.58
Olefiant gas	.25	.49	.30	.15
Carbonic oxide	.45	.73	.55	.60
Carbonic acid	.25	.26	.29	.30
Oxygen	.35	.42	.30	.55
Nitrogen	3.53	3.02	2.80	3.42
Sulphureted hydrogen	.15	.15	.18	.20

The specific gravity, calculated on the theory that the paraffines of the gas are entirely marsh gas, is 0.57, but determination by other methods, including direct weighing, is claimed to give a higher gravity of possibly 0.6 or even more.

Production of the gas wells.—The largest of the gas wells in Indiana at the date when the field work pertaining to this paper was completed, namely, in June, 1887, was the first well drilled at Fairmount, Grant County. The well was measured before it was tubed, and the volume of gas escaping from the casing was found to be 11,500,000 feet every twenty-four hours. The temperature of the escaping gas was below 32° Fahr.

Several other wells of very large volume have been drilled since in different parts of the State, as at Anderson, Hartford City, Kokomo, Noblesville, and other towns, and it is possible that one of these has somewhat exceeded the figures above given. The Fairmount well would be great in any field, but it lacks 3,500,000 cubic feet daily of equaling the largest Trenton limestone well of Ohio, namely, the Van Buren well of Hancock County. In other words, its production is about three-fourths of the production of the Van Buren well. From these highest figures the production shrinks rapidly in most parts of the field, but in each of the centers where development has been most active and successful wells of 1,000,000 to 4,000,000 cubic feet have been obtained, and as already stated, at a few points larger ones have been brought in ranging from 5,000,000 to 11,000,000 cubic feet per day. No field is counted of great importance unless its several wells each reach a daily production of at least 500,000 cubic feet. In the popular reports of the volume of the wells of different towns very great exaggerations prevail. Many of the figures that are current have no adequate basis whatever, but are simply random guesses or reckless inventions.

CENTERS OF PRODUCTION.

It is not the purpose of this paper to give any extended account of the actual developments and applications of natural gas in either of the States in which it has recently been found, such as would be demanded if the report were designed exclusively or mainly for the residents of these States. Only the more general features of the production require to be presented here, with enough of detail to show the real character and the immense importance of this surprising discovery.

The heart of the Indiana gas field, as has been already shown, is included in six counties: Delaware, Blackford, Madison, Grant, Hamilton, and Howard.

These counties embrace an area as fertile and beautiful as any of equal extent in the noble State to which they belong. Wealth has been rapidly accumulated in them from agricultural sources since the country was first occupied. Thriving towns have sprung up at many points within them; manufactories have been established on a large scale.

It is not often that great mineral wealth is directly associated with great agricultural resources, but in this case the wonderful stocks of power that have so recently been discovered are added to regions that were already pre-eminent for the wealth of their soils and forests. These favored districts ought to reap an enormous advantage from the addition that has thus been made to their resources. To this end it is necessary that they speedily learn the real nature of their newly-discovered sources of power, and speedily introduce a wise economy in the use of the same. A vandal-like waste has characterized the early exploitation of most of the subdivisions of the field.

The principal development of natural gas within the district under consideration has been made at the county seats, which are naturally the larger towns in their respective counties. As one after another of these towns has come into possession of the new fuel sharp competition has arisen between them in securing such manufacturing establishments as were seeking location in the new gas belt. Most of these towns have offered land for building purposes free of charge, and also free fuel. Some have added a free water supply, and frequently cash subscriptions have been made by the citizens individually or by the town either to the stock of the companies or to cover the expenses of moving the manufacturing plant.

The influence and results of this policy might easily have been forecast. There is little or nothing to be said in its favor. The natural advantages of the new field would be sure to command consideration in a little while at most, and no extraneous inducements of the sort here named were required. In connection with the discovery of gas at these several centers speculative excitement in real estate has broken out at many points, with more or less intensity. Prices of town property have advanced in some instances several hundred per cent., and outlying lands in equal or greater proportion. Large additions have been planned to the several towns, exceeding in some cases the areas of present occupation. In short, provision has been made in the new gas field for an immediate increase of population to be counted only by tens and even hundreds of thousands. Large amounts of foreign capital have come in for investment, and the volume of real-estate transactions has been unprecedented.

This was the state of things in the spring and summer of 1887, but it is already evident that the area of production is too large to allow all the towns that have discovered gas to base great expectations on that alone. The advantages of the several towns and districts are found to be fairly well balanced and distributed. The violence of the excitement has abated, and a safer and more rational view of the situation has taken its place.

There are now being brought into these fortunate towns varied industries, including, especially, glass manufactories and rolling-mills, and a rapid and substantial growth is going forward in many of them.

A brief account will now be given of the development that has taken place at several of these county towns.

Muncie, the thriving county seat of Delaware County, was early in the field, and its first well was successful. Eight wells have been drilled here. The Trenton limestone is found in them at a depth of about eight hundred and seventy-five feet, or from sixty to seventy feet above tide. None of the early wells were large ones, but they were ample for all immediate demands. The last is said to be much the best of the series, yielding several million cubic feet a day. The town has already attracted some extensive manufacturing establishments, and it seems sure to gain very important advantages from its great discovery. In the light of present developments Muncie is situated well toward the southern margin of the productive field.

Hartford City, the county seat of Blackford County, due north of Muncie, brought in two wells during 1887. The first was completed in March. The gas rock was found at a depth of 963 feet, or about eighty feet below tide. The record of the well, reduced to its lowest terms, is as follows, namely:

	Feet.
Drift	126
Upper limestone (Niagara)	149
Shales	688

The daily production of this well was found to be 875,000 feet, but the measurement was made under conditions that were sure to reduce the flow to a considerable extent. It is safe to say that if the flow had been measured from the casing its volume would have been found not below 1,000,000 cubic feet a day. The rock pressure is 350 pounds to the square inch. The second well brought in during the summer proved to be one of the great wells of the new field. The open pressure as reported by Mr. C. R. Cooley is two and a half pounds in the casing, and this pressure stands for a daily production of 10,000,000 cubic feet a day. The town is small, and manufacturing is yet to be begun here.

Anderson, Madison County, has drilled four wells, and is preparing to make the best use of the splendid gifts that fortune has bestowed upon her. The second is one of the four or five great wells of the new field. The open pressure of the gas in the casing is reported by Mr. N. C. McCullough to be four pounds and thirteen ounces. This pressure indicates a daily volume of 13,500,000 cubic feet, which is just about equal to the original production of the Karg well of Findlay. The town has wealth and enterprise and railroad facilities, and manufactories seem sure to be established here on a very large and successful scale.

Marion, the county seat of Grant County, lies about thirty miles north of Anderson. The line which connects these two towns crosses the most prolific portion of the Indiana gas field. Wells have been drilled in at least four of the intermediate towns, and not only has no failure occurred, but in the list we find one well that would be counted great in any field, namely, the Fairmount well, the daily yield of which has already been given as 11,500,000 cubic feet. The production of the second well drilled at Fairmount is much smaller than that of the first. At Jonesborough is also a large well, yielding, when first struck, little if any short of 6,000,000 cubic feet a day.

Marion has drilled five or more wells, all of them fairly vigorous. The production of the third was decidedly larger than that of the first and second. No authentic figures of the production of these wells were obtained, but it is judged that the third, which is the best of them, yields from 3,000,000 to 4,000,000 cubic feet a day. The rock pressure of the gas as observed is 323 pounds per square inch. It is reported as rising to 330 pounds. The gas supply is ample for all present and prospective demands of the town. The Marion wells are about 875 feet deep, and the Trenton limestone is found at about 60 feet below tide.

Marion is beautifully situated at the center of a very productive county. Its water supply is exceptionally generous for central Indiana. Its accumulated wealth and its ambition are pledges that it will reap the full rewards of this recently discovered addition to its great natural endowment.

Noblesville, the county seat of Hamilton County, is situated in the White River Valley, at the center of one of the most fertile and picturesque districts of the State. It is so near Indianapolis, however, as to be overshadowed by it, and its new gas resources, which are very ample and promising, are developed rather with reference to use in the capital city than at home. Nine wells have been drilled here by capitalists from abroad, with the purpose here indicated. A section of one of these wells is as follows:

	Feet.
Drift	60
Upper limestones	400
Shales	392

The Trenton limestone was struck at 852 feet, or about eighty feet below tide. The well was finished at 859 feet, or at seven feet in the gas rock.

While no well in the Noblesville district is known to reach the extreme volume of two or three of those already described, one at least deserves to be counted in with the great wells of the State, namely, the Wainwright. Its volume, measured a few days after the well was completed, was found to be about 7,000,000 cubic feet a day.

Kokomo, Howard County, is the last of the county seats that is to be included in the present review. Happily situated in every respect, a little nearer Chicago than any other point at which the new fuel has been found, already a center of successful manufacturing industries, it has seemed to many that no town in the new gas field is more certain of a rapid and substantial growth. Capital from abroad has been freely invested here, not only in real estate, but also in manufacturing enterprises. Of the latter, five establishments, involving an outlay of half a million dollars in plant, are already begun.

Kokomo is situated on the very edge of the gas field, as is seen from the following facts. The Trenton limestone is struck at a depth of nine hundred to nine hundred and thirty-five feet, or at about eighty to ninety feet below tide. The section of the Junction well, or No. 4 in the city series, as carefully kept by Mr. William Moore, is as follows:

	Feet.
Drift	60
Limestone (Waterlime and Niagara)	360
Hudson River shale (blue shale, 130; blue fossiliferous shale, 130; highly fossiliferous shale, 20)	280
Utica shale (dark shale)	236

The Trenton was struck at 936 feet and gas was found at a depth of eight feet. The drill descended 22 feet into the gas rock. The last two feet were most productive of gas, but unfortunately salt water came with these last supplies. In the first and second wells salt water was also struck with the gas. In the third it was avoided by going very carefully into the Trenton limestone and stopping at a depth of 12 feet, without exhausting the possibilities of gas supply. The fact that three out of four of the first wells of Kokomo reached, at a shallow depth in the Trenton limestone, a considerable volume of salt water, shows that if the wells had been located even a mile westward of the town they would probably have failed of gas altogether. According to data secured by Mr. Moore at the date of the completion, the flow of wells Nos. 2 and 3, respectively, was 820,800 and 1,123,200 cubic feet a day. No. 4 was apparently as large as No. 3, but so large a volume of salt water appeared with the gas as to make the separation difficult. Similar trouble has been experienced in well No. 2. Still the flow of gas was ample for all immediate demands.

All the facts in hand pointed to the east and south as more promising territory for the next well that was to be drilled. While it seemed probable that the city wells proper would sooner or later be overrun with the fatal floods of salt water which they had already tapped, it was still hoped that productive fields of dry gas could be found near by the town, from which an abundant supply could be brought in. Relief came, however, sooner and more easily than could have been reasonably expected. Well No. 5 in the city list, known as the Shrader well, was drilled a mile and a quarter southeast of well No. 3. It found the Trenton limestone at 898 feet, showing a slight rise in the interval between this and well No. 3. At a depth of 14 feet in the rock the drill unlocked one of the great gas fountains of the State. The open pressure of the flow was determined soon after the well was finished, and the figures reported are vouched for by Mr. J. T. Stringer, secretary of the Board of Trade of Kokomo. These show the production of the well to be 7,500,000 cubic feet a day. This fortunate experience relieved all anxiety as to the gas supply of Kokomo, and made it safe for the town to go forward in the way of inviting and locating manufacturing enterprises on the largest scale.

This completes the brief review that was undertaken of the heart of the gas field. No catalogue of wells has been attempted here. Numerous important centers of production have not even been named; for example, Greenfield, Hancock County, so far as can be judged from the experience of a single well, commands an abundant supply of natural gas. Portland, Jay County, was among the first of the towns of the State to try its fortune in the new search. Eight wells have been already drilled there, and while none of them are vigorous, the town has all the present advantages that the new fuel can afford. It is probable that the small production of these wells is determined by the character of the Trenton limestone at this point.

It will be borne in mind that analysis of the stratum at Fort Recovery, on the east side of the county, shows that the limestone is there of the barren type. The change, however, is effected very soon to the west and south, as is seen in the composition of the limestone at Ridgeville, which is given on a preceding page, and better still, in the excellent production of the Dunkirk well.

The outcome and the duration of this field it is difficult to forecast, largely from the fact that the field is unique. The storage capacity of its plateau-like expanse is in any case immense, and while the rate of exhaustion of the wells has not yet been even approximately determined anywhere, the supply of gas is certain to prove of incalculable value to the fortunate regions that have discovered it beneath them, and to cities and towns that lie nearest. A manufacturing district comparable with the "Black Country" of England in the magnitude and variety of its industries, but marvelously free from the grime and soot that have heretofore been counted inseparable from such centers, is sure to be secured and maintained here. How long it will be maintained will depend to a large extent on the economy with which the gas is used.

Competition on the part of manufacturers dependent upon bituminous coal for their fuel with those that use natural gas would be very difficult, even if the new fuel were to cost as much as the old; but when in addition to all its other advantages this most admirable source of power is furnished to all comers, literally "without money and without price," the conditions are seen to threaten distress, if not extinction, to many industries and to many manufacturing centers elsewhere.

CHAPTER VI.

SUMMARY.

In the preceding pages it has been shown that in certain districts of Ohio and Indiana the Trenton limestone has been recently found to be one of the most important sources of petroleum and gas of the entire geological scale of the country. In productive area it far exceeds any known oil sand of the eastern fields and in the amount of oil and gas which it is able to furnish it gives promise of like superiority.

Two principal conditions under which this new oil rock has proved petroliferous on a large scale have been pointed out, viz; *porosity* and *relief*.

The first has been shown to be connected with and apparently dependent on the chemical transformation of the upper portion of the limestone, for a number of feet in thickness, into a highly crystalline dolomite; the second results from some slight warping of these ancient strata in the course of their history, whereby the common contents of the porous portions of the Trenton limestone have been differentiated by gravity, the gas and oil seeking the highest levels and the salt water maintaining a lower but definite elevation in every field. The salt water level is necessarily the dead-line of oil and gas production in the several subdivisions of the productive territory.

The dolomitization of the Trenton limestone seems to have been in the main regional. It extends from the present southern and eastern boundaries of oil and gas production in Ohio and Indiana to the north and northwest. Northwestern Ohio and northern Indiana, and perhaps Michigan, are underlaid with the porous or dolomitic phase of the Trenton limestone. In the larger part of this territory the limestone is saturated with salt water.

Eastward of the Ohio gas field the boundary is not definite, but dolomitization appears to have been accomplished in small areas and for a shallow depth, while the great mass of the rock remains of the original or calcareous type. Northeastward the dolomitic cap is much more frequently found, but it appears to be very thin.

The analyses now in hand from various points beyond the main boundary furnish ground for these conclusions.

To the southward no such irregularities or interruptions of chemical composition have been found, but the rock is everywhere and uniformly wanting both in dolomite and in porosity.

Within the areas of gas and oil production small patches of unaltered limestone are occasionally found. Some cases occur in the very centers of the most important portions of the field, as, for example, at Findlay and Saint Mary's. In certain of the wells at these and other points the Trenton limestone is found at normal depth and under the usual conditions in all respects, except that its uppermost beds are in composition true limestone and are fossiliferous, instead of being non-fossiliferous dolomite. The dolomitic phase, even in these cases, is not far distant; or in other words, this cap of fossiliferous Trenton limestone is thin.

The presence of this calcareous sheet is, in all the cases observed, attended with a great diminution in the volume of the gas produced as compared with the volumes of adjacent wells. When such wells are torpedoed, as they are quite likely to be, the fragments of the calcareous cap are the most conspicuous part of the débris thrown from the well or left dislodged within it. They are on this account naturally but erroneously taken for the gas rock.

In the appended Table No. 1, the following lines of facts are given: (1) Analyses of the Trenton limestone from various points within the areas of oil and gas production and also from an equal or greater number of points beyond the limits of production; (2) elevations of the upper surface of the limestone with reference to sea-level; (3) lower limit of gas and also of oil production in the field to which the sample belongs; (4) results of drilling so far as gas, oil, and salt water are concerned.

For the numerous cases in which gas and oil are wanting in the rock, it is obvious that two lines of explanations are required, based respectively on the two conditions above given. The rock may be lacking in porosity by reason of its chemical composition, while its elevation with reference to sea-level may be entirely within the needful limits, or it may lie too low with reference to its particular field while its composition may fit it for the largest production. Numerous examples of failures from each of these sources are shown in the appended table.

In the arrangement of the table a rude geographical order is followed, beginning with the towns to the east of the Findlay field and proceeding to the west and south until the productive fields are passed.

For the sake of convenience the following named compounds will be indicated in the third column of the table by chemical symbols as follows:

Carbonate of lime	$CaCo_3$
Carbonate of magnesia	$MgCo_3$
Alumina and oxide of iron	Al_2O_3 Fe_2O_3
Insoluble matter	Insol.

TABLE NO. 1.

OHIO.

	Location.	Analyst.	Composition of Trenton limestone (sample usually obtained from uppermost 10 to 20 feet).	Elevations of upper surface of Trenton limestone referred to sea level.	Upper limit of salt water, or dead line of oil and gas in each field.	Results of drilling.
1	Sandusky (well No. 1).	Clarke....	$CaCo_3$, 54.62; $MgCo_3$, 33.67; Al_2O_3, Fe_2O_3, 4.58; Insol. 3.65	−1610	....	Gas in small volume (7,000 cubic feet a day), also oil and salt water.
2	Port Clinton (test well).	....do.....	$CaCo_3$, 71.96; $MgCo_3$, 14.34; Al_2O_3, Fe_2O_3, 4.16; Insol. 7.46	−1080	....	Well dry.
3	Plymouth (test well).	Lord.....	$CaCo_3$, 67.50; $MgCo_3$, 11.40; Al_2O_3, Fe_2O_3, 2.60; Insol. 16.60	−1910	.. ..	Do.
4	Fremont (well No. 1)..	....do.....	$CaCo_3$, 75.74; $MgCo_3$, 13.37; Al_2O_3, Fe_2O_3, ...; Insol. 6.35	−720	(*)	Gas in small volume (O, 20,000 cubic feet per day) without value.
5	Waggoner well (near Fremont).	Clarke....	$CaCo_3$, 52.93; $MgCo_3$, 32.75; Al_2O_3, Fe_2O_3, 6.32; Insol. 5.22	(†) −700	(*)	Gas in considerable volume.
6	Tiffin—Loomis & Nyman well (upper beds of Trenton 6 to 8 feet).	....do.....	$CaCo_3$, 52.89; $MgCo_3$, 33.46; Al_2O_3, Fe_2O_3, 4.86; Insol. 5.66	−725	(*)	Gas in small volume (60,000 cubic feet a day).
7	Same well (Trenton, 10 feet lower).	....do.....	$CaCo_3$, 79.39; $MgCo_3$, 6.20; Al_2O_3, Fe_2O_3, 1.46; Insol. 9.88	−725	....	No addition to gas.
8	Fostoria (well No. 1)..	Lord......	$CaCo_3$, 61.50; $MgCo_3$, 27.30; Al_2O_3, Fe_2O_3, ...; Insol. 5.82	−472	−500	Well dry.
9	Arcadia (test well)....	Clarke....	$CaCo_3$, 84.23; $MgCo_3$, 5.44; Al_2O_3, Fe_2O_3, ...; Insol. 8.56	−370	−500	Gas in small volume.

Local relief. † Approximate.

TABLE No. 1—Continued.

OHIO—Continued.

	Location.	Analyst.	Composition of Trenton limestone (sample usually obtained from uppermost 10 to 20 feet).	Elevations of upper surface of Trenton limestone referred to sea level.	Upper limit of salt water, or dead line of oil and gas in each field.	Results of drilling.
10	Carey (city well No. 1).	Clarke....	$CaCo_3$, 80.107 $MgCo_3$, 8.09 Al_2O_3, Fe_2O_3, 3.08 Insol. 5.72	−515?	−500	Gas in very small volume; well without value.
11	Upper Sandusky (city well No. 2).	... do	$CaCo_3$, 64.25 $MgCo_3$, 15.93 Al_2O_3, Fe_2O_3, 4.31 Insol. 8.18	−492	−500	Well dry.
12	Toledo (Air-line Junction well).	...do	$CaCo_3$, 54.68 $MgCo_3$, 25.73 Al_2O_3, Fe_2O_3, 8.68 Insol. 2.88	−800	−500	Salt water.
13	Bryan (well No. 3).....	....do	$CaCo_3$, 49.00 $MgCo_3$, 38.59 Al_2O_3, Fe_2O_3, 1.51 Insol. 9.22	−1225	(*)	Gas in small volume.
14	Wauseon (test well) ..	....do	$CaCo_3$, 42.82 $MgCo_3$, 28.11 Al_2O_3, Fe_2O_3, 7.28 Insol. 18.24	−1367	....	Salt water.
15	Napoleon (test well) ..	....do	$CaCo_3$, 53.85 $MgCo_3$, 37.33 Al_2O_3, Fe_2O_3, 2.14 Insol. 2.66	−1114	....	Do.
16	Bowling Green (well No. 3).	Lord......	$CaCo_3$, 51.78 $MgCo_3$, 36.80 Al_2O_3, Fe_2O_3, ... Insol. 4.89	−400	−500	Fair volume of gas.
17	Bowling Green (100 feet below surface of Trenton limestone).	....do	$CaCo_3$, 88.64 $MgCo_3$, 6.77 Al_2O_3, Fe_2O_3, ... Insol. 2.15	−400	−500	No addition to production.
18	Findlay (Jones well).	....do	$CaCo_3$, 53.50 $MgCo_3$, 43.05 Al_2O_3, Fe_2O_3, 1.70 Insol. 1.25	−328	−500	Very large production of gas.

TABLE NO. I—Continued.

OHIO—Continued.

	Location.	Analyst.	Composition of Trenton limestone (sample usually obtained from uppermost 10 to 20 feet).	Elevations of upper surface of Trenton limestone referred to sea level.	Upper limit of salt water, or dead line of oil and gas in each field.	Results of drilling.
19	Findlay (well No. 1)	Lord	$CaCo_3$, 47.05 $MgCo_3$, 33.38 Al_2O_3, Fe_2O_3, ... Insol. 11.73	−314	−500	Large volume of gas.
20	Kenton (McElree well)	Clarke	$CaCo_3$, 84.32 $MgCo_3$, 8.43 Al_2O_3, Fe_2O_3, 5.26 Insol. 1.10	−375	−500	Moderate volume of gas. (Dolomite found below.)
21	Lima (well No. 1)	Lord	$CaCo_3$, 52.66 $MgCo_3$, 37.53 Al_2O_3, Fe_2O_3, ... Insol. 4.15	−395	−400	Oil and salt water.
22	Lima (Woolsey well)	...do	$CaCo_3$, 55.90 $MgCo_3$, 38.85 Al_2O_3, Fe_2O_3, .75 Insol. 2.94	−406	−400	Oil and salt water, the latter filling the well.
23	Lima (Hume well)	...do	$CaCo_3$, 63.47 $MgCo_3$, 24.20 Al_2O_3, Fe_2O_3, 5.10 Insol. 2.75	−392	−400	Large production of oil.
24	Lima (Simons well)	Clarke	$CaCo_3$, 57.40 $MgCo_3$, 36.45 Al_2O_3, Fe_2O_3, ... Insol. 1.64	−394	−400	Oil, good production.
25	Kossuth (well No. 1)	...do	$CaCo_3$, 90.72 $MgCo_3$, 6.69 Al_2O_3, Fe_2O_3, .66 Insol. 1.08	....	−400	Well unproductive.
26	Saint Mary's (Pauck well).	...do	$CaCo_3$, 52.18 $MgCo_3$, 38.42 Al_2O_3, Fe_2O_3, 3.12 Insol. 3.18	−310 (*)	−350	Large production of gas.
27	Saint Mary's (Bennett well).	...do	$CaCo_3$, 56.94 $MgCo_3$, 35.55 Al_2O_3, Fe_2O_3, 2.48 Insol. 1.66	−310	−350	Large production of gas.

*Approximate.

TABLE No. I—Continued.

OHIO—Continued.

	Location.	Analyst.	Composition of Trenton limestone (sample usually obtained from uppermost 10 to 20 feet).	Elevations of upper surface of Trenton limestone referred to sea level.	Upper limit of salt water, or dead line of oil and gas in each field.	Results of drilling.
28	Celina (well No. 1)	Clarke....	$CaCo_3$, 68.41 $MgCo_3$, 24.18 Al_2O_3, Fe_2O_3, 2.95 Insol. 2.95	—235	—350	Well dry.
29	Franklin township, Mercer County, (Doenzes well).	....do.....	$CaCo_3$, 69.53 $MgCo_3$, 10.68 Al_2O_3, Fe_2O_3, 8.38 Insol. 3.68	—325	—350	Production of gas large. (Dolomite found below.)
30	Fort Recovery (test well).	....do.....	$CaCo_3$, 87.88 $MgCo_3$, 7.43 Al_2O_3, Fe_2O_3, 1.57 Insol. 1.89	—200 (*)	—350	Well dry.
31	Saint Henry's (well No. 2), calcareous cap).	Orton	$CaCo_3$, 93.64 $MgCo_3$, 3.87 Al_2O_3, Fe_2O_3, ... Insol. 1.27	—200	—350	Moderate production of gas. (Dolomite found below.)
32	Union City (test well).	Clarke....	$CaCo_3$, 83.21 $MgCo_3$, 12.48 Al_2O_3, Fe_2O_3, 1.23 Insol. 2.14	—70	—100	Well dry.
33	New Madison.........	Lord......	$CaCo_3$, 64.91 $MgCo_2$, 17.98 Al_2O_3, Fe_2O_3, 3.60 Insol. 11.11	—100?	....	Do.
34	Sidney (well No. 2) ...	....do.....	$CaCo_3$, 62.30 $MgCo_3$, 28.30 Al_2O_3, Fe_2O_3, 4.40 Insol. 3.60	—279	—350	Small production of gas. Well without value.
35	Huntsville (well No. 1).	Clarke....	$CaCo_3$, 57.23 $MgCo_3$, 33.16 Al_2O_3, Fe_2O_3, 3.15 Insol. 4.41	—285	....	Trenton limestone; unproductive. Well dry.
36	Piqua (Cathcart well).	Lord......	$CaCo_3$, 78.70 $MgCo_3$, 1.70 Al_2O_3, Fe_2O_3, 1.20 Insol. 17.70	—300	....	Well dry.

*Local relief.

TABLE NO. I—Continued.

OHIO—Continued.

	Location.	Analyst.	Composition of Trenton limestone (sample usually obtained from uppermost 10 to 20 feet).	Elevations of upper surface of Trenton limestone referred to sea level.	Upper limit of salt water, or dead line of oil and gas in each field.	Results of drilling.
37	Springfield (well No 1.)	Lord......	$CaCo_3$, 80.78; $MgCo_3$, 6.29; Al_2O_3, Fe_2O_3, ...; Insol. 9.63	—200	....	Well dry.
38	London (test well)....	Clarke....	$CaCo_3$, 77.69; $MgCo_3$, 1.89; Al_2O_3, Fe_2O_3, 1.84; Insol. 15.90	550	....	Do.
39	Columbus (test well).	Lord	$CaCo_3$, 69.30; $MgCo_3$, 4.30; Al_2O_3, Fe_2O_3, 2.70; Insol. 23.60	—1188	....	Do.
40	Prospect (test well)...	Clarke....	$CaCo_3$, 66.02; $MgCo_3$, 3.77; Al_2O_3, Fe_2O_3, 2.57; Insol. 26.12	750	....	Do.
41	Dayton (Findlay st. well).	....do.....	$CaCo_3$, 82.36; $MgCo_3$, 1.67; Al_2O_3, Fe_2O_3, .58; Insol. 12.34	—115	....	Do.
42	Osborn (well No. 1)....	Lord......	$CaCo_3$, 81.80; $MgCo_3$, 2.60; Al_2O_3, Fe_2O_3, 1.30; Insol. 14.40	—170	....	Do.
43	Xenia (well No. 1).....	Clarke....	$CaCo_3$, 86.54; $MgCo_3$, 2.99; Al_2O_3, Fe_2O_3, .18; Insol. 9.23	—114	....	Do.
44	New Vienna (te t well).	....do.....	$CaCo_3$, 82.43; $MgCo_3$, 3.19; Al_2O_3, Fe_2O_3, ...; Insol. 8.47	—100 (*)	....	Do.
45	Hillsborough (test well).	Lord.....	$CaCo_3$, 85.00; $MgCo_3$, 2.00; Al_2O_3, Fe_2O_3, 0.60; Insol. 11.80	—100 (*)	....	Do.

*Approximate.

TABLE No. I—Continued.

OHIO—Continued.

	Location.	Analyst.	Composition of Trenton limestone (sample usually obtained from uppermost 10 to 20 feet).	Elevations of upper surface of Trenton limestone referred to sea level.	Upper limit of salt water, or dead line of oil and gas in each field.	Results of drilling.
46	Hamilton (well No. 3).	Lord.....	$CaCO_3$, 84.70; $MgCO_3$, 1.50; Al_2O_3, Fe_2O_3, 1.50; Insol. 12.00	+70 (*)	....	Well dry.
47	Cincinnati (Water works well).	....do.....	$CaCO_3$, 78.70; $MgCO_3$, 1.93; Al_2O_3, Fe_2O_3, 5.04; Insol. 12.95	+184 (*)	....	Do.
48	Point Pleasant (outcrop).	....do.....	$CaCO_3$, 79.30; $MgCO_3$, 0.91; Al_2O_3, Fe_2O_3, 7.00; Insol. 12.00	+450		

INDIANA.

	Location.	Analyst.	Composition	Elevations	Upper limit	Results of drilling.
49	Bluffton (well No. 2)..	Clarke....	$CaCO_3$, 53.43; $MgCO_3$, 37.47; Al_2O_3, Fe_2O_3, 4.48; Insol. 2.37	−225	−100	Salt water filling well.
50	Wabash (well No. 3)..	....do.....	$CaCO_3$, 53.18; $MgCO_3$, 30.53; Al_2O_3, Fe_2O_3, 7.58; Insol. 3.52	−200	−100	Do.
51	Kokomo (well No. 4)..	Lord.....	$CaCO_3$, 52.80; $MgCO_3$, 39.50; Al_2O_3, Fe_2O_3, 2.40; Insol. 4.60	−86	−100	Gas, large volume, with salt water.
52	Ridgeville (well No. 1).	....do.....	$CaCO_3$, 54.30; $MgCO_3$, 33.60; Al_2O_3, Fe_2O_3, 3.90; Insol. 6.10	+40	−100	Well dry.
53	Muncie (well No. 8)...	Clarke....	$CaCO_3$, 51.96; $MgCO_3$, 38.11; Al_2O_3, Fe_2O_3, 3.72; Insol. 3.30	+74	−100	Gas, large volume.

* Approximate.

TABLE No. I—Continued.

INDIANA—Continued.

	Location.	Analyst.	Composition of Trenton limestone (sample usually obtained from uppermost 10 to 20 feet).	Elevations of upper surface of Trenton limestone referred to sea level.	Upper limit of salt water, or dead line of oil and gas in each field.	Results of drilling.
54	Union City (well No. 1)	Clarke....	$CaCo_3$, 83.21 $MgCo_3$, 12.48 Al_2O_3, Fe_2O_3, 1.23 Insol. 2.14	−71	−100	Well dry.
55	Vernon (well No. 1)...	....do.....	$CaCo_3$, 85.56 $MgCo_3$, trace. Al_2O_3, Fe_2O_3, 0.60 Insol. 8.00			Do.
56	Greensburgh (well No. 2) (probably calcareous cap.)	....do.....	$CaCo_3$, 94.60 $MgCo_3$, 0.36 Al_2O_3, Fe_2O_3, 0.55 Insol. 0.87	+82?	....	Do.

In Table No. II the composition of the rock is given as found in the analysis of the drillings from some representative well from each of the best known centers of production that appear in Table No. I. All the specimens are gas rock except that of Lima.

TABLE No. II.

	Findlay—Lord.	Bowling Green—Lord.	Lima Oil Rock—Lord.	Saint Mary's—Clarke.	Muncie—Clarke.	Kokomo—Lord.
Carbonate of lime	53.50	51.78	55.90	52.18	51.96	52.80
Carbonate of magnesia......	43.05	36.80	38.85	38.42	38.11	39.50
Alumina and oxide of iron...	1.70	....	0.75	3.12	3.72	2.40
Insoluble matter	1.25	4.89	2.94	3.18	3.30	4.60

All facts that have been secured by chemical analysis are given in these tables. In addition to these results of analysis it is to be observed that the composition of the drillings can be made out fairly well in a general way by inspection, after one becomes acquainted with typical examples of the different sorts. The dolomite is especially distinct and recognizable, and it can be positively asserted on the strength of such determinations, in addition to the analyses already given, that this phase overwhelmingly preponderates in the productive oil and gas fields, if it does not indeed constitute an essential condition of all productiveness. The first table does not by any means show the real state of the case. Several of the samples there reported were selected for analysis because they constituted exceptions in appearance to the common run of the drillings. Among these a few examples of the calcareous cap of the dolomite already described found place. Table No. II is a fair representation of the gas rock. The analyses are made to cover the length and breadth of the entire field.

CONCLUSION.

The influence of the remarkable discovery of oil and gas in the new horizon of Ohio and Indiana has been felt far and wide. Drilling directed specifically to the Trenton limestone has been undertaken, on the strength of this discovery, in many States and in localities 1,000 miles distant from the regions in which it was first found profitable.

What the prospects of success are in these numerous and widely separated tests of the limestone can be learned from a due consideration of the facts embodied in the preceding table. It is sufficient to say that there is nothing in the new experience to make it safe to count the Trenton limestone an oil rock or a gas rock in any locality unless it can be shown to have undergone the *dolomitic replacement* by which its porosity is assured. Even in case it has undergone this transformation it will not be found a reservoir of oil or gas in an important sense unless, in the accidents of its history, some parts of its deeply-buried surface have acquired the *relief* that is essential to a due separation of its liquid and gaseous contents. It is not known, nor has it been rendered even probable, that the limestone meets these two inexorable conditions anywhere in its wide extent except in regions that are now undergoing development, as the gas fields and oil fields of Ohio and Indiana. In other words, there is a strong presumption that the Trenton limestone will not prove an oil rock or a gas rock in any new field.

THE GEOGRAPHICAL DISTRIBUTION

OF

FOSSIL PLANTS.

BY

LESTER F. WARD.

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ILLUSTRATION.

THE GEOGRAPHICAL DISTRIBUTION OF FOSSIL PLANTS.

By Lester F. Ward.

INTRODUCTION.

RELATIONS OF THE PRESENT PAPER TO PRECEDING AND PROSPECTIVE CONTRIBUTIONS.

The present article is intended as a continuation of the Sketch of Paleobotany which appeared in the Fifth Annual Report. That paper, as explained in a foot-note (p. 363), was written as the first part of the introduction to a larger work that is to deal exclusively with the literature of the science, and it was necessary that the treatment should proceed primarily from a bibliographical point of view. The early history and the subsequent progress of paleobotany were there sketched down to the year 1850, the method of treatment being as nearly chronological as the subject would permit. The reason why it was made to terminate at that date is that the works had begun to multiply so rapidly by that time, that in order to do justice to them by that method far more space would have been required than would comport with the plan of the work in hand. It became evident that some system of classifying the general results attained by paleobotanists during the last thirty-five or forty years must be adopted, and that the subject must be presented in the form of distinct problems toward the solution of which the rapidly accumulating facts are tending. In this way, without departing from the chiefly bibliographical method, the progress made in attacking and solving these problems can be recorded in a more condensed and logical form than could be done by strict adherence to the order of dates.

The most important of these problems was, of course, the development of plant life throughout the geologic history of the earth, and this, in consequence of its prominence, was discussed, somewhat in advance of its natural place, in the first paper. Next to this has seemed to me the need of setting forth clearly the nature and extent of the work actually accomplished in paleobotany in the development of the extinct floras of the globe and the number, location, and geological age of the plant-bearing beds that have been discovered in all parts of the world. I had proposed to call this field of study the Geographical and Geological Distribution of Fossil Plants, but inasmuch as the geological distribution has already been treated in a general way apart from the geographical, and is to be discussed in detail in future papers, at least so far as the American plant-bearing beds are concerned, it seems preferable to use the shorter designation and speak of this topic as simply the Geographical Distribution of Fossil Plants. This is the subject of the present paper, which constitutes the second contribution of the series.

There are many other problems, more properly so called, both geological and biological, which paleobotany promises to solve, or at least elucidate, and it had been my intention to pass most of them rapidly in review in one communication, in addition to dealing with the geographical aspect of the question; but after having compiled much of the data for the discussion of these outlying problems, I found that to do justice to the single subject of geographical distribution, even according to the plan of leaving the reader to rely for all details upon the references given in the foot-notes, would occupy all the space that I had proposed to occupy in the annual report of the survey. I am therefore compelled to leave all such considerations for another paper, which may properly bear the title that I originally proposed for this one, or Problems of Paleobotany.

ENUMERATION OF THE LOCALITIES, WITH THE GEOLOGICAL HORIZONS, AS FAR AS PRACTICABLE, AT WHICH VEGETABLE REMAINS HAVE BEEN FOUND IN THE STRATA OF THE GLOBE.

It is always difficult to decide upon a geographical order for the natural land areas and the political divisions of the globe, and any that might be adopted would doubtless be open to objection. I shall begin with Europe, where by far the greatest activity has taken place, arranging the countries in such order as may seem convenient, closing with Russia; and passing thence naturally to the Russian possessions in Asia, I shall take up the points on that great continent that have yielded vegetable remains; then deal with Africa, the East Indies, and Australasia. Passing to America, after mentioning Kerguelen Land, the Madeiras, and the West Indies, the several points where vegetable débris have been observed will be noted from the most southerly locality on Terra del Fuego to Mexico. Thence, in order to assign to the United States the last place in the enumeration, it seems best to pass directly to the northern regions and treat the Arctic fossil flora as a whole. The proximity of all the most interesting points to North America, even though belonging properly to the eastern hemisphere, and especially the general unity of all the north polar floras where species of the same geologic age are compared, fully justify their treatment as one general district and there is perhaps no more appropriate place for their consideration than as introductory to that of the North American fossil floras. From Melville Island and Banks's Land the transition to the Mackenzie River district is natural, and leads us in a logical sequence to British Columbia, the British Northwest Territory, Canada, and the maritime provinces. The United States may then be properly treated, the customary order of enumeration being somewhat modified so as to pass as naturally as possible from east to west.

As regards the amount of detail given to these several countries, it should be remarked that the great number of small beds that have been discovered on the continent of Europe and the number of monographs that have been published in relation to them render it obviously impossible for me to do more than hurriedly pass them in review without much attempt at analysis of the forms furnished by each. So far as England, France, Germany, Austria, and to a great extent Italy, Sweden, and Russia are concerned, very little more than a bibliographical reference to the principal localities and their products can be undertaken. For other parts of the world, however, the interest being greater from the points of view of latitude, geographical remoteness, and consequent differences of living flora, more will be said as to the nature of the fossil floras that have there come to light. The flora of the Arctic regions has been so exclusively intrusted to Prof. Oswald Heer, and so magnificently treated in his magnum opus, the Flora Fossilis Arctica, that I have made little effort to pick up the collateral matter that has from time to time been brought out by other authors in connection with his work. Nearly the same is true of Ottokar Feistmantel's titanic labors in India, and Dr. J. W. Dawson's work in Canada.

But in treating the United States I have felt it incumbent on me to make the geographical review as complete as the data in my possession would permit. I am aware that it is practically impossible to make the treatment of a subject of this nature absolutely complete, and some will doubtless easily recall a few cases which have failed to receive mention. I have occasionally found myself deciding to exclude some trifling find to which I had a reference, merely on the ground of its lack of importance; but upon the whole I have sought to record all the discoveries and important facts relating to fossil plants within the territory of the United States of which I was cognizant, and to append such notes as would enable the student to put himself in possession of any details that are elsewhere attainable. As, however, this paper is in the nature of a preliminary essay, it will be in the power of those who read it to render the final report much more complete by kindly notifying me of any omissions within their personal knowledge.

GEOGRAPHICAL DISTRIBUTION.

EUROPE.

In treating the countries of Europe, where the literature is so voluminous, considerable embarrassment arises as to the best method of arranging the works under consideration. Undoubtedly the logical and scientific method would be to arrange the localities, first, in the order of their geologic age, and second, in chronologic order of their discovery and of the works in which they are monographed or otherwise treated. But this plan is subject to many difficulties, arising not only from the varying opinions as to their real geologic age, which change with the progress of knowledge in geology, but also from the great variety in the nature of such works, some of which are true local monographs, while others are general works, and deal with many localities and different geological formations. A second objection to this strictly logical method is that it produces too abrupt and radical a change in the general historical plan thus far followed, which was essentially chronologic with the minimum of classification consistent with the necessary condensation and clearness of presentation. I have therefore decided, at the risk of some repetition in the mention of localities and of abruptness in passing from one formation to another, to adhere as closely as possible to the order of dates, and give for Europe a very concise and rapid survey, supplemented by as copious citations as space will permit and as will be necessary to place the investigator in a position to complete the history for himself.

GREAT BRITAIN.

As the geographical order is more important here than the political rank or even the territorial area of countries, it has seemed best to arrange the divisions of the United Kingdom in the following order: England, Wales, Scotland, Ireland—the smaller islands being assigned to their appropriate countries.

England.—The remarkable work of Edward Lhwyd, 1699,[1] referred to in my Sketch of Paleobotany[2] as the earliest but one in which impressions of the appendicular organs of fossil plants were mentioned, gives the localities at which the specimens were found with great care and exactness, although the Latin names of these places can only be recognized by one who is familiar with those ancient designations. It is at least certain that many of them came from the counties of Gloucester, Northumberland, Salop, Lincoln, Chester,

[1] Edvardi Luidii. Lithophylacii Britannici Ichnographia, sive lapidum aliorumque fossilium britannicorum, etc., Londini, 1699, 144 pp., 23 pl.; Editio Altera, Oxonii, 1760, pp. i–viii, 1–61, 25 pl. 8° (See pp. 11–14 of either edition.)

[2] U. S. Geol. Survey. 5th Ann. Rept., 1885, pp. 389, 425.

Berks, Oxford, Surrey, Northumberland, Stratford, York, and Somerset. Among the smaller places mentioned we recognize Acton, Cirencester, Bristol, Dean Forest, Faringdon, Byfield, Ashley, Cowley, Witley, Kidlington, Stonesfield, Frampton, Witney, etc. The plants were all of Carboniferous age.

Parsons's memoir on the petrified fruits of the island of Sheppey,[1] 1757, also sufficiently characterized in my previous paper[2] seems the next most ancient contribution of this class; and here only a single locality is considered, which will come up for more special treatment as we progress.

Martin's Petrificata Derbiensia, 1809,[3] as the name implies, treats the fossils of Derbyshire, which seems to contain only Carboniferous plant-bearing strata. The plant remains were found at or near Whittington, Staveley, Tupton, Alfreton, Chesterfield, Padley, Bakewell, Buxton, Worksworth, and Chapel-in-the-Frith.

In Young and Bird's Geological Survey of the Yorkshire Coast, 1822,[4] several pages are devoted to vegetable remains. A number of species are discussed, and the ligneous origin of coal is set forth. Two rudely executed colored plates are given to fossil plants which are described as coming from Saltwick, Fryop, Castleton, Sandsend, High Whitby, Stainton Cliff, Rockcliff, Runswick, Kirkham, and Haiburn Wyke.

Dr. Mantell, in his Geology of Sussex, 1822,[5] noted the presence of vegetable remains at various points and in different horizons in that county. Here are first mentioned[6] the peculiar objects found in the strata of the Tilgate Forest, at the base of the Greensand or Lower Cretaceous formation, which have since been the subject of so much comment and investigation, consisting of wood, culms, petioles of ferns, and even confused foliage. In the upper chalk at Southstreet and Offham he also found wood, and near Lewes occurred impressions of narrow leaves, also apparently needles of Larix or Pinus, which he figures. At Hamsey, Brighton, and Steyning sup-

[1] An account of some fossil fruits and other bodies, found in the island of Sheppey (a letter to the Earl of Macclesfield, Pres. Royal Soc., dated September 25, 1757; read December 15, 1757) by James Parsons: Philos. Trans. Royal Soc. London, vol. 50, pt. 1, 1757, pp. 396–407, pl. xv, xvi; vol. 11, of abridged Trans., pp. 165–168, pl. vi, with 46 figs.

[2] U.S. Geol. Survey, 5th Ann. Rept., 1885, pp. 394, 397, 413.

[3] Petrificata Derbiensia; or, Figures and Descriptions of Petrifactions Collected in Derbyshire. By William Martin. Wigan, 1809; 52 pl., with 101 pp. of explanations, and 28 pp. of lists, 4°.

[4] A Geological Survey of the Yorkshire Coast, by George Young and John Bird, artist. Whitby, 1822, 328 pp., 17 pl. and map, 4°. (See pp. 179–192, pl. ii, iii, iv, fig. 9.)

[5] The Fossils of the South Downs, or Illustrations of the Geology of Sussex, by Gideon Mantell. London, 1822, 325 pp., 42 pl., 4°.

[6] Ibid., pp. 42–45.

posed aments were collected, and near Bignor, in western Sussex, a peculiar fruit.[1] Finally, in the red marl of the Tertiary plastic clay formation at Castle Hill dicotyledonous leaves were obtained.[2]

The fossil vegetables of the Tilgate Forest formed the subject of a short notice by the same author of a collection made by him near Cuckfield, published in 1824.[3]

Artis's Antediluvian Phytology, 1825,[4] was the earliest English work devoted exclusively to fossil plants. Its literary and artistic merits were mentioned in my previous article.[5] The author was quite careful to give the source of his material, and we find the Else-car coal mine near Wentworth and Hoyland, in the West Riding of Yorkshire; the Lea-brook and Hober quarries in the same vicinity; Rowmarsh and Swinton Common, near Rotherham; a sandstone quarry near Altofts; another at Banktop; at Crudling near Stanley, and Alvethorpe near Wakefield; coal mines near Leeds (all the above in Yorkshire); a place in the bishopric of Durham, and one in the county of Northumberland near Newcastle, among the leading localities set down in that work.

The paper published by Buckland in 1828 on the cycadean trunks of the Isle of Portland (upper Jurassic)[6] was an important contribution in its day, and the excellent figures show that these objects bore a close resemblance to those that have been found in Maryland in the Potomac formation, which can not greatly differ in age from the Portland beds. (See infra, p. 872.)

Phillips, in Illustrations of the Geology of Yorkshire, 1829,[7] gives three plates of fossil plants representing the upper sandstone and shale (Oolite) of White Nab, Stonesfield, Scalby, and the island between Red Cliff and Gristhorpe Cliff, with several species consisting of vascular cryptogams and monocotyledons from the Lower carbonaceous sandstones and shales of High Whitby, Stainton Wyke, Haiburn Wyke, Cleveland Hills, Saltwick, Egton Moors, and Hawsker.

Lindley and Hutton's Fossil Flora of Great Britain, 1831–1837,[8]

[1] The Fossils of the South Downs, or Illustrations of the Geology of Sussex, by Gideon Mantell. London, 1822, pp. 157–159.

[2] Ibid., p. 262, pl. viii.

[3] Description of some fossil vegetables of the Tilgate Forest in Sussex, by G. Mantell: Trans. Geol. Soc. London, 2d series, vol. 1, 1824, pp. 421–424, pl. xlv–xlvii.

[4] Antediluvian Phytology, by E. T. Artis. London, 1825, xiii, 23 pp., 23 pl., 4°; 2d ed. 1838.

[5] Fifth Annual Report U. S. Geol. Survey, 1885, p. 405.

[6] On the Cycadeoideæ, a family of fossil plants found in the Oolite quarries of the Isle of Portland. By William Buckland: Trans. Geol. Soc. London, 2d series, vol. 2, pt. 3, 1828, pp. 395–401, pl. xlvi–xlix.

[7] Illustrations of the Geology of Yorkshire, by John Phillips. Pt. 1, York, 1829, 192 pp., 14 pl., 4°.

[8] The Fossil Flora of Great Britain; or Figures and Descriptions of the Vegetable Remains found in a fossil state in this country; by John Lindley and William Hutton. vol. 1, 1831–1833, 218 pp., pl. i–lxxix; vol. 2, 1833–1835, xxviii, 208 pp., pl. lxxx–clvi; vol. 3, 1837, 209 pp., pl. clvii–ccxxx; London, 8°.

which was somewhat thoroughly analyzed in the Sketch of Paleobotany,[1] aimed to be a complete monograph of the subject for the British Islands. The principal localities in England were the following: The Jarrow, Felling, and Killingworth collieries near Newcastle-upon-Tyne and numerous lesser points in that vicinity; the coal fields of Somerset, Northumberland, Lancaster, and other counties; the Oolitic beds of Yorkshire at Gristhorpe Bay, Scarborough, Whitby, Cloughton Wyke, Haiburn Wyke, etc., the Greensand of Lyme Regis, the Wealden of Yarenland on the Isle of Wight. Many other special points can not be enumerated here.

Many of the fossils figured by Witham in his Internal Structure of Fossil Vegetables, 1833,[2] were from localities in Scotland, but he includes others from High Heworth and Ushaw in Durham, and from Wideopen, Newbiggin, and Hesley Heath near Rothbury, Northumberland, the last named being the place at which his *Lepidodendron Harcourtii* was collected.

The flora of the Ashby coal field, in the parish of Ashby-de-la-Zouch, was magnificently illustrated by Mammatt in 1834, in a work[3] which is not as well known to paleobotanists as it should be.

Fitton, in a paper read before the Geological Society of London, on June 15, 1827, and published in the transactions of that society in 1836,[4] reports six species of fossil plants and numerous cones, petrified trunks, and other vegetable remains from the strata above the Oxford Oolite and below the Chalk. This paper was the result of prolonged and careful research and amounts almost to a geological survey of the south of England. The plants were found in the Lower Greensand of Folkstone, Willsborough, Broughton (near Maidstone), and Brasted, in Kent, and of Atherfield on the Isle of Wight; in the Upper Greensand of Petersfield in Hants and at the east end of the Isle of Wight; in Purbeck and Portland strata, between Totterdale and Walmead in the Vale of Wardour, Wiltshire, at Quainton and Brill, in Bucks, and at Great Hazely in Oxfordshire; and in the Wealden at Saint Leonard's, Cuckoo Hill, Mulsey near Pullborough, Pippingford, Hastings, and the Tilgate Forest, in Sussex; on Sandown Bay, east of Barnes's Chine, on the Isle of Wight, at different points on the Isle of Purbeck and on the Isle of Port land, on Swanage Bay and at Lulworth Cove, Punfield, and between

[1] Fifth Ann. Rept. U. S. Geol. Survey, 1885, pp. 408–410, 429, 430.

[2] The Internal Structure of Fossil Vegetables found in the Carboniferous and Oolitic Deposits of Great Britain, described and illustrated by Henry T. M. Witham. Edinburgh, 1833, 83 pp., 16 pl., 4°.

[3] A collection of geological facts and practical observations intended to elucidate the formation of the Ashby coal-field, etc., by Edward Mammatt. Ashby-de-la-Zouch, 1834, xii, 101 pp., 102 pl. of foss. veg., 4°.

[4] Observations on some of the strata between the Chalk and Oxford Oolite in the southeast of England, by W. H. Fitton: Trans. Geol. Soc. London, 2d series, vol. 4, pt. 2, 1836, pp. 103-378, 379–388, pl. xi–xxiii. (See pl. xix, xx, xxii.)

Upton and Poxwell, in Dorsetshire, at Wansford in Northampton, Tunbridge Wells in Kent, and Garsington near Wheatley in Oxfordshire.

Bowerbank's Fossil Fruits and Seeds of the London Clay, 1840,[1] would have had a much greater value could he have indicated with more thoroughness the source of his specimens, but they had probably been accumulating from a date before the time of Parsons, and, as is the case with such old material, were perhaps largely without labels. The most of them were probably from the island of Sheppey.

The fossil plants of the Isle of Wight were first systematically treated by Mantell in 1847, in the first edition of his Geology of the Isle of Wight,[2] and the age of most of the beds containing them was determined.

Several short papers calling attention to vegetable remains at specific localities in England appeared between 1845 and 1850, by Ick,[3] Dawes,[4] Mantell,[5] and Binney,[6] and by Phillips and Salter.[7]

We then have, as marking the close of the first half century of the science, the important monograph by King of the Permian Fossils of England.[8] He found the fossil plants in the red marl at Newton, near Manchester, and in the marl slate of Thickley, Thrislington Gap, Midderidge, Cornforth, Whitley, Cullercoats Bay, Brusselton, and at a New Red Sandstone quarry between Westoe and South Shields, in the counties of Northumberland and Durham.

Buckman's fossil plants from the Lower Lias, 1850,[9] came from the insect-bearing limestone of Strensham, in Worcestershire

[1] A History of the Fossil Fruits and Seeds of the London Clay, by J. S. Bowerbank. London, 1840, 144 pp., 17 pl., 8°.

[2] Geological Excursions round the Isle of Wight and along the adjacent coast of Dorsetshire: By Gideon Mantell. London, 1847; 2d ed., London, 1851; 3d ed., London, 1854, 356 pp., 20 pl., 8°.

[3] Description of the remains of numerous Fossil Dicotyledonous Trees in an outcrop of the Bottom Coal, at Parkfield Colliery, near Bilston; by William Ick: Quart. Jour. Geol. Soc. London, vol. 1, 1845, pp. 43–46.

[4] Some account of a Fossil Tree found in the Coal Grit, near Darlaston, South Staffordshire; by John S. Dawes: Quart. Jour. Geol. Soc. London, vol. 1, 1845, pp. 46, 47.

[5] Description of some Fossil Fruits from the Chalk Formation of the southeast of England, by G. A. Mantell: Quart. Jour. Geol. Soc. London, vol. 2, 1846, Proc. pp. 51–54, pl. ii.

[6] On Fossil Calamites found standing in an erect position in the Carboniferous strata near Wigan, Lancashire, by E.W. Binney: Philos. Mag., London, 3d series, vol. 31, November, 1847, pp. 259–266.

[7] Palæontological Appendix to Professor John Phillips's Memoir on the Malvern Hills, compared with the Palæozoic districts of Abberly, etc., by John Phillips and J. W. Salter: Memoirs Geol. Survey of Great Britain, vol. 2, pt. 1, London, 1848, pp. 331–386. (See p. 386, pl. xxx, fig. 4.)

[8] A Monograph of the Permian Fossils of England, by William King: Palæontogr. Soc. London, 1850, pp. i–xxxv, 1–258, ; 28 plates (pl. i, fossil plants).

[9] On some fossil plants from the Lower Lias, by James Buckman : Quart. Jour. Geol. Soc. London vol. 6, 1850, pp. 413–418.

Bunbury's paper on the Yorkshire flora, 1851,[1] described ten new species from Gristhorpe, Cloughton, Haiburn, and Whitby.

The localities on the eastern borders[2] below the Scottish boundary from which in 1853 Tate described fossil plants of the mountain limestone formation are as follows: Hesley Heath, near Rothbury) where the much discussed *Lepidodendron Harcourtii* was obtained), Alnwick Moor, Howick, Shilbottle, Budle, Bamburgh, and Netherwitton, all in Northumberlandshire.

The next year Prestwich[3] and Hooker[4] made the first attempts to illustrate and identify the fossil leaves from Reading (Eocene), and in the next volume of the Quarterly Journal, 1855, the latter of these authors discussed the seed vessels found in the Eocene beds of Lewisham[5] and the Bovey Tracey Coal in Devonshire.[6]

It was also in 1855 that Hooker and Binney's important memoir on Trigonocarpons from the Lancashire coal field[7] appeared.

On April 14, 1858, Dr. John Phillips gave an account to the Geological Society of a fossil fruit found in the Wealden deposits of Swanage Bay on the Isle of Purbeck.[8]

In Bristow's Geology of the Isle of Wight, 1862, are published De la Harpe and Salter's Notes on the Eocene Flora of Alum Bay,[9] which is the most important contribution we have to the fossil flora of that island. It was supplemented in the same year by Heer's

[1] On some fossil plants from the Jurassic strata of the Yorkshire coast, by Ch. J. F. Bunbury: Quart. Jour. Geol. Soc. London, vol. 7, 1851, pp. 179–194, pl. xii, xiii.

[2] The Fossil Flora of the Mountain Limestone Formation of the Eastern Borders in connection with the Natural History of Coal, by George Tate: The Natural History of the Eastern Borders, by George Johnston, vol. 1, London, 1853, pp. 289–317, pl. xii, xiii, 8°.

[3] On the structure of the strata between the London Clay and the Chalk in the Hampshire Tertiary system, by J. Prestwich; pt. 2, Woolwich and Reading Series: Quart. Jour. Geol. Soc. London, vol. 10, 1854, pp. 75–170, pl. i–iv.

[4] Note on the fossil plants from Reading, by J. D. Hooker: Quart. Jour. Geol. Soc. London, vol. 10, 1854, pp. 163–170, pl. iii, iv.

[5] On some minute seed-vessels (*Carpolithes Ovulum* Brongn.), from the Eocene beds of Lewisham, by J. D. Hooker: Quart. Jour. Geol. Soc. London, vol. 11, 1855, pp. 562–565, pl. xvi.

[6] On some small seed-vessels (*Folliculites minutulus*, Brown) from the Bovey Tracey Coal, by J. D. Hooker: Ibid., pp. 566–570, pl. xvii.

[7] On the structure of certain Limestone Nodules enclosed in seams of bituminous coal, with a description of some Trigonocarpons contained in them, by Joseph Dalton Hooker and Edward William Binney: Philos. Trans. Royal Soc. London, 1855, pp. 149–156, pl. iv, v.

[8] On a Fossil Fruit found in the upper part of the Wealden Deposits, in Swanage Bay, by J. Phillips: Quart. Jour. Geol. Soc. London, vol. 15, 1859, pp. 46–49.

[9] Notes on the Eocene Flora of Alum Bay, etc., by Philippe De la Harpe and J.W. Salter: (In "Geology of Isle of Wight," by H. W. Bristow), Mem. Geol. Survey Gt. Brit., sheet 10, London, 1862, pp. 102–120, pl. v–vii.

paper[1] on the fossil plants of the Hempstead beds of that island, describing ten species and giving figures of them.

It was also in 1862 that Pengelly[2] and Heer's[3] memoirs on the geology and fossil flora of the lignites and clays of Bovey Tracey, Devonshire, appeared, maintaining the Miocene age of the principal deposit, which is overlain by diluvial white clay also containing plant remains. The flora of the Miocene bed as worked up by Heer amounts to fifty species, and five species were found in the clay above.

In June, 1863, Mr. John Leckenby presented to the Geological Society of London[4] a list of seventy-three s ecies that had thus far been found at Gristhorpe Bay and Cloughton, including one new species (*Phlebopteris Woodwardii* Leckenb.), which latter, together with eighteen others, is figured and characterized more specially.

Most of the forms discussed by Binney in the Philosophical Transactions, 1865,[5] came from North Owram near Halifax, Yorkshire, and Wigan, Lincolnshire, but a valuable list of localities at which fossil woods are found in the Carboniferous series of England, is given on page 581 of that memoir. These localities are all in Lancashire and Yorkshire, and are much more specifically detailed than can be done in this paper.

Before speaking of Binney's principal work several short contributions that appeared during the years 1865–1868 by Carruthers,[6] Mitchell,[7] and Maw[8] are deserving of mention.

The great work of Binney,[9] second only in importance to the later

[1] On certain Fossil Plants from the Hempstead Beds of the Isle of Wight, by Oswald Heer, with an introduction by W. Pengelly: Quart. Jour. Geol. Soc. London, vol. 18, 1862, pp. 369–377, pl. xviii.

[2] The Lignites and Clays of Bovey Tracey, Devonshire, by William Pengelly: Philos. Trans. Royal Soc. London, vol. 152, pt. 2, 1862, pp. 1019–1038, pl. lii–liv.

[3] On the Fossil Flora of Bovey Tracey, by Oswald Heer: ibid. pp. 1039–1086, pl. lv–lxxi.

[4] On the Sandstones and Shales of the Oolites of Scarborough, with descriptions of some new species of fossil plants, by John Leckenby: Quart. Jour. Geol. Soc. London, vol. 20, 1864, pp. 74–82, pl. viii–xi.

[5] A description of some fossil plants, showing structure, found in the Lower Coal seams of Lancashire and Yorkshire, by E. W. Binney: Philos. Trans. Royal Soc. London, vol. 155, 1865, pp. 579–604, pl. xxx–xxxv (Ai–Avi).

[6] On *Caulopteris punctata*, Göpp., a tree-fern from the Upper Greensand of Shaftesbury in Dorsetshire, by William Carruthers: Geol. Mag., London, vol. 2, 1865, pp. 484–487, pl. xiii.

On an aroideous fruit from the Stonesfield Slate, by William Carruthers: Ibid., vol. 4, 1867, pp. 146, 147, pl. viii.

[7] On some hitherto unrecorded Leaf-forms from the Pipe-clay of Alum Bay, Isle of Wight, by W. Stephen Mitchell: Geol. Mag., London, vol. 2, 1865, pp. 515, 516.

[8] On a flower-like form from the leaf-bed of the Lower Bagshot Beds, Studland Bay, Dorsetshire, by George Maw: Geol. Mag., London. vol. 5, 1868, pp. 74, 75.

[9] Observations on the Structure of Fossil Plants found in the Carboniferous Strata, by E. W. Binney; London, 1868–1872; Palæontographical Society of London, vol. 21, 1867 (1868), pp. 1–32, pl. i–vi; vol. 24, 1871, pp. 33–62, pl. vii–xii; vol. 25, 1871 (1872), pp. 63–96, pl. xiii–xviii; vol. 29, 1875, pp. 97–147, pl. xix–xxiv.

one of Williamson on the organization of the fossil plants of the Coal Measures, treats the subject entirely from the point of view of internal structure. His cabinet contained specimens from many parts of Britain, but most of those specially collected by himself and treated in this monograph were, like those already mentioned, from the Yorkshire and Lancashire coal fields, especially the latter. Among the localities specified in Lancashire are Clough Head near Burnley, Quarlton, New Mills, Upholland, Arlay, and Oldham. In Yorkshire are specially noted South Owram, and Halifax. In other counties we find enumerated Dudley (Worcester), South Shields (Durham), Bolton (Westmoreland), and Hady near Chesterfield (Derby), while some specimens came from North Stafford and Northumberland.

In 1869 Dr. Nicholson described three species of supposed plants from the Skiddaw slates[1] (Silurian) on Thornship Beck near Shap (Westmoreland), near Melmerby (Yorkshire), on Rake Beck and at Barff near Keswick (Cumberland), which are of special importance on account of the age of the rocks containing them.

Two more papers by Carruthers, published in 1869 and 1870, add to our knowledge of the Oolitic flora of Scarborough, Yorkshire,[2] and the Eocene flora of Herne Bay in Kent.[3]

Prof. W. C. Williamson's masterpiece "On the Organization of the Fossil Plants of the Coal Measures,"[4] began to appear in 1871. Through the generosity of the distinguished author, who has sent me the first fourteen parts (all that have thus far appeared) in separate form, I am able to consult it without the labor of handling the ponderous volumes of the Philosophical Transactions. I hope at the proper time to refer in an appropriate way to the merits of this work, but for the present can only note the sources from which the materials for his investigations proceeded. He states that his own field observations were chiefly made in the Lancashire coal fields, but he is very careful in giving full credit to the numerous corre-

[1] On the occurrence of Plants in the Skiddaw Slates, by Henry Alleyne Nicholson: Geol. Mag., London, vol. 6, 1869, pp. 494–498, pl. xviii.

[2] On Beania, a new genus of Cycadean Fruit, from the Yorkshire Oolites, by William Carruthers: Geol. Mag., London, vol. 6, 1869, pp. 97–99, pl. iv.

[3] On the Structure of a Fern-stem from the Lower Eocene of Herne Bay, and on its Allies, Recent and Fossil, by William Carruthers: Quart. Jour. Geol. Soc. London, vol. 26, 1870, pp. 349–353, pl. xxiv, xxv.

[4] On the Organization of the Fossil Plants of the Coal Measures, by W. C. Williamson: Philos. Trans. Royal Soc. London, pt. 1, vol. 161, 1871, pp. 477–510, pl. xxiii–xxix; pt. 2, vol. 162, 1872, pp. 197–240, pl. xxiv–xxxi; pt. 3, vol. 162, 1872, pp. 283–318, pl. xli–xlv; pt. 4, vol. 163, 1873, pp. 377–408, pl. xxii–xxxi; pt. 5, vol. 164, 1874, pp. 41–81, pl. i–ix; pt. 6, Ibid., pp, 675–703, pl. li–lviii; pt. 7, vol. 166, 1876, pp. 1–25, pl. i–vii; pt. 8, vol. 167, 1877, pp. 213–270, pl. v–xvi; pt. 9, vol. 168, 1878, pp. 319–364, pl. xix–xxv; pt. 10, vol. 171, 1880, pp. 493–539, pl. xiv–xxi; pt. 11, vol. 172, 1881, pp. 283–305, pl. xlvii–liv; pt. 12, vol. 174, 1883, pp. 459–475, pl. xxvii–xxxiii; pt. 13, vol. 78, 1887, B., pp. 289–304, pl. xxi–xxiv; pt. 14, vol. 179, 1888, B., pp. 47–57, pl. viii–xi.

spondents in different parts of Britain who have favored him with valuable specimens. Besides localities in Scotland and Ireland, the following seem to have been the leading English ones: Oldham, Shaw, Huyton, Bacup, Urmston, and Ardwick beds, and the Gannister bed at Moorside near Ashton-under-Lyne in Lancaster; South Owram, Akroydon, and other points in Yorkshire; the Newcastle coal field in Northumberland.

The Carboniferous ferns of Ravenhead near Liverpool, so carefully collected by the Rev. Henry H. Higgins, were thoroughly studied by Mr. F. P. Marrat and a good illustrated paper upon them was published in 1872.[1] Sixty-two species, all belonging to that family, were identified from this locality.

In 1875 Sorby called attention to a so-called fossil forest in the Coal Measures at Wadsley (Yorkshire),[2] and in 1877 Carruthers described a new Araucarites from the Coralline Oolite of Malton in the same county.[3]

The localities in Lebour's Illustrations of Fossil Plants, 1877,[4] where given at all, are usually the same as those of Lindley and Hutton's fossil flora of Great Britain, to which this work may be regarded as a supplement.

The New Edition of Dixon and Jones's Geology of Sussex, 1878,[5] contains two chapters by Carruthers that deal with the fossil plants of the Eocene beds of Bracklesham and Worthing[6] and of the Cretaceous of Lewes, Brighton, Bignor, Sutton, Tilgate, Lyme Regis (Dorsetshire), and numerous other points,[7] greatly advancing our knowledge of them beyond the state in which Mantell and Fitton left it.

As preliminary to the important monograph of Gardner and Ettingshausen on the British Eocene Flora, the latter of these authors

[1] On some Fossil Ferns in the Ravenhead Collection, Free Public Museum, Liverpool, by Henry H. Higgins: Abstracts of the proceedings of the Liverpool Geological Society, 1872, vol. 2, pp. 94–96.

On the Fossil Ferns in the Ravenhead collection, by F. P. Marrat: Ibid., pp. 97–109, pl. i–xiii.

[2] On the remains of a Fossil Forest in the Coal-measures at Wadsley, near Sheffield, by H. C. Sorby: Quart. Jour. Geol. Soc. London, vol. 31, 1875, pp. 458–460.

[3] Description of a new species of Araucarites from the Coralline Oolite of Malton, by William Carruthers: Quart. Jour. Geol. Soc. London, vol. 33, 1877, p. 402, pl. xvii.

[4] Illustrations of Fossil Plants, being an autotype reproduction of selected drawings, by G. A. Lebour. London, 1877, pp. 1–139, pl. i–lxiv, 8°.

[5] The Geology of Sussex; or the Geology and Fossils of the Tertiary and Cretaceous Formations of Sussex, by Frederick Dixon; new edition, revised and augmented, by T. Rupert Jones. Brighton, 1878, pp. 1–469, 64 pl., 4°.

[6] Description of Tertiary Plant-remains from Bracklesham and Worthing, Sussex, by William Carruthers: Dixon and Jones's Geology of Sussex, 2d ed., 1878, pp. 162–167, pl. ix (10), xii (13), xvi (17),.

[7] The Plant-remains of the Upper and Lower Cretaceous (Neocomian) Formations in England, by William Carruthers: Dixon and Jones's Geology of Sussex; Brighton, 1878, pp. 277–282.

made, in the years 1878,[1] 1879,[2] and 1880,[3] three reports to the Royal Society on phyto-paleontological investigations relating to that flora. They were published in the proceedings of the Royal Society. The first of these reports gives a list of the Eocene ferns of Great Britain, with the localities at which they were found, namely, Studland, Bournemouth, Counter Hill, and Bovey Tracey.

It is still too early to treat the British Eocene Flora,[4] of which only the first two volumes have thus far reached me, completing the Cryptogams and the Coniferæ. Baron von Ettingshausen's name is associated with that of Gardner in the first but not in the second volume, and the latter author seems to have undertaken the completion of the work. The following localities, in addition to those already given, and some others, most of which have been mentioned in connection with other papers, have already been set down in the work as yielding Eocene plants: Bromley, Woolwich, and Herne Bay in Kent; Reading (Berks); Bembridge (Hants); Hempstead, Hordwell, and Gurnet Bay, on the Isle of Wight, besides several in Scotland and Ireland, which will be mentioned under those countries.

The Silurian rocks of the Isle of Man at Laxey have yielded one presumed fossil plant (*Psilophytum Monense* Binney) which Mr. Binney made the subject of two short papers in 1878 and 1879,[5] a form which, curiously enough, closely resembles an American fossil from the Lower Helderberg of Michigan.

Messrs. Cash and Hick undertook in 1878 a very important piece of work upon the flora of the Lower Coal Measures of Halifax, Yorkshire.[6] Their investigations into the fossil fungi of that place attracted the attention of Professor Williamson, and these and similar

[1] Report on Phyto-Palæontological Investigations generally and on those relating to the Eocene Flora of Great Britain in particular, by Constantin Baron von Ettingshausen: Proc. Royal Soc. London, vol. 28, 1878, pp. 221–227.

[2] Report on Phyto-Palæontological Investigations of the Fossil Flora of Sheppey, by Constantin Baron von Ettingshausen: Proc. Royal Soc. London, vol. 29, 1879, pp. 388–396.

[3] Report on Phyto-Palæontological Investigations of the Fossil Flora of Alum Bay, by Constantin Baron von Ettingshausen: Proc. Royal Soc. London, vol. 30, 1880, pp. 228–236.

[4] British Eocene Flora, by John Starkie Gardner and Constantin Baron von Ettingshausen: Palæontographical Society, vol. 1, 1879–1882, Filices: pt. 1, 1879, pp. 1–38, pl. i–v; pts. 2 and 3, 1880, pp. 39–86, pl. vi–xiii; vol. 2, 1883–1886, Gymnospermæ: pt. 1, 1883, pp. 1–60, pl. i–ix; pt. 2, 1884, pp. 61–92, pl. x–xx; pt. 3, 1885, pp. 91–159, pl. xxi–xxvii, 4°.

[5] Notice of a Fossil Plant found at Laxey, in the Isle of Man, by E. W. Binney: Proc. Lit. and Philos. Soc. Manchester, vol. 17, 1878, pp. 85–88, fig. 1; Mem. Lit. and Philos. Soc. Manchester, 3d series, vol. 6, 1879, pp. 214–217, 1 fig.

Remarks on a Fossil Plant found at Laxey, in the Isle of Man, by E. W. Binney: Proc. Lit. and Philos. Soc. Manchester, vol. 18, 1879, pp. 19–21.

[6] A contribution on the Flora of the Lower Coal Measures of the Parish of Halifax, by W. Cash and Thomas Hick: Proc. Yorkshire Geol. Polytech. Soc., vol. 7, pt. 1, 1878, pp. 73–82; pt. 2, 1879, pp. 115–121, pl. vi; pt. 3, 1881, pp. 400–405, pl. xxi; pt. 4, vol. 8, 1884, pp. 370–377, pl. xix.

objects were made the subject of discussion in one of his masterly memoirs. In 1883 Messrs. Williamson, Cash, and Hick, as a committee of the British Association appointed for that purpose, made a report upon the fossil plants of Halifax, and in 1887 the first two of these gentlemen made a second report on the same subject.[1]

Gardner's paper on *Alnus Richardsoni* from the London clay of Herne Bay, 1884,[2] is doubtless an earnest of what we may expect when the Eocene Flora shall have advanced to that group of plants,

The Newer Pliocene "Cromer Forest-Bed" in Norfolk was carefully worked up by Clement Reid and described in a paper presented by him to the Norfolk and Norwich Naturalists' Society on Jan. 26. 1886.[3] Determinable plants were found at Sidestrand, Mundesley, Ostend, Beeston, Triningham, West Runton, Happisburgh, Pakefield, Kessingland, and Bacton, on the coast of both Norfolk and Suffolk, as well as at Cromer. They all belonged to living flora that had been buried by the silt and raised out of the water.

The next paper which we shall notice is Professor Williamson's splendid monograph of Stigmaria ficoides[4] which I have just received from the distinguished author's hand fresh from the press. The enormous specimen which is described in the appendix to this paper was found in the sandstone quarry of Murgatroyd at Clayton, near Bradford in Yorkshire. The specimens whose internal structure is so exhaustively worked out in this memoir came for the most part from the Gannister series, the Staffordshire coal-field, Bayles's brick-yard near Leeds, Oldham Forest, Newcastle-upon-Tyne, and Darley street, Bradford, besides localities in Scotland.

An admirable catalogue of the celebrated Hutton collection of fossil plants now in the Museum of the Natural History Society of Newcastle-upon-Tyne has recently been prepared by Mr. Richard Howse and published in the society's transactions.[5] The localities are very ac-

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[1] Report of the committee, consisting of Professor W. C. Williamson, Mr. Thomas Hick, and Mr. W. Cash (secretary), appointed for the purpose of investigating the fossil plants of Halifax: Brit. Assoc. Adv. Sci., 53d Rept., 1883, p. 160.

Report of the committee, consisting of Prof. W. C. Williamson and Mr. Cash, for the purpose of investigating the Carboniferous flora of Halifax and its neighborhood: ibid., 57th Rept., 1887, pp. 235, 236.

[2] *Alnus Richardsoni* (*Petrophiloides* Bowerbank), a Fossil Fruit from the London Clay of Herne Bay, by J. S. Gardner: Jour. Linn. Soc., Bot., vol. 20, London, 1884, pp. 417–423, pl. xxxi.

[3] On the flora of the Cromer Forest-bed, by Clement Reid: Trans. Norfolk and Norwich Naturalists' Soc., vol. 4, pt. 2, 1886, pp. 189–200.

[4] A monograph on the Morphology and Histology of Stigmaria ficoides, by William Crawford Williamson: Palæontographical Society, London, 1886 (1887), pp. i–vi, 5–62, pl. i–xv, 4°.

[5] Catalogue of those specimens of the Hutton Collection of Fossil Plants that have been presented to the Natural History Society by the Council of the Mining Institute, and are now exhibited in the geological room of the Museum, at Barras Bridge, Newcastle-upon-Tyne. By Richard Howse: Trans. Nat. Hist. Soc. Northumberland, Durham, and Newcastle-upon-Tyne, vol. 10, Newcastle-upon-Tyne, 1888, pp. 19–151, pl. i–vi.

curately given from the labels accompanying the specimens, but there appear to be none not already enumerated in Lindley and Hutton's Fossil Flora of Great Britain and other works.

Among the numerous recent papers by Mr. Robert Kidston, to be mentioned further on, there is an important one[1] based on material collected in England. The species from the Radstock Series were found at Braysdown Colliery; the Tyning and Ludlow Pits, Middle Pit, Wellsway Pit, and Kilmerston and Lower Writhlington Pits, near Radstock; at the Camerton Pits; the Upper and Lower Conygre Pits, Timsbury, Withy, and Dunkerton. The plants from the Farrington series, which is paleontologically inseparable from the Radstock series, were found at Parkfield, Farrington-Gurney, Radstock, Foxcate, Pucklechurch near Mangotsfield, and in the vicinity of Bristol. Specimens were obtained from Kingswood and Warmley, near Bristol, from Golden Valley, in the New Rock series; also from Edford near Radstock, and the Ashton Pits near Bristol, in the Vobster series.

Wales.—It was natural that Lhwyd, himself a Welshman, should have embraced fossils from Wales in his Lithophylacii Britannici Ichnographia, 1699, to which we have already referred, and accordingly we find localities for fossil plants mentioned in the counties of Denbigh, Flint, Glamorgan, etc.

Messrs. Lindley and Hutton in the Fossil Flora of Great Britain (supra, p. 674), also described plants from Wales, as for example, *Polyporites Bowmani* L. and H., from the Vale of Llangollen near Wrexham, in Denbighshire, and *Favularia tessellata* L. and H., from the Garthen colliery, near Ruabon, in the same county.

Other allusions to these well-known beds are to be found scattered through the literature of the science,[2] but in 1880 Messrs. Salter and Etheridge[3] in treating the fossils of North Wales, although scarcely recognizing the existence of plants, enumerate in their lists a number of the disputed forms, such as Scolithus and Cruziana (Annelida) from the Lower Lingula flags of Carnedd Ffiliast, Maentwrog, Ffestiniog, and Tremadoc; Fucoids in the Caradoc or Bala beds at Bala Lake in Merionethshire, at Llanfyllin, and in the Upper Llandovery. The genus Dicotyonema also occurs in the Lower Arenig of Whitesand Bay, Saint Davids, Road Uchaf, and Ramsey Island; in the Lingula flags of Tremadoc, Plas Oakley, and Maentwrog;

[1] On the Fossil Flora of the Radstock Series of the Somerset and Bristol coal field (Upper Coal Measures). By R. Kidston. Pts. I and II; Trans. Royal Soc. Edinburgh, vol. 33 (1887), 1888, pt. 2, pp. 335–417, pl. xviii–xxviii.

[2] On Fossil Remains in the Cambrian Rocks of the Longmynd and North Wales, by J. W. Salter: Quart. Jour. Geol. Soc. London, vol. 12, 1856, pp. 246–251, pl. iv.

[3] On the Fossils of North Wales, by J. W. Salter; greatly enlarged and partly rearranged by Robert Etheridge: Mem. Geol. Survey Gt. Brit., vol. 3, 2d ed., 1880; Appendix, pp. 331–557, pl. i–xxvi.

and in the Llandovery at Bryn-y-Carnau, Devil's Bridge, and Aberystwyth. The next year Messrs. Hicks and Etheridge described the peculiar markings on the Silurian slates of the Pen-y-Glog quarry two miles east of Corwen in Denbighshire,[1] which was supplemented in the subsequent volume of the Quarterly Journal by other papers by Hicks[2] and Dawson[3] on the same subject.

The supposed fossil algæ and other problematical forms of the Silurian rocks of Cardiganshire, Central Wales, have formed the subject of a somewhat protracted discussion participated in by Mr. Walter Keeping[4] and Dr. A. G. Nathorst,[5] the latter, of course, denying their vegetable nature.

Scotland.—Perhaps the earliest mention of fossil plants in Scotland is the account given by Koenig[6] in 1827 of the plant found by Murchison in the Brora coal (Sutherland).

Witham's investigations began in 1830,[7] and the two important papers on the fossil tree of Craigleith,[8] led to his more extended Observations on Fossil Vegetables,[9] his study of *Lepidodendron*

[1] On the Discovery of some Remains of Plants at the Base of the Denbighshire Grits, near Corwen, North Wales, by Henry Hicks, with an appendix by R. Etheridge: Quart. Jour. Geol. Soc. London, vol. 37, 1881, pp. 482–495, pl. xxv.

[2] Additional Notes on the Land Plants from the Pen-y-Glog Slate-quarry near Corwen, North Wales, by Henry Hicks: Ibid., vol. 38, 1882, pp. 97–102, pl. iii.

[3] Notes on *Prototaxites* and *Pachytheca* from the Denbighshire Grits of Corwen, North Wales, by Principal J. W. Dawson: Geol. Mag., London, new series, vol. 9, 1882, pp. 40, 41.

[4] On some Remains of Plants, Foraminifera and Annelida, in the Silurian Rocks of Central Wales, by Walter Keeping: Ibid., pp. 485–491, pl. xi.

On Silurian Plants from Central Wales, by Walter Keeping: Ibid., vol. 10, 1883, p. 192.

[5] On the so-called "Plant Fossils" from the Silurian of Central Wales, by A. G. Nathorst: Ibid., pp. 33, 34.

On the so-called Plant-Fossils from Central Wales, by A. G. Nathorst: Ibid., pp. 286, 287.

[6] Description of Oncylogonatum carbonarium from the roof of the Brora Coal, by Charles Koenig; in Murchison "On the Coal field of Brora," etc.: Trans. Geol. Soc. London, 2d series, vol. 2, 1827, pp. 292–326, pl. xxxi, xxxii (Koenig, pp. 298–300, pl. xxxii).

[7] On the Vegetable Fossils found at Lennel Braes, near Cold Stream, upon the Banks of the River Tweed, in Berwickshire, by Henry Witham: Philos. Mag. or Annals of Chem. Math., etc., vol. 8, London, 1830, pp. 16–21.

[8] A Description of a Fossil Tree, discovered in the Quarry of Craigleith, near Edinburgh, in the month of November, 1830, by Henry Witham: Trans. Nat. Hist. Soc. of Northumberland, Durham, and Newcastle-on-Tyne, vol. 1, 1831, pp. 294–301, pl. xxiv, xxv.

A Description of a Fossil Tree, discovered in the Quarry of Craigleith, near Edinburgh, in the month of November, 1830; with a short account of a Fragment and Branch found in 1831; by Henry Witham: Trans. Royal Soc. Edinburgh, vol. 12, pt. 1, 1834, pp. 147–152, pl. iv–vi.

[9] Observations on Fossil Vegetables, accompanied by Representations of their Internal Structure, by Henry Witham: Edinburgh Jour. Sci., vol. 5, 1831, pp. 183–190, 6 pl.

Harcourtii, and finally to his great work on the Internal Structure of Fossil Vegetables. Besides the points in England already men-mentioned and the Craigleith quarry, there were, among the Scotch localities for his fossils, Lennel Braes, Allanbank, Tweed Mill, in Berwickshire, and the Scuir of Egg, one of the Inner Hebrides.

Messrs. Lindley and Hutton also examined some material from Scotland, viz., from the Edinburgh coal field, Burdie House, etc.

In 1844 Mr. J. Shedden Patrick described a number of Carboniferous species from Ayrshire.[1]

In 1851 the Duke of Argyll published his account of the discovery of a leaf bed at Ardtun Head, on the Island of Mull,[2] which is followed by Professor Forbes's enumeration of the species, which he figures on three plates. In this paper the duke directs attention to a "Post-Tertiary leaf bed in Kintyre, which has been discovered in cutting an outfall drain through the flat area called the Laggan," which locality had been pointed out to him by Professor Nicol.

The Scotch localities given in Tate's Fossil Flora of the Eastern Borders, 1853 (supra, p. 677), are: Lennel Braes, Tweed Mill, Hutton Mill, Allanbank, Dunse, and Lammerton, all in Berwickshire.

In 1853 Dr. Hooker published a note on some Calamitean forms collected by the Rt. Hon. Henry Tufnell, on the Shetland Islands, South Ness quarry, near the Tower of Lerwick, in the Old Red Sandstone.[3] In 1854, Dr. J. H. Balfour showed that recognizable vegetable structure exists in the coal of Fordel, near Inverkeithing, Fifeshire.[4]

In 1855 Hugh Miller first announced his studies into the less known fossil floras of Scotland,[5] subsequently expanded for publication in his popular work entitled The Testimony of the Rocks.[6] Among the localities given for the organisms here described are the trilobite-bearing schists of Girvan in Ayrshire (Silurian), Cromarty Frith in Ross; Caithness Moor, Thurso, and Dunnet Head in Caithness; Stromness, Hoy, South Ness quarry near Lerwick, already mentioned, and other points on the Orkney islands; Clockbriggs near Forfar, and many other places in the Devonian. Mr. J. T. Richards, in

[1] On the Fossil Vegetables of the Sandstone of Ayrshire, by J. Shedden Patrick: Annals Mag. Nat. Hist., vol. 13, London, 1844, pp. 283–291, pl. v.

[2] On Tertiary Leaf-Beds in the Isle of Mull, by the Duke of Argyll; with note on the Vegetable Remains from Ardtun Head, by Prof. E. Forbes: Quart. Jour. Geol. Soc. London, vol. 7, 1851, pp. 89–103, pl. ii–iv. Note, p. 103, explaining plates ii–iv.

[3] Note on the Fossil Plants from the Shetlands, by Dr. Joseph D. Hooker: Quart. Jour. Geol. Soc. London, vol. 9, 1853, pp. 49, 50.

[4] On certain Vegetable Organisms in Coal from Fordel, by J. H. Balfour: Trans. Royal Soc. Edinburgh, vol. 21, pt. 1, 1854, pp. 187–193, pl. ii.

[5] On the less known Fossil Floras of Scotland, by Hugh Miller, Rept. Brit. Assoc. Adv. Sci., 1855, pt. 2, pp. 83–85.

[6] The Testimony of the Rocks, by Hugh Miller; Boston, 1857; 502 pp., 8°. [Chap. XI, pp. 429–502, "On the less known Fossil Floras of Scotland."]

1884,[1] found some interesting fossil plants in Hugh Miller's collection, from Eathie near Cromarty in Ross and from Helmsdale in Sutherland (Oolite). In Mr. Salter's paper, 1855, on plants in the Old Red Sandstone of Caithness,[2] and in that of Mr. John Miller,[3] immediately following it, we have a further development of the Devonian flora of Scotland.

Mr. Carruthers's original cone of *Flemingites gracilis* came from the Carboniferous beds of Airdrie, Lanarkshire, and was first distinguished by him from Lepidostrobus in 1865.[4]

From 1871 to 1877 Mr. Charles W. Peach manifested much activity in making known the fossil flora of Falkirk, Slamannan, Deeside, and Tillicoultry, in the counties of Stirling, Lanark, and Clackmannan; of Slateford, Craigleith, and West Calder, county of Edinburgh, and of other localities in Caithness, Sutherland, Forfarshire, and the Shetland and Orkney islands.[5]

The few Scotch localities from which Professor Williamson received material for his great work were Laggan Bay, in Arran, and Binns Cliff in Burntisland, Fifeshire.

In 1877 Messrs. Jack and Etheridge[6] noted plant remains (Psilophytum, etc.), near Callander, and Gartmore, Perthshire; Drymen

[1] On Scottish Fossil Cycadaceous Leaves contained in the Hugh Miller collection, by J. Theodore Richards: Proc. Royal Phys. Soc. Edinburgh, April 23, 1884, pp. 116–123.

[2] On some remains of Terrestrial Plants in the Old Red Sandstone of Caithness, by J. W. Salter: Quart. Jour. Geol. Soc. London, vol. 14, 1858, pp. 72–76, pl. v.

[3] Note on the Plant-bearing Devonian beds of Caithness, by John Miller: Ibid., pp. 76–78.

[4] On an undescribed Cone from the Carboniferous Beds of Airdrie, Lanarkshire, by William Carruthers: Geol. Mag., London, vol. 2, 1865, pp. 433–440, pl. xii.

[5] Charles W. Peach: Notes on the Coal-fields at Falkirk, illustrated with specimens of Antholithes and its Fruit, Halonia, and other Fossil Plants: Geol. Mag., London, vol. 8, 1871, pp. 187, 188.

Notice of Antholithes Pitcairnæ and its Fruits (Cardiocarpum), with other Fossil Plants from Falkirk. Trans. Botan. Soc. Edinburgh, vol. 11, 1873, pp. 108, 109.

On Fossil Plants from the Coal-fields of Slamannan, Falkirk, Deeside, Tillicoultry, etc. Ibid., pp. 342, 343.

Note on the structure of fossil stems (Araucarioxylon) from Redhall and Craigleith quarries. Ibid., pp. 541, 542.

Notice of a new Lepidodendroid Fossil from Devonside, Tillicoultry, with remarks on other fossil plants. Ibid., vol. 12, 1874, pp. 99–101.

Note on specimens of fossil plants (*Sphenopteris affinis*), from West Calder. Ibid., p. 162.

Remarks on specimens of Ulodendron and Halonia, collected by Messrs. Galletly and Lumsden, near West Calder. Ibid., pp. 174, 175.

Notes on the Fossil Plants found in the Old Red Sandstone of Shetland, Orkney, Caithness, Sutherland, and Forfarshire. Trans. Edinburgh Geol. Soc., vol. 3, 1879, pp. 148–152.

[6] On the discovery of Plants in the Lower Old Red Sandstone of the neighborhood of Callander, by R. L. Jack and R. Etheridge: Quart. Jour. Geol. Soc. London, vol. 33, pt. 1, 1877, pp. 213–222.

and Cardross, Stirlingshire; and Alexandria and Loch Lomond, Dumbartonshire, in the Old Red Sandstone.

Among the Scotch localities for Eocene plants, already recorded in Gardner and Ettingshausen's British Eocene Flora, may be noted Ardtun Head, on the Island of Mull, Isle of Canna, and Uig in Skye.

Since the year 1882 no paleobotanist in Europe has shown greater zeal, energy, and ability than Mr. Robert Kidston. Many of his papers relate to plants from the strata of Scotland, especially in Eskdale, Liddesdale, Midlothian, and Lanarkshire.[1]

The Duke of Argyll's famous leaf-bed at Ardtun Head, Isle of Mull, has recently received a special distinction in being made the subject of an extended geological and paleobotanical essay by Mr. J. Starkie Gardner and Mr. Grenville Cole, in which Forbes's original specimens are redrawn and others added in four lithographic plates.[2]

Ireland.—Exclusive of the more or less problematical Cambrian fossils,[3] the Paleozoic flora of Ireland has been chiefly made known

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[1] Robert Kidston: Report on Fossil Plants, collected by the Geological Survey of Scotland in Eskdale and Liddesdale. Trans. Royal Soc. Edinburgh, vol. 30, pt. 2, 1882, pp. 531–550, pl. xxx–xxxii.

On the Affinities of the Genus Pothocites, Paterson; with the Description of a specimen from Glencartholm, Eskdale. Annals Mag. Nat. Hist., London, 5th series, vol. 11, 1883, pp. 297–314, pl. ix–xii.

On a new species of Schutzia from the Calciferous Sandstones of Scotland. Ibid., vol. 13, 1884, pp. 77–80, pl. v, fig. 2. Proc. Royal Phys. Soc. Edinburgh, Session 1883–1884, vol. 8, 1884, pp. 127–131, pl. v, fig. 2.

On a new species of Lycopodites, Goldenberg (*L. Stockii*), from the Calciferous Sandstone Series of Scotland. Annals Mag. Nat. Hist., London, vol. 14, 1884, pp. 111–117, pl. v.

On a new species of Psilotites from the Lanarkshire coal-field. Ibid., vol. 16, June, 1886, pp. 494–496.

Notes on some Fossil Plants collected by Mr. R. Dunlap, Airdrie, from the Lanarkshire coal-field. Trans. Geol. Soc. Glasgow, 1886, vol. 8, pp. 47–71, pl. iii.

Notes on the Fossil Plants from Lochrim Burn, Corrie; in J. Macadam's Notice of a new fossiliferous bed in the Island of Arran. Trans. Geol. Soc. Edinburgh, vol. 5, pt. 2, 1887, pp. 316–317.

[2] On the Leaf-beds and Gravels of Ardtun, Carsaig, etc., in Mull, by J. S. Gardner, with notes by Grenville A. J. Cole: Quart. Jour. Geol. Soc. London, vol. 43, 1887, No. 170, pp. 270–300, pl. xiii–xvi.

[3] On the Rocks at Bray Head, by Thomas Oldham: Jour. Royal Geol. Soc. Ireland, vol. 3, 1844, p. 60–61.

John Robert Kinahan: On Oldhamia, a genus of Cambrian fossils. Trans. Royal Irish Acad., vol. 23, 1859, pp. 547–562.

On Annelidoid Tracks in the Rocks of Bray Head, County of Wicklow. Jour. Royal Geol. Soc. Ireland, vol. 7, 1855–'57, pp. 184–187, pl. v, figs. 1–5.

On the Organic Relations of the Cambrian rocks of Bray (county of Wicklow), and Howth (county of Dublin); with notices of the most remarkable Fossils. Ibid., vol. 8, 1857–'60, pp. 68–72, pl. vi, vii.

The Cambrian Rocks of the British Islands, with especial reference to the occurrence of this Formation and its Fossils in Ireland, by William Hellier Baily: Geol. Mag., London, vol, 2, 1865, pp. 385–400.

by Dr. Haughton and Professor Baily since 1856, but in 1852 Prof. E. Forbes[1] called attention to the presence of well preserved ferns in the Devonian flagstones of Knoctopher (Kilkenny) which he called *Cyclopteris Hibernicus*, a plant which has since played quite an important rôle. Other vegetable remains were associated with this form.

At the meeting of the Dublin Natural History Society for November, 1858, Dr. Samuel Haughton presented some illustrations of fossil plants of the same geologic age as the last, from Harrylock Bay, Wexford.[2] In 1859 he founded his new genus Cyclostigma on specimens from Kiltorkan (Kilkenny) and described two species, both of which have since been found on Bear Island, in the Bergkalk,[3] and he has since published other papers[4] relating to the same flora in Ireland.

To Prof. William Hellier Baily is due the greater part of what is known respecting the paleontology of Ireland. His papers, which are too numerous to be discussed separately, range from 1864 to 1883. Many important plant localities have been developed through his energies, among which may be mentioned those of Kiltorkan in Kilkenny; Wexford, Tallow Bridge, and Salter Bridge near Lismore, in the county of Waterford; Cappagh, eight miles east of the last-named place; a bed near Cork; one at Tracarta, near Castle Townshend; Gokane Point, on the west side of the Gap of Dunloe; at Geortelunny and Rossacossane, in the county of Kerry; also points in the counties of Limerick, Tipperary, Tyrone, Queen's, and Antrim.[5] Especially important was the discovery of an Eocene bed in the last-named county on the Belfast and Northern Counties

[1] On the Fossils of the Yellow Sandstone of the South of Ireland, by Prof. E. Forbes: Proc. Brit. Assoc., 23d (Belfast) meeting, London, 1852, Trans., p. 43.

[2] Illustrations of the Fossil Flora of the Lower Carboniferous beds of Ireland, by Rev. Samuel Haughton: Proc. Nat. Hist. Soc. Dublin, vol. 2, 1856–'59, p. 122, pl. viii, ix.

[3] On Cyclostigma, a new genus of Fossil Plants, by Rev. Samuel Haughton: Jour. Royal Soc. Dublin, vol 2, 1858–'59, pp. 407–420.

Oswald Heer: On the Carboniferous Flora of Bear Island (lat. 74° 30′ N). Quart. Jour. Geol. Soc. London, vol. 28, 1872, pp. 161–169.

On Cyclostigma, Lepidodendron and Knorria, from Kiltorkan. Ibid., pp. 169–173, pl. iv.

[4] On some additions to the Yellow Sandstone Flora of Donegal. By Samuel Haughton: Jour. Royal Geol. Soc. Ireland, vol. 9, 1860–'62, p. 13.

[5] William Hellier Baily: On Fossil Plants from the South of Ireland (read before the Nat. Hist. Soc. of Dublin, May 3 and June 7, 1866). Dublin, 1867, pp. 1–11, 8°.

Notice of Plant Remains from beds interstratified with the Basalt in the County of Antrim. Quart. Jour. Geol. Soc. London, vol. 25, 1869, pp. 162, 357–362, pl. xiv–xv.

On Fossils obtained at Kiltorkan Quarry, Co. Kilkenny. Rept. Brit. Assoc. Adv. Sci., 39th meeting, 1869, p. 73–75.

Notes on the Fossil Flora of Ireland. Geol. Mag., new series, vol. 9, London, 1872, pp. 90, 91.

Railway, between Templepatrick and Deoagh stations, about seven miles east of Antrim, from which he was the first to figure dicotyledonous leaves and other characteristic Tertiary plants.

In his Figures of Characteristic British Fossils,[1] he enumerates and figures most of the fossil plants of Ireland, giving in the explanations of his plates the localities at which they are found. As this work is arranged in the ascending order of strata, it becomes an important guide to the fossil flora of Ireland.

In view of his well known ability as a paleontologist, the British Association did him the honor on four separate occasions to appoint him, with Professor Williamson, on a committee instructed to report on the Tertiary flora of the north of Ireland. These reports were all drawn up by Professor Baily.[2] Among the localities at which this flora occurs may be mentioned: Sandy Bay, Lough Neagh, Ballypalady, Glenarm, and Glenalvy River, all in the county of Antrim. Some of these localities are mentioned by Gardner in his British Eocene Flora, although they were regarded by the committee as of Miocene age. Mr. Gardner, in a paper in the Linnæan Society's Journal for 1885,[3] has described certain fossil ferns from this district and others from the island of Mull.

Several species of fossil plants of Pleistocene age have been discovered by Mr. Robert Lloyd Praeger,[4] in the estuarine clays at Belfast.

FRANCE.

Antoine Jussieu's study of the impressions on the rocks of St. Chaumont, 1718;[5] was alluded to in my Sketch of Paleobotany

[1] Figures of Characteristic British Fossils, with descriptive remarks, by William Hellier Baily. Vol. 1, Paleozoic, London, 1875, lxxx, 126 pp., 42 pl., 8°.

[2] (1) Report of the committee, consisting of the Rev. Maxwell Close, Professor W. C. Williamson, and Mr. W. H. Baily, appointed for the purpose of collecting and reporting on the Tertiary (Miocene) Flora, etc., of the Basalt of the North of Ireland; Rept. Brit. Assoc. Adv. Sci., 49th (Sheffield) meeting, London, 1879, pp. 162–164. (2) Second report of the committee, consisting of Professor W. C. Williamson and Mr. W. H. Baily, appointed, etc. Ibid., 50th (Swansea) meeting, London, 1880, pp. 107–109, pl. ii, iii. (3) Third report of the committee, consisting of Professor W. C. Williamson and Mr. W. H. Baily, appointed, etc. Ibid., 51st (York) meeting, London, 1882, pp. 152–154, pl. i, ii. (4) Fourth report of the committee, consisting of Professor W. C. Williamson and Mr. W. H. Baily, appointed, etc. Ibid., 53d (Southport) meeting, 1883, pp. 209–210, pl. i.

[3] Eocene Ferns from the Basalts of Ireland and Scotland, by J. Starkie Gardner: Jour. Linn. Soc., Bot., London, vol. 21, 1885, pp. 655–664, pl. xxvi.

[4] The estuarine clays at the new Alexandra dock, Belfast, with a list of fossils, by Robert Lloyd Praeger: Ann. Rept. and Proc. Belfast Naturalists' Field Club, 1886–'87, 2d series, vol. 2, appendix 2, 1888, pp. 29–51, 1 geol. plate.

[5] Examen des causes des impressions des plantes marquées sur certaines pierres des environs de Saint Chaumont, par Antoine Jussieu: Mém. Acad. roy. sci., Paris, ann. 1718, pp. 287–297, pl. xiii, xiv.

(U. S. Geol. Survey, Fifth Ann. Rept., p. 397) as a landmark in the history of the earliest record made in France.

The fossil plants of the lavas of Rochesauve, and the marls of Chaumerac, in the Department of Ardèche, were the next to receive scientific mention, and were investigated by M. Barthélémy Faujas de Saint-Fond in 1803 and 1815.[1] The same author, as early as 1806, discovered the remains of both fish and plants in the gypsum beds of Aix in Provence,[2] since brought into so great prominence in the paleontological history of France by the Marquis Saporta.

In 1811 Messrs. Cuvier and Alexandre Brongniart published their essay on the geography and mineralogy of the environs of Paris,[3] in which they note the presence of leaves and stems in the coarse limestone at Chatillon, St.-Nom, Saillancourt, Sèvres, and other points. Some of these are figured on plate ii, and we recognize the Caulinites and several of the Phyllites of Adolphe Brongniart's subsequent reports.

Alexandre Brongniart published a paper on the fossil plants of the Carboniferous series of France in 1821,[4] which seems to be the only one on the subject from his pen. The mines in which these remains were observed were those of St. Etienne, and this is therefore the first account of the vegetation of that important region. In this paper M. Brongniart makes the interesting statement that his son had a long time previously commenced a separate work on that branch of botany, clearly referring to the Histoire des végétaux fossiles of Adolphe Brongniart.

The new editions of Cuvier and Brongniart's geological description of the environs of Paris[5] and of Cuvier's researches on fossil bones[6] both appeared in 1822, and both contained Adolphe Brongniart's de-

[1] Faujas de Saint-Fond : Notice sur les plantes fossiles de diverses espèces qu'on trouve dans les couches fossiles d'un schiste marneux, recouvert par des laves, dans les environs de Rochesauve, Département de l'Ardèche : Annales Muséum d'hist. nat., Paris, vol. 2, 1803, pp. 339–344, pl. lvi, lvii.

Nouvelle notice sur des plantes fossiles renfermées dans un schiste marneux des environs de Chaumerac et de Rochesauve, Département de l'Ardèche: Mém. Muséum d'hist. nat., Paris, vol. 2, 1815, pp. 444–459, pl. xv.

[2] Notice sur le gisement des poissons fossiles et sur les empreintes de plantes d'une des carrières à plâtre des environs d'Aix, par Barthélémy Faujas de Saint-Fond: Annales Muséum d' hist. nat., Paris, vol. 8, 1806, pp. 220–226.

[3] Essai sur la géographie minéralogique des environs de Paris, avec une carte géognostique, et des coupes de terrain, par G. Cuvier et Al. Brongniart. Paris, 1811, 278 pp., 2 pl. 4°. Plantes fossiles, pp. 22, 126, pl. ii.

[4] Notice sur des végétaux fossiles traversant les couches du terrain houiller, par Alexandre Brongniart: Annales des mines, Paris, vol. 6, 1821, pp. 359–370, pl. iii.

[5] Description géologique des environs de Paris, par Georges Cuvier et Alexandre Brongniart. Nouv. ed., Paris, 1822, 428 pp. 17 pl., 4°. [Vég. foss. par Ad. Brongniart, pp. 353–371, pl. viii, x, xi.;] 3d ed., 1835, 685 pp., 8°, with atlas, 17 pl., 4°. [Vég. foss., pp. 57, 69, 649, 650, pl. P, R, S.]

[6] Recherches sur les ossemens fossiles, par Georges Cuvier, nouv. ed., Paris, 1822; 4th ed., Paris, 1835.

scription of the fossil plants of the Tertiary deposits[1] of the Paris basin. This memoir underwent important revisions and received considerable additions in the subsequent editions of both these works.

The fourth volume of the Paris Annals of Science, 1824, contains a paper by Adolphe Brongniart on the Oolitic ferns of Mamers (Sarthe),[2] and in the fifteenth volume, 1828, he takes up the Tertiary plants of Armissan, near Narbonne (Aude),[3] and also names the Carboniferous forms from Chardonet, department of Hautes-Alpes, which Élie de Beaumont labored so hard on stratigraphical grounds to place in the Jurassic.[4]

In the second chapter of his Prodrome,[5] which appeared in 1828, he enumerates all the localities then known to him where vegetable fossils were found, among which occur the following in France: Montrelais (Loire Inférieure); Langeac (Haute-Loire); St. Etienne (Loire); Saint George-Chatellaison (Maine-et-Loire); Saint Hippolyte (Doubs); Alais (Gard); Plessis and Litry (Calvados); Montagne des Rousses en Oisans (Jura); Saint Priest (Cher); Anzin, Fresnes, Vieux-Condé, and near Valenciennes (Nord); Ronchamp (Haute-Saône); Terrasson (Dordogne); and Aubin (Aveyron).

The appearance of this work was followed by a series of short monographs of more or less importance on the floras of the various beds of France, which, as the localities are given in their titles, need not be specially dwelt upon. Thus Murchison and Lyell in 1829 noticed plants at Aix[6] (Eocene) and Fuveau (Senonian). Pomel, 1845, made further studies into those of Paris,[7] and Brongniart made a contribution on the Lower Triassic plants of Lodève (Hérault).[8]

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[1] Description des végétaux fossiles du terrain de sédiment supérieur, par Adolphe Brongniart. In Cuvier: Recherches sur les ossemens fossiles, 4th ed., vol. 4, Paris, 1835, pp. 645, 650; vol. 5, 1835, pp. 636–674. Atlas, vol. 2, 1836, pl. P to S.

[2] Note sur les végétaux fossiles de l'Oolite à Fougères de Mamers, par Adolphe Brongniart: Annales sci. nat., vol. 4, Paris, 1825, pp. 417–423, pl. xix.

[3] Notice sur les plantes d'Armissan près Narbonne, par Adolphe Brongniart: Annales sci. nat., vol. 15, Paris, 1828, pp. 43-51, pl. iii.

[4] Sur un gisement de végétaux fossiles et de graphite, situé au col du Chardonet Département des Hautes-Alpes), par L. Élie de Beaumont: ibid., pp. 353–381.

[5] Prodrome d'une histoire des végétaux fossiles, par Adolphe Brongniart, Paris, 1828, 223 pp., 8°.

[6] On the Tertiary fresh-water formations of Aix in Provence, including the coal (field of Fuveau; by Sir Roderick Murchison and Sir Charles Lyell: Proc. Geol. Soc. London, vol. 1, 1826–'33, pp. 150, 151. Edinburgh New Philos. Jour., vol. 7, 1829, pp. 287–298, pl. v, vi.

[7] M. A. Pomel: Note sur des végétaux fossiles nouveaux découverts dans le calcaire grossier des environs de Paris: Bull. Soc. géol. France, 2d series, vol. 2, Paris, 1845, pp. 307–316.

Résumé d'une flore fossile du calcaire grossier du bassin de Paris: Bull. Soc. d'hist. nat. Moselle, vol. 3, Metz, 1845, pp. 42–46.

[8] Note sur les plantes fossiles des schistes de Lodéve, par Adolphe Brongniart: Explication de la carte géologique de la France, vol. 2, Paris, 1848, pp. 145-147.

In Pomel's more extended memoir on the Jurassic flora of France, 1849,[1] the following localities are given: Chateauroux (Indre); St. Mihiel (Meuse); Seyssel (Ain); Morestel (Isère); Bourges (Cher); Hettange (Moselle), and Castellane (Basses-Alpes).

In 1848 Bunbury renewed the discussion of the flora of Savoy (Col de Chardonet, Col de Balme, Chamounix, Petit Cœur, etc.), and found twenty-four species of Carboniferous plants in the Turin Museum collected in that district.[2] This discussion was resumed in 1857 by M. A. Sismonda[3] and Élie de Beaumont,[4] and the fossil floras of Tanninge and Col des Encombres were made known.

M. Marie Rouault, in 1850, first called attention to the "problematical organisms" of the Lower Silurian of Brétagne,[5] the nature of which have in recent times been so thoroughly discussed by Saporta, Nathorst, and others. The posthumous works of this author were edited and published in 1883 by M. P. Lebesconte in a fine quarto memoir, in which the localities are carefully given (see infra, pp. 699, 700).

Coquand's "Synopsis," 1860,[6] is merely a catalogue of the fossils of the two Charentes and Dordogne, which are chiefly shells. Only nine species of plants are enumerated,[7] all from his Gardonian stage (Lower Cretaceous), and all but one (*Brachyphyllum Brardii* Brong., from Pialpinson, Dordogne) were from the celebrated bed of the Ile d'Aix.

As was stated in my Sketch of Paleobotany,[8] the Count (now Marquis) Saporta set out on his remarkable phyto-paleontological career with a letter to M. Charles Gaudin, 1860, on the fossil plants of Provence, which the latter published in the Bulletin of the Society of Vaudois.[9] The next year a much fuller report was published of this

[1] Matériaux pour servir à la flore fossile des terrains jurassiques de la France, par Auguste Pomel: Amtl. Ber. über die 25. Versammlung deutscher Naturforscher und Aertzte in Aachen, Aix la Chapelle, 1849, pp. 332-354.

[2] On Fossil Plants from the Anthracite Formation of the Alps of Savoy, by C. J. F. Bunbury: Quart. Jour. Geol. Soc. London, vol. 5, 1849, pp. 130-142.

[3] Sur la constitution géologique de quelques parties de la Savoie, et particulièrement sur le gisement des plantes fossiles de Tanninges, par Ange Sismonda: Comptes rendus Acad. Sci., vol. 45, Paris, 1857, pp. 612-617.

[4] Sur les gisements de fossiles végétaux et animaux du col des Encombres, en Savoie, par Élie de Beaumont: Ibid. pp. 942-952.

[5] Sur une nouvelle formation découverte dans le terrain silurien inférieur de la Bretagne, par Marie Rouault: Bull. Soc. géol. France, 2d series, vol. 7, 1850, pp. 724-744.

[6] Synopsis des animaux et des végétaux fossiles observés dans les formations secondaires de la Charente, de la Charente-Inférieure, et de la Dordogne, par H. Coquand. Marseille, 1860, pp. 1-146, 8°.

[7] Op. cit., p. 40.

[8] U. S. Geol. Survey, 5th Ann. Rept., 1885, p. 383.

[9] Note sur les plantes fossiles de la Provence, par le Comte Gaston de Saporta: Bull. Soc. Vaud., Lausanne, vol. 6, 1860, pp. 505-514.

flora in Gaudin's translation of Heer's general discussion of the flora of Switzerland[1] which forms the latter part of the third volume of his Flora Tertiaria Helvetiæ.

His great work on the Tertiary floras of the southeast of France began to appear in 1862[2] and was completed in 1888. The several floras treated in this work were as follows: The Upper Cretaceous (Senonian) flora of Fuveau, the Eocene flora of Aix, the Oligocene flora of St. Zacharie and Gargas, the Miocene floras of the Marseilles Basin (Saint-Jean de Garguier, Fenestrelle near Aubagne, Montespin near Allauch, Camoins-les-Bains, Marseilles), of Armissan and Peyrac near Narbonne (Aude), of the fish beds of Bonnieux (Vaucluse), of the lignites of Manosque (Basses-Alpes), and of the clays of Marseilles.

In 1863, M. Paul Gervais supplemented Saporta's treatment of the flora of Armissan by a contribution of considerable merit.[3]

Four papers appeared in 1864, bringing to light as many different floras of different ages and in different parts of France, viz, at Aygalades and Viste (Bouches-du-Rhône),[4] and Montpellier[5] in the Quaternary; near Martigues[6] on the Étang de Berre (Bouches-du-Rhône) in the Cretaceous; and a much older formation (Lias of La Caine and Tournay, Oxfordian of Vaches-Noires) in Calvados.[7] In 1866, Saporta contributed an important paper on the Miocene flora

[1] Examen analytique des flores tertiaires de Provence, précédé d'une notice géologique et paléontologique sur les terrains tertiaires lacustres de cette region par M. Philippe Matheron: par le Comte de Saporta [Inséré dans les Recherches sur le climat et la végétation du pays tertiaire, par O. Heer, traduit par Ch. Th. Gaudin, Zurich, 1861, folio, pp. 133–171].

[2] Gaston Comte de Saporta: Études sur la végétation du sud-est de la France à l'époque tertiaire: Annales des sci. nat., botanique: pt. 1, 4th series, vol. 16, 1862, pp. 307–345, pl. xvii; vol. 17, 1862, pp. 191–311, pl. i–xiv; vol. 19, 1863, pp. 5–124, pl. i–xi: pt. 2, 5th series, vol. 3, 1864, pp. 5–152, pl. i–viii; vol. 4, 1865, pp. 5–264, pl. i–xiii: pt. 3, vol. 8, 1867, pp. 5–136, pl. i–xv; vol. 9, 1868, pp. 5–62, pl. i–vii: Supplement I, Révision de la flore fossile des gypses d'Aix, Ibid., vol. 15, 1872, pp. 277–351, pl. xv, xvi; vol. 17, 1873, pp. 5–44, pl. i–v; vol. 18, 1873, pp. 23–146, pl. vi–xviii: Dernières adjonctions à la Flore Fossile d'Aix-en-Provence, Ibid., 7th series, vol. 7, 1888, pp. 1–104.

[3] Sur les empreintes végétales trouvées à Armissan (Aude) et détails géologiques et paléontologiques sur cette localité, par Paul Gervais: Mem. Académie des sciences et lettres de Montpellier, section des sciences, vol. 5, 1863, pp. 309–324, pl. x, xi.

[4] Sur les tufs quaternaires des Aygalades et de la Viste, par G. Saporta: Bull. Soc. géol. France, vol. 21, 1864, pp. 495–499.

[5] Étude des tufs de Montpellier au point de vue géologique et paléontologique, par G. Planchon. Paris, 1864, pp. 1–73, pl. i–iii, 4°.

[6] Communication à propos des empreintes végétales trouvées dans la craie moyenne, aux bords de l'étang de Berre dans la course des Martigues, par Gaston Comte de Saporta: Bull. Soc. géol. France, vol. 21, 1864, pp. 499–502.

[7] Note sur deux végétaux fossiles trouvés dans le Département du Calvados, par J. Morière: Mém. Soc. Linn. Normandie, vol. 14, Caen, 1869, no. 7, pp. 1–4, pl. i, ii.

of Brognon,[1] and Bureau a note on the Carboniferous plant deposit of the Rhune.[2]

In the same year there also appeared what should have been one of the most important works of its time, namely, Watelet's description of the fossil plants of the Paris Basin.[3] The author had access to the accumulated material of half a century, and worked in the time of Saporta, Heer, Unger, and Ettingshausen, but it is generally agreed that he did not prepare a work commensurate with his advantages. For our present purpose, however, it has value, since his specimens seemed to have generally been well labeled, and he has told us the places from which they came. We may profitably enumerate a few of the localities: Jouy, Vaugirard, Montjavoult, Gentilly, Arceuil, Belleu, Courcelles, Lac de Rilly, Sézanne, Montmorency, Acy en Mulcien, Passy, Pontchartrain, Vervins, Lonjumeau, Sables de Bracheux, Meudon, Vailly; and there are many others, most of which are in the immediate vicinity of Paris, but several, as Sézanne, Bracheux, Vervins, and Belleu, at some distance and at a lower horizon.

The flora of the travertines of Sézanne on the Lac de Rilly was made the subject of an important memoir by Saporta, which appeared in 1868,[4] in which he pointed out its earlier age and proposed for it and similar beds the name of Paleocene.

In 1868 were also published Ebray's fossil plants of Beaujolais, department of Lyonnais (Devonian ?),[5] with excellent figures, Saporta's note on vegetable impressions from Saint Gély (Hérault),[6] probably Eocene, and the first of a long and valuable series of contributions by M. Bernard Renault, on the Carboniferous plants of Autun (Saône-et-Loire),[7] a second appearing in 1869,[8] and a third in

[1] Notice sur les plantes fossiles des calcaires concrétionnés de Brognon (Côte-d'Or), par Gaston Comte de Saporta: Bull. Soc. géol., France, 2d series, vol. 23, 1866, pp. 253–280, pl. v, vi.

[2] Note sur les plantes fossiles du dépôt houiller de la Rhune (Basses-Pyrénées), par Ed. Bureau: Ibid., pp. 846–850, pl. xiv.

[3] Description des plantes fossiles du basin de Paris, par Ad. Watelet, Paris, 1866, 264 pp., 4°. Accompagné d'un atlas de 60 planches, 4°.

[4] Prodrome d'une flore fossile des travertins anciens de Sézanne, par Gaston Comte de Saporta. Mém. Soc. géol. France, 2d series, vol. 8, 1868, pp. 289–436, pl. xxii–xxxvi.

[5] Végétaux fossiles des terrains de transition du Beaujolais, par Théophile Ebray. Paris et Lyon, 1868, pp. 1–20, pl. i–xi, 8°.

[6] Note sur les calcaires concrétionnés à empreintes végétales de Saint-Gély (Hérault), par G. de Saporta: Bull. Soc. géol. France, 2d series, vol. 25, 1868, pp. 892–895.

[7] Note sur un pétiole de fougère fossile de la partie supérieure du terrain houiller d'Autun, par B. Renault: Annales sci. nat., botanique, 5th series, vol. 9, 1868, pp. 282–286, pl. xv.

[8] Notice sur quelques végétaux silicifiés des environs d'Autun, par Bernard Rénault: Annales sci. nat., botanique, 5th series, vol. 12, 1869, pp. 161–190. Comptes rendus Acad. sci., vol. 70, 1870, pp. 119–121. Jour. chém. méd., vol. 6, 1870, pp. 199–202.

1870.[1] Renault's researches were deemed of sufficient importance to be considered by the Academy, and Brongniart's report upon them was published in the Comptes Rendus for May 16, 1870.[2]

Grand 'Eury began in 1869 to publish the results of his protracted investigations into the Carboniferous flora of St. Etienne,[3] and laid the manuscript before the Academy in that year for examination, which was not, however, reported upon until 1872.[4]

Saporta's preliminary announcement of his studies in the Pliocene flora of Meximieux (Ain) was also made in 1869.[5]

The paper of Prof. A. F. Marion on the fossil plants of the argillaceous limestones of Ronzon (Haute-Loire), 1872,[6] is a careful piece of work and proves the wisdom which the Marquis Saporta displayed in associating him with himself in much of his later work.

Saporta's next great work, on the Jurassic flora of France, commenced to appear in 1873.[7] Throughout this gigantic undertaking the same painstaking care is displayed, not only in the strictly scientific matter, but also in the points that pertain to good book-making. The only difficulty, therefore, that we experience in giving the localities which have yielded this rich flora is our inability for want of space to record more than a small fraction of the data at hand. It can only be said in general that the leading Rhetic beds in France are at Couche-les-Mines, near Autun, and at Chirac near Mende

[1] Notice sur le gisement de végétaux silicifiés de la partie supérieure du terrain houiller d'Autun, par B. Renault: Bull. Soc. botanique, France, vol. 17, 1870, pp. l–liii.

[2] Rapport sur un mémoire de M. B. Renault, intitulé: Études sur quelques végétaux silicifiés des environs d'Autun; par Adolphe Brongniart: Comptes rendus Acad. sci., Paris, vol. 70, 16 mai, 1870, pp. 1070–1074.

[3] F. C. Grand 'Eury: Observations sur les Calamites et les Asterophyllites. Comptes rendus Acad. sci., vol. 67, 1869, pp. 705–709. Annals Mag. nat. hist., 4th series, vol. 4, 1869, pp. 124–128.

Sur les forêts fossiles du terrain houiller. Comptes rendus Acad. sci., vol. 68, Paris, 1869, pp. 803–805.

[4] Rapport sur un mémoire de M. Grand 'Eury, intitulé: Flore carbonifère du Département de la Loire; par A. T. Brongniart: Comptes rendus Acad. sci., vol. 75, Paris, 1872, pp. 391–411. Annales sci. nat., botanique, vol. 16, 1872, pp. 202—227.

[5] Gaston de Saporta: Sur l'existence de plusieurs espèces actuelles observées dans la flore Pliocène de Meximieux (Ain). Bull. Soc. géol. France, 2d series, vol. 26, 1869, pp. 752–773.

Sur la flore des tufs pliocènes de Meximieux (Ain). Bull. Soc. bot. France, vol. 16, 1869, pp. 117–124.

[6] Description des plantes fossiles des calcaires marneux de Ronzon (Haute-Loire), par A. F. Marion: Annales sci. nat., botanique, 5th series, vol. 14, 1872, pp. 326–364, pl. xxii, xxiii.

[7] Paléontologie française, sér. 2. Végétaux fossiles de la France, terrains jurassiques, par le Comte de Saporta. Vol. 1, introduction générale, Algues, Equisetacées, Characées, Fougères, Paris (1872–1873,) 1873, 506 pp., 8°, atlas, 70 pl,; vol. 2, Cycadées, (1873–1875) 1875, 352 pp., atlas, 58 pl.; vol. 3, Conifères ou Aciculariées (1876–1883), 576 pp., atlas, 98 pl.; vol. 4, Ephédrées, Spirangiées et types proangiospermiques, 1885–1888, pp. 1–176, atlas, pl. i–xxii. (Incomplete.)

(Lozère); those of the Lower Lias are the sandstones of Hettange (Moselle), and the blue limestones of Mende; those of the Upper Lias, or Toarcian, are at St.-Romain, near Lyons, and in the vicinity of Digne (Basses-Alpes); those of the Bajocian or Lower Oolite, are at Vienne, along the Rhone, near Lyons, and at many other points; those of the Bathonian, or Oolite proper, are at Mamers (Sarthe), at Pont-les-Moulins near Baume-les-Dames (Doubs), etc.; those of the Cornbrash are at Etrochey near Châtillon-sur-Seine (Côte d'Or), at Ancy le-Franc (Yonne), and near Rians (Var); those of the Oxfordian are chiefly in the vicinity of Poitiers (Vienne); those of the Corallian, or Coral Rag, are at Saint-Mihiel, near Verdun (Meuse), and at Tonnerre (Yonne); those of the Kimmeridgian are at Creys and Morestel (Isère), at Cirin, the Lac d'Armaille and d'Orbagnoux in the department of Ain, etc.; those of the Portland are at Maninghen near Wimmille (Pas-de-Calais), while traces of Chara have been found in the Purbeck beds of the Department of Doubs.

Two papers by Saporta on the Pliocene flora of the Pas-de-la-Mougudo and St. Vincent in Cantal,[1] appeared in 1873, and three others of a local character in 1874, relating to the plants of the Kimmeridgian fish-beds of Cerin (Ain),[2] of the Molasse (Miocene) of Vaquières (Gard),[3] and to the Quaternary beds of Paris.[4]

In that year, too, Adolphe Brongniart published his last important paper on fossil plants, namely, the preliminary sketch of his researches into the silicified seeds of Saint Etienne,[5] although the great work on that subject which he had projected has been published posthumously by his assistants as far as it was completed at the time of his death in a fine folio volume[6] with twenty plates, sixteen of

[1] Gaston le Comte de Saporta: Sur les caractères propres à la végétation Pliocène, à propos des découvertes de M. J. Rames, dans le Cantal: Bull. Soc. géol. France, 3d series, vol. 1, 1873, pp. 212–232.

Forêts ensevelies sous les cendres éruptives de l'ancien volcan du Cantal, observées par M. J. Rames, et conséquences de cette découverte pour la connaissance de la végétation dans le centre de la France à l'époque Pliocène: Comptes rendus Acad. sci., vol. 76, 1873, pp. 290–294.

[2] Notice sur les plantes fossiles du niveau des lits à poisson de Cerin, par G. Saporta: Ann. Soc. Agric., Lyon, vol. 5, 1873, pp. 87–142, pl. xiv.

[3] Sur les couches supérieures à la Molasse du bassin de Théziers (Gard) et les plantes fossiles de Vaquières, par Gaston de Saporta et A. F. Marion: Bull. Soc. géol. France, 3d series, vol. 2, 1873–'74, pp. 272–287, pl. vii, viii.

[4] Sur l'existence constatée du figuier aux environs de Paris à l'époque quaternaire, par Gaston de Saporta: Bull. Soc. géol. France, 3d series, vol. 2, 1874, pp. 439–443.

[5] Études sur les graines fossiles trouvées à l'état silicifié dans le terrain houiller de Saint-Étienne, par Adolphe Brongniart: Annales sci., nat., bot., Paris, 5th series, vol. 20, 1873, 32 pp., pl. xxi–xxiii; Comptes rendus Acad. sci., Paris, vol. 79, 1874, pp. 343–351, 427–435, 497–500.

[6] Recherches sur les graines fossiles silicifiées, par Adolphe Brongniart, précédées d'une notice sur ses travaux, par J. B. Dumas. Paris, 1881. pp. i–xiv 1–93, pl. a–c, i–xxi, folio, with portrait.

which are colored, prefaced by a notice of his works by M. J. B. Dumas.

The splendid illustrated memoir of Saporta and Marion on the Pliocene flora of Meximieux (Ain),[1] which appeared in 1875, is unquestionably the most important contribution thus far made to the botany of that geological formation.

The researches of M. Renault and Grand 'Eury, chiefly on the rich deposits of Autun, commenced about this time to assume special prominence. We can give only the titles of such of their papers as have a local character.[2]

The most exhaustive work on the coal flora of France was that of M. Cyrille Grand 'Eury on that of the department of the Loire and central France.[3] The localities are stated with far greater minuteness

[1] Recherches sur les végétaux fossiles de Meximieux, par G. Saporta, et A. F. Marion; précédées d' une introduction stratigraphique, par M. Albert Falsan: Nouv. archiv. du Mus. d'hist. nat. Lyon, vol. 1, livraison 4, Lyon, 1876, pp. 131–335, pl. xxii–xxviii.

[2] Recherches sur les végétaux silicifiés d'Autun.

I. Étude du Sigillaria spinulosa, par B. Renault et C. Grand 'Eury: Mém. Acad. sci. savants étrang., vol. 22, No. 9, 1876, pp. 1–23, pl. i–vi.

II. Étude du genre Myelopteris, par B. Renault: Ibid., No. 10, 1876, pp. 1–28, pl. i–vi..

Bernard Renault: Recherches sur les végétaux silicifiés d'Autun et de Saint-Étienne. Des Calamodendrées et leurs affinités botaniques probables. Comptes rendus Acad. sci., vol. 83, Paris, 4 Sept., 1876, pp. 546–549.

Recherches sur quelques Calamodendrées et sur leurs affinités botaniques probables. Ibid., 11 Sept., pp. 574–576.

Nouvelles Recherches sur la structure des Sphenophyllum et sur leurs affinités botaniques. Annales sci. nat., botanique, 6th series, vol. 4, 1877, pp. 277–311, pl. 7–9.

Structure de la tige des Sigillaires. Comptes rendus Acad. sci., vol. 87, Paris, 1878, pp. 114–116.

Structure comparée des tiges des Lépidodendrons, et des Sigillaires. Ibid., pp. 414–416.

Recherches sur la structure et les affinités botaniques des végétaux silicifiés recueillis aux environs d'Autun et de St.-Étienne. Autun, 1878, 216 pp., 30 pl., 8°.

Structure comparée de quelques tiges de la flore carbonifère. Nouvelles Archives Muséum d'hist. nat., Paris, 2d series, vol. 2, 1879, mem., pp. 213–348, pl. x–xvii.

Sur l'organisation du faisceau foliaire des Sphenophyllum. Comptes rendus Acad. sci. Paris, vol. 97, 1883, pp. 649–651.

Recherches sur les végétaux fossiles du genre Astromyelon. Ann. des sciences géologiques, Paris, vol. 17, 1885, art. no. 3, pp. 1–34, pl. vii–ix.

Sur les racines des Calamodendrées. Comptes rendus Acad. sci., vol. 102, Paris, 25 jan., 1886, pp. 227–230.

Sur les fructifications des Calamodendrons. Ibid., 15 mars, 1886, pp. 634–637.

Sur le Sigillaria Menardi. Ibid., 22 mars, 1886, pp. 706–709.

Sur les fructifications mâles des Arthropitus et des Bornia. Ibid., 15 juin, 1886, pp. 1410–1412.

[3] Mémoire sur la flore carbonifère du Département de la Loire et du centre de la France, par F. Cyrille Grand 'Eury Mém. Acad. sci. Inst. France, vol. 24, Paris, 1877, No. 1, pp. 1–624, pl. i–xxiii, A–D. 4°.

than it would be possible to give them here, though most of them are in the vicinity of Saint Etienne. Among the most important may be classed the following: Forez (Loire); Saint-Foy-l'Argentière (Rhône); Brassac and Saint-Eloi (Puy-de-Dôme); Langeac and Chapelle-sous-Dun (Haute-Loire); Blanzy and Autun (Saône-et-Loire); Bruxière-la-Grue, Bert, Commentry, and Doyet (Allier); Queune and Decize (Nièvre); Champagnac and Mauriac (Cantal); Bosmoreau and Ahun (Creuse); Saint-Perdoux (Lot); Decazeville (Aveyron); Carmeau (Tarn); Graissessac (Hérault), Cévennes (Languedoc); Ronchamp (Haute-Saône); Saint-Pierre-la-Cour (Mayenne); Kergogne (Finistère); Littry (Calvados), and Plessis (Manche). The author also gives an elaborate account of all coal floras of the globe, with an attempt at their correlation and comparison with those of France. He had traveled extensively and much of his information is at first hand, but it seems to me (and I have carefully read it all) the work lacks clearness of presentation and of style as well as cogency of reasoning upon the principal problems treated. It has been thoroughly discussed by Brongniart, Saporta,[1] Zeiller,[2] Williamson, Newberry, and others.

Two papers by Saporta on the Quaternary beds of Moret (Seine-et-Marne) on the Celle, 1877,[3] and an Eocene leaf bed at Brives near Puy-en-Velay (Haute-Loire), 1878,[4] should be mentioned here. This latter, quite important, may be passed over, and we come to the researches of Crié in the west of France (Fyé, Mans, Angers, etc., in Sarthe and Maine-et-Loire,) which began in 1877,[5] most of which

[1] Sur la flore carbonifère du Département de la Loire et du centre de la France de M. Cyrille Grand 'Eury, par G. de Saporta: Bull. Soc. géol. France, 3d series, vol. 5, 1877, pp. 365–384.

[2] Détermination des étages houillers à l'aide de la flore fossile. Résumé des travaux de M. Grand 'Eury, par R. Zeiller: Annales des mines, Paris, 7th series, mémoires, vol. 12, 1877, pp. 341–391.

[3] Sur le climat des environs de Paris à l'époque du Diluvium gris, à propos de la découverte du laurier dans les tufs quaternaires de la Celle, par G. Saporta: Assoc. franç. Avanc. Sci., vol. 5, 1876, Paris, 1877, pp. 640–654, pl. xiii.

[4] Essai descriptif sur les plantes fossiles des Arkoses de Brives près le Puy-en-Velay, par le Comte G. de Saporta: Ann. de la Soc. d'agricult., sci., etc., du Puy, vol. 33, Le Puy, 1878, pp. 1–72, pl. i–vi.

[5] L. Crié: Considérations sur la flore tertiaire de Fyé (Sarthe). Bull. Soc. Linn. Normandie, 3d series, vol. 1, 1877, pp. 121–123.

Note sur le Carpolites Decaisneana nob. des Grès Éocènes de la Sarthe. Ibid., pp. 123–125.

Note sur les Morinda de la flore eocène du Mans et d'Angers. Ibid., vol. 2, 1878, pp. 46–50.

Recherches sur la végétation de l'ouest de la France à l'époque tertiaire. Annales sci. géol., vol. 9, Paris, 1877, pp. 1–72, pl. viii–xxii.

Contribution à l'étude, des fougères eocènes de l'ouest de la France. Comptes rendus Acad. sci., vol. 100, Paris, 1885, pp. 870, 871.

Contribution à l'étude des palmiers miocènes de la Bretagne: Ibid., vol. 102, 1886, pp. 562, 563.

relate to Tertiary, but one to Silurian plants, with the comments of Saporta[1] and Heer upon them.

In 1879 the Abbe Boulay published, in the Bulletin of the Natural History Society of Colmar, a little work on the Carboniferous plants of the Vosges,[2] giving the result of his activity in collecting them. The principal localities are Ronchamp, Lalaye, Saint Hippolyte, Lubine, Honcourt, and Hury, several of which are in Alsatia. Nearly one hundred species are enumerated in this paper, most of which are identified with Grand 'Eury's descriptions.

In 1879 M. R. Zeiller, in addition to two illustrated papers on the Permian plants of Corrèze,[3] and on Devonian plants of Caffiers,[4] came out with his important work on the Carboniferous flora of France.[5]

This is a systematic work in which the principal species found in any part of France are described and figured from fresh specimens in the author's hands, with copious synonymy, careful revision, and numerous bibliographical references. The localities are given with great precision under each species, and the geological formation of each bed is distinctly indicated. Among those set down as Permian we find Chambois, Millery, Lally, Autun, and Charmois in Saône-et-Loire, Brive (Corrèze), Bert (Allier), Plan-de-la-Tour (Var), and Lodève (Hérault). The Carboniferous deposits are practically the same as given by Grand 'Eury, and those desiring more extended enumeration may find it in either of these works.

In 1882 Messrs. Fliche and Bleicher made known a fossil flora in the Oolite of Nancy (Meurthe-et-Moselle,)[6] and M. Cornuel a coniferous bed in the Lower Cretaceous of Saint-Dizier (Haute-Marne);[7] and in 1883 M. Parran, president of the Geological Society of France, noted the existence of plants in the lacustrine Tertiaries of Alais (Gard) between Mons and Rousson.[8]

The same year M. P. Lebesconte presented to the Geological So-

[1] Sur une nouvelle découverte de plantes terrestres siluriennes dans les schistes Ardoisiers d'Angers due à M. L. Crié, par G. de Saporta: Ibid., vol. 87, 1878, pp. 767–769.

[2] Recherches de paléontologie végétale sur le terrain houiller des Vosges, par l'Abbé Boulay. Colmar, 1879, pp. 1–47, 8°.

[3] Note sur quelques plants fossiles du terrain permien de la Corrèze, par R. Zeiller: Bull. Soc. géol. France, 3d series, vol. 8, 1879, pp. 196–211, pl. iv, v.

[4] Note sur les empreintes végétales des grès dévoniens de Caffiers, par R. Zeiller: Ibid., pp. 501–504.

[5] Végétaux fossiles du terrain houiller, par R. Zeiller: Explication de la carte géologique de la France, vol. 4, 2d part, 1879, pp. 1–185, Atlas, pl. clix–clxxvi, Paris, 1880. 4°.

[6] Etude sur la flore de l'Oolithe inférieure aux environs de Nancy, par MM. Fliche et Bleicher: Bull. Soc. sci. nat. Nancy, 14e année, 13e fascicule, 1881, Nancy, 1882, pp. 1–49, and plate.

[7] Note sur les cônes de Pinus elongata découverts à Saint-Dizier (Haute-Marne), et sur des cônes de cèdre du sable vert de la Houpette (Meuse), par J. Cornuel: Bull. Soc. géol. France, 3d series, vol. 10, No. 4, 1882, pp. 259–263, pl. vii.

[8] Coupe des terrains tertiaires lacustres entre Rousson et Mons, arrondissement d'Alais (Gard), par M. Parran: Ibid., vol. 12, 1883, pp. 131–137.

ciety of France in a fine folio volume the posthumous works of Marie Rouault on the Lower Silurian organisms of Brittany, with his own views on Rhysophycus and Cruziana.[1] The problematical forms were chiefly found in the department of Ille-et-Vilaine at Pontréan, Merquelande near Janzé, Paimpont, Plélan, Saint-Thurial, Laillé, Bagaron, Saint-Aubin-du-Cormier, and Redon, though some came from Soulvache, Sion, Châteaubriant, and Saint-Aubin-des-Châteaux in the department of Loire-Inférieure, and from Bagnoles, department of Orne.

Considerable attention has recently been paid to the development of the fossil floras of the north of France, by Fliche[2] in the Rhetic about Nancy; by Zeiller[3] and Six[4] in the Carboniferous of Pas-de-Calais and Nord; by Gosselet in the Eocene sands of Ostricourt at Artres near Valenciennes, Lewarde and Buignicourt near Douai in Nord, and at Proix near Guise in Aisne,[5] and by Stanislas Meunier[6] and Charles Barrois[7] on the Bilobites and Nereites of Boulogne-sur-Mer and Equihen in the department of Pas-de-Calais, Bagnoles (Orne), and Bourg-d'Oueil (Haute-Garonne).

Next may be noted a series of papers in the Comtes Rendus of the Paris Academy, 1884–1887, relating to some interesting collections made by M. Fayol in the Carboniferous of Commentry (Allier),[8]

[1] Présentation à la Société géologique des œuvres posthumes de Marie Rouault, par P. Lebesconte, suivies d'une note sur les Cruziana et Rysophycus: Ibid., vol. 11, 1883, pp. 466–472.

Œuvres posthumes de Marie R uault; suivies de Les Cruziana et Rysophycus, connus sous le nom général de Bilobites, sont-ils des végétaux ou des traces d'animaux, par M. Rouault and P. Lebesconte. Oberthur, 1883, pp. 1–73, pl. i–xxii, folio.

[2] Note sur la flore de l'étage rhétien aux environs de Nancy, par P. Fliche: Bull. Soc. Sciences nat., Nancy, 2d series, vol. 8, fasc. xix, 1886, pp. 150–153.

[3] Note sur les Fougères du terrain houiller du Nord de la France, par R. Zeiller: Bull. Soc. géol. France, 3d series, vol. 12, 1883, pp. 189–204.

[4] Les Fougères du terrain houiller du Nord, par Achille Six: Annales Soc. géol. du Nord, vol. 11, Lille, 1884, pp. 201–212.

[5] Quelques remarques sur la flore des sables d'Ostricourt, par J. Gosselet: Ibid., vol. 10, Lille, 1883, pp. 100–106, pl. v.

[6] Sur quelques empreintes problématiques des couches boloniennes du Pas-de-Calais, par Stanislas Meunier: Bull. Soc. géol. France, vol. 14, 1886, pp. 564–568, pl. xxix, xxx.

[7] Sur les ardoises à Nereites de Bourg d'Oueil (Haute-Garonne), par Charles Barrois: Annales Soc. géol. du Nord, vol. 11, 1884, pp. 219–226, pl. iii.

[8] B. Renault et R. Zeiller: Sur un nouveau genre de graines du terrain houiller supérieur. Comptes rendus Acad. sci., Paris, vol. 99, 7 juillet, 1884, pp. 56–58.

Sur l'existence d'Astérophyllites phanérogames: Ibid., 22 déc., 1884, pp. 1133–1135.

Sur un Equisetum du terrain houiller supérieur de Commentry: Ibid., vol. 100, 5 jan., 1885, pp. 71–73.

Sur des mousses de l'époque houillère: Ibid., 2 mars, pp. 660–662.

Sur un nouveau type de Cordaitée: Ibid., 23 mars, pp. 867–869.

Sur les troncs de fougères du houiller supérieur: Ibid., vol. 102, jan. 4, 1886, pp. 64–66.

Sur quelques Cycadées houillères: Ibid., 8 feb., pp. 325–328.

Sur l'attribution des genres Fayolia et Palæoxyris. Ibid., vol. 107, 17 déc., 1888, pp. 1022–1025.

all of which may be regarded as preliminary to their great work on this flora, the first part of which, prepared by M. Zeiller, has already appeared.[1] In this work, so far as published, a very large number of species have been described and superbly illustrated in a folio atlas of forty-two plates. No attempt can, of course, be here made to review this magnificent production, which can only be mentioned in terms of the highest praise. Most of the plants are from the coal mines in the immediate vicinity of Commentry, and the particular strata, mines, cuts, etc., are carefully stated. A few specimens, however, are figured from Terrasson (Dordogne), Blanzy (Saône-et-Loire), Doyet (Allier), and La Machine near Decize (Nièvre).

We may conveniently mention here several short papers by the last named author, whose titles sufficiently indicate their geographical character,[2] as also Vélain's note on the Permian flora of the Vosges,[3] one by Boule on some Tertiary plants discovered at Malzieu in the department of Lozère,[4] and a third by Morière on a new cycad from Montigny (Calvados).[5]

The Comptes Rendus of the Paris Academy for the years 1886 and 1887 contain summaries of more or less important papers by Crié[6] on the floras of Bretagne and western France, in which the Eocene flora of that region is compared with that of Saxony and Dalmatia, and the Oolitic flora with that of England.

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[1] Études sur le terrain houiller de Commentry, par Ch. Brongniart, H. Fayol, De Launay, Stanislas Meunier, B. Renault, Sauvage, et R. Zeiller: Bull. Soc. Industrie Minérale, Saint Etienne, 3d series, vol. 2, livraison 2. Saint Etienne, 1888; Livre 2, Flore fossile, par B. Renault et R. Zeiller. Première Partie par R. Zeiller, pp. 1–366, 8°. Atlas: Soc. Ind. Min., 3d series, vol. 2, livrais. 2, Livre 2, Flore Fossile, par B. Renault et R. Zeiller. Saint Etienne, 1888, pp. 1–10, pl. i–xlii, folio.

[2] R. Zeiller: Note sur la flore et sur la niveau relatif des couches houillères de la Grande'Combe (Gard): Bull. Soc. géol. France, 3d series, vol. 13, 1884, pp. 131–149, pl. viii, ix.

Détermination, par la flore fossile, de l'âge relatif des couches de houille de la Grand-Combe: Comptes rendus Acad. sci., vol. 100, Paris, 1885, pp. 1171–1172.

Note sur la flore des lignites de Simeyrols: Bull. soc. géol. France, 3d series, vol. 15, 1887, pp. 882–884.

Sur la présence dans le grès bigarré des Vosges, de l'*Acrostichides rhombifolius*, Fontaine. Ibid., vol. 16, 1888, pp. 693–699.

[3] Le Permien dans la région des Vosges, par Charles Vélain: Bull. Soc. géol. France, 3d series, vol. 13, No. 6, 1885, pp. 536–564.

[4] Note sur le Bassin tertiare de Malzieu (Lozère), par M. Marcellin Boule: Ibid., vol. 16, 1888, pp. 341–345.

[5] Note sur une nouvelle Cycadée du Lias, par M. Morière: Bull. Soc. Linnéenne de Normandie, 4th series, vol. 1, Année 1886–87, Paris, 1888, pp. 125–134, pl. i–iii.

[6] Louis Crié: Recherches sur la végétation miocène de la Bretagne: Comptes rendus Acad. sci., vol. 103, Paris, 1886, No. 4, pp. 290–292.

Sur les affinités des fougères éocènes de la France occidentale et de la province de Saxe: Ibid., No. 10, pp. 487–489. [Note continued on p. 702.]

A very important work on the fossil plants of the coal basin of Valenciennes, by R. Zeiller,[1] has recently been published by the French Department of Public Works, the atlas of which forms a volume of ninety-four plates, with figures of a large number of species of coal plants drawn by Ch. Cuisin. This beautiful series of fossils has been obtained from the coal mines of Anzin, Aniche, Vicoigne, Escarpelle, Douchy, in the department of Nord; those of Azincourt, Nœux, Lens, Liévin, Bully-Grenay, Hardinghen, Meurchin, Ferfay, Dourges, Courrières, Annœullin, Marles, Auchy-au-Bois, Bruay, Carvin, Courcelles-les-Lens, Fléchinelle, in the department of Pas-de-Calais, and from a number of localities in Belgium which will be enumerated when treating of that country (infra, p. 777).

Finally may be mentioned a valuable memoir by M. Ed. Bureau, of the Paris Museum of Natural History, on certain fossil plants, chiefly monocotyledonous, from the coarse limestone of the Paris basin.[2] This paper derives its chief importance from being founded upon certain rare specimens not previously studied, which the author discovered in the botanical gallery of the Museum and has thus brought to light.

SPAIN.

Little, indeed, is known of the fossil flora of Spain, there being few active workers in this department in that country.

Brongniart[3] mentions receiving *Pecopteris dentata* from Sama, north of Oviedo in Asturias, collected by Le Play, and Lindley and Hutton described one fossil plant from Spain, a very perfect pine cone, which they were unable to distinguish from that of *P. Canariensis* Lambert, and they actually described it under that name,[4] stating that "it was found in the year 1832 by Colonel Silvertop in a deposit of indurated whitish marle, containing powerful beds of sul-

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[Continuation of note on page 701.]

Sur les affinités des flores oolithiques de la France occidentale et de l'Angleterre. Ibid., No. 11, p. 528–530.

Contributions à l'étude des flores tertiaires de la France occidentale et de la Dalmatie. Ibid., No. 16, pp. 699–701.

Sur les affinités des flores éocènes de la France occidentale et de la province de Saxe. Ibid., No. 19, pp. 894,895.

Contribution à l'étude des fruits fossiles de la flore éocène de la France occidentale. Ibid., No. 22, pp. 1143,1144.

[1] Études des gîtes minéraux de la France. Bassin houiller de Valenciennes. Description de la flore fossile, par R. Zeiller. Ministère des Travaux publics, Paris, 1888. Text pp. 1–731, 1 col. map folio. Atlas, Dessins de Ch. Cuisin, Paris, 1886, 6 pp., 94 pl., folio.

[2] Études sur la flore fossile du calcaire grossier Parisien, par M. Ed. Bureau: Mémoires publiés par la Société Philomathique à l'occasion du centenaire de sa fondation, 1788–1888. Paris, 1888, pp. 235–265, pl. xxii, xxiii, 4°.

[3] Histoire des végétaux fossiles, vol. 1, 1828, p. 346.

[4] Fossil Flora of Great Britain, vol. 3, p. 85, pl. clxxxii.

phur, near the town of Hellin, in the province of Murcia," which they regarded as of Tertiary age.

Later (1845) MM. Verneuil and d'Archiac[1] published the first Carboniferous plants from Asturias obtained at Arnas and Ferroñes.

Of native workers Sr. de Areitio y Larrinaga seems to have been the earliest to grapple seriously with the subject, although Prado[2] in 1864 had determined a few species. The first of Areitio's papers, published in 1873,[3] consists of a bare list of twenty-nine species of Carboniferous plants and one Cretaceous species from Reocin (Santander), collected by a number of geologists and submitted to him for determination. The Carboniferous localities given are: Puerto de Leitariegos, Matallana, road from Arlanza to Noceda, Orzonaga, Toreno, Puerto Manzanal, Brañuela, all in Leon; San Juan de las Abadesas, in Gerona; and Espiel and Belmez in Cordova, besides points in Asturias.

The second paper, published one year later,[4] besides describing one new species (*Xilomides eradiatus*) from the Carboniferous of Espiel and Belmez gives tolerably full synonymy, contains some explanatory remarks, and enumerates one hundred and ten species from various parts of the kingdom and from several geological horizons, though chiefly Carboniferous. The following localities are Silurian and yielded the characteristic Silurian genus Rysophycus, Bythotrephis, and Cruziana (Biolibites, Fræna, etc.): Guadalmes and Almaden in Ciudad Real, Puebla de la Mujer Muerta, and el Atazar in Madrid. The following Carboniferous localities occur in addition to those given in the previous paper: Cangas de Tineo, el Roton (puente de San Andrés), Quiros, Sama, Termino de Pajares, Ferroñes, Mieres, Sorriba, Ciaño, Langreo, Forcada, Ballina de Sotrondio, Cerredo, valley of the Aller, and Santo Firme, in Asturias; Villanueva del Rio, and el Viar near Cantillana, in Seville; Sabero, Canteras de Villablin, Villajer, and la Magdalena, in Leon; Barruelo, la Florida, Orbó, Otero de las Dueñas, Vergaño, Guardo, Vegacervera, Rio Oscuro, lake Lomas, and San Felices, in Palencia; San Adrian de Juarros, in Búrgos; Coto de la Seca, Aurelio, valley of the Turon, and San Martin del Rey, in Salamanca; Retienla, arroyo Palencar, Tortuero, and Valdesotos, in Guadalajara; Puerto Llano and el Viso, in

[1] Note sur les fossiles du terrain paléozoique des Asturies, par MM. Édouard Poullitier de Verneuil et Étienne Jules de Archiac: Bull. Soc. géol. France, 2d series, vol. 2, 1844–1845, pp. 458–485, pl. xiii–xv.

[2] Descripcion física y geológica de la Provincia de Madrid, por Casiano de Prado: Junta general de estadística, Madrid, 1864, xvi, 219 pp., 4°.

[3] Materiales para la flora fósil española, por Alfonso de Areitio y Larrinaga: Anales Soc. españ. hist. nat., vol. 2, 1873, pp. 379–383.

[4] Enumeración de plantas fósiles españolas, por Alfonso de Areitio y Larrinaga: Ibid., vol. 3, 1874, pp. 225–259.

Ciudad Real; Berlanga in Badajoz; Fuente Ovejuna and arroyo del Albardado in Cordoba; and Surroca in Gerona.

Two localities are set down as Triassic: Valle de la Cierva (Cuenca), and Javacin (Morata de Jalon, Zaragoza), and one as Cretaceous: Reocin (Santander), which last was treated as Carboniferous in the previous paper.

Perhaps the most interesting part of the paper is that referring to Tertiary plants, which were found at Teruel in Aragon; at Hellin in Albacete, and at the sanctuary of Santa Eulalia in the mountains of Totana, Baños de Mula, and Cabezos de la Trisca in Múrcia, and at Zarra in Valencia. Thirteen Tertiary species are named from these localities, including one Chara, two conifers, and ten dicotyledonous forms, all of which are identified with species previously described from the European Tertiaries. Unfortunately no figures of these Spanish fossil plants are published.

M. Grand 'Eury, in 1877, had received quite a collection made by Gregorio de Aurre at Langreo, Santo Firme, and Arnao. He had also received from M. Reydellet a collection made at Puerto Llano, in the province of Ciudad Real, and MM. Héral, Estival, and Breuilhes had prior to that date sent to the School of Mines at Paris numerous specimens from the Carboniferous deposits at Belmez, near Cordoue, Andalusia, in the Sierra-Morena, to which Grand 'Eury had access. He had also seen specimens from San Juan de la Abadesas, Gerona (Flore Carbonif. de la Loire, pp. 429–433).

Reydellet, in a paper published in 1875,[1] enumerates some of the forms from Puerto Llano, determined in part at Madrid and in part by Messrs. Zeiller and Grand 'Eury.

M. Reydellet's collection contained a new species of Spirophyton from the Silurian or Devonian of Almaden, to which M. Bayan called attention in 1874.[2]

Don Carlos Castel, in 1878, described a coniferous plant obtained by him in a Triassic deposit (probably Buntersandstein) between Campillo and Molina, in the province of Guadalajara,[3] which was identified by Sr. Laguna as *Albertia elliptica* Schimp.

Barrois, in his large work on the Geology of Asturias, 1882,[4] which

[1] Sur le terrain houiller de Puertollano (Espagne), par M. Reydellet: Bull. Soc. géol. France, 3d series, vol. 3, 1875, pp. 160–165.

[2] Sur la présence du genre Spirophyton dans les terrains paléozoïques de l'Espagne, par M. Bayan: Ibid., vol. 2, 1874, pp. 170–172.

[3] Una conifera del Trias, por Don Carlos Castel: Anales Soc. españ. hist. nat., vol. 7, Madrid, 1878, pp. 277–279.

[4] Recherches sur les terrains anciens des Asturies et de la Galice, par Charles Barrois: Mém. Soc. géol. du Nord, vol. 2, No. 1, Lille, 1882, 630 pp.; atlas, pl. i–xx. (See pp. 551–570.)

Investigaciones sobre los terrenos antiguos de Asturias y Galicia, por Charles Barrois: Extracto de J. Egozcue, in Bol. Comisión del Mapa geol. de España, vol. 10, Madrid, 1883, pp. 177(1)–341 (165).

must have been prematurely dated, describes Bilobites and Scolithus from the Silurian of Arniella, Cadebo, Fontaneira, Caroges, Canero, Caba Busto, and other localities in that province; he also gives lists of all the plants found at different horizons in the Carboniferous series, which were determined by Zeiller[1] and Grand 'Eury. They were found in the basin of Sama de Langreo, on the river Nalon at Santa Ana, Ciaño, Felguera, Mosquitera, Carbayin, in the basins of Ferroñes, of Arnas, and of Tineo.

No plants are figured in the atlas of this work. A Spanish translation of this paper may be found in the Bulletin of the Commission.[2]

In the catalogue of Spanish fossils in the mineralogical exhibition of Madrid in 1883, prepared by Sr. Egozcue,[3] plants are represented from the Silurian, Carboniferous, and Triassic, but the localities are for the most part the same as those already enumerated. The following, however, are additional: *Silurian*—Sierra de Carrascalejo and Villuercas (Cáceres); Redipollos, and San Pedro de los Burros (Leon); Herrera, Suesme, Villafeliche, and Santa Cruz de Atea (Zaragoza). *Carboniferous*—Erill-Castell (Lérida); Venta Velasco (Leon); Rubagon and Revilla (Palencia); Arroyo de la Ermita (Córdoba). *Triassic*—La Cierva, Henarejos (Cuenca).

Plants from the Carboniferous and Miocene of the province of Gerona are enumerated by Vidal[4] in 1886, but no localities are stated.

Attention should also be called to the papers of Rérolle and Depéret on the Miocene plants of Cerdagne,[5] and as some of these were collected at Bellver and Sanavastre, in the Spanish portion, they require to be mentioned here.

PORTUGAL.

In Portugal a number of beds have been discovered yielding fossil plants, the first descriptive paper being by Bunbury;[6] later elaborated

[1] Note sur la flore houillère des Asturies, par R. Zeiller: Mém. Soc. géol. du Nord, vol. 1, Lille, 1882, No. 3, pp. 1–22.

[2] Notas acerca de la flora hullera de Asturias, por R. Zeiller: Traduction por Justo Egozcue, in Bol. Comisión del Mapa geol. de España, vol. 11, 1884, pp. 159–182 (1–24).

[3] Catalogo de los fósiles presentados en la Exposición de mineria en Madrid en 1883, por Justo Egozcue: Ibid., vol. 10, 1883, pp. 119–154 (27–62).

[4] Reseña geológica y minera de la Provincia de Gerona, por D. Luis M. Vidal: Boll. Comisión Mapa geol. de España, vol. 13, No. 2, 1886, pp. 1–172.

[5] Études sur les végétaux fossiles de Cerdagne, par L. Rérolle: Rev. Sci. nat. Montpellier, 3rd series, vol. 4, 1884–'85, Nos. 2, 3.

Note sur la géologie et sur les mammifères fossiles du bassin lacustre miocène supérieur de la Cerdagne, par Ch. Depéret et L. Rérolle: Bull. Soc. géol. France, 3d series, vol. 13, No. 6, 1885, pp. 488–506, pl. xvii, xviii.

[6] On the Carboniferous and Silurian Formations of the neighborhood of Bussaco, in Portugal, by Senhor Carlos Ribeiro, with notes and a description of the Animal Remains by Daniel Sharpe, J. W. Salter, and T. Rupert Jones; and an account of the vegetable remains by Charles J. F. Bunbury: Quart. Jour. Geol. Soc. London, vol. 9, 1853, pp. 135–163, pl. vii–ix. (Bunbury, pp. 143–147, pl. vii.)

more thoroughly by Gomes,[1] Geinitz[2] and Feistmantel,[3] all relating to the Carboniferous formation. The Mesozoic and Tertiary plants, early collected by Ribeiro, were determined by Heer and the results published in 1881.[4]

Ribeiro's specimens, and others previously collected by Choffat,[5] were obtained from Rhetic beds at Rapozeira and Vacariça near Pego and Coimbra (Busaco), province of Beira; from the Lias (Toarcian) at Porto de Moz, and Casal Comba, north of Lisbon; from the Oolite (Dogger, Bajocian), at Verride Porto de Moz, Revelles, Quiaios, and Thomar, north of the Tagus in the province of Estremadura and not very far from Lisbon, at Cape Mondego and Soure in the province of Beira, and at Sagres in the province of Algarne in the extreme south; from the Malm (Wealden ?) at São Louiz (peninsula of Setubal), São Pedro near Cintra, and at the tunnel of Chão de Maçans, province of Estremadura and south of Lisbon, as well as at Cape Mondego; from the Cretaceous (Neocomian or perhaps Wealden) at Almargem near Bellas, and the Valle de Lobos near Sabugo, on the road from Lisbon to Mafra (Estremadura); and finally, from the Tertiary (Miocene) at Agambuja (basin of the Tagus, lat. 39°), Bacalhao and the Portella road near Quinta da Cruz, and also at Campo Grande, all of which places are only a few miles northeast or north of Lisbon in the province of Estremadura.

To the above-named Cretaceous localities may now be added, through the continued activity of M. Choffat, of the Portuguese Geological Survey, those of Nazareth, Buarcos, and Alcantara, in the Upper Cenomanian, and those of Padrão and Busaco, in the Lower Cenomanian or Carentonian, specimens from which places were sent to the Marquis Saporta and made the subject of a short paper in the Comptes Rendus for 1888.[6]

[1] Flora fossil do terreno carbonifero das visinhanças do Porto, Serra do Bussaco, e Moinho d'Ordem proximo a Alcacer do Sal, por Bernardino Antonio Gomes: Comm. geol. de Portugal, vegetales fosseis, I, Lisboa, 1865, 44 pp., 6 pl. (Portuguese and French).

[2] Beiträge zur älteren Flora und Fauna, von Dr. H. B. Geinitz. I, Die fossile Flora in der Steinkohlen-Formation von Portugal nach B. A. Gomes: Neues Jahrbuch für Mineral., 1867, pp. 273–290, pl. iii.

[3] Kleine paläontologisch-geologische Mittheilungen, von Ottokar Feistmantel. Ueber Steinkohlenpflanzen aus Portugal: Lotos, vol. 25, October, 1875, pp. 149–155.

[4] Contributions à la flore fossile du Portugal, par Oswald Heer: Section des travaux géologiques du Portugal, Lisbonne, 1881, pp. 1–51, pl. i–xxviii, folio.

[5] Paul Choffat: Étude stratigraphique et Paléontologique des terrains jurassiques du Portugal. 1st liv., Le Lias et le Dogger du Nord du Tage: Section des travaux géologiques du Portugal, Lisbonne, 1880, 72 pp., 4°.

[6] Sur les Dicotylées prototypiques du système infra-crétacé du Portugal. Note de M. G. de Saporta: Comptes rendus Acad. Sci., vol. 106, Paris, 1888, No. 22, 28 mai, pp. 1500–1504.

The extensive series of Bilobites and other Silurian organisms that formed the subject of Delgado's prolonged studies and memoirs[1] were obtained at Portas-de-Rodam near Villa Velha, on the right bank of the Tagus; Penha-Garcia, Loredo, Sernadas-do-Galhano; Pé-do-Viso, Cassemes, Zuvinhal, Pedorido, Luso, Goes, Penacova, Portella-de-Oliveira, Amendoa, and Aguiar-de-Sousa, in the province of Beira; at Freixo-d'Espada-a-Cinta, Moz near Torre-de-Moncorvo, Brucó between Villar-de-Rei and Lagoaça, Poiares, Ligares, Estevaes, etc., in the province of Tras-os-Montes; at or near Sardoal and Maçao in Estremadura; on Mount San Miguel near Niza, in Alemtejo; on the Serra Colorada in Barrancas; and on the Serra de Santa Justa, near Vallonga, in the province of Minho.

ITALY.

One of Faujas de Saint-Fond's early papers, 1807,[2] related to supposed palm-wood and seeds found in the tufas of Montecchio Maggiore, in the province of Vicenza, Venetia, and this is perhaps the earliest mention of fossil plants in Italy. He was also the first to call attention to the rich beds of Monte Bolca in Verona, which he did in 1815 in a paper already cited (supra, p. 690), treating them somewhat elaborately in two subsequent papers in 1819 and 1820.[3]

Brocchi[4] states that he found among the manuscripts of Giovanni Targioni an extensive work on the fossil fucoids of Tuscany, chiefly from the Galestro limestones within seven miles of Florence.

Rozan's Conjecture sur les plantes fossiles de Monte Bolca, 1823,[5] a paper which I have not been able to consult, is the next notice I find of the celebrated Eocene beds of that place.

[1] J. F. Nery Delgado: Sobre a existencia do terreno siluriano no Baixo Alemtejo. Terrenos paleozoicos di Portugal, Lisboa, 1876, pp. 1–35, [French, pp. 1–38,] 4 pl.; Mem. Acad. sci. Lisboa, new series, vol. 5, Lisbon, 1878, pt. 2, No. 2, pp. 1–56, pl. i, ii, with map.

Note sur les échantillons de Bilobites envoyés à l'exposition géographique de Toulouse. Bull. Soc. d'hist. nat., Toulouse, vol. 18, 1884, pp. 126–131, pl. i, ii.

Étude sur les Bilobites et autres fossiles des quartzites de la base du système silurique du Portugal: Section travaux géol. du Portugal, Lisbonne, 1886, pp. 1–113, pl. i–xliⁱ, folio. Supplement, Lisbonne, 1888, pp. 1–78, pl. i–viii, viii*a*, ix, x. (Portuguese and French).

[2] Faujas de Saint-Fond: Notice sur une portion de tronc de palmier trouvée à 60 pieds de profondeur, au milieu d'un tuffa ou brèche volcanique de Montecchio Maggiore dans le Vicentin. Annales Muséum d'hist. nat., Paris, vol. 9, 1807, pp. 388–391.

[3] Faujas de Saint-Fond: Sur quelques-unes des plantes fossiles qu'on trouve dans les couches calcaires de Monte Bolca, dans le Véronnais, et de Vestena Nova, dans le Vicentin, dans les mêmes gisements où sont les poissons fossiles. Mém. Muséum d'hist. nat., Paris, vol. 5, 1819, pp. 162–167, pl. xii.

Notice sur quelques plantes fossiles qu'on trouve dans les couches calcaires du Monte Bolca. Annales générales des sci. phys. etc., vol. 4, Paris, 1820, pp. 45–50.

[4] Biblioteca Italiana, vol. 10, 1818, p. 206.

[5] Conjecture sur les plantes fossiles de Monte Bolca par M. Rozan; (dans les "Essais de littér. et d'hist. nat.", avec la traduct. ital. par Morcaldi); Naples, 1823, xii, 122 pp., 4°.

Procaccini-Ricci's labors in the Upper Miocene beds of Sinigaglia, Province of Ancona, were first made known in a somewhat extended paper published at Rome in 1828,[1] discussing the geological and mineralogical conditions and laying special stress upon the leaf impressions (filliti), which abound in the strata of that place. This was followed by his two remarkable series of letters on the same subject, addressed to Lodovico Bianchini[2] and Professor Alessandrini,[3] 1838–1840.

Viviani's letter to Pareto on the Tertiary gypsum beds of Stradella in Lombardy, which was published in 1833,[4] was accompanied by figures that have been much quoted by later writers.

Three other papers, one by Philippi, who found Amphitoites on the island of Ischia, 1837,[5] one by Savi, who observed vegetable impressions in the Carboniferous of Monte Bamboli, 1843,[6] and one by Moretti, Visiani, and Parlatore on the leaf-prints of Montescano, 1844,[7] together with two by Tornabene on the recent impressions found in the lavas at the foot of Mount Etna,[8] bring the record down to the year 1850 and the era of Massalongo and Zigno.

Massalongo's papers are very numerous and relate to a number of

[1] Osservazioni sulle gessaje del territorio Sinigagliesi, sui filliti, gl'ictioliti ed altri oggetti contenuti nelle medesime, fatte da Vito Procaccini-Ricci. Rome, 1828, 102 pp., 5 pl., 8°.

[2] Vito Procaccini-Ricci: Lettera (I) al Cav. Lodovico Bianchini sulle filliti Sinigagliesi. Il Progresso, Scienze, Lettere, etc., quader. xxx, Napoli, 1836, pp. 202–206.

Lettera (II) al Cav. Lodovico Bianchini sulle filliti Sinigagliesi. Ibid., quader. xxxiv, Napoli, 1837, pp. 238–247.

Lettera (III) al Cav. Lodovico Bianchini sulle filliti Sinigagliesi. Ibid., Napoli, 1838.

Lettera (IV) al Cav. Ludovico Bianchini sulle filliti Sinigagliesi. Ibid., quader. xlii, Napoli, 1838, pp. 197–214.

[3] Vito Procaccini-Ricci: Lettera prima a Prof. Ant. Alessandrini, sull' anatomia delle filliti Sinigagliesi. Nuovi Annal. di Sci. nat., Ann. I, vol. 1, Bologna, 1838, pp. 190–213, pl. iv, v.

Lettera seconda al Prof. Alessandrini sull' anatomia delle filliti Sinigagliesi. Ibid., Ann. I, vol. 2, Bologna, 1838, pp. 14–36, pl. i, ii.

Lettera terza al Prof. Alessandrini sui vegetabili delle colline Sinigagliesi. Ibid., Ann. II, vol. 4, Bologna, 1840, pp. 127–135.

[4] Lettre à M. Pareto sur les restes de plantes fossiles trouvés dans les gypses tertiaires de la Stradella, près de Pavie, par Vinc. Viviani: Mém. Soc. géol. France, vol. 1, part 1, no. 7, 1833, pp. 129–135, pl. ix–xi.

[5] Ueber die subfossilen Seethier-Reste von Pozzuoli bei Neapel und auf der Insel Ischia, von R. A. Philippi: Neues Jahrbuch für Mineral., 1837, pp. 285–292, pl. iii, figs. 4, 5.

[6] Impronte vegetabili osservate nel terreno carbonifero di Monte Bamboli, de Pietro Savi: Miscel. med. chir., Pisa, 1843, pt. 2, pp. 40–44.

[7] Moretti, Visiani e Parlatore: Sulle filliti di Montescano; Atti d. sesta riun. d. scienz. ital., tenuta in Milano nel settembre, 1844, Milano, 1845, pp. 512, 526.

[8] Francesco Tornabene: Intorno ad alcuni resti di vegetabili che trovansi nella formazione dell' argilla presse Catania. Atti Accad. Gioenia sci. nat. Catania, 2d series, vol. 2, 1845, p. 380.

Sopra i tufi di Fasano e Leucatia al piede dell' Etna, con fossili vegetali. Rend. R. Acc. d. sci. di Napoli, Anno V, Napoli, 1846, p. 394.

plant beds in different parts of Italy, but his chief attention was directed to the development of those of Monte Bolca, and Sinigaglia. His prelude to the flora of Monte Bolca[1] appended to his geognostic sketch of the valley of the Progno, 1850,[2] is a descriptive paper of merit, but unfortunately, like too many of Massalongo's papers, without illustrations. His monograph of the Nereids, 1855,[3] I have not yet seen, and can only presume that it treats of the numerous rather problematical forms so abundant at the base of the Eocenes of most countries. The preliminary account of new discoveries there, published in the Neues Jahrbuch für Mineralogie, etc., for 1857,[4] gives a list of additions made to that flora since the appearance of the Præludium. These and many others are described in his Palæophyta Rariora, 1858,[5] the remainder of which is devoted to the somewhat higher (Oligocene) floras of Vegroni in Verona and Chiavon in Vicenza.

His flora of Vicenza appeared in 1851,[6] a large octavo pamphlet with systematic Latin descriptions, to which is appended his Prospetto of the Tertiary flora of Europe, enumerating in systematic order all the plants known to him at that time, which was also published in separate form in 1852.[7] The principal localities in Vicenza are Salcedo and Chiavon.

One locality in Lombardy,[8] a number in Verona,[9] at Monte Spilecco,

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[1] Præludium floræ Bolcensi. [This title covers the systematic part (pp. 21–77) of the Schizzo geognostico, by Abramo Massalongo, 1850.]

[2] Abramo Massalongo: Schizzo geognostico sulla valle del Progno o torrente d'Illasi, con un saggio sopra la flora primordiale del Monte Bolca. Verona, 1850. 77 pp., 8°.

[3] A. Massalongo: Monografia delle Nereidi fossili del Monte Bolca. Verona, 1855, 55 pp., 6 pl., 8°.

[4] Vorläufige Nachricht über die neueren paläontologischen Entdeckungen am Monte Bolca, von A. Massalongo: Neues Jahrbuch für Mineral., 1857, pp. 775–778.

[5] A. Massalongo: Palæophyta rariora formationis tertiariæ agri Veneti. Atti Adun. I. R. Ist. veneto sci., etc., 1857–'58, pp. 729–793.

[6] A. Massalongo: Sopra le piante fossili dei terreni terziarj del Vicentino, Osservazioni, etc. Padova, 1851, 264 pp., 8°.

[7] A. Massalongo: Conspectus floræ tertiariæ orbis primævi. Patavii, 1852, pp. 1–37, 12°.

[8] A. Massalongo: Nota sopra due frutti fossili del bacino lignitico di Leffe nel Bergamasco. Nuovi annali sci. nat., vol. 6, Bologna, 1852, pp. 253–258, pl. iii.

[9] A. Massalongo: Sopra un nuovo genere di pandanee fossili della Provincia Veronese. Dissertazione. Mem. Accad. Agric., etc., vol. 29, Verona, 1853, pp. 187–207, pl. i–iv.

Descrizione di alcuni fuchi fossili della calcaria del Monte Spilecco nella Provincia Veronese. Rivista Period. I. R. Accad. Padova, vol. 4, 1855–'56, pp. 207–233, pl. i–vi.

Nuova scoperta di pianti fossili nelle Provincie Veronesi. Notitizie scientifiche dell' Ibis, Anno I, Verona, 1856–'57 (Vegroni, p. 89: Ronca, p. 144).

Musacearum Palmarumque fossilium Montis Vegroni (prov. Veron.) Sciagraphia, Mem. I. R. Ist. veneto Sci., etc., vol. 9, 1861, pp. 339–357, pl. xiv–xxiv.

A. Massalongo e Mauritius Lotze. Specimen photographicum animalium quorumdam plantarum que fossilium agri Veronensis. Verona, 1859, pp. 1–101, 4°; Atlas, pl. i–xl, 4°. (Italian and Latin.)

Monte Vegroni, Ronca, Monte Colle and Monte Pastello, and one, Zovencedo, in Vicenza, are mentioned.[1] In his Syllabus[2] of all the fossil plants of Venetia, 1859, we find additional localities: Colognola, Novale, Pugnello, Giabusa near Cavolo, Muzzolone, Scaluccie, Valle Rovina, Granella, Malo, Teolo, Leffe, Lavarda, Altissimo, Purga di Velo, Caldiero.

In central Italy we find Massalongo describing plants from the Tertiary of Forli in Emilia, Cavaceppo in Marches, Bobbio in Lombardy, Sarzana in Liguria,[3] Sassateglo and Bologna (this of doubtful vegetable nature), province of Bologna,[4] and at Sinigaglia on the east coast (Marches).[5] It was upon the Upper Miocene flora of this last-named place that the only complete illustrated monograph[6] from his pen was written. This work, for which Scarabelli wrote a geological introduction, deserves more space than can be given to it here, restricted as it is to a single locality, but it may be said that it contains the full Latin description of three hundred and eighty-eight species, illustrated by forty-five large quarto plates, the figures being for the most part admirably drawn.

Associated with Visiani, Massalongo, in 1854, further elaborated the flora of Novale in Vicenza,[7] in a very complete monograph.

The paleobotanical work of Baron Achille de Zigno has been confined almost exclusively to the Oolitic strata of the Venetian Alps. Aside from his great work, which will presently claim attention, we find half a dozen or more papers, the earliest of which were chiefly

[1] A. Massalongo: Plantæ fossiles novæ in formationibus tertiariis regni veneti nuper inventæ. Veronæ, 1853, 24 pp., 8°.

Flora fossile del Monte Colle nella provincia veronese. Mem. d. I. R. Ist. veneto Sci., vol. 6, 1856, pp. 557–575, pl. i–viii.

Reliquie della flora fossile eocena del Monte Pastello nella provincia veronese. Atti I. R. Ist. veneto Sci., 3d series, vol. 4, 1857–'58, pp. 169–186, pl. i–viii.

Sulle piante fossili di Zovencedo e dei Vegroni. Lettera al Prof. Visiani. Verona, 1858, pp. 1–20, 8°.

[2] A. Massalongo: Syllabus plantarum fossilium hucusque in formationibus tertiariis agri Veneti, detectarum. Veronæ, 1859, pp. i–x, 1–179, 8°.

[3] A. Massalongo: Descrizione di alcune piante fossili terziarie dell' Italia meridionale. Nuovi annali sci. nat., 3d series, vol. 8, Bologna, 1853, pp. 193–201, pl. i, ii.

[4] Sopra una pianta fossile della provincia bolognese. Lettera del Dottor A. Massalongo al Chiar. geologico Giuseppe Scarabelli d' Imola: Ibid., pp. 258–261, pl. iii.

[5] A. Massalongo: Prodromus floræ fossilis Senogalliensis. Giorn. I. R. Ist. sci., etc., new series, vol. 5, Milano, 1853, pp. 197–230, pl. ii–v.

Sulla flora fossile di Sinigaglia. Lettera a Scarabelli. Verona, 1857, pp. 1–52, 8°.

Synopsis floræ fossilis Senogalliensis. Verona, 1858, pp. 1–138, 8°.

[6] A. Massalongo e G. Scarabelli: Studii sulla flora fossile e geologia stratigrafica del Senigalliese. Imola, 1858–'59, pp. 1–504, pl. i–xlv, folio.

[7] Roberto de Visiani and A. Massalongo. Synopsis plantarum floræ tertiariæ novalensis. Flora, new series, 12th Jahrg., vol. 1, Regensburg, 1854. no. 8, pp. 113–124.

Flora de' terreni terziarii di Novale nel Vicentino. Mem. R. Accad., Sci. di Torino, class. sci. fis. e math., 2nd series, vol. 17, Torino, 1858, pp. 199–244, pl. i–xiii.

geological, relating to this subject,[1] and several others[2] of equal or greater importance, which were based on his researches in this field.

The first volume of Zigno's Flora fossilis formationis Oolithicæ[3] bears date 1856–1868, and the second volume, 1873–1885. A third is in preparation. The treatment is systematic, the first volume embracing the Cryptogams, chiefly ferns; the second the Monocotyledons, strangely (for a paleobotanist) placed before the Gymnosperms and the Cycadaceæ, wrongly called dicotyledons; and the third is to treat the Coniferæ. I have thus far seen only the first two volumes, being all which at this time have been published. The entire Oolitic flora of the globe is intended to be embraced in the work, but Italian localities are carefully given, and from them a few of the more common ones may be introduced here: Monte Pernigotti near San Bartolamio, in the Valle Tanaro and Valle Zuliani, at Salaorno near Rovere di Velo, Monte Alba near Campo Fontana, Monte Raut and Bienterle near Selva di Progno, and at Scandolara and Squaranton, in Verona; at Monte Pisano, Monte Spitz, and in the Val d'Assa near Rotzo in the Septem Communes, Vicenza; and at Monte Repole in Etruria.

Visiani's work in paleobotany was exclusively confined to the fossil flora of Venetia. In 1852 he wrote a critical review of Massalongo's Tertiary flora of Vicenza;[4] in 1864 appeared his illus-

[1] Achille de Zigno: Uebersicht der geschichteten Gebirge der venetianischen Alpen. Jahrbuch k.-k. geol. Reichsanstalt, Wien, I. Jahrg., 1850, pp. 181–196, pl. iii.

Coup d'oeil sur les terrains stratifiés des Alpes vénitiennes. Haidinger abhandl., vol. 4, Wien, 1851, no. 1, pp. 1–16, pl. i.

Découverte d'une flore jurassique analogue à celle de Scarboroug, dans les couches oolitiques des Alpes Vénitiennes. Bull. Soc. géol. France, 2d series, vol. 10, 1852–'53, pp. 268, 269.

Découverte de plantes fossiles dans les terrains jurassiques des Alpes de la Vénétie. Ibid., vol. 11, 1853–'54, pp. 289–291.

Sulle piante fossili del trias di Recoaro raccolte dal Prof. A. Massalongo. Mém. I. R. Ist. veneto Sci., etc., vol. 11, 1862, pp. 1–31, pl. i–x.

Descrizione di alcune Cicadeacee fossili rinvenute sull' Oolite delle Alpi venete. Atti I. R. Ist. veneto Sci., etc., 3d series, vol. 13, 1867–'68, pp. 1213–1228, pl. iv.

Fossile Pflanzen aus Marmorschichten im Venetianischen. Verhandl. k.-k. geol. Reichsanstalt, Wien, 1871, pp. 54, 55.

[2] Achille de Zigno: Sulle Cicadee fossili dell' Oolite. Rivista Periodica, lavori I. R. Accad. sci., etc., Padova, vol. 1, 1851–'53, pp. 345–349.

Osservazioni sulle felci fossili dell' Oolite, ed enumerazione delle specie finora rinvenute nei varii piani di quella formazione, etc. (Mém. letta all' I. R. Accad. sci. litt. ed arti di Padova, 11 Giugno, 1865.) Padova, 1865, pp. 1–40, chart.

Sulla distribuzione geologicae geografica delle conifere fossili. Rivista Periodica, lavori I. R. Accad. sci., etc., Padova, vol. 27, 1878, 16 pp., 3 charts.

[3] Achille de Zigno: Flora fossilis formationis Oolithicæ. Le piante fossili dell' oolite. Vol. 1, Padova, 1856–1868, pp. 1–223, pl. i–xxv; vol. 2, 1873–1885, pp. i–vii, 1–199, pl. xxvi–xlii.

[4] Relazione critica di un'opera "Sopra le piante fossili dei terreni terziarii del Vicentino" dell Dott. A. Massalongo; R. de Visiani: Atti adun. I. R. Ist. veneto Sci., etc., vol. 3, 1852, pp. 98–104.

trated memoir on the Tertiary feather-palms of Venetia;[1] in 1868, he described another new species of palm;[2] and in 1869 he established his new genera, Agavites and Aloites,[3] which he carefully figured and described in a larger paper in 1875.[4]

Sismonda's two memoirs on the Miocene flora of Piedmont, 1859, 1865,[5] have great value both from being the only treatment of that flora and from their own intrinsic merits as thorough, systematic, illustrated papers. The principal plant beds in Piedmont are: Guarene, Morra, San Damiano, Bagnasco, Brusasco, Cocconato, Tortona, Astesan, Piobesi, and near Turin, but the author also describes species from Cadibona, Sarzanello, San Remo, and Stella, in Liguria, from Stradella near Pavia, in Lombardy, and from Mezzano, Belforte, and the valley of the Trebbia, in Emilia.

Schauroth's two papers on the Triassic beds (Muschelkalk) of Recoaro in Vicenza, 1855, 1859,[6] give an account of the plants to which Zigno was the first to call attention in 1862, and which have since received fuller treatment by Schenk[7] and Gümbel.[8]

Gaudin's important researches into the Miocene and Pliocene floras of Tuscany, Sicily, and the Lipari Islands were commenced in 1857[9] by a short paper, with one plate, describing plants from the beds of Montajone, the valleys of the Arno and Magra, Massa Marittima, Poggio-Montone, Alcetò, Monte Fiascone, Abbruzes, etc., which was followed by a series of six "Contributions" in the Mem-

[1] Roberto de Visiani: Palmæ pinnatæ tertiariæ agri veneti. Mem. I. R. Ist. veneto Sci., vol. 11, 1864, pp. 435–460, pl. xii–xxiii.

[2] Rob. de Visiani: Descrizione di una nuova specie di palma fossile. Atti Soc. ital. sci. nat., vol. 11, Milano, 1868, pp. 360, 361.

[3] Rob. de Visiani: Di due nuovi generi di pianti fossili. Accad. sci., lett. ed arti, Padova, Feb., 1869.

[4] Rob. de Visiani: Di alcuni generi di piante fossili. Mem. I. R. Ist. veneto Sci., etc., vol. 18, 1875, pp. 457–466, pl. xix–xxvi.

[5] Eugène Sismonda: Prodrome d'une flore tertiaire du Piémont. Mém. Accad. sci., Torino, classe sci. fis. e math., 2d series, vol. 18, Turin, 1859, pp. 519–547, pl. i–iv.

Matériaux pour servir à la paléontologie du terrain tertiaire du Piémont. Ibid., vol. 22, 1865, pp. 391–471, pl. i–xxxiii.

[6] Karl Schauroth: Uebersicht der geognostischen Verhältnisse der Gegend von Recoaro im Vicentinischen. Sitzungsber. k. Akad. Wiss., Wien, math.-naturw. Cl., vol. 17, 1855, pp. 481–562, pl. i–iii, map. (Foss. plants, pp. 498, 499, pl. i).

Kritisches Verzeichniss der Versteinerungen der Trias im Vicentinischen. Ibid., vol. 34, 1859, pp. 283–356, pl. i–iii.

[7] Ueber die Pflanzenreste des Muschelkalks von Recoaro, von A. Schenk. Benecke: Geognostisch-palæontologische Beiträge, vol. 2, München, 1866–'69 (1868), pp. 71–87, pl. v–xii.

[8] C. W. Gümbel: Gli strati d' arenaria a piante fossili di Rocoaro. Bull. R. Comitato geol. d' Italia, vol. 10, 1879, pp. 249–270.

Die Pflanzenführenden Sandstein-Schichten von Recoaro, von C. W. Gümbel: Sitzungsber. k. bayer. Akad. Wiss., München, math.-naturw. Cl., vol. 9, 1879, Heft 2, pp. 33–85.

[9] Note sur quelques empreintes végétales des terrains supérieurs de la Toscane, par C. T. Gaudin: Bull. Soc. Vaud., vol. 5, Lausanne, 1857, pp. 330–339, 1 pl.

oirs of the Swiss Society. The first of these was published in 1858, and treats a large collection chiefly made by the Marquis Strozzi, who contributed a stratigraphical introduction from the localities in Tuscany mentioned above.

The second "Contribution" covers a somewhat wider field, embracing Siena, Monte Bamboli, Castro, Montalceto, and other places in Tuscany, and also Sarzanello in Liguria and Sinigaglia in Ancona. The third is chiefly confined to the description of specimens from Massa, Jano, and Poggio, all in Tuscany; the fourth to those of the Pliocene beds of Cava Rovis, Galleraje, Perolla, Prata, and Monsummano, in the same province; the fifth entirely to the volcanic tuffs of the Lipari Islands, studied and collected by the Baron Piraino de Mandralisca, while the sixth and last completes the description of unpublished material from Tuscany, representing the following localities not hitherto mentioned: Bozzone, Gavillè, Castelnuovo, Avane, Cafaggio, Parrane, Limone, Piombino, Puzzolente, Poggione, and Montemasso. These six memoirs run through three volumes of the Swiss Society's Memoirs and extend from 1858 to 1862.[1] In 1864 M. Gaudin gave an account of a leaf-bed at Palermo, in Sicily.[2]

In 1858 Santagata found *Cylindrites funalis* at Mongardino, near Asti in Piedmont;[3] Lyell,[4] Heer,[5] and especially Tornabene,[6] have studied the Quaternary tufa beds of Bronte, Trappeto, Pietraperzia, etc., at the foot of Mount Etna; and in 1860 Capellini[7] supplemented Gaudin's work in the Val di Magra (S. Lazzaro, S. Martino, and Sarzanello).

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[1] Contributions à la flore fossile italienne. [Memoirs 1–4 by Charles Théophile Gaudin and Carlo Strozzi.] (1st Memoir) Mémoire sur quelques gisements de feuilles fossiles de la Toscane: Nouv. Mém. Soc. Helvétique Sci. Nat., vol. 16, Zürich, 1858, no. 3., pp. 1–47, pl. i–xiii; (2d Memoir) Val d'Arno, ibid., vol. 17, 1860, no. 4, pp. 1–59, pl. i–x; (3d Memoir) [continuation] ibid., pp. 1–20, pl. i–iv; (4th Memoir) Travertins toscans, ibid., no. 7, pp. 1–30, pl. i–vii; (5th Memoir) Tufs volcaniques de Lipari, par Ch. Th. Gaudin, et le Baron Piraino de Mandralisca: ibid., no. 7, pp. 1–12, pl. i–iii; (6th Memoir) [General and descriptive] par Ch. Th. Gaudin et le Marquis Carlo Strozzi: ibid., vol. 20, 1862, no. 3, pp. 1–31, pl. i–iv.

[2] Gisement de feuilles fossiles aux environs de Palermo, par C. T. Gaudin: Bull. Soc. vaud., vol. 7, Lausanne, 1864, pp. 414, 415.

[3] D. Santagata: Piante fossili che si trovano a Mongardino. Rend. Accad. sci. Ist. Bologna, 1857–'58, pp. 69–71.

[4] Leaf bearing tuffs of Fasano, near Catania. In "On the Structure of Lavas which have Consolidated on Steep Slopes; with Remarks on the Mode of Origin of Mount Etna, and on the Theories of Craters of Elevation," by Sir Charles Lyell: Philos. Trans. Royal Soc. London, vol. 148, 1858, pp. 776, 777, pl. li.

[5] Remarks on the Fossil Plants from the Volcanic Tuff of Fasano, near Catania, on Mount Etna, by Oswald Heer. Extracted from a letter to Sir Charles Lyell, dated April, 1858: ibid., pp. 782, 783, pl. li.

[6] Francesco Tornabene: Flora fossile dell' Etna. Atti Accad. Gioen. Catania, 2d series, vol. 16, 1860, pp. 1–147, pl. i–x.

[7] Cenni geologici sul giacimen to delle lignitidella bassa Val di Màgra, del Prof. Giovanni Capellini: Mem. R. Accad. Sci. Torino, 2d series, vol. 19, Turin, 1860, Cl. sci., fis. e mat., pp. 1–34, pl. i–iv.

In 1867 Molon[1] undertook a revision of the Tertiary flora of the Venetian Alps, and Geinitz[2] in 1869 maintained that the plants obtained by Curioni[3] in the Val Camonica and Val Trompia, in the southern Alps, and described as Carboniferous, really belong to his Dyas, or Permian.

Sordelli's three contributions in the Milan Society to the fossil flora of Lombardy are important.[4] He finds a Pliocene flora at Folla d'Induno, S. Colombano, Almenno, Nese, and at Pontegana, near Balerna. He also finds a Carboniferous (Dyas?) flora at Manno, Collio, Val Trompia; Triassic plants at Regoledo, (Buntersandstein), Valsassina (Muschelkalk), Val Trompia, near Zigole, Varenna, Col di Zambla, Cappella S. Rocco near Oneta, Schilpario, Perledo, and Besano (the last seven places being placed in the upper Trias, or Keuper); Liassic plants on Lakes Piano and Como, at Taleggio, Val Brembilla, Val Serina, Monte Misma, Moltrasio, and Mombello, near Laveno; Cretaceous at Mere in Brianza, Biandronno, Induno, Morosolo, Fraschirolo, Casletto, Lake Oggionno, Pusiano, Breno, Centemero, Camnago, and Camisasca; post-Pliocene plants at Leffe, Pianico, and Adrara; and Quaternary or recent impressions in the tufas of Civate, Valmadrera, and Brumano, and in the peat of Rogeno, Bodio, Cerete, Bosisio, and on Lake Verese.

Sordelli has also developed a small Tertiary (Upper Miocene or Pliocene) florula near Bassano, in Venetia, discovered by Dr. Casati,[5] and still another at Badia, near Brescia (Lombardy), of somewhat earlier age.[6]

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[1] Sulla flora terziaria delle Prealpe venete, etc., Francesco Molon: Mem. Soc. ital., sci. nat., vol. 2, Milano, 1867, No. 3, pp. 1–140.

[2] Ueber fossile Pflanzenreste aus der Dyas von Val Trompia von Hans Bruno Geinitz: Neues Jahrbuch für Mineral., 1869, pp. 456–461, pl. v.

[3] Giulio Curioni: Di alcuni vegetali dell' epoca carboniferi scoperti nei monti della Val Camonica. Rend. I. R. Ist. Lomb., vol. 2, Milano, 1865, pp. 214–216.

Osservazioni geologiche sulla Val Trompia. Rend. I. R. Ist. Lomb., 3d series, vol. 3, Milano, 1870, pp. 294–298; Mem. R. Ist. Milano, 1873, vol. 12, pp. 41–100, 1 pl. Boll. Com. geol. ital., vol. 1, 1870, Nos. 9, 10, pp. 249–257.

[4] F. Sordelli: Descrizione di alcuni avanzi vegetali delle argille plioceniche Lombarde coll' aggiunta di un elenco delle piante fossili finora conosciute in Lombardia. Atti Soc. ital. sci. nat., vol. 16, Milano, 1874, pp. 350–429; pl. iv^{a}–viii^{a}.

Le filliti della Folla d' Induno presso Varese e di Pontegano tra chiasso e Balerna nel canton Ticino, paragonate con quelle di altri depositi terziari e posterziari, etc. Atti Soc. ital. sci. nat., vol. 21, Milano, 1879, pp. 877–897.

Sulle pianti fossili recentemente scoperte a Besano circondario di Varese. Ibid., vol. 22, Milano, 1879, pp. 81–94.

[5] F. Sordelli: Cenno preventivo sul giacimento a filliti scoperto dal Dott. F. Beltramini de'Casati, presso Bassano Veneto. Atti Soc. ital. sci. nat., vol. 24, Milano, 1881, 8 pp.

[6] Ferdinando Sordelli: Sui fossili e sull' Età del deposito terziario della Badia, presso Brescia. Ibid., vol. 25, Milano, 1882, 9 pp.

In 1876, Geyler described in Palæontographica[1] a collection of Upper Tertiary plants from the sulphurous gypsum bed of Cannatone north of Raculmuto and Grotte, in the Province of Girgenti, on the island of Sicily, made by Emil Stöhr and Dr. Nocito, in which he found twenty-one species, most of which he identified with Oeningen and Sinigaglia species. Kraus[2] has also found fossil wood in these Silician sulphur beds.

In 1878, Göppert detected a leaf impression, which he named *Laurus Gemellariana,* in a specimen of amber collected by Dr. Gemellaro of Palermo, in the vicinity of Catania, Sicily.[3]

The leaf-prints identified and enumerated by Capellini in the gabbro diatom schists of the mountains of Leghorn in 1878,[4] received more special mention by him in a paper published in the Rendiconti of the Bologna Institute in 1881.[5]

Dr. Cavara's still more recent memoir on the Pliocene flora of Mongardino (Piedmont), on the northern slope of the Emilian Apennines, from which he reports some sixty species, with a dozen or more new forms,[6] may also be mentioned.

The fossil plants from the Cambrian of Sardinia have been described by G. Meneghini[7] and J. G. Bornemann,[8] the latter of whom has described several species of somewhat problematical organisms.

Finally should be noted Dr. Portis's notice of the discovery of Carboniferous plants at Viozene, in the valley of the Tanaro,[9] in Pied-

[1] Ueber fossile Pflanzen aus den obertiären Ablagerungen Sicilien's, von H. Th. Geyler: Palæontographica, vol. 23, Cassel, 1876, pp. 317–328, pl. lxviii, lxix.

[2] Beiträge zur Kenntniss fossiler Hölzer. I. Hölzer aus den Schwefelgruben Siciliens, von Gregor Kraus: Abhandl. naturf. Gesell. zu Halle, vol. 16, 1882, pp. 77–111, pl. i, 4°.

[3] H. R. Göppert: Sull' ambra di Sicilia e sugli oggetti in essa rinchiusi. Mem. cl. sci. fis., etc., Accad. Lincei, Roma, 3d series, vol. 3, anno 1878–'79, pp. 51–62.

[4] G. Capellini: Il carcare di Leitha il Sarmatiano e gli strati a congerie nei monti di Livorno, di Castellina marittima, di Miemo e di Monte Catini. Mem. cl. sci. fis., etc., Accad. Lincei, 3d series, vol. 2, Roma (3d marzo), 1878, pp. 275–291.

[5] G. Capellini: Le filliti dei tripoli schistosi del Gabro nei monti Livornesi. Presentazione della 1ª parte. Rend. sess. R. Accad. sci. Ist., Bologna, anno, 1880–'81, Bologna, 1881, p. 142.

[6] Sulla flora fossile di Mongardino. Studj stratigrafici e paleontologici. Memoria del Dottor Fridiano Cavara: Mem. R. Accad. sci. Ist., Bologna, 4th series, vol. 7, 1886, pp. 701–752, pl. i–iii.

[7] G. Meneghini: Bilobiti cambriani di Sardegna. Atti Soc. Tosc. sci. nat., proc. verb., vol. 4, Pisa, 1885, pp. 184–189.

[8] J. G. Bornemann: Palæontologisches aus dem cambrischen Gebiete von Canalgrande in Sardinien. Zeitschr. deutsch. geol. Gesell., vol. 35, 1883, pp. 270–274.

Die Versteinerungen des Cambrischen Schichtensystems der Insel Sardinien, nebst vergleichenden Untersuchungen über analoge Vorkommnisse aus andern Ländern. Nova Acta Acad. Leop.-Carol., vol. 51, Halle, 1886, no. 1, pp. 1–83, pl. i–xxxiii.

[9] A. Portis: Sulla scoperta delle piante fossili carbonifere di Viozene nell' alta valle del Tanaro. Boll. R. Com. geol. d' Italia, 2d series, vol. 8, 1887, pp. 417–420.

mont, Senofonte Squinabol's contributions to the Carboniferous and Tertiary floras of Liguria,[1] not yet completed, and a good paper by Luigi Meschinelli on the Miocene flora of Monte Piano in Vicenza, describing twenty-six species and figuring one.[2]

GREECE.

The fossil plants collected by the expedition to the Morea were identified by Adolphe Brongniart in 1832,[3] and the now widely known Miocene species, *Taxodium Europæum*, was originally named by him in 1833 from specimens collected by M. Virlet, on the island of Iliodroma, in the Devil's Archipelago, opposite the Gulf of Volo.[4]

In a paper by Doctor Landerer, professor of chemistry at Athens,[5] besides the Koumi beds soon to be mentioned, it is stated that well preserved impressions of Filices, Gramineæ, and Marsiliaceæ have been found near Lamia (Zeitun), and dicotyledonous plants and lignite in the diluvial marl of Limni.

The occurrence of fossil wood on the island of Lesbos was observed by Baron Prokesch-Osten in 1829, and a collection from the island was made by the Archduke Johann about the year 1837, which he sent to Professor Unger. The latter referred to this material in a paper that appeared in 1842,[6] and also in his Chloris Protogæa (p. 37). It was also made the subject of a joint contribution by Baron Prokesch-Osten and Professor Unger in 1852.[7]

The Tertiary deposits of Koumi on the island of Eubœa, and Oropo in the northern part of Attica, were further explored in 1861 by M. Gaudry, whose collection was reported upon by Brongniart[8] and care-

[1] Senofonte Squinabol: Nota preliminare su alcune impronte fossili nel carbonifero superiore di Pietratagliata. Giorn. Soc. letter. convers. scientif., Genova, giugno 1887, pp. 1–8, 1 pl, Contribuzioni alla flora fossiledei terreni terziarii della Liguria. Pt. 1, Fucoidi ed Elmintoidee: Boll. Soc. geol. ital., vol. 6, 1887 (1888), pp. 545–561, pl. xiv–xix.

[2] Studio sulla flora fossile di Monte Piano, del Dottor Luigi Meschinelli: Atti Soc. Veneto-Trentina, sci. nat., vol. 10, fasc. 2, Padova, 1889, 31; pp. pl. vi.

[3] Expédition scientifique en Morée, entreprise et publiée par ordre du gouvernement français. Travaux de la Section des sciences physiques sous la direction de M. le Colonel Bory de Saint-Vincent. Paris, 1832–37, large 4°; atlas, folio. Plantes fossiles par Adolphe Brongniart, in vol. 3, Géologie, pp. 235, 364, pl. iii, xii.

[4] Notice sur une conifère fossile du terrain d'eau douce de l'île d'Iliodroma, par Adolphe Brongniart: Annales sci. nat., vol. 30, Paris, 1833, pp. 168–176.

[5] Ueber die in Griechenland vorkommenden Petrefakte, von Landerer: Neues Jahrbuch für Mineral., 1848, pp. 513–518.

[6] Ueber die Untersuchung fossiler Stämme holzartiger Gewächse, von Franz Unger: Neues Jahrbuch für Mineral., 1842, pp. 149–178.

[7] Die versteinerten Holzstämme im Hafen von Sigri auf der Insel Lesbos, von Prokesch-Osten und Franz Unger: Sitzungsber. k. Acad. Wiss., Wien, math.-nat. Classe, vol. 9, 1852, pp. 855–858.

[8] Note sur une collection de plantes fossiles recueillies en Grèce par M. Gaudry; par Ad. Brongniart: Comptes rendus Acad. sci., vol. 52, Paris, 1861, pp. 1232–1239.

fully worked up by Count Saporta,[1] who has since published several other papers upon its flora.[2]

Dr. Franz Unger, who gave an account of it in 1862,[3] wrote a somewhat extended systematic paper on the fossil plants in 1867,[4] which, however, bears no internal evidence of his acquaintance with Saporta's memoir above referred to.

ROUMELIA.

Four of the eleven species named by Unger in Tchihatcheff's "Asie Mineure," 1866–1869,[5] were collected in Roumelia (Thrace), the leaf specimens (Quercus) between the Gulf of Grand-Pont and the village of Kumbourghas, and the fossil wood upon which he founded his two new genera, Constantinium and Tchihatcheffites, on the south shore of Lake Derkos.

BOSNIA.

From Bjelo Brdo, near Vyšegrad in Bosnia, a small collection of Tertiary (Miocene?) plants was made by Dr. Ottomar Novák and described by Engelhardt in 1883.[6] They are all dicotyledonous leaves, and with the exception of one new species (*Lomatia australis*) were previously known in the European Miocene. The specimens are unusually well preserved in a fine marl, and the figures made of them are clear and instructive.

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[1] Notice sur les plantes fossiles de Coumi et d'Oropo, par le Comte Gaston de Saporta. In A. Gaudry, Animaux fossiles et géologie de l'Attique, Paris, 1862, pp. 1–17, pl. lxiv, lxv.

[2] Gaston de Saporta: Note sur la flore fossile de Coumi (Eubée). Bull. Soc. géol. France, 2d series, vol. 25, 1868, pp. 315–328.

Examen critique d'une collection de plantes fossiles de Koumi (Eubée). Annales Scientif. École Norm. Sup. 2d series, vol. 2, Paris, 1873, pp. 323–352, pl. ii.

Sur la présence d'une Cycadée dans le dépôt miocène de Coumi (Eubée). Comptes rendus, Acad. sci., Paris, vol. 80, 1874, pp. 1318–1321.

Notice sur l'Encephalartos Gorceixianus, Cycadée fossile, du dépôt miocène de Koumi (Eubée). Bull. Soc. botanique et horticole de Provence, Marseille, 1880, pp. 41–44, 1 pl.

[3] Wissenschaftliche Ergebnisse einer Reise in Griechenland und in den ionischen Inseln. Wien, 1862, pp. i–xii, 1–213, pl. i–xxviii, 8°. Die fossile Flora von Kumi auf Eubœa, pp. 143–186, with numerous figures.

[4] Die fossile Flora von Kumi auf der Insel Eubœa, von Franz Unger Denkschr.: k. Akad. Wiss., Wien, math.-nat. Cl., vol. 27, 1867, pp. 27–90, pl. i–xvii.

[5] Flore tertiaire moyenne, par Franz Unger. In Pierre de Tchihatcheff: Asie Mineure. Description physique de cette contreé. Paris, 1866–'69, 8°, IV[e] partie, Paléontologie, 1866. See pp. 319–325. Atlas, fol. 1866, pl. xvii.

[6] Ueber bosnische Tertiärpflanzen, von Hermann Engelhardt: Sitzungsber. naturwiss. Gesell. Isis, Dresden, 1883, pp. 85–88, pl. v.

AUSTRIAN EMPIRE.

The political subdivisions of the Austrian empire are so much more distinct than those of France or Italy, and the literature is so voluminous, that it seems best to treat each of the provinces or Crown lands separately. In doing so they will be taken up as nearly as practicable in the general direction from southeast to northwest. The following possess plant-bearing strata, and the order named will be that in which they will be mentioned:

Dalmatia, Croatia, Slavonia, Styria, Hungary, Transylvania, Galicia, Moravia, Austrian Silesia, Bohemia, Austria proper, Carniola, Carinthia, Tyrol, and Vorarlberg.

Notwithstanding the great number of papers and works on the fossil flora of Austria, the number of plant beds is not greater than in other countries. The literature has been chiefly swelled by repetition and the re-elaboration of the several florules. It will therefore be necessary in treating these localities to refer in one place to most or all of the titles that relate to each one, and the limits of space require that this be done largely at the expense of the more important monographs, which will often receive very little more mention than do some of the minor ones. Wherever it is practicable, however, the relative importance of papers will be indicated in such manner as the case will permit.

Dalmatia.—The only locality for fossil plants of any importance in Dalmatia is that of Monte Promina, northeast of Sebenico, first mentioned by Leopold von Buch[1] in 1851 and chiefly studied and published by Baron von Ettingshausen[2], in 1854, whose papers, however, were ably supplemented by one from Visiani in 1858.[3]

Croatia.—Three fossil plant localities are known in Croatia, namely, Radoboj, Tergove, and Sused, the first of which has become one of the most celebrated in the world. It was first brought prominently into notice in 1839 by the publication by Dr. Franz Unger in the Steiermärkische Zeitschrift of his Reisenotizen[4] of the year previous, in which he enumerates about thirty species of plants, Monocotyledons, Dicotyledons, and Coniferæ, that he obtained from the lignite beds of that place.

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[1] Ueber die Lagerung der Braunkohlen in Europa, von Leopold von Buch: Bericht. k. Akad. Wiss., Berlin, 1851, pp. 683–701. Karsten Archiv, vol. 25, 1853, pp. 143–173.

[2] Constantin von Ettingshausen: Die eocene Flora des Monte Promina. Denkschr. k. Akad. Wiss., Wien, math.-nat. Cl., vol. 8, 1854, pp. 17–44, pl. i–xiv.

Nachtrag zur eocenen Florā des Monte Promina in Dalmatien. Sitzungsber. k. Akad. Wiss., Wien, math.-nat. Cl., vol. 12, 1854, pp. 180–182.

[3] Pianti fossili della Dalmazia, dell Dott. Rob. de Visiani: Mem. R. Ist. Veneto, Sci. etc., vol. 7, 1858, pp. 421–455, pl. i–vi.

[4] Reisenotizen vom Jahre 1838, von Franz Unger: Steiermärkische Zeitschrift, neue Folge, 5th Jahrg., 1839, 54 pp.

When in 1841 he began the publication of his Chloris Protogæa[1] he found himself in possession of a large amount of splendid material, which forms a large part of the matter of that noble work. In both his Iconographia, 1852,[2] and his Sylloge, 1859,[3] he made many further additions to this flora, and in 1869 he published his Fossil Flora of Radoboj,[4] giving many new forms and a complete list of the plants thus far known from that place. This was supplemented the following year by Baron von Ettingshausen's paper on the same subject,[5] which he treats in a similar manner, and he enumerates two hundred and ninety-five species as the total flora of Radoboj. The beds were at one time thought to be Eocene, but are now generally regarded as Lower Miocene.

The Carboniferous bed at Tergove is of less importance, and the flora has been studied by both Geinitz[6] and Stur,[7] 1868.

The Upper Miocene deposits of Sused, Nedelja, and Dolje, in the vicinity of Agram, have been the subject of two comparatively recent papers, the first by Vukotinovic, in 1870,[8] in the Bulletin ("Rad") of the South Sclavish Academy of Science and Arts, describing about thirty specimens collected by himself. The second is the complete and excellent monograph of the Flora of Sused, by Professor Pilar, of the same Academy, published in 1883,[9] at Agram, in Croatian and French en regard, and making a fine quarto volume of 163 pages and 15 plates of beautifully drawn figures, a model of book-making, as well as of systematic treatment.

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[1] Chloris protogæa. Beiträge zur Flora der Vorwelt, von Franz Unger. Leipzig, 1841–1847, pp. i–cx, 1–150, pl. i–l, folio.

[2] Iconographia plantarum fossilium. Abbildungen und Beschreibungen fossiler Pflanzen; von Franz Unger: Denkschr. k. Akad. Wiss., Wien, math.-nat. Cl., vol. 4, 1852, pp. 73–118, pl. xxiv–xlv.

[3] Sylloge plantarum fossilium. Sammlung fossiler Pflanzen besonders aus der Tertiärformation, von Franz Unger. 3 parts (Pugilli), Wien, 1859–1865. I, 1859, pp. 1–48, pl. i–xxi; II, 1862, pp. 1–36, pl. i–xii; III, 1865, pp. 1–76, pl. i–xxiv, 4°.

[4] Die fossile Flora von Radoboj in ihrer Gesammtheit und nach ihrem Verhältnisse zur Entwickelung der Vegetation der Tertiärzeit, von Franz Unger: Denkschr. k. Akad. Wiss., Wien, math.-nat. Cl., vol. 29, 1869, pp. 125–170, pl. i–v.

[5] Beiträge zur Kenntniss der fossilen Flora von Radoboj, von C. von Ettingshausen: Sitzungsber. k. Akad. Wiss., Wien, math.-nat. Cl., vol. 61, I. Abth., 1870, pp. 829–906, pl. i–iii.

[6] Ueber die fossilen Pflanzenreste aus dem Schiefergebirge von Tergove in Croatien, von H. B. Geinitz: Verhandl. k.-k. geol. Reichsanstalt, Wien, 1868, pp. 165–167.

[7] Fossile Pflanzenreste aus dem Schiefergebirge von Tergove in Croatien, von D. Stur: Jahrbuch k.-k. geol. Reichsanstalt, Wien, vol. 18, 1868, pp. 131–138.

[8] O petrefaktih u obce i o podzemnoj fauni i flori susedskih lapora. Ljndevit Vukotinovic: Rad Jugosl. Akedemije, vol. 13, Zagreb, 1870, 41 pp., pl. ii.

[9] Flora fossilis Susedana. (Flore fossile de Sused.) Descriptio plantarum fossilium quæ in lapicidinis ad Nedelja, Sused, Dolje, etc., in vicinitate civitatis Zagrabiensis hucusque repertæ sunt, Auctore Georgio Pilar: Acta Acad. Sci. Slav. merid., vol. 1, No. 1, Zagrabiae, 1883, pp. 1–163, pl. i–xv.

Slavonia.—One unimportant Miocene plant bed has been made known in Slavonia, namely, at Vrdnik, in the county of Syrmia, where Dr. Lenz, in 1872, collected some twenty species, which were determined by Stur.[1] None of them were probably new, but further explorations in that locality may reveal an important deposit of fossil plants.

Styria.—The principal localities for fossil plants in Styria are Parschlug, Gleichenberg, Leoben, and Köflach, which are Miocene, and Sotzka, which is usually classed as Oligocene. But they have also been found at Rein, near Gratz[2] (Tertiary), in the so-called Stangalpe,[3] at Schönstein,[4] Würmberg, Voitzberg, Hauenstein, Wartberg, Arnfels, Winkel, and many other places.

The Parschlug flora has been separately treated by Unger[5] and Ettingshausen,[6] besides entering largely, as do all the other localities mentioned, into the Chloris Protogæa, the Iconographia, and the Sylloge, of the first-named author.

Sotzka, which lies west of Gonobitz and north of Cilli, had scarcely received more than a passing notice[7] prior to the appearance of Unger's large monograph on its fossil flora in 1850,[8] which was supplemented in 1858 by a fine memoir by Ettingshausen,[9] illustrated with physiotypic figures of the most nearly allied living species.

Gleichenberg was visited by Unger in his journey above mentioned in 1838, and plants from the beds in its vicinity were described in his Chloris Protogæa. In 1854 he published his monograph of its fossil

[1] Pflanzen-Reste von Vrdnik in Syrmien, von D. Stur: Verhandl. k.-k. geol. Reichsanstalt, Wien, 1872, pp. 340, 341.

[2] Geognostische Bemerkungen uber die Badelhöhle bei Peggan, von Franz Unger: Steiermärkische Zeitschr., neue Folge, 5th Jahrg., 1839, 12 pp.

[3] Ueber ein Lager Vorweltlicher Pflanzen auf der Stangalpe in Steiermark, von F. Unger: Ibid., vol. 6, Steiermark, 1840, 14 pp.

[4] Die Pflanzenreste der Lignit-Ablagerung von Schönstein in Unter-Steiermark, von Franz Unger: Sitzungsber. k. Akad. Wiss., Wien, math.-nat. Cl., vol. 40, 1860, pp. 47–52, pl. iv, v, with chart.

[5] Franz Unger: Die fossile Flora von Parschlug. Steiermärkische Zeitschr., neue Folge, 9th Jahrg., 1848, Heft 1, pp. 27–62. Neues Jahrbuch für Mineral., 1848, pp. 505–510.

[6] C. Ettingshausen: Bericht über die fossile Flora von Parschlug. Sitzungsber. k. Acad. Wiss., Wien, math.-nat. Cl., vol. 5, 1850, pp. 136, 137.

Beiträge zur Kenntniss der fossilen Flora von Parschlug in Steiermark. I, Blattpilze und Moose. Denkschr. k. Akad. Wiss., Wien, math.-nat. Cl., vol. 38, 1877, Abth. I, pp. 81–92, pl. i–v.

[7] Fossile Pflanzen von Sotzka, von C. von Ettingshausen: Jahrbuch k.-k. geol. Reichsanstalt, Wien, vol. 1, 1850, No. 1, pp. 175.

[8] Die fossile Flora von Sotzka, von Franz Unger: Denkschr. k. Akad. Wiss., Wien, math.-nat. Cl., vol. 2, 1850, pp. 131–197, pl. xxii–lxviii.

[9] Beiträge zur Kenntniss der fossilen Flora von Sotzka, in Untersteiermark, von C. von Ettingshausen: Sitzungsber. k. Akad. Wiss., Wien, math.-nat. Cl., vol. 28, 1858, pp. 471–567, pl. i–vi.

flora,[1] which, with Andrä's short note in 1856,[2] adding two species, and frequent mention in all later general works, is all we have for that locality. Besides the bed on a knoll near the village of Gleichenberg, there are three others in the immediate vicinity at Gossendorf, in sandstone, at Wirrberge, in tufaceous basalt, and at St. Anna in marl. They are all of the same (Miocene) age.

A collection of fossil plants was made at Köflach, near Gratz, by Archduke Johann, and presented to the Austrian Reichsanstalt, an acknowledgment of which was made by the director, Dr. Haidinger, at the session of December 15, 1857.[3] This material was elaborated by Baron von Ettingshausen, and the results were communicated to the Reichsanstalt on the 12th of January, 1858.[4]

In Stur's exhaustive paper on the flora of the Süsswasserquarze,[5] which will be more specially treated under Hungary, the beds of Karlsdorf, near Ilz, the mill-stone quarry at Gleichenberg, and the several beds at Waldsberg, Wirrebergen, Hermannskogel, Gossendorf, Kapfenstein, Absötze, St. Anna, and Straden, in the vicinity of Gleichenberg, are systematically enumerated as contributing to that flora.

To Ettingshausen we are indebted for a thorough knowledge of the fossil plants of Leoben, which is contained in his paper on the Tertiary flora of Styria,[6] 1869, chiefly confined to the comparison of his Leoben species with those of other localities, and to their description and illustration, but especially in his excellent monograph of that flora published in 1888,[7] in which he reviews the entire subject, describes and figures a large number of new plants, and enumerates four hundred and eleven species as constituting the known flora of these beds at that date. The new material was chiefly collected by Rachoy and Adolf Hofmann at Unterbuchwieser and the Walpurgis shaft in the Seegraben and on the Münzenberg and the Moskenberg, in the vicinity of Leoben.

[1] Die fossile Flora von Gleichenberg, von Franz Unger: Denkschr. k. Akad. Wiss., Wien, math.-nat. Cl., vol. 7, 1854, pp. 157–184, pl. i–viii.

[2] Zur tertiären Flora von Gleichenberg, in Steiermark, von C. J. Andrä: Zeitschr. Naturwiss., vol. 7, Halle, 1856, pp. 395–398, pl. v.

[3] Jahrbuch k.-k. geol. Reichsanstalt, Wien, vol. 8, 1857, p. 811.

[4] Die fossile flora von Köflach in Steiermark, von C. von Ettingshausen: Ibid., pp. 738–756, pl. ii–iv.

[5] Beiträge zur Kenntniss der Flora der Süsswasserquarze, der Congerien- und Cerithien-Schichten im Wiener und ungarischen Becken, von D. Stur: Ibid., vol. 17, 1867, pp. 77–188, pl. iii–v, tab.

[6] Beiträge zur Kenntniss der Tertiärflora Steiermark's, von Constantin, Freiherrn von Ettingshausen: Sitzungsber. k. Akad. Wiss., Wien, math.-nat. Cl., vol. 65, 1869. Abth. I, pp. 17–100, pl. i–vi.

[7] Die fossile Flora von Leoben in Steiermark, von Prof. Dr. Constantin, Freiherrn von Ettingshausen: Denkschr. k. Akad. Wiss., Wien, math.-nat. Cl., vol. 54, 1888, Abth. I, pp. 261–384, pl. i–ix.

Hungary.—The chief localities for fossil plants in Hungary are those of Schemnitz and Kremnitz; of Hegyallya, which includes Tokay, Tállya, Erdöbénye, and Szántó; of Fünfkirchen, and other points in Baranya County, and of Frusca-Gora; all but one (Fünfkirchen) of which are probably of Miocene age.

Pettko in 1850 found his *Astrochlæna Schemniciensis* (*Osmunda Schemniciensis* Stur), at Ilia, near Schemnitz,[1] and in 1852 Ettingshausen described a fine series of specimens from Heiligenkreuz near Kremnitz.[2]

The region about Tokay is still more fruitful. Kovats made a journey through Hegyallya in 1850,[3] and sent his collections to Ettingshausen. With these and another collection which he had received from Professor Hazslinszky he was able to prepare his well-known monograph of the flora of Tokay,[4] which appeared in 1853. This was followed three years later by two papers by Kovats on the floras of Tállya[5] and Erdöbénye,[6] the latter of which is second only in importance to that of Ettingshausen.

The Hungarian localities mentioned by Stur in the work quoted on the preceding page as furnishing fossil plants in the Süsswasserquarze formation (Miocene) are as follows: Ilia, Hliník, Móčár, Teplá, Rybník, Tisová, Skalamlin, and Törines, near Schemnitz; Lutilla, Kaiser Ferdinand-Erbstollen, and Jastraba, near Heiligenkreuz; Fony, Tállya, Telkibánya, Czekeháza, Erdöbénye, and Szántó, in the Tallygallya district; Megyászó, Gesztely, and Avashegy near Miskolcz; Erlau and Nagy Astoros, in that neighborhood; Scheibelberg and Hohe Drauschel, near Handlova; Szerednye between Munkács and Ungvár, Buják, places to the east and northeast of Waizen, and Szölläs near Pásztó.

Szántó, which, with Tállya and Erdöbénye, completes a triangle in this district, has since yielded fossil plants which the Hungarian Geological Society had from time to time sent to Dr. Unger for identification. In 1869 he published his monograph of this florule,[7] which is characteristic of his ability as a phyto-paleontologist. Many very

[1] Tubicaulis von Ilia bei Schemnitz, von Johann von Pettko: Haidinger, Naturwiss. Abhandl., vol. 3, Wien, 1850, Abth. I, pp. 163–169, pl. xx.

[2] Fossile Pflanzenreste aus dem trachytischen Sandstein von Heiligenkreuz bei Kremnitz, von Constantin von Ettingshausen: Abhandl. k.-k. geol. Reichsanstalt, Wien, vol. 1, Abth. III, 1852, No. 5, pp. 1–14, pl. i, ii.

[3] Ergebnisse einer Reise in die Hegyallya bei Tokai, von Julius von Kovats: Jahrbuch k.-k. geol. Reichsanstalt, Wien, vol. 2, Abth. II, 1851, p. 178.

[4] Beitrag zur Kenntniss der fossilen Flora von Tokay, von C. von Ettingshausen: Sitzungsber. k. Akad. Wiss., Wien, math.-nat. Cl., vol. 11, 1853, pp. 779–816, pl. i–iv.

[5] Fossile Flora von Tállya, von Julius von Kovats: Arb. geol. Gesell. für Ungarn, vol. 1, Pest, 1856, Heft 1, pp. 39–52, 1 pl.

[6] Fossile Flora von Erdöbénye, von Julius von Kovats: Ibid., pp. 1–34, pl. i–vii.

[7] Die fossile Flora von Szántó in Ungarn, von Franz Unger: Denkschr. k. Akad. Wiss., Wien, math.-nat. Cl., vol. 30, 1869, pp. 1–15, pl. i–v.

perfect specimens are figured in a manner at once artistic and scientific, being drawn by his own hand.

At Fünfkirchen and vicinity several horizons are represented.[1] Stur found plants in Boeckh's collections from the Keuper and the Lias, while those collected by Boeckh in 1875 and sent to Heer[2] were from a still lower horizon (Permian) at Kövágó-Szöllös, Töttös, and Boda, in the same district. Finally the later collections of Boeckh and Hofmann made in the Komlóthal, at Abaliget, Puszta-Szobák, Rákos, Magyar-Hidas, Nádasd, Tekeres, and Ó-Falu, in Baranya County, which were elaborated by Staub in 1882,[3] indicate a flora which agrees in most respects with those of Sotzka, Radoboj, and Parschlug, and may be regarded as Lower Miocene.

The flora of Frusca-Gora, elaborated by Staub in 1881,[4] is also regarded by him as Lower Miocene (Aquitanian).

The Jurassic (Lias) plant bed at Steierdorf in Banat, in the southeastern part of Hungary, was known to Baron von Ettingshausen in 1852, the date of his monograph of the Lias and Oolite flora,[5] and five of the species there described were from that place. This flora has been more fully treated by Andrä.[6]

In a report on the condition of the phyto-paleontological collection of the Hungarian Geological Survey in 1885,[7] Dr. Staub communicated a useful catalogue of the species, arranged by horizons and localities. The Hungarian specimens were collected in the Carboniferous of Eibenthal and Szekul, Krassó-Szörény County; the Upper Permian of Kövágó-Szöllös, Töltös, Boda, and Cserkút, Baranya County; in the Upper Trias at Pécs, and the Rhetic of the Nagybánya Valley, both in Baranya County; in the Lower Lias at Domán and Steierdorf-Anina, Krassó-Szörény County; Pécs, Somogy, Hosszú-Hetény, and Vasas, Baranya County, and Váralja, in the

[1] Joh. Boeckh: Neueste Ausbeute an fossilen Pflanzenresten in der Umgegend von Fünfkirchen, von D. Stur. Verhandl. k.-k. geol. Reichsanstalt, Wien, 1874, pp. 115–118.

[2] Ueber Permische Pflanzen von Fünfkirchen in Ungarn, von Oswald Heer: Mitth. aus Jahrbuch k. ungar. geol. Anstalt, vol. 5, Budapest, 1876, pp. 1–18, pl. xxi–xxiv.

[3] Mediterrane Pflanzen aus dem Baranyaer Comitate, von Dr. M. Staub: Ibid., vol. 6, 1882, Heft 2, pp. 23–45, pl. i–iv.

[4] A Frusca-Gora aquitaniai florája. Móricz Staub: Értekezések a természettudományok köréből. Kiadja a Magyar Tudományos Akadémia, vol. 11, No. 2. Budapest, 1881, pp. 1–39, pl. i–iv.

[5] Begründung einiger neuen oder nicht genau bekannten Arten der Lias- und der Oolithflora, von C. von Ettingshausen: Abhandl. k.-k. geol. Reichsanstalt, Wien, vol. 1, No. 3, Abth. III, 1852, pp. 1–10, pl. i–iii.

[6] C. J. Andrä: Fossile Pflanzen der Tertiärformation von Szakadat und Thalheim in Siebenbürgen und der Lias Formation von Steierdorf in Banat. Zeitschr. Naturwiss., vol. 5, Halle, 1855, pp. 201–207.

[7] Stand der phytopaläontologischen Sammlung der konigl. ungarischen geologischen Anstalt am Ende des Jahres 1885, von M. Staub: Jahresb. k. ungar. geol. Anstalt, 1885, Budapest, 1887, pp. 205–234.

county of Tolna; the Lower Cretaceous (Tithonian) at Solymos Bucsáva, Arad County; the Cenomanian at Nadróg, in the county of Krassó-Szörény; in the Eocene at Gyalu Rupdie, county Szatmar, Nagy-Kovácsi, Pest-Pilis-Solt-Kiskún County, Odorin, Szepes County, Dorogh and Tokod, Esztergom County, Oszlop, in the county of Veszprém, and at Budapest; in the Lower Oligocene at Budapest, and the Upper Oligocene at Vrdnik and Kameniocza, Szerém County, and at Budapest; in the Miocene at Salgó-Tarján and Lörinczi, county of Nógrád, Ó-Falu, Nádasd, Magyar-Hidas, Német-Hidas, Abaliget, Tekeres, Rákos, and Pécs, in Baranya County, Dévény-Ujfalu, Pozsony County, Rákos, Brennberg, Harka, and Lajta-Ujfalu, Soprony County, Mariafalva and Gyepüfüzes, county of Vas, Alsó-Hagymás, Szolnok County, Ó-Borleven, Mehadia, Petrilova, Kricsova, Dalbosecz, Krassó-Szörény County, Erdöbénye and Megyaszó, Zemplén County, Czekeháza, Abauj-Torna County, Tepla, in the county of Bars, Valia-Lázuluj, Szatmár County, Szilisztye, Gömör County, Szliács, Zólyom County, Bodos, Parndorf, Mosony County, and Felsöbánya, Beocsin, Paptelke, and Czemek, in Szatmar, Szerem, Szilágy, and Pozsega Counties, respectively; in the Pliocene at Keresztúr and Szt.-Lörincz, in Pest-Pilis-Solt-Kiskún County; and in the Diluvium at Gánócz and Szepes-Olaszi, Szepes County. Fossil wood had been collected at Fony, Zemplén County, Lutila and Gyékényes, Bars County, Beregszász, Bereg County, Gács and Kékkö, in Nógrád County, Maria-Nostra, county Hont, Csömör, Puszta-Szt.-Mihály, Pilis-Szt.-Kereszt, and Hidegkút, in Pest-Pilis-Solt-Kiskún County, and at Budapest.

The silicified and opalized wood found so abundantly in Hungary has been made the subject of two excellent papers by Dr. Johannes Felix.[1] The specimens he studied were from Gyepüfüzes, Tapolesán, Medgyaszó, Sajba, Libet-Bánya, Zamuto, Ranka, Selmecz-Bánya, Budafok, and Blocksberg near Budapest, but many of the specimens were simply labeled "Hungary," without more definite designation.

Transylvania.—Ettingshausen, in 1851, mentioned the silicified wood of Vöröspatak, in the gold mines of Siebenbürgen (Transylvania),[2] but to Andrä is due the greater part of what we know of the Tertiary (Miocene) flora of Szakadat, and Thalheim, which is set

[1] Johannes Felix: Die Holzopale Ungarns in palæophytologischer Hinsicht. Mitth. aus Jahrbuch k. ungar. geol. Anstalt, vol. 7, Budapest, 1884, pp. 1–43, pl. i–iv.

Beiträge zur Kenntniss der fossilen Hölzer Ungarns. Paläophytologische Studien. Ibid., vol. 8, Heft 5, Budapest, 1887, pp. 145–162, pl. xxvii, xxvii^{a}.

[2] Das verkieselte Holz von Vöröspatak in der Goldbergbau von Vöröspatak in Siebenbürgen, von C. von Ettingshausen: Jahrbuch k.-k. geol. Reichsanstalt, Wien, vol. 2, 1851, No. 4, pp. 73–74. In F. von Hauer: Der Goldbergbau von Vöröspatak in Siebenbürgen.

forth in a paper already referred to (see foot-note 6 on page 723), and also in the later contributions.[1] Two other Miocene florules are known in Transylvania, namely, that of the Zsily-Thal, in the southeastern corner, described by Hofmann in 1870,[2] and upon which Heer published a paper in 1872[3] and Staub another in 1887;[4] and that of Felek, six miles south of Klausenberg, which has yielded only a few species thus far, but these few have been very carefully studied by Staub.[5]

Besides these Tertiary floras, plant remains have been found in the Cretaceous (Cenomanian) of Déva, reported by Unger in 1865,[6] and in the Lias of Hollbach and Neustadt, near Kronstadt, to which Stur called attention in 1872.[7]

In Staub's carefully prepared enumeration of the fossil plants of Hungary from which we have so freely drawn above for localities in that kingdom, he has, of course, included those of Transylvania which ceased in 1878 to have a separate political existence. The following completes his enumeration by including the counties (Hunyad, Háromszék, and Szeben) that fall within the boundaries of the old principality of Siebenbürgen or Transylvania, most of which have been previously mentioned: the Cenomanian and Miocene at Déva,

[1] C. J. Andrä: Tertiär-Flora von Szakadat und Thalheim in Siebenbürgen. Abhandl. k.-k. geol. Reichsanstalt, Wien, vol. 2, Abth. III, No. 4, 1855, pp. 1–48, pl. i–xii.

Ein neuer Beitrag zur Kenntniss der Tertiärflora Siebenbürgens. Abhandl. Naturwiss. Verein für Sachsen und Thür. Staaten, vol. 2, Berlin, 1858–1861, pp. 429–435, pl. i.

Berichtigungen zu den "Beiträgen zur Kenntniss der fossilen Flora Siebenbürgens und des Banats." Ibid., 1861, pp. 435–436, pl. vi.

[2] Das Kohlenbecken des Zsily-Thales in Siebenbürgen, von K. Hofmann: Jahrbuch k.-k. geol. Reichsanstalt, Wien, vol. 20, 1870, pp. 523–530.

[3] Ueber die braunkohlen-Flora des Zsily-Thales in Siebenbürgen, von Oswald Heer: Jahrbuch k. ungar. geol. Anstalt, vol. 2, Pest, 1872, Lieferung I, pp. 3–25, pl. i–vi.

[4] Die Aquitanische flora des Zsilthales im Comitate Hunyad, von Moritz Staub: Mitth. aus Jahrbuch k. ungar. geol. Anstalt, vol. 7, Heft 5, 1887, pp. 221–417, pl. xviii–xlii.

[5] Moritz Staub: Tertiäre Pflanzen von Felek bei Klausenburg. Jahrbuch k. ungar. geol. Anstalt, vol. 6, Heft 8, Budapest, 1883, pp. 263–281, pl. xviii.

Adalék a Feleki palaszén Kérdéséhez. Földtani Közlöny, vol. 14, Budapest, 1884, pp. 522–524.

Die Schieferkohlen bei Frek in Siebenbürgen. Verhandl. k.-k geol. Reichsanstalt, Wien, 1884, No. 15, pp. 306–308.

[6] Ueber einige fossile Pflanzenreste aus Siebenbürgen und Ungarn, von Franz Unger: Sitzungsber. k. Akad. Wiss., Wien, math.-nat. Cl., vol. 51, Abth. I, 1865, pp. 375–380, pl. i.

[7] Beiträge zur Kentniss der Liasablagerungen von Hollbach und Neustadt in der Umgegend von Kronstadt in Siebenbürgen, von D. Stur: Verhandl. k.-k. geol. Reichsanstalt, Wien, 1872, pp. 341–347.

the Oligocene in the Zsil Valley, the Miocene at Farkaspatak and Nagyág in Hunyad County, and the Pliocene at Bibarczfalva and Közép-Ajta in Hàromszék County; and the Diluvium at Felek in Szeben County.

Some of the specimens of fossil wood described by Felix in the papers mentioned above were also from Felek, Déva, and the Zsily-Thal; also from Nagy-Almás and Kristyor (Petrosza), in Hunyad County.

Galicia.—Pusch in his Polens Paläontologie, 1836 (see infra., p. 782), reported Carboniferous plants from Niedzielisko, Dabrowa, Bobrek, and Strzyzowice, Cretaceous plants from Biala, Zywiec, and Trabki, and Tertiary plants from Busko and Lemberg, in Galicia. The two important plant deposits of Galicia, however, are those of Swoszowice and Wieliczka, both in the western part of that province not far from each other, the former quite near the Polish frontier and the city of Crakow. Zeuschner early sent specimens from Swoszowice to Dr. Unger for the determination not only of the species but of the age of the sulphurous deposit in which they occur, and in 1850 the latter, who had already described several of them in his Chloris Protogæa, published a monograph of that flora in Haidinger's Memoirs,[1] which was followed in the same volume by a geological discussion by Zeuschner.[2] Twenty species from that locality were enumerated in Unger's paper.

Almost at the same time appeared a similar monograph by the same author on the flora of the saline beds of Wieliczka,[3] previously studied by Göppert.[4] Fifteen species were then known from that place, which, singularly enough, had only been increased by one species in 1873, when Stur undertook a revision of that flora.[5] The deposits are both Miocene.

From another plant bed, probably of the age of the Oolite, at Grojec,[6] Dr. Stur has recently described a number of species, nine of which are new.

Moravia.—Extensive Subcarboniferous plant-bearing deposits occur along the boundary of Moravia and Austrian Silesia, and west-

[1] Blätterabdrücke aus dem Schwefelflötze von Swoszowice in Galicien, von Franz Unger: Naturwiss. Abhandl. von Haidinger, vol. 3, Abth. I, Wien, 1850, pp. 121–128, pl. xiii, xiv.

[2] Geognostische Beschreibung des Schwefellagers von Swoszowice bei Krakau, von L. Zeuschner: Ibid., pp. 171–178, pl. i.

[3] Die Pflanzenreste im Salzstocke von Wieliczka, von Franz Unger: Denkschr. k. Akad. Wiss., Wien, math.-nat. Cl., vol. 1, 1850, pp. 311–322, 1 pl.

[4] Ueber Vegetationsreste im Salzstock im Wieliczka, von H. R. Göppert: Verhandl. schles. Gesell. Vaterl. Cultur, 1847, Breslau, 1848, p. 73.

[5] Beiträge zur genaueren Deutung der Pflanzenreste aus dem Salzstocke von Wieliczka, von D. Stur: Verhandl. k.-k. geol. Reichsanstalt, 1873, pp. 6–10.

[6] Ueber die Flora der feuerfesten Thone von Grojec in Galizien, von D. Stur: Ibid., 1888, No. 4, pp. 106–108.

ward at the foot of the Riesengebirge across the northern part of Bohemia. These deposits have been studied from a phyto-paleontological point of view since 1853, when Ettingshausen published a note on the fossil flora of Ostrau in Moravia.[1] In 1865 the same author described quite a number of plants from strata of the same age in Altendorf and Tschirm, and from five localities in Silesia.[2] This work was continued by Stur in several short notices in 1866,[3] preliminary to his great work on the Culm Flora.[4]

Ettingshausen, in 1852, published a number of Wealden species from Murk, near Neutitschein, and from Blansko, in Moravia.[5]

The important Cretaceous (Cenomanian) deposit at Moletein was elaborately studied by Heer, whose memoir[6] upon its fossil plants has become well known to paleobotanists. The stone-quarries in the Moletein Valley are near Mährisch-Altstadt, northwest of Olmutz, near the Bohemian frontier.

Austrian Silesia.—The following localities for the flora just described are in Austrian Silesia: Mohradorf, near Meltsch, Morawitz, Kunzendorf, Schönstein, southwest of Troppau, and Grätz, also near Troppau; and in addition we have in the Urgonian formation, Wernsdorf and Teschen, with the neighboring localities, Grodischtz, Straçonka, Lippowetz, Mistrowitz, Leipnik, Niedeck.[7]

Bohemia.—There is no province of Europe that has greater interest for the paleobotanist or in which the study of fossil plants has

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[1] Ueber die fossile Flora der Steinkohlenmulde von Mährisch-Ostrau, von C. von Ettingshausen: Jahrbuch k.-k. geol. Reichsanstalt, vol. 4, 1853, pp. 434–435.

[2] C. von Ettingshausen: Die fossile Flora des mährisch-schlesischen Dachschiefers. Sitzungsber. k. Akad. Wiss., Wien, math.-nat. Cl., vol. 51, Abth. I, 1865, pp. 201–214. Denkschr., vol. 25, Wien, 1866, Abth. I, pp. 77–116, pl. i–vii.

[3] D. Stur: Fossile Pflanzen aus der Steinkohlenformation von Rossitz und Oslawan. Verhandl. k.-k. geol. Reichsanstalt, Wien, 1866, pp, 70–72.

Vorlage einer Sammlung von fossilen Pflanzen aus der Steinkohlenformation der Rossitzer Gegend. Ibid., pp. 80–84.

Vorlage einer von Herrn Max Machanek geschenkten Sammlung von fossilen Pflanzen und Thierresten aus den Dachschiefern des mährisch-schlesischen Gesenkes. Ibid., pp. 84–86.

[4] Beiträge zur Kenntniss der Flora der Vorwelt. Vol. 1, Die Culm-Flora, von D. Stur: Abhandl. k.-k. geol. Reichsanstalt, Wien, vol. 8, 1875–1877. Heft I, Die Culm-Flora des mährisch-schlesischen Dachschiefers. Wien, 1875, pp. 1–106, pl. i–xvii. Heft II, Die Culm-Flora der Ostrauer und Waldenburger Schichten. Wien, 1877, pp. 1–366, pl. i–xxvii (xviii–xliv).

[5] Beitrag zur näheren Kenntniss der Flora der Wealdenperiode, von Constantin von Ettingshausen: Ibid., vol. 1, Abth. 3, No. 2, 1852, pp. 1–32, pl. i–v.

[6] Beiträge zur Kreideflora, von Oswald Heer. I, Flora von Moletein in Mähren. Neue Denkschr. allgem., schweiz. Gesell. Naturwiss., vol. 23, Zürich, 1869–'72, Mém. 2, pp. 1–24, pl. i–xi.

[7] Beiträge zur Flora der Vorwelt. III, die fossilen Pflanzen der Wernsdorfer Schichten in den Nordkarpathen, von August Schenk: Palaeontographica, vol. 19, 1871, pp. 1–34, pl. i–vii.

been more assiduously pursued than Bohemia. As the home of Sternberg and Corda, this might have been expected, and well have their successors, Feistmantel, Engelhardt, Stur, Velenovský, and the rest, sustained the character of those early workers.

It will be convenient in this case, even at the expense of chronologic exactness, to treat the fossil floras of Bohemia, as nearly as may be, in the order of their geological age, beginning at the lowest plant-bearing beds known.

Silurian.—Barrande in 1852[1] announced the existence of fucoids in the Silurian of Central Bohemia, but no attempt to develop the Silurian flora seems to have been made until 1881, when Stur worked up the material collected and sent him by Novak, Dusl, and Laube.[2] Six species are elaborately treated in that memoir, all of which were collected at Srbsko, but three of them were also found at Hostin, and two of them occurred at a third locality, namely Hlubočep.

Subcarboniferous.—The Culm of Stur, the flora of which he treats so elaborately in the large work already referred to, takes its name from the city of Culm, in the northwestern part of Bohemia, but all the fossil plants, with a few trifling exceptions (Ebersdorf, Peterswald, etc., near the boundary line), come from Moravia and Silesia, some of the localities for which have been given.

Carboniferous.—At the time that Sternberg[3] and Corda[4] wrote their great works on fossil plants, a large amount of material belonging to this formation existed in the Museum of Prag, which had been collected from time to time from Chomle, near Radnitz, Swina, Brás, Wranowitz, Muhlhausen, Nachod, Neupaka (Permian), etc. The more noted localities that have since been worked are: Stradonitz,[5] Radowentz (where Göppert's petrified forest occurs),[6] Přilep, Lisek,

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[1] Systéme Silurien du centre de la Bohème, par J. Barrande. Prague et Paris, 1852, xxx, 935 pp., 4°; atlas, 52 pl.

[2] Die Silur-Flora der Etage H-h₁ in Böhmen, von D. Stur: Sitzungsber. k. Akad. Wiss., Wien, math.-nat. Cl., vol. 84, Abth. I, 1881, pp. 330–391, pl. i–v.

[3] Versuch einer geognostisch-botanischen Darstellung der Flora der Vorwelt, von Kaspar Maria, Graf von Sternberg. Prag. 1820–1838, 8 Hefte, folio, pl. i–lix, *a–e*; i–lxviii, *a*, *b*. Essai d'un exposé géognostico-botanique de la flore d'un monde primtif, traduit par le comte F. G. de Bray. Ratisbonne, 4 Cahiers, with "Tentamen," 1820–1826, folio.

[4] Beiträge zur Flora der Vorwelt, von A. C. J. Corda. Prag, 1845, pp. i–viii, 1–128. pl. i–lx, folio.

[5] Die Steinkohlenflora von Stradonitz in Böhmen, von Constantin von Ettingshausen: Abhandl. k.-k. geol. Reichsanstalt, Wien, vol. 1, Abth. III, 1852, No. 4, pp. 1–18, pl. i–vi.

[6] H. R. Göppert: Ueber den versteinten Wald von Radowenz bei Adersbach in Böhmen und über den Versteinungsprocess überhaupt. Jahrbuch k.-k. geol. Reichsanstalt, Wien, 8th Jahrg., 1857, pp. 725–738.

Ueber die versteinten Wälder im nördlichen Böhmen und in Schlesien. 36th Jahresber. schles. Gesell., Breslau, 1858, pp. 41–49, pl. i–iii.

Miroschau;[1] Kralup[2] the so-called Nyřaner Gasschiefer,[3] Rakonitz,[4] Merklin,[5] Brandau,[6] and Schatzlar.[7] The number of papers and works relating more exclusively to the Radnitz flora is large, and Ettingshausen,[8] Krejči,[9] Feistmantel,[10] and Stur have contributed to its

[1] Fossile Pflanzen von Miroschau, Brás, Swina, und Saserberg, von D. Stur: Verhandl. k.-k. geol. Reichsanstalt, Wien, 1861, pp. 140-145.

Karl Feistmantel: Die Steinkohlenbecken bei Přilep, Lisek, Stilec, Holoubkau, Mireschau, und Letkow. Archiv für naturwiss. Landes-Durchforschung Bohmens, vol. 2, Prag, 1869, pp. 19-98.

Zur Flora von Miröschau (Aus einem Briefe an D. Stur). Verhandl. k.-k. geol. Reichsanstalt, Wein, 1874, pp. 256, 257.

[2] Steinkohlenflora von Kralup, in Böhmen, von O. Feistmantel: Abhandl. k. böhm. Gesell. Wiss., 6th series, vol. 5, Prag, 1871, pp. 1-38, pl. i-iv.

[3] Ottokar Feistmantel: Ueber Pflanzenpetrefackte aus dem Nyřaner Gasschiefer sowie seine Lagerung und sein Verhältniss zu den übrigen Schichten. Sitzungsber. k. böhm. Gesell. Wiss., Prag, 1870, pp. 56-73.

Beitrag zur Kenntniss der Ausdehnung des sogenannten Nyřaner Gasschiefers und seiner Flora. Jahrbuch k.-k. geol. Reichsanstalt, Wien, vol. 22, 1872, pp. 289-308.

[4] D. Stur: *Odontopteris bifurcata* St., sp. aus dem gräflich Nostitz'schen Kohlenbau in Lubna bei Rakonitz. Verhandl. k.-k. geol. Reichsanstalt, Wien, 1874, pp. 262-266.

Ueber das Niveau der in der Umgegend von Rakonitz abgebauten Flötze. Ibid., p. 267.

J. Kušta: Der Brandschiefer von Herrendorf bei Rakonitz. Ibid., 1878, pp. 354-358.

Zur Kenntniss der Steinkohlen-Flora des Rakonitzer Beckens. Ibid., pp. 380-385.

Ueber die fossile Flora der Rakonitzer Steinkohlenbeckens. Sitzungsber, k. böhm. Gesell. Wiss., Prag, 1883, pp. 157-186.

Weitere Beiträge zur Kenntniss der Steinkohlenflora von Rakonitz. Sitzungsber. k. böhm. Gesell. Wiss., Prag, 1886, pp. 487-498, 1 pl.

[5] Ueber Pflanzenreste aus dem Steinkohlenbecken von Merklin, von Ottokar Feistmantel: Sitzungsber. k. böhm. Gesell. Wiss., Prag, 1872, pp. 45-59.

[6] Ueber die Steinkohlenablagerung bei Brandau im Erzgebirge, von Ottokar Feistmantel: Sitzungsber. k. böhm. Gesell. Wiss., Prag, 1873, pp. 49-54.

[7] Ueber die Steinkohlenflora der Ablagerung am Fusse des Riesengebirges, von Ottokar Feistmantel: Sitzungsber. k. böhm. Gesell. Wiss., Prag, 1871, pp. 70-107.

D. Stur: Funde von untercarbonischen Pflanzen, der Schatzlarer Schichten am Nordrande der Centralkette in den nordöstlichen Alpen. Jahrbuch k.-k. geol. Reichsanstalt, Wien, vol. 33, 1883, pp. 189-206.

Beiträge zur Kenntniss der Flora der Vorwelt, vol. 2; Die Carbon-Flora der Schatzlarer Schichten. Abhandl. k.-k. geol. Reichsanstalt, vol. 11, Wien, 1885-1887. Abth. I, Die Farne der Carbon-Flora der Schatzlarer Schichten. Ibid., Abth. 1, 1885, pp. 1-418, pl. xviii-xxv, xxv*b*, xxvi-lxv. Abth. II, Die Calamarien der Carbon-Flora der Schatzlarer Schichten. Ibid., Abth. 2, 1887, pp. 1-240, pl. i-ii, ii*b*, iii-iv*b*, v-vii*b*, viii-xi*b*, xii, xii*b*, xiii, xiii*b*, xiv, xiv*b*, xv, xv*b*, xvi, xvi*b*, xvii.

[8] C. von Ettingshausen: Ueber die Steinkohlenflora von Radnitz in Böhmen. Bericht. 29th Versamml., Deutsch. Naturf. in Wiesbaden, 1852, pp. 148-149.

Die Steinkohlenflora von Radnitz in Böhmen. Abhandl. k.-k. geol. Reichsanstalt, Wien, vol. 2, Abth. III, 1855, no. 3, pp. 1-74, pl. i-xxix.

[9] J. Krejči: O kameném a hnedem uhli zoláště v Čechách (Ueber Stein- und Braunkohle, nämentlich in Böhmen). Živa, Prag, 1853, pp. 33-41, 97-104, 146-154, 168-175, 213-218, 353-361.

O kamenouhelném útvaru v Cechách (Ueber die Steinkohlen-Formation Böhmens). Časopis musea královstvá českého, 1865.

[10] Karl Feistmantel: Die Steinkohlengebilde in der Umgebung von Radnitz in

literature.[1] Permian plants have also been found at Budweis,[2] Kounova, Lhotitz, Nürschan,[3] and Radowentz.

The Schatzlar region lies at the foot of the Riesengebirge and embraces as its principal localities those of Schatzlar, Schwadowitz, and Zdárek, near Hronow. The Kralup and Rakonitz district to the northwest of Prag embraces Wotwowitz, Kladno, Zemech, Lana, Rapic, etc. The Lisek basin, in which Stradonitz is situated, contains also Hyskow, Zlejcina, and Dibři. To the Pilsen district belong the plant beds at Blattnitz, Třemošna, Mantau, Lihn, Zebnitz near Plass, Dobraken, Břiz, etc.; while the Radnitz basin includes Brás, Chomle, Swina, Wranowitz, Stupnai, Mostitz, and Lochowitz.

Karl Feistmantel in his paper on Araucaroxylon[4] enumerates the following Carboniferous localities in central Bohemia for trunks and stems belonging to this genus, which have not been previously mentioned: Slatina, Klobuk, Hředl, Tuřan, Kriegern, Kottiken, Guscht, Liehn, Routhoujezd, Manetin, Prohoř, Lochotin, Kreuzuntersatz, Libowitz, Zaboř, Ledeč, Wscherau, Zwoln, Mutiowitz.

Cretaceous.—Corda in 1845[5] described a large series of fossil plants from the Planer- and Quader-sandstein (Cenomanian) of Bohemia, and among the localities mentioned by him we find Tržiblitz, Laun, Perutz, Kutschlin, Weberschan near Polsterberg, Hradek, Smolintz, Hundorf, Czenczic, Drahomischel, Neubidschow, Msseno near Schlan, and Luschitz.

The sandstones of Perutz have received the name of that place and

Böhmen. Sitzungsb. k. böhm. Gesell. Wiss., Prag, 1860, vol. 2, pp. 17–25. Abhandl., 5th Folge, vol. 11, 1861, pp. 327–351.

Beobachtungen über einige fossile Pflanzen aus dem Steinkohlenbecken von Radnic. Abhandl. k. böhm. Gesell. Wiss., Prag, 1868, 6th Folge, vol. 2, pp. 1–24, pl. i, ii.

Die Steinkohlen-Becken in der Umgebung von Radnic. Archiv. für naturwiss. Landesdurchforschung von Böhmen, section 2, Geologische Untersuchungen, vol. 1, Wien, 1869, pp. 1–122, pl. i, ii.

[1] D. Stur: Pflanzenreste aus dem Hangenden des oberen Flötzes der Steinkohlen-Mulde von Břas bei Radnitz in Böhmen. Verhandl. k.-k. geol. Reichsanstalt, Wien, 1873, pp. 151–153.

Zur Kenntniss der Fructification der Noeggerathia foliosa St., aus dem Radnitzer Schichten des oberen Carbon in Mittel-Böhmen. Ibid., 1878, pp. 329–334.

[2] Vorläufige Notiz über die dyadische Flora der Anthracit-Lagerstätten bei Budweis in Böhmen, von D. Stur: Ibid., 1872, pp. 165–168.

[3] Ueber den Nürschaner Gasschiefer, dessen geologische Stellung und organische Einschlüsse, von O. Feistmantel: Zeitschr. deutsch. geol. Gesell., vol. 25, 1873, pp. 579–601, pl. xviii.

[4] Ueber Araucaroxylon in der Steinkohlenablagerungen von Mittel-Böhmen, von Karl Feistmantel: Abhandl. k. böhm. Gesell. Wiss., 6th series, vol. 12, Prag, 1883, No. 6, 24 pp., 2 pl.

[5] Pflanzen beschrieben und gebildet von A. C. J. Corda. [In] Reuss (A. E.): Die Versteinerungen der böhm ischen Kreideformation, Stuttgart, 1845–'46, pp. 81–96, pl. xlvi–li, 4°.

have been the subject of several papers by Krejči,[1] Feistmantel,[2] and Stur.[3]

With the exception of a note by Feistmantel, in 1870, on a few forms found at Kuchelbad,[4] nothing further than the frequent mention of Cretaceous plants from Bohemia in general works on paleobotany appears until the year 1881, when Velenovský came out with his preliminary report on the dicotyledonous plants of the Bohemian Cretaceous formation,[5] and announced the commencement of his large work, which began to appear in 1882,[6] and is still unfinished.

His Gymnosperms of the Bohemian Cretaceous[7] was published as a separate work through a subvention from the committee for the investigation of the natural history of Bohemia. The following localities appear to have yielded no dicotyledons: Nehvizd, Vysočan, Vojice near Jičín, Hořic, Choceň, Melník on the Sazava, Landsberg, Lipenec near Laun, Citov near Beřkovic, Slavětín, Kněživka, Hospazin, Raudnic, and Bezdĕkov in the vicinity of Reichenau.

Among the localities named by Velenovský that have not already been mentioned occur those of Chlomek near Leipa, Hodkovic, Vyšerovic, Kaunic, Vydovle near Jinonic, Kozákov, Trubějov near Náchob, Mšeno, Lidic, Onjezd near Jičín, Weissenberg, Počernic, and Hasenberg near Prague, Liebenau, Cibulka.

Tertiary.—All the Tertiary plant beds in Bohemia are probably Miocene, although they doubtless represent quite different horizons of that formation.

In 1839, Haidinger mentioned the occurrence of plants in the so-called Elbogener Kreis,[8] and, in 1840, Rossmässler published his re-

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[1] Časopis prirodnicky, vol. 1, 1853.

[2] Vorbericht über die Perucer Kreideschichten in Böhmen und ihre fossilen Reste, von Ottokar Feistmantel: Sitzungsber. math.-nat. Cl., k. böhm. Gesell. Wiss., Prag, 1874, pp. 255–276.

[3] Vorkommen einer Palmenfrucht-Hülle, Lepidocaryopsis Westphaleni, n. g. et sp., im Kreide-Sandstein der Peruzer-Schichten bei Kaunitz in Böhmen, von D. Stur: Verhandl. k.-k. geol. Reichsanstalt, Wien, 1873, pp. 1–3.

[4] Ueber Reste der Kreideformation bei Kuchelbad, von Ottokar Feistmantel: Sitzungsber. k. böhm. Gesell. Wiss., Prag, 1870, pp. 73–75.

[5] Vorläufiger Bericht über die dicotyledonen Pflanzen der böhmischen Kreideformation, von J. Velenovský: Ibid., 1881, pp. 212–219.

[6] Die Flora der böhmischen Kreideformation, von J. Velenovský. Theil I: Beiträge zur Paläontologie Oesterreich-Ungarns und des Orients, von Mojsisovics und Neumayr, vol. 2, Hefte 1, 2, Wien, 1882, pp. 9–32 (1–25), pl. iii–viii (i–vi); Theil II: Ibid., vol. 3, Heft 1, Wien, 1883, pp. 1–22 (26–47), pl. i–vii (ix–xv); Theil III: Ibid., vol. 4, Heft 1, Wien, 1884, pp. 1–14 (48–61), pl. i–viii (xvi–xxiii); Theil IV: Ibid., vol. 5, Heft 1, Wien, 1885, pp. 1–14 (62–75), pl. i–viii (xxiv–xxxi).

[7] Die Gymnospermen der böhmischen Kreideformation, von Josef Velenovský. Prag, 1885 (veröff. mit Subvention d. Com. für die naturwiss. Durchforsch. Böhmens), pp. 1–34, pl. i–xiii, folio.

[8] Ueber das Vorkommen von Pflanzenresten in den Braunkohlen- and Sandstein-Gebilden des Elbogner Kreises in Böhmen, von W. Haidinger: Abhandl. k. böhm. Gesell. Wiss., vol. 1, No. 3, Prag, 1839, pp. 1–12.

markable work on the fossils of Altsattel[1] in the same region. Ettingshausen's splendid series of papers on the flora of Bilin was commenced in 1851[2] and closed in 1869. Jokély, 1858, enumerated the plants of the Saaz basin,[3] and the tufaceous basalts of Altwarnsdorf in northern Bohemia, 1862,[4] and Stur, 1866, those of Leinisch on the Elbe.[5]

Then commenced the critical and carefully descriptive studies of Engelhardt on the fossil floras of the Leitmeritz Mittelgebirge (Salesl, Holaikluk), 1876;[6] of Tschernowitz, 1877;[7] of the Cypris shales of Egerufer between Falkenau and Königswerth, the Krottensee, and Grasseth, 1879;[8] of Liebotitz and Putschirn, 1880;[9] of Grasseth, 1881;[10] of Waltsch, 1884;[11] and of the Jesuitengraben at Kundratitz, in northern Bohemia, 1885.[12]

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[1] Beiträge zur Versteinerungskunde, von E. A. Rossmässler, Heft 1. Die Versteinerungen des Braunkohlensandsteins aus der Gegend von Altsattel in Böhmen (Elnbogener Kreises). Dresden und Leipzig, 1840, pp. 1–48, pl. i–xii, 8°.

[2] Constantin von Ettingshausen: Ueber fossile Flora der nächsten Umgebung, von Bilin und Teplitz. Jahrbuch k.-k. geol. Reichsanstalt, Wien, vol. 2, 1851, No. 1, pp. 154–155.

Die fossile Flora des Tertiär-Beckens von Bilin. I. Theil, Denkschr. k. Akad. Wiss. Wien, math.-nat. Cl., vol. 26, Abth. I, 1867, pp. 79–176, pl. i–xxx; II. Theil, Ibid., vol. 28, Abth. I, 1868, pp. 191–242, pl. xxxi–xxxix; III. Theil, Ibid., vol. 29, Abth. I, 1869, pp. 1–110, pl. xi–xiv.

[3] Die Tertiärablagerungen des Saazer Beckens und der Teplitzer Bucht, von Johann Jokély: Jahrbuch k. -k. geol. Reichsanstalt, Wien, vol. 9, 1858, pp. 519–548.

[4] Pflanzenreste aus dem Basaltutuffe von Alt-Warnsdorf in Nord-Böhmen, von Johann Jokély: Ibid., vol. 12, 1861–1862, pp. 379–381.

[5] Blattabdrücke aus dem Polierschiefer am Fahrwege von Leinisch nach Aussig an der Elbe, oberhalb Priesnitz, von D. Stur: Verhandl. k. -k. geol. Reichsanstalt, Wien, 1866, pp. 138, 139.

[6] Tertiärpflanzen aus dem Leitmeritzer Mittelgebirge. Ein Beitrag zur Kenntniss der fossilen Pflanzen Böhmens, von Hermann Engelhardt: Nova Acta Acad. Leop.-Carol., vol. 38, Dresden, 1876, pp. 341–440, pl. xvi–xxvii.

[7] Ueber die fossilen Pflanzen des Süsswassersandsteins von Tschernowitz. Ein neuer Beitrag zur Kenntniss der fossilen Pflanzen Böhmens, von Hermann Engelhardt: Ibid., vol. 39, No. 7, Dresden, 1877, pp. 356–400, pl. xx–xxiv.

[8] Ueber die Cyprisschiefer Nord-Böhmens und ihre pflanzlicher Einschlüsse, von Hermann Engelhardt: Sitzungsber. naturwiss. Gesell. Isis. Dresden, 1879, pp. 131–152, pl. vii–ix.

[9] Ueber Pflanzenreste aus den Tertiärablagerungen von Liebotitz and Putschirn, von Hermann Engelhardt: Ibid., 1880 (Dresden, 1881) pp. 77–86, pl. i, ii.

[10] Ueber die fossilen Pflanzen des Süsswassersandsteins von Grasseth. Ein neuer Beitrag zur Kenntniss der fossilen Pflanzen Böhmens, von Hermann Engelhardt: Nova Acta Acad. Leop.-Carol., vol. 43, Halle, 1881, pp. 275–324, pl. x–xxi.

[11] Ueber tertiäre Pflanzenreste von Waltsch, von Hermann Engelhardt: Leopoldina, vol. 20, Halle, 1884, pp. 129–132, 145–148.

[12] Die Tertiärflora des Jesuitengrabens bei Kundratitz in Nordböhmen. Ein neuer Beitrag zur Kenntniss der fossilen Pflanzen Böhmens, von Hermann Engelhardt: Nova Acta Acad. Leop.- Carol., vol. 48, Halle, 1885, No. 3, pp. 1–112, pl. viii–xxviii.

The late Dr. Sieber, in 1879–'80,[1] worked up the Miocene plant beds of Kutschlin, Sobrussan, Priessen, Preschen, Kostenblatt, Prohn, Waltsch, etc.; Wentzel in 1881, those of Sulloditz;[2] and Velenovský the same year the burnt clays of Vřsovic near Laun.[3]

Austria proper.—As compared with Bohemia, Hungary, Styria, and other acquired provinces, Austria proper furnishes little of interest to the paleobotanist. In the Tertiary beds of Vienna, both the Eocene (Nummulitic) algæ[4] and the higher Miocene forms have been chiefly studied by Baron von Ettingshausen, whose Fossil Flora of Vienna appeared in 1851.[5] Some of the more exact localities in the vicinity of that city from which fossil plants have been taken are Inzersdorf, Laa, Liesing, and Hernals; also, the oft-mentioned Eichkogel near Mödling, the plants from which were named by Unger and published by Karrer,[6] and the marine conglomerate of Kalksburg, where Wiesbaur[7] found fruits and nuts, and whence came the so-called "Palm of Kalksburg," which is in the natural history cabinet of that place.

There is also a Miocene plant bed at Wildshuth, in Upper Austria, on the Salzach River, which was made the subject of a short monograph by Ettingshausen in 1852.[8]

The material from the Flysch, in the quarries of Bergheim and Muntigl, described by Fugger and Kastner in 1885,[9] should be men-

[1] Johann Sieber: Ein Beitrag zur Kenntniss der Flora der Diatomaceenschiefer von Kutschlin bei Bilin. Verhandl. k.-k. geol. Reichsanstalt, Wien, 1879, pp. 241–243.

Zur Kenntniss der nordböhmischen Braunkohlenflora. Sitzungsber. k. Akad. Wiss., Wien, math.-nat. Cl., vol. 82, 1880, Abth. I, pp. 67–101, pl. i–v.

[2] Die Flora des tertiären Diatomaceenschiefers von Sulloditz im böhmischen Mittelgebirge, von Joseph Wentzel: Sitzungsber. k. Akad. Wiss., Wien, math.-nat. Cl., vol. 83, Abth. I, 1881, pp. 241–265, pl. i.

[3] Die Flora aus den ausgebrannten tertiären Letten von Vřsovic bei Laun, von J. Velenovský: Abhandl. k. böhm. Gesell. Wiss., 6th series, vol. 11, math.-nat. Cl., No. 1, Prag, 1882, pp. 1–54, pl. i–x.

[4] Die fossilen Algen des Wiener und des Karpathen-Sandsteines, von Constantin Ritter von Ettingshausen: Sitzungsber. k. Akad. Wiss., Wien, math.-nat. Cl., vol. 48, Abth. I, 1863, pp. 444–467, pl. i, ii.

[5] C. von Ettingshausen: Notiz über die fossile Flora von Wien. Jahrbuch k.-k. geol. Reichsanstalt, Wien, vol. 2, No. 4, 1851, pp. 39–46.

Die Tertiär-Floren der Oesterreichischen Monarchie. No. I, Fossile Flora von Wien. Abhandl. k.-k. geol. Reichsanstalt, Wien, vol. 2, Abth. III, 1851, pp. 1–36, pl. i–v.

[6] Der Eichkogel bei Mödling, von Felix Karrer: Jahrbuch k.-k. geol. Reichsanstalt, Wien, vol. 10, 1859, pp. 25–29.

[7] Fossile Pflanzen im marinen Tertiär-Conglomerate zu Kalksburg bei Wien, von J. Wiesbaur: Verhandl. k.-k. geol. Reichsanstalt, Wien, 1874, pp. 157–165.

[8] Beitrag zur Kenntniss der fossilen Flora von Wildshuth in Oberösterreich, von Constantin von Ettingshausen: Sitzungsber. k. Akad. Wiss., Wien, math.-nat. Cl., vol. 9, 1852, pp. 40–48, pl. ii–v.

[9] Naturwissenschaftliche Studien und Beobachtungen aus und über Salzburg . . . von Eberhard Fugger und Carl Kastner. Salzburg, 1885. 132 pp., 2 pl., 12 text fig., 8°. [Die Steinbrüche von Bergheim und Muntigl, pp. 62–77.]

tioned here, as both these localities are located on the Salzach. The plant forms justify the statement of these authors that the beds are an extension of the Flysch of Switzerland.

Stur, in his Flora of the Süsswasserquarze (supra, p. 721), enumerates most of the above-mentioned beds and adds those of the Belvedersandgruben, Arsenale, Laaerberg, Simmering, Gumpendorf, Reissenberg, Moosbrunn, Zillingsdorf, Tanzbodenberg in the Upper Danube Valley, Neufeld, the Breitensee, and Nussdorf.

There are also Cretaceous plant-bearing deposits in Austria; namely, one at Ischl, probably in the Lower Quader or Cenomanian, and two others, which, though widely separated, have been placed in the Gosau formation or Senonian system. One of these latter is at Sanct Wolfgang, in Upper Austria, and the other at Neue Welt, in Lower Austria, which must not be confounded with another plant bed of the same name but different age in Switzerland. Plants from all three of these beds were studied by Unger in 1867.[1]

The Wealden beds of Zöbing, in Lower Austria, were made known by Ettingshausen in his contribution to the flora of the Wealden period, published in 1852.

An important Keuper (Lettenkohle) plant-bearing deposit occurs in the vicinity of Lunz, in Lower Austria, at the head of the river Ips, on the northern slope of the so-called North Kalkalp, near the Styrian boundary. It was surveyed in 1863–'64 by Stur, Lipold,[2] Hertle, Rachoy, and Sternberg, and a collection of the plant remains was then made. A list of these plants was given in Stur's Geology of Styria, 1871, p. 250. The subject rested here until 1885, when the same author published a paper on this flora compared with that of Raibl in Carinthia[3] which had been much longer known, and the conclusion was here reached that the latter is considerably older than the deposit at Lunz, which is regarded as upper Keuper. On receipt of Prof. William M. Fontaine's Monograph of the Older Mesozoic Flora of Virginia, the distinguished Director of the Austrian Survey was struck with the resemblance of the Virginia plants to those of Lunz, and requested Professor Fontaine to send him some specimens of that flora. Through the intervention of the U. S. Geological Survey this request was complied with, and a study of these specimens led him to the conclusion not only that the two floras were practically identical and at the same geological horizon as those of Stuttgart and Neue Welt (near Basle, in Switzerland), but that a large number of Professor Fontaine's species were the same as those

[1] Kreidepflanzen aus Österreich, von Franz Unger: Sitzungsber. k. Akad. Wiss., Wien, math.-nat. Cl., vol. 55, Abth. I, 1867, pp. 642–654, pl. i, ii.

[2] Lipold und Stur: Das Kohlengebiet in den nordöstlichen Alpen. Jahrbuch k.-k. geol. Reichsanstalt, Wien, vol. 15, 1865, pp. 1–163.

[3] Die obertriadische Flora der Lunzer-Schichten und des bituminösen Schiefers von Raibl, von D. Stur: Sitzungsber. k. Akad. Wiss., Wien, math.-nat. Cl., vol. 111, Abth. I, 1885, pp. 94–103.

named, but neither described nor figured, by him in the paper above quoted—one of the best illustrations of the futility of publishing new species in mere lists, which can have no meaning to any but the author of such lists. These views were set forth in a recent paper published as soon as such comparisons had been completed.[1]

Finally might be noted the recent mention by Gümbel[2] of the discovery of the remains of supposed algæ in the Silurian clay shales of the Schwarz-Leogang Valley near Saalfelden, west of Dienten, in Salzburg.

Carniola.—The only important district in Carniola from which fossil plants have been obtained is that of Sagor, in the northeastern portion of the province, on the Save and near the Styrian boundary, although three dicotyledonous species were collected by Hauer at Laak, northwest of Laibach, and determined by Ettingshausen in 1851.[3] With the exception of a small florule at Möttnig, to the north of Sagor, in which Stur in 1870[4] found two new species of fern, which he correlates with the Sotzka beds of Styria (Oligocene), the fossil flora of Sagor has been elaborated entirely by Baron von Ettingshausen from materials collected by Morlot and other officers of the Austrian Geological Survey and deposited in the museum of that institution. The plants have been found at a number of points in the close vicinity of Sagor, among which the following are the principal ones: Friedhof, Bach, Francisci, Godredesch, Savine, Islaak, Hrastnigg, Bresno, Trifail, and Tüffer, the last three of which are just over the boundary in Styria. These places are, however, of very unequal importance, Savine having yielded 313 species, Bach 79, Trifail 76, and Friedhof 40 of the 387 species that belonged to the Sagor flora in 1885. The splendid series of memoirs in which Ettingshausen has monographed this flora can not receive too great praise. It began in 1851 and closed in 1885.[5]

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[1] D. Stur: Die Lunzer-(Lettenkohlen-)Flora in den "older Mesozoics beds of the Coal-Field of Eastern Virginia." Verhandl. k.-k. geol. Reichsanstalt, Wien, 31 Juli 1888, No. 10, pp. 203–217.

[2] Algenvorkommen im Thonschiefer des Schwarz-Leogangthales bei Saalfelden, von C. W. von Gümbel: Verhandl. k.-k. geol. Reichsanstalt, Wien, 1888, No. 9, pp. 189–190.

[3] Fossile Pflanzenreste von Laak in Krain (Daphnogene cinnamomifolia Ung., Flabellaria latania, Rossm.), von C. von Ettingshausen: Berichte über Mitth. Fr. Naturwiss., Wien, von Haidinger, vol. 7, 1851, pp. 112, 113.

[4] Ueber zwei neue Farne aus den Sotzka-Schichten von Möttnig in Krain von D. Stur: Jahrbuch k.-k. geol. Reichsanstalt, Wein, vol. 20, 1870, pp. 1–14, pl. i, ii.

[5] Constantin von Ettingshausen: Ueber die fossile Flora von Sagor in Krain. Ibid., vol. 2, 1851, part 2, pp. 185, 186, 188, 189. Anzeiger Akad. Wiss., Wien, Jahrg., 1871, No. 10, pp. 88–90.

Die fossile Flora von Sagor in Krain. I. Theil, Denkschr. k. Akad. Wiss., Wien, math.-nat. Cl., vol. 32, 1872, Abth. I, pp. 159–202, pl. i–x. II. Theil, Ibid., vol. 37, 1877, Abth. I, pp. 161–216, pl. xi–xxvii. III. Theil, Ibid., vol. 50, 1885, Abth. I, pp. 1–56, pl. xxviii–xxxii.

As regards its geological position, the plants indicate considerable range of horizon from that of Friedhof, which may be Upper Eocene, to that of Savine, which is evidently Aquitanian, or Lower Miocene. The Bach and Trifail beds may perhaps be best classed as Oligocene.

Plants of paleozoic age have also been noted near Assling by Stur,[1] who has assigned them to the age of the Upper Carboniferous.

Carinthia.—Fossil plants have been found in Carinthia at several horizons, namely in the Carboniferous of the southern portion between the Gail and Canal valleys at Vogelbach, Nassfeld, Weissenbach, Kovatsch, Rothenstein, and the Kron and Zirkel Alps, from which Unger described about twenty species in 1870;[2] the celebrated black shales of Raibl (Keuper) in the extreme southern point below the Canal valley in which Bronn[3] (1858), Schenk (1866),[4] Zwanziger (1871–1873),[5] and Stur (1868,[6] 1885[7]) have so successfully worked; in the Gosau (Senonian) formation at Althofen and Guttaring, in the northeastern section, from which Unger described one species (*Rosthornia Carinthiaca*) in the second supplement to Endlicher's Genera Plantarum, 1843, page 101; and in the Tertiary (Miocene) of Prevali in the Lavantthal, still farther to the northeastward and 53 kilometers east of Klagenfurt, which was the subject of a little paper by Unger[8] in 1855; and of Liescha, in the same immediate district

[1] Obercarbonische Pflanzenreste vom Bergbau Reichenberg, bei Assling, in Oberkrain, von D. Stur: Verhandl. k.-k. geol. Reichsanstalt, Wien, 1886, No. 15, pp. 383–385.

[2] Anthracit-Lager in Kärnthen, von Franz Unger: Sitzungsber. k. Akad. Wiss., Wien, math.-nat. Cl., vol. 60, 1870, Abth. I, pp. 777–792, pl. i–iii.

[3] Beiträge zur triassischen Fauna und Flora der bituminösen Schiefer von Raibl, etc., von Heinrich G. Bronn: Neues Jahrbuch für Mineral. 1858, pp. 1–32; 129–144, pl. i–x. [Reprint, Stuttgart, 1858, 63 pp., 10 pl., 8°.] Verhandl. Nat. Med. Ver. Heidelberg, vol. 1, 1857–1859, pp. 108–110. Heidelberg Jahrbuch Lit., 1858, pp. 342–344.

[4] Ueber die Flora des schwarzen Schiefers von Raibl, von A. Schenk: Würzburger naturwiss. Zeitschr., vol. 6, 1866–'67, pp. 10–20, pl. i–ii.

[5] Gustav Adolf Zwanziger: Ein botanischer Ausflug nach Raibl. Jahrbuch naturhist. Landes-Museums v. Kärnten, Heft 10, Klagenfurt, 1871, pp. 85–113.

Die Farn- oder Zapfenpalmen. Carinthia, 1872, No. 12, pp. 337–350.

Sphenozamia augustæ Zwgr. Ein Cycadeenwedelabdruck von Raibl in Kärnten. Jahrbuch naturh. Landes-Museums von Kärnten, Heft 9, Klagenfurt, 1873, pp. 212–218.

[6] Beiträge zur Kenntniss der geologischen Verhältnisse der Umgegend von Raibl und Kaltwasser, D. Stur: Jahrbuch k.-k. geol. Reichsanstalt, Wien, vol. 18, 1868, pp. 71–122.

[7] Die obertriadische Flora der Lunzer-Schichter und des bituminösen Schiefers von Raibl, von D. Stur: Sitzungsber. k. Akad. Wiss., Wien, math.-nat. Cl., vol. 111, 1885, Abth. I, pp. 94–103.

[8] Bemerkungen über einige Pflanzenreste im Thonmergel des Kohlenflötzes von Prevali, von F. Unger: Sitzungsber. k. Akad. Wiss., Wien, math.-nat. Cl., vol. 18, 1855, pp. 28–33, plate.

where Zwanziger[1] has worked since 1872, and of the flora of which he published in 1878 a valuable little monograph of thirty-six species.[2]

Tyrol.—The celebrated leaf-bed at Häring was known to Schlotheim[3] and Sternberg,[4] and down to the year 1850 the general works of Göppert and Unger had enumerated nineteen species from that place. It remained for Ettingshausen, in 1853, to develop it in a thorough manner, as was done in his Tertiary Flora of Häring in Tyrol.[5] Its geological position has been definitively fixed as Oligócene.

No other important papers relating to the Tyrol have appeared, but Schenk, in 1875,[6] described eight species from Brandenberg near Brixlegg, in north Tyrol, belonging to the Gosau formation (Senonian); Gümbel, 1877,[7] found Permian plants at Neumarkt on the Etsch, north of Trient; and Stur has more recently (1886)[8] discovered quite a flora in the interglacial (Quaternary) calcareous tufas or breccia of Hötting near Innsbruck, one species of which, *Rhododendron Ponticum* L., has been very fully discussed by Wettstein (1888).[9]

Vorarlberg.—In Escher von der Linth's Darstellung der Gebirgsarten in Vorarlberg, 1853,[10] Heer contributed the report on the fossil

[1] Gustav Adolf Zwanziger: Die urweltliche Pflanzendecke Kärntens. Carinthia, 1872, No. 4, pp. 97–104.

Neue Funde von Tertiärpflanzen aus den Braunkohlenmergeln von Liescha. Carinthia, 1873, No. 4, pp. 99–102.

Nachtrag zu den neuen Funden von Tertiärpflanzen aus den Braunkohlenmergeln. Ibid., pp. 102–104.

Neue Pflanzenabdrücke von Liescha. Klagenfurter Zeitung, No. 93, 24 April, 1873, p. 629.

[2] Beiträge zur Miocänflora von Liescha, von Gustav Adolf Zwanziger: Jahrbuch natur-hist. Landes-Museum von Kärnten, Heft 13, Klagenfurt, 1878, pp. 1–111, pl. i–xxviii.

[3] Petrefaktenkunde, 1820, pp. 393, 416.

[4] Sternberg, Flora der Vorwelt, vol. 1, fasc. 2, 1820, p. 28.

[5] Die tertiäre Flora von Häring in Tirol, von C. von Ettingshausen: Abhandl. k.-k. geol. Reichsanstalt, Wien, vol. 2, Abth. III, No. 2, 1853 pp. 1–118, pl. i–xxxi.

[6] Beiträge zur Flora der Vorwelt. VI. Ueber einige Pflanzenreste aus der Gosauformation Nordtirols, von Dr. A. Schenk: Palæontographica, vol. 23, Cassel, 1875–'76, pp. 164–171, pl. xxviii–xxix.

[7] Vorläufige Mittheilung über das Vorkommen der Flora vom Fünfkirchen im sogensunten Grodner Sandstein Südtyrols (Ullmaniensandstein), von C. W. Gümbel: Verhandl. k.-k. geol. Reichsanstalt, Wien, 1877, pp. 23–26.

[8] Beitrag zur Kenntniss der Flora des Kalktuffes und der Kalktuff-Breccie von Hötting bei Innsbruck, von D. Stur: Abhandl. k.-k. geol. Reichsanstalt, Wien, vol. 12, 1886, No. 2, pp. 33–58, pl. i, ii.

[9] Rhododendron Ponticum L., fossil in den Nordalpen, von Rich. R. v. Wettstein: Sitzungsber. k. Akad., Wiss.. Wien, math.-nat. Cl., vol. 97, Abth. I, 1888, pp. 38–49, 1 pl.

[10] Geologische Bemerkungen über das nördliche Vorarlberg und einige angrenzenden Gegenden, von A. Escher von der Linth: N. Denkschr. schweiz. Gesell. naturwiss., vol. 13, Zürich, 1853, Mem. No. 5. Beschreibung der angeführten Pflanzen und Insekten, von Prof. O. Heer. A, Pflanzen, Mem. Ibid., pp. 117–135, pl. vi–viii.

plants. Besides the six diatoms, eight species of plants are described from Weissenbach, Thannberg in the Lechthal, and Val Trompia, and San Rocco near Oneta (Val Gorno in Val Seriana) over the boundary in Italy (see supra, p. 714), in strata ranging from the Buntersandstein to the Keuper.

SWITZERLAND.

Our knowledge of the fossil flora of Switzerland is so largely due to the herculean labors of Oswald. Heer that it might almost be set forth without the mention of other names. Yet looking at the subject from a historical point of view we find that, aside from the old works of Lange, Scheuchzer, etc., and the accidental collections which found their way into the great museums and were mentioned in the early general works of Schlotheim, Sternberg, and Brongniart, at least one author, Peter Merian, had anticipated Heer's earliest memoir by publishing a paper on the fossil flora of the Keuper formation of Basle, 1835.[1] Ten distinct forms are described in this memoir, chiefly ferns and Cycads.

Heer began his investigations in 1846 and a popular lecture, published in the proceedings of the Swiss Society,[2] gives an account of the fossil plants discovered in the Hohe Rhonen. In 1850 he contributed an important paper to the Swiss Naturalist's Society,[3] on the Anthracite plants of the Alps, with a list of the species contained in the museums of Zürich and Basle, which included many from the Tarentaise, but the greater number were from the Col de Balme and Erbignon in the canton of Valais.

Three years later were published in the same serial his notes giving a summary of the Tertiary flora of Switzerland, which he had prepared and sent to Professor Studer at Berne.[4] This series of five papers presents a clear view of the history of the investigations that led to his great work on this flora. Especially important for our present purpose is the description of the localities at which his extensive series of specimens was obtained. These, in the order given, were mainly as follows: The Hohe Rhonen, canton of Zug, chiefly at Greith, where he says he spent three vacations collecting; the Albis, in the same general section of Switzerland; Saint Gall and Mönzlen (Solitude), and Riethhüsli in that vicinity, also in the canton of Appenzell adjacent; Eriz in the Zulgthal near the Thunersee

[1] Ueber die fossile Flora der Keuperformation in den Umgebungen von Basel, von Peter Merian: Bericht über Verhandl. naturf. Gesell., Basel, vol. 1, 1835, pp. 36–38. Bibl. Univ. vol. 4, 1836, pp. 182–183.

[2] Ueber die von ihm an der hohen Rhonen entdeckten fossilen Pflanzen, von Oswald Heer: Verhandl. schweizer. naturf. Gesell., 31st Versamml., 1846, pp. 35–38.

[3] Ueber die Anthrazitpflanzen der Alpen, von Oswald Heer: Mitth. naturf. Gesell., Zürich, vol. 2, Nos. 48 und 49, 1850, pp. 129–153.

[4] Uebersicht der Tertiärflora der Schweiz, von O. Heer. Sendschreiben an Herrn Prof. B. Studer: Mitth. naturf. Gesell., Zürich, vol. 3, 1853, Nos. 84–88, pp. 88–153.

in central Switzerland, canton of Berne; Delsberg, in the northwest, but still in Berne; Lausanne, on the north side of Lake Geneva, canton of Vaud; Stettfurt, canton of Thurgau; the Irchel Mountain at Neftenbach, and Rorbas, in the northern part of the canton of Zürich; Moos Leerau, canton of Luzern; and Mornex near Geneva. He also includes in this enumeration the fossil plants of Oeningen near Stein, which is across the Untersee, in the Duchy of Baden, and will be considered in connection with that State. The whole number of species enumerated in these papers was 308.

From these and other materials was prepared his great work on the Tertiary flora of Switzerland, the first volume of which appeared in 1855, the second in 1856, and the third in 1859.[1] All paleobotanists may be assumed to be acquainted with this work, so that even if here were the place, an analysis of its contents would be unnecessary. The geographical and geological considerations, however, that occupy the early portion of the general part of the third volume, require special attention here.

The localities are carefully specified and classified as follows: (1) Canton of Vaud: Valley of the Paudèze near Lutry; vicinity of Lausanne; Monod near Chexbres. (2) Canton of Berne: Ralligen, Eriz, Aarwangen, Weinhalde above Münsingen. (3) Jura Mountains: Delsberg in Berne, La Chaux-de-Fonds and Locle in Neuchâtel. (4) Vicinity of Luzern: Wäggis, Rossberg. (5) Valley of the Linth; Käpfnach southeast of Horgen, Oberalbis, Mühleberg, the Faletsche southeast of Zürich, Schwamendigen northeast of Zürich, Irchel Mountain northwest of Winterthur, the above all in the canton of Zürich; Hohe Rhonen at Greith, and Wurf, canton of Zug; Utznach and Rüfi between Kaltbrunn and Schännis, canton of Saint Gall. (6) Saint Gall: Solitude, Riethhüsli, Lindau between Farnach and Alber-Schwendi south of Bregenz. (7) Region of Steckborn and Oeningen: Berlingen on the Johalde north of Frauenfeld, and east of Steckborn near the lake shore, canton of Thurgau; also at Oeningen and near Wangen in Baden, on the north shore of the opening of the Untersee that forms the source of the Rhine.

As regards the geologic age of the plant-bearing Tertiaries of Switzerland, Heer follows the classification of K. Mayer and regards the entire Molasse as Miocene, dividing it into three general and five special stages: The Lower Miocene, further subdivided into Tongrian and Aquitanian; the Middle Miocene, with its Mainz and Helvetic stages; and the Upper Miocene or Oeningen stage. This last was treated as Pliocene by Brongniart in 1849,[2] and is so regarded by some

[1] Flora tertiaria Helvetiæ, Die tertiäre Flora der Schweiz, von Oswald Heer. Winterthur, vol. 1, 1855, vi, 1–117 pp., pl. i–l; vol. 2, 1856, pp. 1–110, pl. li–c; vol. 3, 1859, pp. 1–378, pl. ci–clvii.

[2] Exposition chronologique des périodes de végétation et des flores diverses qui se sont succédé à la surface de la terre, par Adolphe Brongniart: Annales sci. nat., Botanique, 3rd series, vol. 11, Paris, 1849, pp. 285–338.

geologists of the present day, while both the Tongrian and Aquitanian are classed by most modern geologists as Oligocene.

No plants are reported from the lowest or Tongrian deposits. To the Aquitanian are assigned the red Molasse beds at Monod-Rivaz, Paudèze, Vivis and Richevue in the canton of Vaud, Ralligen, in Berne, on the Thunersee, Wäggis, and Horw in Luzern, Hohe Rhonen in the canton of Zug, Rothenthurm and Rossberg, in the canton of Schwyz, and Rüfi near Schännis, in the canton of Saint Gall.

To the third stage, or lower member of the Middle Miocene, that of Mainz (Mayence), are ascribed Eriz in the valley of the Zulg, canton of Berne, Aarwangen in the same canton, Delsberg, in the Berne Jura (Develier and Neucul), also in Berne, Lausanne and vicinity (Solitude, La Borde, Riant-Mont, Jouxtens), Calvaire, Roveréaz and the Tunnel, all in Vaud; Saint Gall, Ruppen, Utznach, Bolligen, canton of Saint Gall, Luzern, and Oberägeri in Zug.

The upper member of the Middle Miocene or Helvetic stage embraces the marine Molasse of the canton of Vaud at Lausanne, Moudon, Peterlingen, Avenches, etc.; at Locle (Neuchâtel), and the stone-quarry in Saint Gall.

Finally, to the Oeningen stage or Upper Miocene (upper lignite formation) are attributed the fresh-water white chalk of Locle, canton of Neuchâtel, Montavon near Delsberg (Berne), Albis and Irchel (Zürich), Schrotzburg, Wangen, and Oeningen, in Baden.

The first German edition of Heer's important popular work, Die Urwelt der Schweiz, appeared in 1865[1] and a second in 1879.[2] A French translation was made by Démole in 1872,[3] and an English translation by Heywood in 1876.[4] The work is largely paleontological, and, as might have been expected, pays considerable attention to the vegetable remains. Until 1876 it contained about all the information there was relative to the fossil plants of formations other than the Tertiary. The Carboniferous flora of Valais, the Arve, Outre-Rhône, Vernayaz, Col de Balme, Grand-Châble, Erbignon, Établon, Servoz, Taninge, Mont-du-Fer, Posettes (the last four of which are just over the boundary in Savoy); the Keuper flora of the canton of Basle at Hämiken, Rütihard, Pratteln near Mönchenstein, and Passwang; the Liassic flora of Schambelen in the canton of Aargau, Piz Padella north of St. Moritz, in the Upper Engadine, canton of Grisons; the Oolite flora of Oberbuchsiten, canton Soleure; Villin-

[1] Die Urwelt der Schweiz, von Oswald Heer. Zürich, 1865, xxix, 622 pp., 17 pl., 8°.

[2] Die Urwelt der Schweiz; zweite umgearbeitete und vermehrte Auflage, von Oswald Heer. Zürich, 1879, viii, 713 pp., pl. i-xii, 417 text figs., 8°.

[3] Le Monde primitif de la Suisse, par Oswald Heer, traduit de l'allemand par Is. Démole. Genève et Bâle, 1872, xvi, 801 pp. 16 pl., 1 geol. map, 8°.

[4] The primæval world of Switzerland, by Oswald Heer, edited by James Heywood. London, 1876, 2 vols. 8°; vol. 1, xv, 1-393 pp., pl. i-x; vol. 2, vii, 324 pp., pl. xi, and four landscapes.

gen, Effingen, Lauffohr, and Birmenstorf, canton of Aargau; summit of the Schilt, canton of Glarus; Zumikon, canton of Zürich; Bargen and Ehrendingen, canton of Schaffhausen; Menveraud, Grenairon, Sommiswyl, and Olten, canton of Soleure; Arveyes, Mont Risoux in the Val de Joux, and Vuarguez (Vaud), and Rubendorf, in Basle; the Neocomian flora of St. Denis, Justithal and Reprächter-Mähren, and Merligen (Berne), Châtillon-de-Taverne, the Ormonds, Meruet below Argentine, canton of Vaud; Marwies on the Sentis (Appenzell); the Eocene (Flysch) flora of the Col de Panix and the Trinserfurkeli, Falknis and the Fähnern, Gründel (upper valley of the Sihl, canton of Schwytz), as well as the great Miocene floras so exhaustively treated in the work last noticed, are all rapidly passed in review in this volume, and in many cases the species are figured.

The great need that these lower floras be systematically treated led Professor Heer to undertake another important work in which this object was secured. It was published in 1876 under the misleading title, "Flora fossilis Helvetiæ,"[1] but the author's plan was to make this and the "Flora tertiaria Helvetiæ" constitute together a complete manual of the fossil flora of Switzerland. The new work was therefore made to conform in size to the earlier one, and thus to form, as it were, a supplementary volume to it. It is, in fact, sometimes quoted as Volume IV.

In this work many localities are given which have not been enumerated here. A few of these are as follows:

Carboniferous.—Alesse, Dorenaz, Morcles, Croix de Boet, Sous les Gorges, Brayas, Combaz, all in the canton of Valais.

Keuper.—Neue Welt, Moderhalde, Asp, Hammiken, Ormelingen, all in the canton of Basle.

Lias.—Rauden, canton of Schaffhausen; upper Schambelen and Betznau on the Reuss, canton of Aargau; Stockhorn range on the Langeneckgrat (Fallbach), and Blattenheid, in the canton of Berne; Fremetlaz in the canton of Freiberg; Bouveret and Bex, canton of Vaud.

Lower Oolite.—Alp Baldovana (Ticino); Moleson (Freiberg); Ganei (Grisons); Böttstein, Frickberg, and Betznau, in Aargau.

Upper Oolite.—Kostracher Strasse, Züniken, Rassden, Endingen, Buron, Möhlin and Chasseral; canton of Aargau; Oberbuchsiten (Solothurn); St. Sulpice (Neuchâtel); Schlit (Glarus).

Neocomian.—Bendling and Merligen in Berne; Merver near Argentine (Vaud); St. Denis and Rapatz in Freiberg.

Upper Cretaceous (Senonian ?).—Jaun and Niremont near Semsales, canton of Freiburg; Opetengraben and Rothenkasten in the Stockhorn range, canton of Berne.

[1] Flora fossilis Helvetiæ. Die vorweltliche Flora der Schweiz, von Oswald Heer. Zürich, 1876–1877, vi, 182 pp., 70 pl., folio.

Eocene (Flysch, Nummulite, Dallenfluh).—Fähnern (Appenzell); Prättigau and Falknis (Grisons); Part-Dieu, Mättenberg, and les Alpettes, canton of Freiburg; Bundelberg and Zimmerboden (Niederhorns), canton Berne; Yberg (Schwytz); Walenbützalp (Zürich?); Val d' Illiez (between Troistorrents and Morgins on the right bank of the Tine in the canton of Valais).

Although Professor Heer published no paleobotanical papers in which other persons were associated with him, he still had the active support and assistance, as well as the warm friendship, of several able workers in that field. Among these M. Charles Th. Gaudin, whose researches into the fossil floras of Italy have already been noticed, rendered him signal aid, and also himself published several papers on the Swiss plants. As early as 1849 he read a paper before the Société vaudoise at Lausanne on the fossil flora of the vicinity of that place, having found plants at many of the localities that have since been made classic,[1] and in 1856 he expanded the subject by issuing a catalogue of all the species he had met with, which was preceded by a stratigraphical description of that region by De la Harpe and a general discussion by himself.[2]

Besides a few other unimportant papers relating to the fossil flora of Switzerland,[3] Gaudin translated considerable portions of Heer's works into French, particularly the introduction to his Flora tertiaria Helvetiæ,[4] and the whole of the general discussion in the third volume of that work,[5] with important additions; also some of his popular lectures.[6]

The important and oft-quoted work of Fischer-Ooster on the fossil Fucoids of the Swiss Alps, 1858,[7] though antedating several of those by Heer, already considered, has been thus far left out of view in order to bring all of Heer's contributions into one unbroken series, and it may be conveniently mentioned here.

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[1] Notice sur la flore fossile des environs de Lausanne, par C. Th. Gaudin: Bull. Soc. vaud. sci. nat., Lausanne, vol. 3, 1849–1853, pp. 247–252.

[2] C. Th. Gaudin: Flore fossile des environs de Lausanne. Ibid., vol. 4., 1855, pp. 347–365, 422–436.

Sur la flore de l'époque tertiaire aux environs de Lausanne. Archives Bibl. univ. sci., Genève, vol. 32, 1856, pp. 28–38.

[3] Nouveau gisement de feuilles fossiles à Lavaux, par C. Th. Gaudin: Bull. Soc. vaud. sci. nat., Lausanne, vol. 6, 1860, p. 456.

[4] Introduction à la flore tertiaire de la Suisse, par Oswald Heer. Traduite par Charles Th. Gaudin: Archives Bibl. univ. sci., Genève, vol. 26, 1854, pp. 293–314.

[5] Recherches sur le climat et la végétation du pays tertiaire, par Oswald Heer. Traduite par Charles Th. Gaudin. Winterthur, 1861, vi, 242 pp., 3 pl., folio.

[6] Die Schieferkohlen von Utznach und Dürnten, von Oswald Heer: Zürich, 1858.

Les charbons feuilletés de Dürnten et à Utznach, par Oswald Heer (Traduite par Ch. Th. Gaudin): Archives Bibl. univ. sci., Genève, vol. 2, 1858, pp. 305–339.

[7] Die fossilen Fucoiden der Schweizer-Alpen, nebst Erörterungen über deren geologisches Alter, von Carl von Fischer-Ooster. Bern, 1858, viii, 74 pp., 18 pl., 4°.

The localities at which these fucoidal shales occur have for the most part been already enumerated, but Fischer-Ooster classifies them in the following manner: 1. The Fähnern, or Fähnern mountains in the canton of Appenzell where the so-called Flysch is specially developed. The particular bed chiefly worked by him in this region lies in a saddle between Kamor and Fähnern, on the eastern slope. 2. Gürbe near Blumenstein, in the canton of Berne. 3. The Gurnigel chain in the same canton, at Seeligraben, Ziegelhubel, and Schüpfen. 4. Bundelberg in the lower Simmen Valley, same canton. 5. Heustrich at the north foot of the Niesen. 6. Hongrin Pass in the western Alps. 7. Aigremont, also in the western Alps. 8. Yvorne, canton of Vaud. 9. Habkeren Valley, between the Harder and the Hohgant, above Lake Thun. 10. Boleck, northeast of the last-named place. 11. Teufenbachtobel above Gersau on Lake Lucerne, canton of Schwytz. 12. Einsiedelen, in the same canton. 13. Hakenpass, in the same vicinity. 14. Weisstannen Valley, canton of Grisons.

The localities which Fischer-Ooster referred to the Cretaceous were as follows: 1. Sulzi in the Justithal above Merligen on Lake Thun. 2. Ringgenberg on Lake Brienz. 3. Glisibach near Brienz. 4. Leissigen on Lake Thun. 5. In the Stockhorn range on the south side of the Ganterisch on the Riprechtenmähre, on the Buntschibach near Bad Weissenburg.

From supposed Jurassic strata, fucoids were obtained in the Langeneckgrat, at Blattenheid, in the Dent de Lys range (Vaud), above Montreux also in Vaud, at Ralligstöcke and Beatenberg, north of Lake Thun.

The geological conclusions of the writers of that date have since been considerably modified.

A much more comprehensive work by W. A. Ooster and C. von Fischer-Ooster, entitled Protozoe Helvetica,[1] devoted mainly to animal remains, describes a number of species of Zoophycos, a supposed fossil plant, Halymenites and Chondrites, from the Rhetic of Fégire in the Freiburg Alps, Gurnigel, Seeligraben, and Ziegerhubel in the Bernese Alps; the Upper Lias and Lower Brown Jura of Rocs des Fares, Aux Prés sous Arveyes, Mont d'Arvel, Chillon, Tabusset on the Hongrin, Cierne aux Bocles on the Veveyse, in the canton of Vaud, and Grand Caudon, in the Alps of Valais; Petit Ganey sur Charmey, Raspail von Dent de Lys, Beveret near Gruyères above Pringy, Vie de Neirive, in the Freiburg Alps; Sulzgraben on the Fallbach, Langeneckschafberg between Langeneck and Blattenheide in the Stock-

[1] Protozoe helvetica. Mittheilung aus dem Berliner Museum der Naturgeschichte über merkwürdige Thier- und Pflanzenreste der schweizerischen Vorwelt. Herausgegeben von W. A. Ooster und C. von Fischer-Ooster. Basel and Genf, 1869–1871, vol. 1, 1869, pp. vi, 45, pl. 13; vol. 2, pt. I, 1870, pp. 27, pl. i–vi; pt. II, 1870, pp. 28–88, pl. vii–xiv; pt. III, 1871, pp. 89–159, pl. xv–xix, 4°.

horn range; Hintisberg on the north side of the Birren, a spur of the Winteregg, in the Faulhorn range; and at Zweilütschinen in the Bernese Alps; and in the Cretaceous of Schwefelberg in the Stockhorn range of the last-named system. It also contains an account of the discovery by Jos. Cardinaux on the Paudèze near Conversion in the vicinity of Lausanne of a fossil fruit of *Nuphar primævum*, with figures and descriptions; also of plants (Equisetum, Carpolithes) from the typical Taviglianа sandstone (Rhetic?) of the Dallefluh, and Nullipora and Münsteria from the Opetengraben.

One other and more recent paper relating to Switzerland requires special mention, namely, that of Rothpletz on the Carboniferous flora of the east side of the Tödi, 1879,[1] where he found it similar to that of Valais and the Tarentaise. He identifies twenty-one species, most of which are figured.

GERMANY.

In treating Germany the following geographical arrangement will be followed as nearly as the nature of the case will permit:

Alsace-Lorraine.	Prussian Saxony and Thuringia.
Baden.	Hesse (including Hesse Nassau).
Würtemberg.	Schleswig-Holstein.
Bavaria.	Hanover and Brunswick.
Kingdom of Saxony.	Westphalia.
Silesia.	Rhenish Bavaria.
Baltic Prussia.	Rhenish Prussia.

As the reader will perceive, the attempt to conform to the exact modern political divisions has been abandoned, and for a variety of reasons. In the first place, the geographical arrangement is the principal one, and it would obviously be a sacrifice of this to treat eastern Prussia in immediate connection with Rhenish Prussia, separated from it, as it is, by a number of important states. Then, again, some of the subordinate political divisions—such as Silesia, for example—have assumed an importance from the paleobotanical point of view very disproportionate to their political significance. Finally, there must be cases, as in the Harz Mountains and the Thuringian Forest, where precise conformity to state lines would do violence to the facts of distribution as shown by the record. These and other considerations have led me to adopt the above arrangement as the most natural I could devise in order to pass with as little abruptness as possible from Switzerland through such of the German states as have contributed to the fossil flora of Europe and to reach the fron-

[1] Die Steinkohlenformation und deren Flora an der Ostseite der Tödi, von A. Rothpletz: Abhandl. Schweiz. palæontol. Gesell., vol. 6, 1879, Zürich, 1880, pp. 1-28, pl. i, ii.

tier of Belgium and the Netherlands, which will require attention when we have done with Germany.

Alsace-Lorraine.—In 1828 Brongniart published an excellent paper in the French Annals of Science[1] on the flora of the Buntersandstein (Grès Bigarré) of the Vosges, based chiefly upon specimens which he had received from Murchison, collected by him at a stone-quarry at Soultz-les-Bains (Sulz-Bad), to the southwest of Strasburg, in a valley of the Mutzig called the Bruche, near Heiligenberg. In the same paper are also described several species from the same formation which Dr. Mougeot had sent him from the western slope of the Vosges at Bruyères in France, and a still larger number collected by M. Voltz, chiefly at Sulz-Bad, and deposited in the museum at Strasburg.

In 1835 MM. Voltz and Schimper published a notice of the petrifactions of Sulz-Bad,[2] and in a communication of the latter author to the Neues Jahrbuch für Mineralogie[3] dated March 14, 1840, we find additional information relating to this interesting flora.

The large and well known work of Schimper and Mougeot, which appeared in 1844,[4] was the final outcome of these investigations and a most valuable contribution to the science of phytogeology. Nearly all the specimens treated in this work were obtained from the famous quarry at Soultz-les-Bains, but a few were found at Jungholz near Mülhausen, Heiligenberg, Wasselonne, Soultzmatt, etc., while others were from Saute-le-cerf near Epinal, Rambervillers, Baccarat, and other points on the western slope of the Vosges, in France.

Schimper's Palæontologica Alsatica appeared in 1853,[5] treating of different formations, as a preparation for his extensive treatise on the flora of the transition period, which he appended to Köchlin-Schlumberger's Geology of the Vosges.[6] Most of the plants described

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[1] Essai d'une flore du grès bigarré, par Adolphe Brongniart: Annales sci. nat., vol. 15, Paris, 1828, pp. 435–460, pl. xv–xx.

[2] W. P. Schimper et M. Voltz: Notice sur le grès bigarré de la grande carrière de Soultz-les-Bains. Mém. Soc. hist. nat. Strasbourg, vol. 2, 1835, No. 2, pp. 1–14.

Notiz über den bunten Sandstein des grossen Steinbruchs von Sulz-Bad. Neues Jahrbuch für Mineral., 1838, pp. 338–342.

[3] Baumfarne, Schachtelhalme, Cycadeen, Æthophyllum, Albertia . . . im bunten Sandstein der Vogesen; Hysterium auf einem Pappel-Blatte der Wetterauer Braunhohle, von W. P. Schimper: Neues Jahrbuch für Mineral., 1840, pp. 336–338.

[4] Monographie des plantes fossiles du grès bigarré de la chaine des Vosges, par W. P. Schimper et A. Mougeot. Leipzig, 1844, pp. 1–83, pl. i–xl, folio.

[5] Paleontologica alsatica ou fragments paléontologiques des différents terrains stratifiés qui se rencontrent en Alsace, par W. P. Schimper: Mém. Soc. hist. nat. Strasbourg, vol. 4, 1853, (HH), pp. 1–10, pl. i–iv.

[6] Le terrain de transition des Vosges; partie géologique par J. Kœchlin-Schlumberger, partie paléontologique, par W. P. Schimper: Mém. Soc. hist. nat. Strasbourg, vol. 5, 1862, pp. 1–348, pl. i–xxx. Végétaux fossiles du terrain de transition des Vosges, par W. P. Schimper; pp. 309–343, pl. i–xxx.

in this work were from the Grauwacke (Subcarboniferous) of the valleys of the Thann at Bitschwiller, Niederburbach, and Wesserling, in Alsatia.

Roehl, in 1878,[1] published a list of nineteen species from Carlingen, near St. Avold, Lorraine, which denoted an age equivalent to that of the Saarbrücken beds (Carboniferous).

In 1886 Förster[2] made known the existence at Mühlhausen (Alsatia) of a deposit which he regards as Oligocene, at which he finds a number of characteristic European species. More recently (1886) Fliche has continued this work and developed four distinct florules probably of the same age at Spechbach, Brunnstatt, Riedisheim and Dornach, all in the vicinity of Mülhausen.[3]

Baden.—The two important sections of Baden at which fossil plants occur are the Upper Miocene deposits of Oeningen and the Carboniferous deposits of the Badish Schwarzwald, or Black Forest.

There is no more famous spot for the paleontologist than Oeningen, some account of which was necessarily given when treating of Heer's labors in Switzerland. As all know, it was here that Scheuchzer obtained his Homo diluvii testis, which proved to be a batrachian.[4] But he also obtained many very beautiful specimens of leaves from this place, and figured quite a number of them in his Herbarium diluvianum, 1709.[5] Karg also (1805)[6] collected here and published an account of the petrifactions, among which were some plants.

In 1837 Alexander Braun prepared a catalogue of the fossil plants of Oeningen for Dr. Buckland, which the latter inserted in his Bridgewater Treatise on Geology and Mineralogy.[7] This list was expanded and published with considerable descriptive matter in 1845,[8] and Braun is also always credited with the list published in

[1] Flora der Zeche Carlingen bei St. Avold in Lothringen von E. von Roehl: Verhandl. k.-k. geol. Reichsanstalt, Wien, 1878, p. 213.

[2] Die oligocänen Ablagerungen bei Mülhausen i. E., von B. Förster: Mitth. Commission geol. Landes-Unters, von Elsass-Lothr., Strasburg, 1886, vol. 1, pt. 1, pp. 42–48.

[3] Note sur les flores tertiaires des environs de Mulhouse, par M. Fliche: Bull. Soc. Industrielle, Mulhouse, vol. 56, Août- Sept., 1886, Mulhouse and Paris, 1886, pp. 348–362.

[4] Συνθεω. Homo diluvii testis et Θεοσκοπος. J. J. Scheuchzer. Tiguri, 1726, 26 pp., 1 pl., 4°.

[5] Herbarium diluvianum collectum a Johanne Jacobo Scheuchzero, Professor Tigurensi, etc., Tiguri, 1709; et Ed. Nov. Lugduni Batav., 1723, pp. 1–119, pl. i–xiv, folio.

[6] Ueber den Steinbruch zu Oeningen bey Stein am Rheine und dessen Petrefacte, von Jos. Max. Karg: Denkschr. vaterländ. Gesell. Aertzte Naturforsch., Schwabens, vol. 1, 1805, pp. 1–73. [Petrefacte aus dem Pflanzenreiche, pp. 47–54.]

[7] Catalogue of fossil plants of Oeningen, by Al. Braun. In Buckland: Geology and Mineralogy in Bridgewater Treatises, London, vol. 1, 1837, pp. 510–514. Letter dated November 25, 1835.

[8] Die Tertiär-Flora von Oeningen, von Alexander Braun: Neues Jahrbuch für Mineral., 1845, pp. 164–173.

1851 by Stitzenberger. Bruckmann, too (1850-'52),[1] tried his hand at list-making, although he confesses that he did little more than follow after Braun's investigations.

Stitzenberger's Summary of the petrifications of Baden (1851)[2] claimed to cover all parts of the grand duchy and all the formations represented in it. Thus he found paleozoic (Carboniferous and Permian) plants at Badenweiler, Diersburg, Zunsweier, Berghaupten, Geroldseck near Lahr, Umwegen, Steinbach near Rastadt, and in the Murg valley near Sulzbach; Triassic (Buntersandstein) species at Durlach, Pforsheim, Rheinfelden, Villingen, Tannheim near Herzogenweiler, and Rohrbach near Heidelberg; Keuper species at Sinsheim, Unadingen, Wittnau near Freiburg, Horrenberg, Eschelbach, and Düren near Sinsheim, Ubstadt, Wiesloch, Hausen vor Wald near Donauöschingen, Dürrheim, and Oestringen; Liassic plants at Märzhausen near Freiburg, Walprechtsweier near Ettlingen, Ewatingen in the Höhgau, Hausbaden near Badenweiler, Rettigheim, and Mundelfingen; a few coniferous stems in the middle Jurassic (Oolite) at Rimsingen in the Breisgau; Miocene plants (besides Oeningen) at Liebburg and Bettershausen near Lake Constance, Haltnau near Meersburg, Oettlinger Mountain near Lörrach, Kleinkembs near Istein, and Ballrechten; and three Quaternary species from the tufa of Schwanningen near Bonndorf and the peat of Dachslanden.

In 1857 Ludwig[3] and Geinitz[4] studied the geology of the Schwarzwald district around Offenburg and published lists of Carboniferous plants, and, in 1864, Sandberger began a similar investigation for Baden-Baden, Hinterohlsbach, Oppenau (Lierbach Valley), and Geroldseck.[5] He also corresponded with Geinitz[6] relative to the section in which he had been working, and published a short paper on Permian plants found at Oberkirch, Durbach, and Bottenau in 1866.[7]

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[1] Flora Oeningensis fossilis. Die Oeninger Steinbrüche, das Sammeln in denselben und die bis jetzt dort gefundenen Pflanzenreste, von A. E. Bruckmann: Jahreshefte Verein vaterl. naturk. Württemberg, vol. 6, 1850, pp. 215–238; Nachtrag, vol. 8, 1852, pp. 252–254.

[2] Uebersicht der Versteinerungen des Grossherzogthums Baden, von Ernst Stitzenberger. Freiburg I. B., 1851, 144 pp., 8°.

[3] Die Steinkohlen-Formation von Offenburg im Grossherzogthume Baden, von Rudolph Ludwig: Jahrbuch k.-k. geol. Reichsanstalt, Wien, vol. 8, 1857, pp. 334–349.

[4] Ueber die Pflanzenreste, in der baden'schen Steinkohlen-Formation, von H. B. Geinitz: Ibid., pp. 350–351.

[5] Die Flora der oberen Steinkohlenformation im badischen Schwarzwald, von F. Sandberger: Verhandl. naturwiss. Ver. Karlsruhe, vol. 1, Karlsruhe, 1864, pp. 30–36, pl. ii–iv.

[6] Nachtrag zu dem von Geinitz gegebenen Verzeichniss der fossilen Kohlenpflanzen der Berghaupten Diersburger Mulde, von F. Sandberger: Neues Jahrbuch für Mineral., 1866, pp. 212–214.

[7] Bemerkungen über fossile Pflanzen aus dem Rothliegenden des badischen Schwarzwaldes, von F. Sandberger: Würzburger naturwiss. Zeitschrift, vol. 6, 1866–'67, pp. 74–77, pl. v.

Würtemberg.—Jæger, in 1827, investigated the flora of the Stuttgart building stone (Keuper),[1] and found plants not only at Stuttgart, but in the same formation at Heilbronn, Wangen, Esslingen, Feuerbach, Herrenberg, etc. This work was ably reviewed by Brongniart, and important corrections were made in the botanical determinations.[2]

Zieten prepared a catalogue of all the petrifactions of Würtemberg in 1839,[3] including fossil plants, and in 1845 Kurr published his contributions to the Jurassic flora of Würtemberg.[4] Plants were found in the Black Jura (Lias) at Möhringen, Mittelbronn, Weidach, Plochingen, Schlierbach, Rommelsbach, Bempflingen, Vaihingen, Wäschenbeuren, Plieningen, Echterdingen, Bodelshausen, Göppingen, Boll, Hechingen (Hohenzollern), Balingen, Heiningen, and Ohmden; in the Lower Oolite, or Brown Jura, at Teufelsloch and Zell, near Boll, Aichelberg, etc.; and in the Upper Oolite, White Jura or coral formation at Schnaitheim, Neuffen, and Gerhausen.

In 1866 Canon J. Probst began publishing a series of papers[5] on the geology and paleontology of the vicinity of Biberach, in Upper Swabia. In the second of these papers he made known the existence of deposits of Tertiary plants at Heggbach, and introduced a long list of species which he had sent to Heer for determination. They bore evidence of belonging to the Upper Miocene, not greatly different in age from the Oeningen deposits. In the third paper his field was somewhat enlarged and fossil plants were reported from the lower freshwater Molasse (Lower Miocene) of Berg, Rottenacker, Schaffelklingen, Dietingen, Risstissen, Donaurieden, Ulm, Steinheim, and Reutlingendorf, also at Günzburg in Bavaria; in the brackish-water Molasse (Middle Miocene) of Kirchberg and Hüttesheim; many additional species from the fresh-water molasse (Upper Miocene) of Heggbach, Biberach and Hochgeländ, also a few from Heinrichs-

[1] Ueber die Pflanzenversteinerungen, welche in dem Bausandstein von Stuttgart vorkommen, von Georg Friedrich Jæger. Stuttgart, 1827, pp. 1–40, pl. i–viii, folio.

[2] Sur les plantes fossiles du grès de construction de Stuttgart, par Adolphe Brongniart: Annales sci. nat., vol. 15, Paris, 1828, pp. 92–98.

[3] Geognostisches Verzeichniss sämmtlicher petrefakte Württembergs, mit Citaten ihrer Abbildungen, und Fundorte von C. H. von Zieten: Correspondenz-Blatt, Württembergisches landwirthschaftl. Verein, vol. 1, Heft 1, Stuttgart, 1839, pp. 1–61.

[4] Beiträge zur fossilen Flora der Juraformation Württembergs, von Joh. Gottlob Kurr. Stuttgart, 1845, pp. 1–21, pl. i–iii, 4°.

[5] J. Probst: Geognostische Skizze der Umgebung von Biberach. Naturwiss. Jahreshefte, Jahrg. 22, Heft 1, Württemberg, 1866, pp. 45–60.

Tertiäre Pflanzen von Heggbach bei Biberach, nebst Nachweis der Lagerungsverhältnisse. Ibid., Jahrg. 24, 1868, pp. 172–185.

Verzeichniss der Fauna und Flora der Molasse in Württembergischen Oberschwaben. Ibid., Jahrg. 35, 1879, pp. 221–304.

Beschreibung der fossilen Pflanzenreste aus der Molasse von Heggbach O. A. Biberach und einigen andern Oberschwäbischen Localitäten. Abth. I. Dicotyledonen, Ibid., Jahrg. 39, Stuttgart, 1883, pp. 166–242, pl. i, ii.

burg, Essendorf, and Randeck near Kircheim. The third paper is devoted to a more thorough discussion and description of the most important forms and contains two plates on which certain ones are figured.

Bavaria.—Two only of the general sections of Bavaria possess important systems of plant-bearing strata, namely, that of eastern Bavaria and Upper Franconia, with Baireuth for its central point, but extending southward as far as Regensburg; and that of Lower Franconia or Aschaffenburg, for which Würzburg has formed the nucleus of activity, but which extends westward to include the Steigerwald. These two districts are really confluent, and the plants have been almost exclusively found in the Rhetic formation, or passage beds between the Keuper and the Lias.

It was Count von Münster who gave the original impetus to the investigation of the paleontology of Bavaria, first in a series of preliminary papers beginning with 1834,[1] and then by his great work which appeared in parts from 1839 to 1846.[2]

In 1845 Göppert described his *Sphenopteris Muensteriana* from the Solenhofen Oolites,[3] and the fruits and other vegetable remains from the lithographic sandstone of that place have since been the subject of special notice by Unger,[4] Ettingshausen, Schenk,[5] and Dyer;[6] while Frischmann's list[7] embraces all the species from this formation, of both plants and animals, known to him in Bavaria. Schafhäutl in 1851[8] reported *Calamites gracilis* from what must be a Carboniferous deposit at Vorderhausberd south of Partenkirchen, species of Chondrites, Muensteria, and Helminthoida (a genus which he here

[1] Georg Graf zu Münster: Fossile Fische . . . Algaciten von Oeningen . . . Glossopteris, Folliculites; Tertiär-Formation in Norddeutschland. Ibid., 1834, pp. 42, 43.

Knochenhöhle . . . Voltzia im Gypse des Steigerwaldes; Equisetum, etc., im Keuper daselbst; Trippel und dessen Pflanzen Reste, bei Regensburg, etc. Ibid., 1834, pp. 538–542.

Ueber einige neue Pflanzen in der Keuper-Formation bei Bayreuth. Neues Jahrbuch für Mineral., 1836, pp. 509–517.

[2] Beiträge zur Petrefactenkunde, von Georg Münster. Bayreuth, 1839–1846, Hefte 1–7, 121 pl., in 7 atlases, 4°.

[3] Ein Beitrag zur Flora des oberen oder weissen Jura., von H. R. Göppert: Uebersicht schles. Gesell., 1845, Breslau, 1846, p. 149.

[4] Franz Unger: Ueber einige fossile Pflanzen aus dem lithographischen Schiefer von Solenhofen. Palaeontographica, vol. 2, 1852, pp. 251–255, pl. xxxi, xxxii.

Jurasische Pflanzenreste. Ibid., vol. 4, 1856, pp. 39–43, pl. vii–viii.

[5] Bemerkungen über einige Pflanzen des lithographischen Schiefers, von A. Schenk: Würzburger Naturwiss. Zeitschr., vol. 3, 1862, pp. 174–177.

[6] On some Coniferous Remains from the Lithographic Stone of Solenhofen, by W. T. Thiselton Dyer: Geol. Mag., vol. 9, London, 1872, pp. 150–153; 193–196, pl. v.

[7] Versuch einer Zusammenstellung der bis jetzt bekannten fossilen Thier- und Pflanzen-Überreste des lithographischen Kalkschiefers in Bayern, von Ludwig Frischmann. Eichstädt, 1853, 46 pp., 4° (Foss. plants, pp. 43–45).

[8] Geognostische Untersuchungen des südbayerischen Alpengebirges, vom Conservator Dr. Schafhäutl. München, 1851, xxxii, 206 pp., 43 pl., geol. map, 8°.

names) from the calcareous marl, apparently Flysch (Eocene) from the Halblech Valley at Halbammer, Kapellengraben near Unterammergau, Hörnle near Kohlgrub, Mühlschartenkopf, Bregenzeraachen, Trauchberg, and on the right bank of Tegern Lake, and other fucoids south of the Reiselsbergerhütte, the left bank of the Weissaachen opposite the mouth of the Schwarzaachen.

Dr. Fredrich Braun, in 1847, made an important list of the Rhetic plants of Veitlahm, near Culmbach;[1] and Popp, in 1863, treated with some care those of the same age found at Jägersburg, near Forchheim.[2]

The Keuper and Rhetic deposits in the Würzburg-Bamberg district have been very thoroughly treated from a phytopaleontologic point of view by Gümbel, Schenk, and Kraus. Gümbel interested himself especially with the geological relations of these deposits and published two papers upon them noting the fossil plants.[3] Schenk took up the flora, as he was so eminently qualified to do, and after issuing a long series of preliminary papers, commencing in 1858[4] and culminating with editing and providing a text for the elegant posthumous drawings of Schönlein,[5] he published his monograph of the Passage-beds between the Keuper and Lias of Franconia, which appeared in 1867.[6] This is a large, systematic work, in which are brought together the results of all his previous labors as well as those of other authors in this field, and to these is added much

[1] Die fossilen Gewächse aus den Gränzschichten zwischen dem Lias und Keuper des neu aufgefundenen Pflanzenlagers in dem Steinbruche von Veitlahm bei Culmbach, von C. F. W. Braun: Flora, vol. 30, Regensburg, 1847, pp. 81–87.

[2] Der sandstein von Jägersburg bei Forchheim und die in ihm vorkommenden fossilen Pflanzen, von Otto Popp: Neues Jahrbuch für Mineral., 1863, pp. 399–417.

[3] C. W. Gümbel: Ueber das Knochenbett (Bonebed) und die Pflanzen-Schichten in der rhätischen Stufe Frankens. Sitzungsber. k. baier. Akad. Wiss., vol. 1, München, 1864, pp. 215–278.

[4] A. Schenk: Ueber einen in der Keuperformation bei Würzburg aufgefundenen fossilen Farnstamm. Verhandl. Phys.-med. Gesell., vol. 8, Würzburg, 1858, pp. 212–216, pl. ix.

Beiträge zur Kenntniss der fossilen Flora von Unterfranken. Ibid., vol. 9, Würzburg, 1858, pp. 191–197, 271–274, pl. iv.

Ueber die allgemeinen Verhältnisse der Flora des Keupers und Bonebed. Würzburger naturwiss. Zeitschr., vol. 4, 1863, pp. 65–70.

Beiträge zur Flora des Keupers und der rhätischen Formation. Bericht. naturf. Gesell., Bamberg, vol. 7, Bamberg, 1864, 91 pp. 8 pl., 8°.

Ueber einige der rhätischen Formation angehörigen Pflanzen. Würzburger naturwiss. Zeitschr., vol. 5, Würzburg, 1864, pp. 53–65.

Bemerkungen Ueber einige Pflanzen der Lettenkohle und des Schilfsandsteines. Ibid., vol. 6, 1866–'67, pp. 49–63.

[5] Abbildung von fossilen Pflanzen aus dem Keuper Frankens, von Dr. J. L. Schönlein; Mit erläuterndem Texte nach dessen Tode herausgegeben von Dr. August Schenk. Wiesbaden, 1865, 22 pp., 13 pl., folio.

[6] Die fossile Flora der Grenzschichten des Keupers und Lias Frankens, von Dr. August Schenk. Wiesbaden, 1867, xxiv, 232 pp., 4°, with atlas, 45 pl., folio.

that belongs peculiarly to the author's own prolonged efforts. From it we learn that Rhetic plants had been found at the following points additional to those which have already been mentioned: Theta, Eckersdorf, Donndorf, Hart, Saaserberg, Forst, Oberwaiz, and Phantaisie, near Baireuth; Schwarzachen near Bergen; Strullendorf, Höfen, Reindorf, Contberg, and Sandhof near Bamberg; Thurnau and Oberleitersbach near Ebensfeld; Hohengüssbach near Schesslitz; Burkersdorf and Kaltenbrunn near Sesslach; Teufelsgraben near Küps; Atzelsberg near Erlangen; Lichtenfels, Mistelbach.

Kraus elaborated the silicified wood of this formation and published several papers upon it.[1]

Kingdom of Saxony.—The kingdom of Saxony contains plant-bearing strata representing the Cambrian, the Grauwacke, or Subcarboniferous, the Permian (Rothliegende, Kupferschiefer, Zechstein, Dyas), the Cenomanian (Quadersandstein), the Oligocene, the Miocene, and the Quaternary. It will be convenient to take up the literature in this order.

Cambrian.—Geinitz, in a somewhat recent paper,[2] pointed out the occurrence of his *Palæophycus macrocystoides* in the Cambrian roof-shales of Lössnitz, and the supposed Calamites of Weesenstein,[3] if true plants, seem to point to a still more ancient date.

Subcarboniferous.—In his great work on the Grauwacke of Saxony, 1852,[4] the same author enumerates only three species of plants, the localities of which in the kingdom of Saxony are Ebersdorf and Berthelsdorf, near Hainichen; Gunzenberg near Plauen; Siebenhitze near Magwitz. Through the subsequent labors of Jentzsch, Siegert, Rothpletz, Weber, and especially of Sterzel,[5] this flora had in 1884 been increased to seventeen species, each of which Sterzel has treated in an exhaustive historical and scientific manner.

Carboniferous.—Investigations into the Carboniferous flora of the Zwickau beds began in 1834, when Gutbier commenced publishing

[1] Gregor Kraus: Einige Bemerkungen über die verkieselten Stämme des fränkischen Keupers. Würzburger naturwiss. Zeitschr., vol. 6, 1866–'67, pp. 64–69.

Ueber einige bayerische Tertiärhölzer. Ibid., pp. 45–48.

[2] H. B. Geinitz: Ueber Palæophycus macrocystoides Gein. aus dem Dachschiefer von Lössnitz. Sitzungsber. naturwiss. Gesell. Isis in Dresden, 1871, pp. 1, 2.

Ueber die ältesten Spuren fossiler Pflanzen in Sachsen. Abhandl. naturwiss. Gesell. Isis in Dresden, 9th Jahrg., 1881, pp. 78–85, pl. i.

[3] Paläontologische Mittheilungen aus dem mineralogischen Museum in Dresden; 1, Calamiten-artiger Körper in dem Knotenschiefer von Weesenstein, von H. B. Geinitz: Sitzungsber. Naturwiss. Gesell. Isis in Dresden, 1872, pp. 126–128, pl. i.

[4] Die Versteinerungen der Grauwackenformation in Sachsen und den augrenzenden Länder-Abtheilungen, von H. B. Geinitz. Leipzig, 1852–'53, folio, 2 Hefte. Heft 1, 1852, pp. 1–58, pl. i–vi; Heft 2, 1853, pp. 1–95, pl. i–xx.

[5] Ueber die Flora und das geologische Alter der Kulmformation von Chemnitz-Hainichen, von Dr. T. Sterzel: 9th Bericht naturwiss. Gesell., Chemnitz, Jan., 1883–Oct., 1884., pp. 181–224, 1 pl.

his series of memoirs on the geology and paleontology of that region.[1] Barrande also treated the floras of the coal basins of Saxony in 1854,[2] or just before the appearance of Geinitz's important works.

The first of these latter[3] compares the flora of the Hainichen, Ebersdorf, and Flöha basins with that of Zwickau, and gives systematic descriptions of many species. Besides the localities indicated by the title of this essay, plants were found at Berthelsdorf, Gückelsberg, Oberhohndorf, Ottendorf, Bockwa, etc., which lie within these and the Zwickau basins.

In his large folio work on the fossils of the Carboniferous formation of Saxony, which immediately followed the last named,[4] and which is chiefly confined to the description of plants, a considerable number of new localities are given, such as Niederwürschnitz, Niedercainsdorf, Planitz, Schedewitz, and Reinsdorf.

Permian.—Geinitz's works relating to Saxony generally include the Saxon duchies, which we shall here treat as Prussian Saxony; and this renders the treatment of the Kingdom of Saxony by itself somewhat difficult. This is not only the case with his Leitpflanzen, 1858,[5] but with his larger treatises on the Dyas;[6] but among the leading localities for Permian plants are those of Chemnitz and vicinity, Lichtentanne and Reinsdorf near Zwickau, Possendorf between Dresden and Dippoldiswalde.

Sterzel, in 1875,[7] published a catalogue of the Permian species of

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[1] August von Gutbier: Geognostische Beschreibung des Zwickauer Schwarzkohlengebirges und seiner Umgebungen. Zwickau, 1834, xvi, 160 pp., 7 pl.

Abdrücke und Versteinerungen des Zwickauer Schwarz-Kohlengebirges und seiner Umgebungen. Lieferung I, Text, Zwickau, 1835, pp. i–viii, 9–80, 8°; Atlas, 1836, pl. i–xi, 4°.

Ueber einen fossilen Farrenstamm, Caulopteris Freieslebeni, aus dem Zwickauer Schwarzkohlengebirge. Zwickau, 1842, 16 pp., 4 pl., 8°.

[2] Notice sur deux ouvrages, par M. le Professeur Geinitz, etc. Sur les flores des bassins houillers de la Saxe, par Joachim Barrande: Bull. Soc. géol., France, vol. 12, Paris, 1854–'55, pp. 678–683.

[3] Darstellung der Flora des Hainichen-Ebersdorfer und des Flöhaer Kohlenbassins, im Vergleich zu der Flora der Zwickauer Steinkohlengebirges, von H. B. Geinitz. Preisschr. Fürstl. Jabl. Gesell., No. 5, Leipzig, 1854, pp. 1–80; Atlas, 14 pl., folio.

[4] Die Versteinerungen der Steinkohlenformation in Sachsen, von Hanns Bruno Geinitz. Leipzig, 1855, vi, 61 pp., 36 pl., folio.

[5] Die Leitpflanzen des Rothliegenden und des Zechsteingebirges, oder der permischen Formation in Sachsen, von Hanns Bruno Geinitz. Programm. k. polytech. Schule Dresden, 1857–1858, pp. 1–27, pl. i, ii.

[6] Hanns Bruno Geinitz: Dyas oder die Zechsteinformation und das Rothliegende; Heft 2, Die Pflanzen der Dyas und Geologisches. Leipzig, 1862, pp. 131–342, pl. xxiv–xlii, 4°.

Nachträge zur Dyas, I. Mitth. k. min.-geol. praehist. Mus. in Dresden, Heft 3, Cassel, 1880, pp. 1–43, pl. i–vii.

[7] Die Fossilen Pflanzen des Rothliegenden von Chemnitz, in der Geschichte der Paläontologie, von J. T. Sterzel: Bericht naturwiss. Gesell., Chemnitz, vol. 5, Jan.-Dec. 1873–'74, Chemnitz, 1875, pp. 71–250.

Chemnitz, and a special paper on the Tæniopterideæ of that flora in 1876.[1] We learn from the first of these that the particular beds in the vicinity of Chemnitz are located at Hilbersdorf, Gablenz, Ebersdorf, Floha, Gückelsburg, Grüna, and Pfaffenhain, and that Permian plants are also found at the following other points in Saxony: St. Egidien, Oelsnitz, Nieder-Würschnitz, Lichtenstein, Neudörfel near Zwickau, Rüdigsdorf near Kohren, Salhausen near Oschatz, Weissig near Pillnitz; Windberg, and Possendorf in the vicinity of Dresden; Burgstädtel near Lockwitz.

Beyond a letter from Sterzel to Dr. Weiss, in 1881, on the flora of the Plauen beds,[2] little else of a local character was published on the Permian of Saxony until the appearance in 1886 of the important memoir by the former of these authors on the flora of the Rothliegende of northwestern Saxony,[3] which is the first of a series of four monographs projected by the author on the Permian and Carboniferous floras of Saxony. The present paper is divided into two parts, the first treating the lower Rothliegende of Plagwitz, from which only five species are enumerated, and the second the middle Rothliegende, yielding a rich flora which occurs chiefly at Saalhausen, Rüdisgdorf and Leukersberg near Kohren, Buchheim, Kreischa, Kleinragewitz, Rochlitz, Wolftitz near Frohburg, Limbach, Lonnewitz, Wechselburg, Naundorf, Stöchigt, Wilden-Bruch, and Lastau (left bank of the Auerbach).

Cretaceous.—We pass next to the Cenomanian beds, the principal of which is that of Niederschöna, near Freiberg. Known to Sternberg, Zenker, Bronn, Cotta,[4] and Geinitz,[5] it was reserved for Baron von Ettingshausen, in 1867,[6] to do full justice to its flora.

The only other important Cretaceous plant beds are those in the vicinity of Dresden and Dippoldiswalde, where von Otto found Glock-

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[1] Taeniopterideen aus dem Rothliegenden von Chemnitz-Hilbersdorf, von J. T. Sterzel: Neues Jahrbuch fur Mineral., 1876, pp. 369–385, pl. v–vi.

[2] Ueber die Flora der unteren Schichten des Plauenschen Grundes, von J. T. Sterzel: Zeitschr. deutsch. geol. Gesell., vol. 33, Heft 2, Berlin, 1881, pp. 339–347.

[3] Die Flora des Rothliegenden in nordwestlichen Sachsen, von J. T. Sterzel: Dames and Kayser's Paleontol. Abhandl., vol. 3, Heft 4, Berlin, 1886, pp. 1–73, pl. i–ix.

[4] C. Bernhard Cotta: Ueber die Niederschöna-Schichten. Neues Jahrbuch fur Mineral., 1836, pp. 584–588.

Geognostische Wanderungen; 1, Geognostische Beschreibung der Gegend von Tharand, Dresden und Leipzig, 1836, viii, 176 pp, 3 geol. pl, map, 8°. [See pp. 57, 58, 125.]

Ueber die Pflanzenabdrucke aus dem unteren Quadersandstein (Wealden-Formation) von Niederschöna bei Freiberg. Isis, von Oken, 1837, col. 442–443.

[5] Characteristik der Schichten und Petrefacten des Sächsischen Kreidegebirges, von Hanns Bruno Geinitz. Dresden, 1839–'42 (Drittes Heft, Dresden and Leipzig, 1842), xxv, 116 pp, pl. i–xxiv.

[6] Die Kreideflora von Niederschöna in Sachsen. Ein Beitrag zur Kenntniss der ältesten Dicotyledonengewächse, von C. von Ettingshausen. Sitzungsber. k. Akad. Wiss, Wien, math.-nat. Cl., vol. 55, Abath. I, 1867, pp. 235–264, pl. i–iii.

er's *Gyrophyllites Kwassizensis*,[1] and which were so carefully worked up in Otto's Additamente, 1852, 1854.[2] The plants came from the Quadersandstein of Malter, Wendischcarsdorf, Paulsdorf, and Oberhäselich, near Dippoldiswalde, and from Rippien, Goppeln, and Welschhufe, near Dresden. They are low forms, and of a character entirely different from that of the Niederschöna flora.

Tertiary.—The earliest notice I have seen of Tertiary plants in Saxony was in 1869, when Engelhardt mentioned the bed at Seifhennersdorf.[3] In his Flora of the Brown Coal Formation in the Kingdom of Saxony, 1870,[4] he describes over fifty species from that locality. In that work he also enumerates ten species from Bockwitz, near Borna (afterwards separately treated),[5] Grimma, Scoplau, and Mittweida, west of the Elbe; thirty-seven species from Bautzen, Zittau, Quatitz, Mirka, Kleinsaubernitz, Schmeckwitz, Tuerchau, Reichenau, Colditz, Harthau, and Berzdorf, near Bernstadt, east of the Elbe. A dozen or more of these latter were founded on fossil wood.

In 1873 he published his admirable monograph of the Tertiary flora of Göhren,[6] between Wechselburg and Lunzenau, based on collections made by Richard Richter, engineer of the Göhren viaduct, in which over forty species are described and figured. Engelhardt regarded these plants as Aquitanian, and Credner[7] would place the Göhren bed in the Oligocene, along with the Leipzig terrane.

In 1882 Beck studied the Mittweida[8] district (Altmittweida, Frankenau) with some care, figuring a number of plants, and called it Oligocene also; and in 1884 Hofmann pronounced the same judg-

[1] Ueber die Kalkführende Sandsteinformation auf beiden seiten der mittleren March, in der Gegend zwischen Kwassitz und Kremsier, von E. F. Glocker: Nova Acta Acad. Leop.-Carol., vol. 19, Suppl. 2, 1841, pp. 309–334, pl. iv.

[2] Additamente zur Flora des Quadergebirges in der Gegend um Dresden und Dippoldiswalde, etc., von Ernst von Otto. Dippoldiswalde and Leipzig, 1852–'54. Part 1, 1852, iv, 29 pp., 7 pl., folio; part 2, 1854, x, 53 pp., 9 pl., folio,

[3] Ueber die Tertiärflora von Seifhennersdorf, von H. Engelhardt: Sitzungsber. Naturwiss. Gesell. Isis, Dresden, 1869, pp. 151, 152

[4] Flora der Braunkohlenformation im Konigreich Sachsen, von Hermann Engelhardt: Preisschr., Fürst. jablows. Gesell., No. 16, Leipzig, 1870, pp. 1–59, 4°, 15 pl., folio.

[5] Ueber Braunkohlenpflanzen von Bockwitz bei Borna, von Hermann Engelhardt: Sitzungsber. Naturwiss. Gesell. Isis, Dresden, Hefte 3, 4, 1876, pp. 92–101.

[6] Die Tertiärflora von Göhren. Ein neuer Beitrag zur Kenntniss der fossilen Pflanzen des Königreichs Sachsen, von Hermann Engelhardt: Nova Acta Acad. Leop.-Carol., vol. 36, No. 3, 1873, pp. 1–42, pl. viii–xiii.

[7] Das Oligocan des Leipziger Kreises, mit besonderer Berücksichtigung des marinen Mittel-Oligocans, von Hermann Credner: Zeitschr. deutsch. geol. Gesell, vol. 30, Berlin, 1878, pp. 615–662, pl. xxiii, xxiv.

[8] Das Oligocän von Mittweida, mit besonderer Berücksichtigung seiner Flora, von Richard Beck: Ibid., vol. 34, 1882, pp. 735–770, pl. xxxi, xxxii.

ment upon the Meerane beds south of Altenburg,[1] where he found both leaves and trunks.

Quaternary.—The so-called Diluvium in the neighborhood of Kamenz contains a large amount of fossil wood, both in a partially lignitized form and also in a silicified state. Geinitz,[2] in 1878, gave the first account of these remains, and in 1883 Morgenroth published quite a systematic treatise upon them.[3] From this we learn that the material belongs to two distinct horizons, the Oligocene lignite beds and the Permian (Rothliegende), and that they have been transported from points to the northward by the Scandinavian ice during the glacial epoch. The lignitized stems possess a coniferous structure of the Sequoia type (Cupressinoxylon); the silicified wood belongs to two groups, the one that of fern stems (Protopteris), and the other with the archaic Araucarian structure referable to Cordaixylon and Dadoxylon.

Silesia.—As the home of Göppert, the most voluminous of all the writers on fossil plants, it would naturally be expected that the resources of Silesia in this department would have been thoroughly explored and made known; and in this we are not disappointed.

One of Göppert's earliest memoirs on the subject was a review of the work of his predecessors in Silesia,[4] notably Schwenckfelt, who enumerated fossil plants in his catalogue of the plants and fossils of Silesia[5] (1861), Volkmann, who figured many in his Silesia Subterranea (1720),[6] and Rhode, who, in 1820–1824, published a large illustrated monograph of the fossil plants of the Subcarboniferous depôsit of Waldenburg, Neurode, and Landshut in Silesia.[7]

As with Saxony, it seems most advantageous to treat Silesia in the ascending order of the geological formations.

Devonian.—The only plant-bearing beds in Silesia that have been recognized as Devonian are those of Oberkunzendorf near Freiburg

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[1] Ueber Pflanzenreste aus den Knollensteinen von Meerane in Sachsen, von H. Hofmann: Zeitschr. Naturwiss., vol. 57, Halle, 1884, pp. 456–461, pl. iii.

[2] Die verkieselten Hölzer aus dem Diluvium von Kamenz in Sachsen, von H. B. Geinitz: Sitzungsber. Naturwiss. Gesell. Isis, Dresden, Hefte 3, 4, 1878.

[3] Die fossilen Pflanzenreste im Diluvium der Umgebung von Kamenz in Sachsen, von E. Morgenroth: Zeitschr. Naturwiss., vol. 56, Halle, 1883, pp. 271–318, 1 pl.

[4] Ueber die Bestrebungen der Schlesier, die Flora der Vorwelt zu erläutern, von H. R. Göppert: Schles. Provinzialblätter, Aug. u. Sept., 1834, Breslau, pp. 1–26, 12°. Karsten und von Dechen, Archiv., vol. 8, Heft 1, 1835, Notizen, pp. 232–249.

[5] Stirpium et fossilium Silesiæ catalogus, in quo præter etymon, natales, tempus, natura et vires cum varijs experimentis affigiuntur. Auctore Casparo Schvvenckfelt. Leipsiæ, 1601, 407 pp., 16°.

[6] Silesia subterranea, oder Schlesien mit seinen unterirrdischen Schätzen, Seltsamheiten, etc., von Georg Anton Volkmann. Leipzig, 1720, 344 pp., pl. i–xxxiv, 16°.

[7] Beiträge zur Pflanzenkunde der Vorwelt, nach Abdrücken im Kohlenschiefer und Sandstein aus schlesischen Steinkohlenwerken, von J. G. Rhode. Breslau, 1820–'24, 40 pp., 10 pl., folio.

and Ebersdorf, in the county of Glatz, from which several species have been reported by Göppert,[1] Tietze,[2] and others since 1859.

Subcarboniferous.—The Grauwacke of the Landshut and Leobschütz districts (the former in Glatz, the latter in Oppeln), with the minor localities, Tschöpsdorf, Ober-Wernersdorf, Schreibersdorf, Leppersdorf, Rudelstadt, Altwasser, Hausdorf, Falkenberg, and Lasitz, has long been celebrated for its vegetable remains, which were treated by Göppert in his Genera of Fossil Plants, 1841,[3] and more especially in certain later papers;[4] more recently Feistmantel has made those of Rothwaltersdorf, in the county of Glatz, the subject of a special memoir;[5] and still later Schütze has gone over both this field and that of northern Bohemia, making lists of all the species.[6]

Carboniferous.—Plants occur in the Carboniferous strata both of lower and upper Silesia. They have nowhere received systematic treatment, but were considered by Göppert in his famous prize essay in 1848[7] and in special papers.[8]

In the lesser prize essay delivered to the same society by Beinert

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[1] H. R. Göppert: Ueber die angeblich in dem sogenannten Uebergangs-oder Grauwackengebirge Schlesiens vorhandenen Kohlenlager. Jahrbuch Schles. Ver. Berg.-Hüttenw., Breslau, 1859, pp. 185–189. (See p. 187.)

Ueber die fossile Flora der silurischen, der devonischen und unteren Kohlenformation oder des sogenannten Uebergangsgebirges. Nova Acta Acad. Leop-Carol., vol. 27, Dresden, 1859, pp. 425–606, pl xxxiv–xlv. (See p. 562.)

[2] Emil Tietze: Ueber die devonischen Schichten von Ebersdorf unweit Neurode in der Grafschaft Glatz. Palæontographica, vol. 19, Cassel, 1870, pp. 108–158, pl. xvi, xvii.

[3] Die Gattungen der fossilen Pflanzen verglichen mit denen der Jetztwelt und durch Abbildungen erläutert. [Les Genres des Plantes Fossiles, etc.] Von H. R. Göppert. Bonn, 1841–'45, xxx, 120 pp., 56 pl., 4°.

[4] H. R. Göppert: Ein Beitrag zur flora des Uebergangsgebirges. Nova Acta Acad. Leop.-Carol., vol. 19, 1842, pp. 379–382, pl. lxviii.

Ueber die fossile Flora der Grauwacke oder des Uebergangsgebirges, besonders in Schlesien. Uebers. Arbeiten schles. Gesell., 1846, pp. 178–184. Karsten und von Dechen, Archiv, vol. 23, Berlin, 1850, pp. 60–72.

[See first title in foot-note [1].]

[5] Das Kohlenkalkvorkommen bei Rothwaltersdorf in der Grafschaft Glatz und dessen organische Einschlüsse, von Ottokar Feistmantel: Zeitschr. deutsch. geol. Gesell., vol. 25, 1873, pp. 463–551, pl. xiv–xvii.

[6] Geognostische Darstellung des niederschlesisch-böhmischen Steinkohlenbeckens, von A. Schütze: Abhandl. zur geol. Specialkarte v. Preussen und Thür. Staaten, vol. 3, Heft 4, Berlin, 1882, pp. 1–278.

[7] Preisschrift. Abhandlung, eingesandt als Antwort auf die Preisfrage: . . . ob die Steinkohlenlager aus Pflanzen entstanden sind, welche an den Stellen, wo jene gefunden werden, wuchsen, etc. Eine mit dem doppelten Preise gekrönte Schrift, von Heinrich Robert Göppert: Natuurk. Verh. Holl. Maatsch. Wetensch., Haarlem, Tweede Verzamel., vol. 4, 1848, xviii, 300 pp., pl. i–xxii.

[8] Ueber die fossile Flora der alten Steinkohlenformation, besonders in Schlesien, von H. R. Göppert: Karsten und von Decken, Archiv., vol. 23, Berlin, 1850, pp. 43–59.

and Göppert in 1849,[1] the flora and stratigraphy of the Waldenburg beds are thoroughly elaborated, and comparative lists of the fossil plants found in the three principal mines (Louise Auguste, Johannis, and Fuchs) are drawn up.

Schütze, in the work last quoted, gives many species both from the Waldenburg beds (which have been considered by some as Grauwacke) and from the so-called Schatzlarer beds on the horizon with Saarbruck. They are in the same general region about Waldenburg, Reichhennersdorf, Hartau, Gottesberg, Ruben,[2] etc.

Permian.—The Wünschendorf beds, near Lauban, have been called Rothliegende by Weiss, who has published a monograph of their flora in the Prussian geological Specialkarte, 1879.[3]

Oolite.—Cycadaceous plants have been described by Göppert from Sternalitz and Wichrow,[4] near the Polish frontier, but beyond this the Jurassic is either absent or barren in Silesia.

Cenomanian.—The only systematic treatment we have of the Quadersandstein flora of Silesia is that which Göppert published in the Nova Acta in 1841[5] and his supplement thereto in 1848.[6] The beds are located at Kieslingswalde, Habelschwerdt, and Wehrau in the county of Glatz on the Queis; at Tillendorf and Doberau near Bunzlau; at Giersdorf near Leoburg; and at Altwaltersdorf, Melling, Nieder- and Ober-Langenau.

Tertiary.—Two localities for Tertiary (Miocene?) plants in Silesia were made known by Göppert in 1842, namely, Dirschel[7] in upper Silesia, and Wohlau near Breslau.[8] The next year he reported a

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[1] Abhandlung über die Beschaffenheit und Verhältnisse der fossilen Flora in den verschiedenen Steinkohlen Ablagerungen eines und desselben Reviers. Eine mit der goldnen Medaille gekrönte Preisschrift, von C. C. Beinert und H. R. Göppert: Natuurk. Verh. Holl. Maatsch. Wetensch., Haarlem, vol. 5, Leiden, 1849, pp. 1–72, 5 geol. pl.

[2] Ueber einige Pflanzenreste aus der Rubengrube bei Neurode in Nieder-Schlesien, von Ernst Weiss: Jahrbuch (Abhandl.) k. preuss. geol. Landesanstalt, 1884, Berlin, 1885, pp. 1–8, pl. i.

[3] Beiträge zur fossilen Flora. II, Die Flora des Rothliegenden von Wünschendorf bei Lauban in Schleisen, von Ch. E. Weiss: Abhandl. geol. Specialk. Preuss. u. Thüring. Staaten, vol. 3, part 1, Berlin, 1879, pp. 1–38; atlas, 3 pl.

[4] Ueber die fossile Flora der mittleren Juraschichten in Oberschlesien, von H. R. Göppert: Uebers. Arbeiten schles. Gesell., 1845, pp. 139–149, pl. i, ii.

[5] Ueber die fossile Flora des Quadersandsteins von Schlesien und der Umgegend von Aachen, von H. R. Göppert: Nova Acta Akad. Leop-Carol., vol. 19, Breslau, 1842, pt. 2, pp. 97–134, pl. xlvi–liii.

[6] Zur Flora des Quadersandsteins in Schlesien. Als Nachtrag zu der früher erschienenen Abhandlung über denselben Gegenstand, von H. R. Göppert: Ibid., vol. 22, pt. 1, Bonn and Breslau, 1848, pp. 353–365 (1–13), pl. xxxv–xxxviii.

[7] Ueber die fossile Flora der Gypsformation zu Dirschel, in Oberschlesien, als dritter Beitrag zur Flora der Tertiargebilde, von H. R. Göppert: Ibid., vol. 19, pt. 2, Breslau und Bonn, 1842, pp. 367–378, pl. lxvi, lxvii.

[8] Erweiterungen der fossilen Flora Schlesiens, von H. R. Göppert: Uebers. Arbeiten schles. Gesell., 1842. Breslau, 1843, pp. 189, 190.

third locality near Grünberg at Schloin (Oligocene), in the northwest quarter,[1] and in 1844 still a fourth at Laasan near Nissam, on the Striegau, not far from Charlottenbrunn.[2] In a more general paper which appeared in 1852,[3] he enumerates the following additional localities: Striese and Prausnitz near Stroppen, Waldenburg, Tarnowitz, Damratsch, Maltsch, Pschow, and Kreuzburg.

In 1855 he published his Tertiary Flora of Schossnitz[4] near Canth, a short distance southwest of Breslau, which is his most important work on the plants of this formation. This, with a few unimportant notes,[5] closed his work upon the Tertiary of Silesia.

From the sulphur springs of Kokoschütz near Pschow, in upper Silesia, specimens collected by Lucke were named by Friedrich in 1881.[6] A larger collection from the same locality was subsequently placed in the hands of Victor Steger, who made them the subject of his inaugural dissertation at the University of Breslau in 1883, identifying and describing them in a systematic way under the name: "Flora fossilis Kokositiensis."[7]

All these Silesian Tertiary beds may be classed as Miocene, although they probably differ in geological position, and some may be found really to be lower or higher in the geological scale, but the fossil wood of Karlsdorf, Oberkassel, Langenau, etc., on the Zobten Mountain near Schweidnitz, is considered by Conwentz, who described it,[8] to be Diluvial (Quaternary).

Baltic Prussia.—I use this designation for those localities from

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[1] Nachrichten über die von ihm im April, 1843, besuchten Braunkohlengruben bei Grünberg, von H. R. Göppert: Uebers. Arbeiten schles. Gesell., 1843, Breslau, 1844, pp. 112–114.

Ueber Tertiärpflanzen von Grünberg in Schl. aus dem Provinzial-Museum zu Königsberg in Pr., von Hermann Engelhardt: Schriften phys.-ökon. Gesell. Königsberg, vol. 27, 1886, 2 pp.

[2] Ueber das Braunkohlenlager bei Laasan, von H. R. Göppert: Uebers. Arbeiten schles. Gesell., 1844, Breslau, 1845, pp. 224–227.

[3] Beiträge zur Tertiärflora Schlesien's, von H. R. Göppert: Palaeontographica, vol. 2, Cassel, 1852, pp. 257–282, pl. xxxiii–xxxviii.

[4] Die tertiäre Flora von Schossnitz in Schlesien, von H. R. Göppert. Görlitz, 1855, xviii, 52 pp., pl. i–xxvi, 4°.

[5] H. R. Göppert: Ueber die Braunkohlen-Formation in Schlesien. Uebers. Arbeiten schles. Gesell., 1856, Breslau, 1857, pp. 13, 14.

Auf mehrfaches Befragen, wie es sich mit den in dem Braunkohlen-Lagern von Naumburg am Bober gefundenen von Heer als Nyssa bestimmten fossilen Früchte. 46th Jahresb. schles. Gesell., 1868, Breslau, 1869, pp. 123, 124.

[6] Ueber Tertiärpflanzen von Kokoschütz, von Paul Friedrich: Zeitschr. deutsch. geol. Gesell., vol. 33, 1881, pp. 501, 502.

[7] Die schwefelführenden Schichten von Kokoschütz in Oberschlesien und die in ihnen auftretende Tertiärflora, von Victor Steger. Ratisbon, 1883, pp. 1–30, 8°.

[8] Die fossilen Hölzer von Karlsdorf am Zobten, ein Beitrag zur Kenntniss der im norddeutschen Diluvium vorkommenden Geschiebhölzer, von H. Conwentz: Schrift. naturf. Gesell., Danzig, vol. 4, No. 5, 1880, pp. 4–47, pl. i–viii.

which the great amber flora of North Prussia has chiefly been derived, as also that of lignite deposits described by Heer in his Miocene Baltic flora, although I am aware that some of this material has been collected in the interior of Prussia, and that Göppert not only found amber, but specimens of his *Pinites succinifer*, or the amber tree, in Silesia in the vicinity of Breslau.

The plants in amber, described by him in his first work, 1845,[1] were from the Museum of Danzig and the private collections of Hagen, Sendel, Berendt and others, where they had long lain, and the exact sources were in many cases not known. Some were labeled from Neidenburg, Rauschen near Königsberg, Danzig, etc.

In the revision of this work, begun by Göppert and Menge in 1883,[2] and completed by Conwentz in 1886,[3] very little could be added to our knowledge of the precise source of these specimens, further than to state where they were then to be seen.

Some work of the same general character was also done by Zaddach[4] and Caspary,[5] but it was Heer who, in 1869, gave us the best systematic work from the geographical point of view that has been produced on the flora of the Baltic Tertiary.[6] Menge and Zaddach had made extensive collections in Samland and also on the west of the Gulf of Danzig at Rixhöft and that vicinity, which they had sent to Heer for determination. The principal localities were Rauschen and Kraxtepellen in Samland and Rixhöft, but a few were also from Gaussup, Kadolling-Spring in Samland.

The age of the amber and overlying lignite beds has been much

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[1] Der Bernstein und die in ihm befindlichen Pflanzenreste der Vorwelt, von H. R. Göppert und G. C. Berendt. In Berendt's "Die im Bernstein befindlichen organischen Reste der Vorwelt," vol. 1, Berlin, 1845, Abth. I, pp. 1–125, pl. i–vii, folio.

[2] Die Flora des Bernsteins und ihre Beziehungen zur Flora der Tertiärformation und der Gegenwart, von H. R. Göppert und A. Menge. (Herausgegeb. von der Naturf. Gesell. Danzig,) vol. 1, Danzig, 1883, pp. 1–63, pl. i–xvi, 4°.

[3] Die Flora des Bernsteins und ihre Beziehungen zur Flora der Tertiärformation und der Gegenwart, von H. R. Göppert und A. Menge. Nach deren Hinscheiden selbstständig bearbeitet und fortgesetzt von H. Conwentz. (Herausgegeb. von der Naturf. Gesell. Danzig) vol. 2, Danzig, 1886, ix, 140, pp., pl. i–xiii.

[4] E. G. Zaddach: Ueber die Bernstein- und Braunkohlenlager des Samlandes. Schriften phys.-ökon. Gesell., Königsberg, vol. 1, 1860, pp. 1–44, pl. i–iv.

Das Tertiärgebirge Samlandes. Ibid., vol. 8, 1868, pp. 85–197, pl. vi–xvii.

[5] Robert Caspary: Einige pflanzliche Bernsteineinschlüsse . . . eine Weisskohlstaude . . . einige in Bernstein eingeschlossene fossile Zweige einer untergegangenen Gnetaceen-Gattung. Ibid., vol. 13, 1872, Sitzungsber., pp. 19, 21.

Pflanzliche Bernsteineinschlüsse. Ibid., Sitzungsber., pp. 17, 18.

Ueber einige pflanzliche Abdrücke und Einschlüsse in Bernstein. Ibid., vol. 21, 1880, Sitzungsber., pp. 28–30.

Ueber neue fossile Pflanzen der blauen Erde, d. h. des Bernsteins, des Schwarzharzes und des Braunharzes. Ibid., vol. 22, 1881, Sitzungsber., pp. 22–31.

[6] Miocene baltische Flora, von Oswald Heer: Beiträge zur Naturkunde Preussens No. 2, Herausgegeben, k. phys.-ökon. Gesell., Königsberg, 1869, 104 pp., pl. i–xxx, 4°.

discussed. It was once supposed that the formation was quite recent or not older than Pliocene, but Heer pronounced the plants of Samland and Rixhöft Miocene, and Göppert and Menge in their last work state that they are not more recent than Middle Miocene, while Conwentz and others regard the flora as Oligocene. Lapparent regards the amber beds themselves as upper Eocene, while admitting the Oligocene character of the plant remains. Credner and Neumayer place the whole in the lower Oligocene.

Much fossil wood of various geological ages has been found at Langenau near Danzig and along the shores of the Baltic in the northern drift of that region, of which Conwentz in his inaugural dissertation at the University of Breslau in 1876 has given some account.[1]

This is also perhaps the most appropriate place to mention the similar material described by Hoffman in 1883[2] and Kobbe in 1887,[3] from various points in the north of Mecklenburg near the Baltic, consisting of vegetable débris showing internal structure, most of which is reported from the "Diluvium," but this does not necessarily indicate the true age of the specimens themselves, and they may all have belonged to the general lignite deposit of the Baltic coast. Those found at Sternberg east of Schwerin are placed by the author in the upper Oligocene. The age of the Glauconite of Below can not probably be ascertained. The other localities are: Wismar, Alt-Gaarz on the Salz-Haff, Rabensteinfeld, Malliss, Conow near Dömitz, Neu-Krenzlin, Lorenzhöhe, Hohenwoos northwest of Bokup, Parchim and Trotzenberg near Parchim, Sonnenberg in the same vicinity, Zwenzow near Mirow, Lübtheen, and Grevesmühlen.

Prussian Saxony and Thuringia.—I use this term in a somewhat loose sense, to embrace all that part of central Germany which is bounded by Bavaria, Saxony, Prussia proper, Hanover, and Hesse, and embraces Coburg, Reuss, Weimar, Altenburg, Gotha, Meiningen, Merseburg, Brunswick, Hildesheim, and Magdeburg, and therefore the Thuringian Forest and the Harz Mountains, Saal Valley, etc. The most important plant beds are at or near Coburg, Blankenburg, Lobenstein, Gera, Altenburg, Eisenach, Manebach, and Ilmenau in the Thuringian Forest, and in the Harz Mountains, at Bornstädt, Wettin, Lobejün, Mansfeld, Stedten near Halle, Magdeburg, and Halberstadt. These places being located in mountainous districts, where different formations occur in close proximity to one another, it would be difficult to adhere to the geological and geographical treatment at the

[1] Ueber die Versteinten Hölzer aus dem norddeutschen Diluvium, von H. Conwentz. Breslau, 1876, 34 pp., 8°.

[2] Ueber die fossilen Hölzer aus dem mecklenburgischen Diluvium, von Hermann Hofmann. Neubrandenburg, 1883, pp, 1–45, 8°.

[3] Ueber die fossilen Hölzer der mecklenburger Braunkohle, von Fr. Kobbe: Archiv Ver. Freunde Naturg. Mecklenburg, 41st Jahr., 1887, Güstrow, 1888, pp. 89–142, pl. ii, iii. (Inaug.-Diss.)

same time, and it therefore seems best to take them up something in the order above named and rapidly designate the chief papers in which the floras have been monographed.

The only monograph of the Keuper beds of Coburg is that of Berger in 1829.[1]

The first author to describe and figure the celebrated Cretaceous (Senonian) leaves of the Blankenburg beds was Zenker, in 1833,[2] who, besides describing several specimens of fossil wood from Altenburg, established the genus Credneria and named four species, as also his *Salix fragilis*, further treated by Roemer in 1840.[3] In 1856 Dunker[4] described another collection from the same place made by Hartig, in which he figured the supposed fruit of Credneria (pl. xxxv, fig. 1), and they have since been mentioned from time to time by Stiehler[5] and other authors.

The Wurzbach deposits, near Lobenstein in Reuss, are of Cambrian age, and have been treated in a series of papers (1864–1871)[6] by Geinitz, who, with Liebe, regarded them as equivalent to the American Taconic of Emmons.

Permian plants are reported from Leimnitz, Thieschitz Trebnitz, Röpsen, and Milbitz, near Gera (Reuss).[7]

The Muschelkalk of the Saal Valley at Wogau and the Rauh-Thal, near Jena (Weimar), has furnished a number of fossil plants, which have been noticed by Schmid and Schleiden;[8] and Cotta in

[1] Die Versteinerungen der Fische und Pflanzen im Sandsteine der Coburger Gegend, von H. A. C. Berger. Coburg, 1829, 29 pp., 4 pl., 4°.

[2] Beiträge zur Naturgeschichte der Urwelt. Organische Reste (Petrefacten) aus der Altenburger Braunkohlen-Formation, dem Blankenburger Quadersandstein, jenaischen bunten Sandstein und böhmischen Uebergangsgebirge, von Jonathan Carl Zenker. Jena, 1833, viii, 67 pp., pl. i–vi, 4°.

[3] Die Versteinerungen des norddeutschen Kreidegebirges, von Freiderich Adolph Roemer. Hannover, 1840, p. 1.

[4] Ueber mehre Pflanzenreste aus dem Quadersandsteine von Blankenburg, von Wilhelm Dunker: Palaeontographica, vol. 4, 1856, pp. 179–183, pl. xxxii–xxxv.

[5] Beiträge zur Kenntniss der vorweltlichen Flora des Kreidegebirges im Harze, von August Wilhelm Stiehler. I, Allgemeine Bemerkungen über das Kreidegebirge zu Blankenburg und in der Grafschaft Wernigerode: Palaeontographica, vol. 5, Cassel, 1855–1858, pp. 45–70, pl. ix–xi.

[6] Ueber organische Ueberreste in dem Dachschiefer von Wurzbach bei Lobenstein, von H. B. Geinitz: Neues Jahrbuch für Mineral., 1864, pp. 1–9, pl. i–ii.

H. B. Geinitz und K. T. Liebe: Ueber ein Aequivalent der takonischen Schiefer Nordamerika's in Deutschland und dessen geologische Stellung: Nova Acta Acad. Leop.-Carol,, vol. 33, Dresden, 1866, pp. 1–52, pl. i–viii.

[Palæophycus macrocystoides Gein. aus dem altsilurischen Dachschiefer von Wurzbach bei Lobenstein], von H.B. Geinitz: Sitzungsber. Isis, Dresden, 1871, p. 2.

[7] Dyas oder die Zechsteinformation und das Rothliegende, von Hanns Bruno Geinitz. Heft II, Die Pflanzen der Dyas und Geologisches, Leipzig, 1862, pp. 131–342, pl. xxiv–xlii, folio.

[8] Die geognostischen Verhältnisse des Saalthales bei Jena, von E. E. Schmid und M. J. Schleiden. Leipzig, 1846, 1 Karte, 24 pl., folio.

Die organischen Reste des Muschelkalkes im Saal-Thale bei Jena, von E. Schmid: Neues Jahrbuch für Mineral., 1853, pp. 9–30.

1834[1] mentioned a bed, probably of Permian age, near Eisenach, where ferns, equisetaceous and cycadean remains were found.

The Culm (Subcarboniferous) flora of Saalfeld and Wurzbach has been thoroughly handled by Unger and Richter[2] and by Weiss;[3] that of Manebach was known to Hoff in 1814,[4] and Geinitz gives a dozen species from there in Gaea von Sachsen;[5] Richter in 1855,[6] and Schütze in 1878[7] made further contributions to it.

Göppert in 1854,[8] and quite recently Count Solms-Laubach,[9] have described the peculiar cones found at Ilmenau (Weimar) and Mansfeld (Merseburg), as also those of Frankenberg in Hesse.

The Keuper, or Lettenkohle, of Bădeleben near Kölleda (Merseburg), Mühlhausen (Erfurt), and Apolda (Weimar), and the peculiar forms that it contains, have received attention from the following authors: Germar (1851),[10] Borneman (1856),[11] Hallier (1858, 1859),[12]

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[1] Ueber Kalamiten-Reste in Keuper bei Eisenach; im alten Kohlen-Gebilde von Hainchen., von Bernhard Cotta: Neues Jahrbuch für Mineral., 1834, pp. 210, 211.

[2] Beitrag zur Paläontologie des Thüringer Waldes. von Reinhard Richter und Franz Unger: Denkschr. k. Akad. Wiss., Wien, math.-nat.-Cl., vol. 11, 1856, pp. 87–186. Erster Theil (Richter), pp. 89–138, pl. i–iii. Zweiter Theil (Unger) pp. 139–186, pl. i–xiii.

[3] Beitrag zur Culm-Flora von Thüringen, von Ernst Weiss: Jahrbuch k. preuss. geol. Landesanstalt u. Bergakad., 1883, pp. 81–100, pl. xi–xv.

[4] Beschreibung des Trümmergebirgs und des älteren Flötzgebirgs, welche den Thüringer Wald umgeben, von K. E. A. von Hoff: Leonh. Taschenb., vol. 8, 1814, pp. 319–436, 1 pl.

[5] Die Versteinerungen von Obersachsen und der Lausitz, von H. B. Geinitz und A. von Gutbier. In Gaea von Sachsen, etc., bearbeitet von C. F. Nauman, B. Cotta, H. B. Geinitz, A. v. Gutbier, M. A. Schiffner, und L. Reichenbach. Dresden, 1843, pp. 61–142, 8°.

[6] [Kohle bei Manebach. Beschreibung eines Calamites transitionis aus dem Culm,] von Reinhard Richter: Zeitschr. deutsch. geol. Gesell., vol. 7, Berlin, 1855, pp. 456–457.

[7] Ueber das angebliche Vorkommen der Sphenopteris distans in Manebach, von A. Schütze: Verhandl. k.-k. geol. Reichsanstalt, Wien, 1878, pp. 209–211.

[8] Ueber die sogenannten Frankenberger, Ilmenauer und Mannsfelder Kornähren, etc. . . . so wie über die Flora des Kupferschiefergebirges oder der Permischen Formation überhaupt, von H. R. Göppert: 32d Jahresber. schles. Gesell., Breslau, 1854, pp. 36–38.

[9] Die Coniferenformen des deutschen Kupferschiefers und Zechsteins, von H. Graf zu Solms-Laubach: Dames u. Kayser, Paläontolog. Abhandl., vol. 2, Heft 2, Berlin, 1884, pp. 81–116 (1–38), pl. xii–xv (i–iii).

[10] Ueber Omphalomela scabra, eine neue Pflanzenversteinerung aus dem Keuper von Badeleben in Thüringen, von E. F. Germar: Palaeontographica, vol. 1, Cassel, 1851, pp. 26–29, pl. iii, fig. *a–c*.

[11] Ueber organische Reste der Lettenkohlengruppe Thüringens. Ein Beitrag zur zur Fauna und Flora dieser Formation, etc., von J. G. Borneman. Leipzig, 1856, pp. 1–85, pl. i–xii.

[12] De Cycadeis quibusdam fossilibus in regione Apoldensi repertis descripsit Ernestus Hallier. Jena, 1858, pp. 1–24, 8°. (Inaug.-Dissert.)

Ueber die bei Apolda aufgefundenen fossilen Cycadeen von E. Hallier: Flora, Regensburg, 1859, No. 4, pp. 49–54, pl. ii; No. 31, pp. 481–483, pl. iv; No. 33, pp. 513–516, pl. ix.

Schmidt (1874),[1] and Compter (1874 and 1883).[2] Fossil wood and other vegetable remains have also been reported by Schmidt[3] from the Keuper in the Wachsenburg (Gotha).

The fossil flora of the Harz Mountains in its several formations, as well as the rest of its paleontology, has been gloriously monographed by Dr. Friedrich Adolph Roemer. His Versteinerungen des Harzgebirges, 1843,[4] was the forerunner of his later work, which appeared in Palaeontographica from 1850 to 1866.[5] The first of these memoirs describes the flora of the later Grauwacke and Posidonomya shales (Subcarboniferous) as they occur in the Gosethal near Goslar, the Lautenthal, Clausthal, Innerstethal, Schulenberg near Grund, Hahnenklee, etc. The second contains a few from about the same horizon at Lauterberg and Mägdesprung, all in Hildesheim; also at Nehden near Brilon, in Westphalia. The third mentions only two plants from the Culm of Zellerfeld (Hildesheim).

In the fourth, however, a very large number of Carboniferous species are described from the southern slope of the Harz, and also from Piesburg near Osnabruck in Hanover, and from Elzebachthal near Zorge, Glücksburg, Flottwell, and Buchholz near Ibbenbüren, in Westphalia, which it would be difficult to treat separately. The leading localities in the Harz are Poppenburg near Ilefeld, Meisdorf in the Selkethal, and Oppenrode. The first part of this memoir (pp. 7–11) enumerates a few more from the Grauwacke of Trogthal and Schaufenhäuerthal near Lauterberg, and from Pochthal near Clausthal; and the last memoir (No. 5) enumerates three others of practically the same age from Kammerberg near Ilsenburg.

Weiss has more recently studied the Carboniferous strata on the north slope of the Harz,[6] and also the lower Devonian flora of the

[1] Ueber den unteren Keuper des östlichen Thüringens, von E. E. Schmid: Abhandl. geol. Specialkarte Preuss. u. Thüring. Staaten, vol. 1, Heft 2, Berlin, 1874, pp. 1–66, pl. i.

[2] Gustav Compter: Ein Beitrag zur fossilen Keuperflora. Nova Acta Acad. Leop.-Carol., vol. 36, Dresden, 1874, pp. 1–10, pl. xiv–xvii.

Zur fossilen Flora der Lettenkohle Thüringens. Zeitschr. Naturwiss., vol. 66, Heft 1, Halle, 1883, pp. 1–29, pl. i, ii.

[3] Die Wachsenburg bei Arnstadt in Thüringen und ihre Umgebung, von E. E. Schmidt: Jahrbuch k. preuss. geol. Landesanstalt u. Bergakad., 1883, Berlin, 1884, pp. 267–309, pl. xxi.

[4] Die Versteinerungen des Harzgebirges, von Friedrich Adolph Roemer. Hannover, 1843, 40 pp., 12 pl., 4°.

[5] Beiträge sur geologischen Kenntniss des nordwestlichen Harzgebirges, von Friedrich Adolph Roemer: Abth. I, Palaeontographica, vol. 3, 1850, pp. 1–52, pl. i–x. Abth. II, Palaeontographica, vol. 3, 1852, pp. 68–111, pl. xi–xv. Abth. III, Palaeontographica, vol. 5, 1855, pp. 1–46, pl. i–viii. Abth. IV, Palaeontographica, vol. 9, 1860, pp. 1–46, pl. i–xii. Abth. V, Palaeontographica, vol. 13, 1866, pp. 201–230, pl. xxxiii–xxxv.

[6] Die Steinkohlen-führenden Schichten bei Ballenstedt am nördlichen Harzrande, von Ch. E. Weiss: Jahrbuch k. preuss. geol. Landesanstalt u. Bergakad., 1881, Berlin, 1882, pp. 595–603.

Harz[1] as he finds it at Oderthal, Schaufenhäuerthal, Kammerberg near Ilsenburg, etc.

The plants of the Mansfeld (Merseburg) copper shales (Permian) were known to Brongniart and Count Münster. They have been further treated by Kurtze in 1839,[2] Germar in 1840,[3] by Geinitz in Gaea von Sachsen, 1843, and by both Geinitz and Gutbier in their fossils of the Zechstein and Rothliegende or Permian system of Saxony, 1848 and 1849;[4] also by Geinitz in his Dyas. A very similar deposit occurs at Pössneck in Saxe-Meiningen, northeast of Saalfeld, where Zerrenner collected a series of specimens representing two species of Ullmannia which were studied and figured by Weber in 1851.[5]

The celebrated Carboniferous beds of Wettin and Löbejün, northwest of Halle in Merseburg, attracted the attention of Germar in 1837[6] and of Rost in 1839,[7] and a large illustrated folio work (German and Latin) in which the plants are magnificently treated, was begun by Germar in 1844 and completed by Andrä in 1853.[8] But the resources of this rich deposit are not yet exhausted. Councillor J. G. Beer's large collection from that place was donated by his heirs to the Austrian Geological Survey in 1873 and its contents were noted by Stur.[9] The fine geological monograph of the region north of Halle, prepared by Dr. Laspeyres and published in 1875 as a memoir

[1] Zur Flora der ältesten Schichten des Harzes, von Ernst Weiss: Jahrbuch k. preuss. geol. Landesanstalt u. Bergakad., 1884, Berlin, 1885, pp. 148–180, pl. v–vii.

[2] De petrefactis quae in schisto bituminoso Mansfeldensi reperiuntur. Quam . . . publice defendet Gustavus Adolphus Kurtze. Halæ, 1839, pp. 1–36, 4°.

[3] Die Versteinerungen des Mansfelder Kupferschiefers, beschrieben von Ernst Friedrich Germar. Halle, 1840, 39 pp., 2 pl., 12°. (See pp. 32–36.)

[4] Die Versteinerungen des Zechsteingebirges und Rothliegenden oder des permischen Systemes in Sachsen, von Hanns Bruno Geinitz und August von Gutbier. Leipzig, 1848–'49, 4°. Heft 1, Die Versteinerungen des deutschen Zechsteingebirges, von H. B. Geinitz, 1848, pp. 1–26, pl. i–viii. (Foss. pl. pp. 19–26, pl. viii.) Heft 2, Die Versteinerungen des Rothliegenden in Sachsen, von A. v. Gutbier, 1849; pp. 1–32, pl. i–xi, with col. geol. pl. (Foss. pl. pp. 7–32, pl. i–xi).

[5] Zur näheren Kenntniss der fossilen Pflanzen der Zechsteinformation, von C. Otto Weber: Zeitschr. deutsch. geol. Gesell., vol. 3, Berlin, 1851, pp. 315–319, pl. xiv.

[6] E. F. Germar: Bemerkungen uber einige Pflanzenabdrücke aus den Steinkohlengruben von Wettin und Löbejün im Saalkreise. Isis, von Oken, 1837, col. 425–431, pl. ii. Neues Jahrbuch für Mineral. 1839, pp. 498–501.

[7] Dissertatio de filicum ectypis obvii in lithanthracum Wettinensium Lobejunensiumque fodinis, von W. Rost. Halæ, 1839, 8°.

[8] Die Versteinerungen des Steinkohlengebirges von Wettin und Löbejün im Saalkreise. Petrificata stratorum lithanthracum Wettini et Lobejuni in circulo Salæ reperta, von Ernst Friedrich Germar, 8 Hefte, Halle, 1844–'53, pp. 1–116; Atlas, pl. i–xl, folio. [Plants in Heft 8, described by C. J. Andrä.]

Verzeichniss der in dem Steinkohlengebirge bei Wettin und Löbejün vorkommenden Pflanzen, von C. J. Andrä: Jahresber. Naturwiss. Ver. in Halle, vol. 2, 1850, pp. 118–130.

[9] Eine beachtenswerthe Sammlung fossiler Steinkohlen-Pflanzen von Wettin, von D. Stur: Verhandl. k.-k. geol. Reichsanstalt, Wien, 1873, pp. 263–270.

for the Prussian Specialkarte,[1] gives long lists of these plants and shows that active work was still going on in this part of Germany at that time.

We will next consider the Tertiary floras of Prussian Saxony. These are chiefly located at Skopau, Stedten, Runthal, Weissenfels, Bornstädt near Eisleben, Riestedt, Dörstewitz, and Trotha, in Merseburg, and at Meuselwitz, in Altenburg, which is so far to the south that it might perhaps have been appropriately treated in the preceding subdivision.

Heer published a memoir in 1861[2] on the floras of Skopau, Stedten, Weissenfels and Helmstedt, the last in Brunswick; and in 1869[3] another on that of Bornstädt near Eisleben, having previously furnished a list of the species to Zincken,[4] who collected the specimens.

Engelhardt in 1876 made some additions to the flora of Stedten,[5] and in 1884 published a paper on that of Meuselwitz in Altenburg,[6] previously unknown. About the same time Fritsch[7] published a paper in the year-book of the Prussian Geological Survey, in which he described new species from the Pliocene at Rippersroda in Thuringia. Finally Friedrich's two papers on the Tertiary flora of the vicinity of Halle[8] constitute a general monograph of this whole field and leave little to be desired.

Concerning the age of these floras the Prussian Geological Survey regards them all as belonging to the Lower Oligocene, but possessing considerable range within this formation.

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[1] Geognostische Darstellung des Steinkohlengebirges und Rothliegenden in der Gegend nördlich von Halle, a. d. Saale, etc., von Hugo Laspeyres: Abhandl. geol. Specialkarte Preuss. u. Thüring. Staaten, vol. 1, Heft 3, Berlin, 1875, pp. 1–603, 1 col. geol. plate.

[2] Beiträge zur nähern Kenntniss der sächsisch-thüringischen Braunkohlenflora, von Oswald Heer; nebst einem Anhange über einige Siebenbürgische Tertiärpflanzen, von C. J. Andrä: Abhandl. naturwiss. Ver. Prov. Sachsen, Thüring., vol. 2, Berlin, 1861, pp. 405–438, pl. i–x.

[3] Ueber die Braunkohlenpflanzen von Bornstädt, von Oswald Heer: Abhandl. naturf. Gesell. zu Halle, vol. 11, 1869, pp. 1–22, pl. i–iv.

[4] [Ueber einige in einem untermiocänen Braunkohlenlager bei Bornstädt unfern Eisleben aufgefundenen Pflanzenreste,] von C. Zincken: Neues Jahrbuch für Mineral., 1867, pp. 82–83.

[5] Bemerkungen über Tertiärpflanzen von Stedten bei Halle a. S., von Hermann Engelhardt: Sitzungsber. naturwiss. Gesell. Isis, Dresden, 1876, pp. 97–101.

[6] Ueber Braunkohlenpflanzen von Meuselwitz, von Hermann Engelhardt: Mitth. aus d. Osterlande, new series, vol. 2, Altenberg, 1884, pp. 1–37, pl. i–ii.

[7] Das Pliocän im Thalgebiete der zahmen Gera in Thüringen, von K. von Fritsch: Jahrb. k. preuss. geol. Landesanstalt u. Bergakad., 1884, Berlin, 1885, pp. 389–437, pl. xxiii–xxvi.

[8] Paul Friedrich: Ueber die Tertiärflora der Umgegend von Halle a. S. Halle, 1883, 12 pp., 8°.

Beiträge zur Kenntniss der Tertiärflora der Provinz Sachsen. Abhandl. geol. Specialkarte Preuss. u. Thüring. Staaten, vol. 4, Heft 3, Berlin, 1884, viii, 305 pp., map, 8°. Atlas, pl. i–xxxi, folio.

In the region around Halberstadt and Quedlinburg in Merseburg, two plant-bearing horizons occur; one in the Lias, from which Dunker described a few species in 1846,[1] the other Upper Cretaceous (Senonian), which has been thoroughly worked up by Geinitz,[2] Stiehler[3] and Heer.[4]

Hesse, including Hesse-Nassau.—Under this geographical group we can make only a passing reference to the Silurian strata at Sinn, in the vicinity of Dillenburg, which yielded to Ludwig the very perfect forms of Bythotrephis, etc.; the Upper Devonian plants from the same place, and also from Bicken in that vicinity, and from Ockstadt, near Bad Nauheim; the Culm (Subcarboniferous) plants from Herborn, Oberndorf, Kombach, Vöhl, Thalitter, Battenberg, Eckelshausen, Rachelshausen, Hommertshausen, and Buchenau, near Biedenkopf, in Nassau, and at Holzhausen, in Hesse, all of which he treated in the seventeenth volume of Palaeontographica in 1869;[5] the Carboniferous plants to which the Sandbergers devote two plates of their Fossils of the Rhenish System in Nassau[6] obtained from Steinsberg near Dietz, Kemmenau near Ems, Niederlahnstein, Astert near Hachenberg, Uckersdorf, Eisemroth, Rehberg, Gondersdorf, Eimelrod, Frankenberg, and Herborn; also across the border in Rhenish Prussia at Winningen, Karthause, Horhausen, Brohl, Vallendar, Capellen, and Brodenbach, in the vicinity of Coblenz; the Permian

[1] Ueber die in dem Lias bei Halberstadt vorkommenden Versteinerungen, von Wilhelm von Dunker: Palaeontographica, vol. 1, 1846–1851, pp. 34–41, 107–125, pl. vi, xiii–xvii. Nachträge, pp. 176–181, 319, 320, pl. xxv, xxxvii.

[2] Ueber die Zusammensetzung und Lagerung der Kreide-Formation in der Gegend zwischen Halberstadt, Blankenburg, und Quedlinburg, von H. B. Geinitz: Neues Jahrbuch für Mineral., 1850, pp. 133–138.

[3] August Wilhelm Stiehler: Ueber fossile Pflanzen aus der Kreideformation von Quedlinburg. Ber. Deutsch. Naturf. Vers., vol. 31, 1854, pp. 69–71.

Die Flora im Quadersandstein des Langenberges bei Quedlinburg. Zeitschr. Naturwiss., vol. 9, Halle, 1857, pp. 452–455.

Beiträge zur Kenntniss der vorweltlichen Flora des Kreidegebirges im Harze. II, Die Flora des Langebirges bei Quedlinburg. Palaeontographica, vol. 5, Cassel, 1855–'58, pp. 71–80, pl. xii–xv.

[4] Beiträge zur Kreideflora. II, Kreideflora von Quedlinburg, von Oswald Heer: Neue Denkschr. schweiz. Gesell. Naturw., vol. 24, Zürich, 1869, No. 2, pp. 1–13. pl. i–iii.

[5] Rudolph Ludwig: Fossile Pflanzenreste aus den paläolithischen Formationen der Umgegend von Dillenburg, Biedenkopf und Friedberg und aus dem Saalfeldischen. Palaeontographica, vol. 17, Heft 3, Cassel, 1869, pp. 105–128, pl. xviii–xxviii.

Nachtrag zu der Abhandlung über fossile Pflanzen aus den paläolithischen Formationen in der Umgegend von Dillenburg, Biedenkopf, und Friedberg, und aus dem Saalfeld'schen. Ibid., pp. 137–140, pl. xix, xx.

[6] Die Versteinerungen des rheinischen Schichtensystems in Nassau, von Dr. Guido Sandberger, und Dr. Fridolin Sandberger. Wiesbaden, 1850–1856, pp. i–xv, 1–564, 4°; [Foss. pl. on pp. 421–432; 447.] Atlas, 1850–'55, 39 pl. folio. [Plants on pl. xxxviii–xxxix.]

plants of Riechelsdorf, to which Althaus called attention in 1851,[1] and which have since become well known; the historic "Kornähren" of Frankenberg, known to Winkelmann in 1697,[2] Lehmann in 1760,[3] Waldin in 1778,[4] and mentioned by all authors who have written on that subject down to Count Solms-Laubach, who has recently written up their history;[5] the Tertiary plants described by Ludwig in 1857 from the tufaceous basalt of Holzhausen near Homberg in Kurhessen,[6] and from the "Spatheisenstein" of Dernbach and Horressen near Montabauer in 1861,[7] and those to which Geyler drew attention in 1874 as occurring at Elsheim and Stadecken in Rhein-Hessen,[8] and finally to the Miocene lignite beds of the Wetterau in the vicinity of Frankfurt, whose investigation was begun in 1856 by Fresenius and Meyer,[9] continued by Ludwig from 1857 to 1859,[10] and closed by Ettingshausen in 1868.[11] This last district and the exhaustive memoirs upon it are of great importance to the science and deserve more attention than space permits us to bestow. The localities have most

[1] Ueber einige neue Pflanzen aus dem Kupferschiefer von Riechelsdorf, von J. Althaus: Palaeontographica, vol. 1, Cassel, 1851, pp. 30–33, pl. i, iv.

[2] Beschreibungen der Fürstenthümer Hessen und Hersfeld, etc., von J. F. Winkelmann. Bremen, 1697. (See p. 37.)

[3] Kurtze Untersuchung derer sogenannten versteinerten Kornähren, etc., von Frankenberg in Hessen, von J. G. Lehmann. Berlin, 1760, 16 pp., 4°.

[4] Die Frankenberger Versteinerungen, nebst ihrem Ursprunge beschrieben von Joh. Gottlieb Waldin. Marburg, 1778, 32 pp., 2 pl., 4°.

[5] Die Coniferenformen des deutschen Kupferschiefers und Zechsteins, von Graf zu Solms-Laubach: Dames und Kayser, Palæontolog. Abhandl., vol. 2, Heft II, Berlin, 1884, pp. 1–38, pl. i–iii.

[6] Fossile Pflanzen aus dem Basalt-Tuffe von Holzhausen, bei Homberg in Kurhessen, von R. Ludwig: Palaeontographica, vol. 5, 1857, pp. 152–161, pl. xxiii–xxv.

[7] Fossile Pflanzen aus dem tertiären Spatheisenstein von Montabauer, von Rudolph Ludwig: Ibid., vol. 8, 1861, pp. 160–181, pl. lxiii–lxx.

[8] Ueber die Tertiärflora von Stadecken-Elsheim in Rheinhessen, von H. Th. Geyler: Jahresber. Senckenberg. naturf. Gesell., 1873–'74, Frankfurt, 1875, pp. 103–114.

[9] Sphaeria areolata aus der Braunkohle der Wetterau, von Georg Fresenius und Hermann von Meyer: Palaeontographica, vol. 4, 1856, pp. 202, 203, pl. xxxvii, fig. 9–12.

Ueber Phelonites lignitum, Phelonites strobilina und Betula Salzhausensis, von Georg Fresenius: Ibid., vol. 8, Cassel, 1861, pp. 155–159, pl. lxii.

[10] R. Ludwig: Ueber mitteldeutsche Tertiärbildungen. Zeitschr. deutsch. geol. Gesell., vol. 9, 1857, pp. 182–184.

Fossile Pflanzen aus der jüngsten Wetterauer Braunkohle. Palaeontographica, vol. 5, Cassel, 1858, pp. 81–109, pl. xvi–xxii.

Fossile Pflanzen aus der mittleren Etage der Wetterau-Rheinischen Tertiär-Formation. Ibid., pp. 132–151, pl. xxvii–xxxiii.

Fossile Pflanzen aus der ältesten Abtheilung der Rheinisch-Wetterauer Tertiär-Formation. Ibid., vol. 8, 1859, pp. 39–154, pl. vi–lx.

Die fossilen Pflanzen in der Wetterauer Tertiärformation. 7th Bericht Oberhess. Gesell. Nat., Heilkunde, Giessen, 1859, pp. 1–12.

[11] Die fossile Flora der älteren Braunkohlenformation der Wetterau, von Constantin von Ettingshausen: Sitzungsber. k. Akad. Wiss., Wien, math.-nat. Cl., vol. 57, Abth. I, 1868, pp. 807–893, pl. i–v, charts i–xi.

of them become familiar to paleobotanists as well as to geologists, especially the leading ones, such as Salzhausen, Bommersheim, Dorheim, Weckesheim, Dornassenheim, Bauernheim, Wölfersheim, Frankfurt, Bönstadt, Bürgel Kleinkarben, Kaichen, Bodenheim, Selzen, Münzenberg, Hochheim, Gronau, Naumburg, Hessenbrücker-Hammer, Steinheim, Rossdorf, Seckbach, Gambach, Dorfgill, Gundhelm, Hütten, Zell, Schlechtenwegen, Grossallmerode, Hattenheim, and Oberingelheim.

Finally, we have the very recent but important memoirs of Geyler and Kinkelin on the Upper Pliocene flora of the Klärbecken near Niederrad and Höchst on the Main,[1] describing some very remarkable coniferous and dicotyledonous fruits.

Schleswig-Holstein.—From a quaternary peat-bed at Lauenberg on the Elbe, K. Keilhach[2] has obtained twenty-two species of vascular plants, sixteen of which are still found in the flora of the vicinity of that place.

Hanover and Brunswick.—This geographical group will unavoidably include localities in Lippe, Cassel, and the upper portion of Hildesheim. Friedrich Hoffmann gave an account of the plants of the coal formation of Piesburg near Osnabrück in Keferstein's "Deutschland," 1826.[3] Roemer, as already stated, included a full account of this district in the last of his memoirs on the Harz flora, and Major von Roehl also stepped aside to include it in his Carboniferous flora of Westphalia, 1868 (see infra, p. 770).

In the supplement to Roemer's Oolite Formation, 1836,[4] plants are described from the Deister and the Osterwald.

The Wealden deposits of Hanover are the most numerous. Dunker, in his Monograph of the North German Wealden formation, 1846,[5]

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[1] Ueber den Schichtenbau, die Pliocänflora und die Diluvialgebild. des Untermainthales, von F. Kinkelin: Zeitschr. deutsch. geol. Gesell., vol. 38, 1886, Heft 3, pp. 684–695.

Oberpliocän-Flora aus den Baugruben des Klärbeckens bei Niederrad und der Schleuse bei Höchst. a. M., von Th. Geyler und F. Kinkelin: Abhandl. Senckenberg. naturforsch. Gesell., vol. 14, No. 8, Frankfurt a. M., 1887, pp. 1–47, pl. i–iv.

Die Geschichte des Mainzer Tertiärbeckens, seine Thier und Pflanzenwelt, von F. Kinkelin: Humbolt, 6th Jahrgang, 1887, (I) Heft 9, Sept., pp. 333–337; (II) Heft 10, Oct., pp. 371–374.

[2] Ueber ein interglaciales Torflager im Diluvium von Lauenberg an der Elbe, von K. Keilhach: Jahrbuch k. preuss. geol. Landesanstalt u. Bergakad., 1884, Berlin, 1885, pp. 211–238, pl. xi.

[3] Ueber die Pflanzenreste des Kohlengebirges von Ibbenbühren und vom Piesberge bei Osnabrück, von Friedrich Hoffmann. In Keferstein's Deutschland geognostisch-geologisch dargestellt, etc., vol. 4, Weimar, 1826, 8°, pp. 150–168.

[4] Die Versteinerungen des norddeutschen Oolithen-Gebirges, von Friedrich Adolph Roemer. Hannover, 1835–'36, pp. (6) 1–218, pl. i–xvi, folio. Nachtrag, Hannover, 1839, pp. (4) 1–60, pl. A (profile), xvii–xx. [Plants in Nachtrag, pp. 9, 10, pl. xvii.]

[5] Monographie der norddeutschen Wealdenbildung, ein Beitrag zur Geognosie und Naturgeschichte der Vorwelt, von W. Dunker. Braunschweig, 1846, xxxii, 86 pp., pl. i–xxi, 4°.

describes plants from Harrel near Bückeburg and Egestorf, Oesede near Osnabrück, Süntel, Bredenbeck, Salzhemmendorf, Koppengraben, near Alefeld, and Suersser Brink, Rehburg, Duingen, Borgloh, and at other points on the Deister and the Osterwald. Ettingshausen noticed forms from the Deister clays in 1851,[1] and Schenk in his fourth and fifth "contributions"[2] adds to this list Stemmen and Knippenbrink.

Roemer in his fossils of the North-German Cretaceous formation already quoted (supra, p. 761), reports Cretaceous plants from Peine in Hanover, and from Wrisbergholzen and Alfeld in Hildesheim as well as at Rothenfelde in Westphalia.

The only important plant-bearing deposit in Brunswick is the Rhetic sandstone of Seinstedt, which Dr. Brauns has so well portrayed in his two memoirs in the ninth and thirteenth volumes of Palaeontographica, 1862–1866,[3] one of the supposed ferns from which Nathorst regards as a species of Ginkgo.[4]

In addition to this, however, should be mentioned the phosphorite and coprolite beds of Brunswick at Helmstedt, Büddenstedt, Schlewecke, Harlingerode, Runstedt, etc., near Harzburg, where a great abundance of fossil wood has been obtained and very thoroughly studied by Vater.[5] Both the geological and the paleodendrological evidence favors the reference of these beds to the Upper Cretaceous, or Senonian.

Westphalia.—The earliest account of fossil plants in Westphalia is in 1854 by Göppert, who made a journey through that province and found them at Stadthagen, Sülbeck, Obernkirchen, Ibbenbüren,

[1] Notiz über einige besonders interessante fossile Pflanzenreste aus dem Wealden-Thon vom Deister, von C. Ettingshausen: In Franz Hauer's Verzeichniss der an die k.-k. geol. Reichsanstalt, gelangten Einsendungen, etc. Jahrbuch k.-k. geol. Reichsanstalt, Wien, vol. 2, Heft II, 1851, pp. 156, 157.

[2] A Schenk: Beiträge zur Flora der Vorwelt. IV, Die Flora der nordwestdeutschen Wealdenformation. Palaeontographica, vol. 19, Cassel, 1871, pp. 203–276, pl. xxii–xliii.

Beiträge zur Flora der Vorwelt. V, Zur Flora der nordwestdeutschen Wealdenformation. Ibid., vol. 23, Cassel, 1875–'76, pp. 157–163, pl. xxv, xxvi.

[3] D. Brauns: Der Sandstein bei Seinstedt unweit des Fallsteins und die in ihm vorkommenden Pflanzenreste. Palaeontographica, vol. 9, 1862–'64, pp. 47–62, pl. xiii–xv.

Der Sandstein bei Seinstedt unweit des Fallsteins und die in ihm vorkommenden Pflanzenreste, nebst Bemerkungen über die Sandsteine gleichen Niveaus anderer Oertlichkeiten Norddeutschlands. (Ein Nachtrag zu Palaeontographica, vol. 9, p. 47.) Ibid., vol. 13, 1866, pp. 237–246, pl. xxxvi.

[4] Om Gingko? crenata Brauns sp. från sandstenen vid Seinstedt nära Braunschweig, af A. G. Nathorst: Ofversigt Kongl. svensk. Vet.-Akad. Förhandl., vol. 35, 1878, No. 3, pp. 81–85, pl. v.

[5] Die fossilen Hölzer der Phosphoritlager des Herzogthums Braunschweig, von Heinrich Vater: Zeitschr. deutsch. geol. Gesell., vol. 36, Berlin, 1884, pp. 783–853, pl. xxvii–xxix.

Dortmund, Bochum, etc.[1] In the coal mines of Ibbenbüren he found certain fucoids which he named and one of which he figured.

It is now known that the different plant-bearing strata of Westphalia represent the Carboniferous, the Wealden, the Lower Cretaceous (Gault and Neocomian), and the Upper Cretaceous (Senonian). The flora of the first of these formations has been chiefly elaborated by Ludwig,[2] Roehl,[3] Andrä,[4] Felix,[5] and Weiss.[6] Von Roehl's specimens came largely from Curl near Camen, Dortmund, and vicinity (Tremonia, etc.), Bochum and vicinity (Ritterburg, etc.), Wintrup near Arnsberg and Herbede and Hattingen near Dilldorf, on the Ruhr, Gelsenkirchen, Hörde, etc., as well as from several points in Rhenish Prussia. Andrä, in his Primordial Plants of the Carboniferous of the Prussian Rhine Lands and Westphalia, of which I have seen only three parts, 1865-1869, described many forms from the Hibernian mines of Gelsenkirchen, from Dortmund, Bochum, and Camen. Most of the specimens which formed the subject of Dr. Felix's investigations, published in 1886, were collected by Wedekind at Langendreer. They occurred in nodules, and the internal structure is remarkably well preserved. Dr. Weiss's memoir in the same volume on the Sigillariæ of the Prussian Carboniferous formation (Favulariæ) embraces a discussion of the structural morphology of a large number of plants belonging to this group from various parts of the German Empire, but the greater number are from Westphalia, and especially from mines near Annen, Werne, Weitmar, Witten, Hörde, Essen, Neu-Essen, Vollmond, Langendreer, Hattingen, Dortmund, and Bochum.

The Wealden plant beds of Westphalia developed by Dunker and Schenk are located at Obernkirchen near Minden, Rosehof, Clus, and Böhlhorst, in the same general section, and on the slope of the Deister.

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[1] Bericht über eine . . . 1850 in dem westphälischen Hauptbergdistrict unternommene Reise zum Zwecke der untersuchung der in der dortigen Steinkohlenformation vorkommenden fossilen flora, von H. R. Göppert: Verhandl. naturhist. Ver. preuss. Rheinl. Westfalens, new series, vol. 11, Bonn, 1854, pp. 225-264, pl. iii.

[2] Calamiten-Früchte aus dem Spatheisenstein bei Hattingen an der Ruhr, von Rudolph Ludwig. Palaeontographica, vol. 10, Cassel, 1861, pp. 11-16, pl. ii.

[3] Fossile Flora der Steinkohlen-Formation Westphalens einschliesslich Piesberg bei Osnabrück, von E. von Roehl: Palaeontographica, vol. 18, Cassel, 1868-'69, pp. 1-192, pl. i-xxxii.

[4] Vorweltliche Pflanzen aus dem Steinkohlengebirge der preussischen Rheinlande und Westfalens, von Carl Justus Andrä. Bonn, 1865-1869, folio; Heft 1, 1865, pp. 1-18, pl. i-v; Heft 2, 1866, pp. 19-34, pl. vi-x; Heft 3, 1869, pp. 35-50, pl. xi-xv.

[5] Untersuchungen über den inneren Bau Westfälischer Carbon-Pflanzen, von Johannes Felix: Abhandl. k. preuss. geol. Landesanstalt u. Bergakad., vol. 7, Heft 3, Berlin, 1886, pp. vi, 153 (I)-225 (73), pl. i-vi.

[6] Beiträge zur fossilen Flora. IV, Die Sigillarien der preussischen Steinkohlengebiete. 1, Die Gruppe der Favularien, von E. Weiss: Abhandl. geol. Specialkarte Preuss. u. Thüring. Staaten, vol. 7, Heft 3, Berlin, 1887, pp. 226-294 (1-68), pl. vii-xv (i-ix).

Probably the Cretaceous plants of Westphalia have the greatest interest for paleobotanists. Roemer in his Cretaceous of North Germany (1840), several times referred to, described one species (*Chondrites furcillatus*) from strata of Cretaceous age (Pläner) at Rothenfelde. In 1863 Von der Marck[1] described about a dozen species from the "Plattenkalk" at the station of Drensteinfurth, between Drensteinfurth and Albersloh, and at Arenfeld and Bracht near Sendenhorst. In 1867 Saporta published a note on a new locality at Haldem.[2] In 1869 Hosius introduced into his Geognosy of Westphalia[3] the general discussion of quite a number of Westphalian species belonging to this formation from Legden, Sendenhorst, Albersloh, etc. The same year appeared his monograph of the dicotyledons of the Westphalian Cretaceous formation,[4] treating a larger number of species of this subclass. They are chiefly from Legden near Coesfeld and from Sendenhorst.

The eleven years that elapsed between the publication of these papers and the appearance of Hosius and Von der Marck's complete monograph of the Cretaceous flora of Westphalia[5] is proved by the latter work to have been well employed. They here divide the Westphalian Cretaceous into two members, the Upper and the Lower Cretaceous. To the former, or Senonian, belong the beds at Baumberge near Havixbeck, Haldem, Höpingen west of Münster, Legden, Arenfeld, Arenhorst, Bracht, Stromberg, Oelde, Dolberg, Drensteinfurt, Albersloh, Rinkhove, Darup Mountain, quarry on the Chaussee, Lemförde, etc.

The Lower Cretaceous they subdivide into two members, the Gault, which occurs at Ahaus (Frankenmühle, Barler Berg), and the Neocomian, which is found at Oerlinghausen, Ebberg, between the last-named place and Bielefeld, in the Teutoburg forest, and Tecklenburg. They also describe specimens from Velmerstoot near Horn in Lippe, and Hohnsberg near Iburg, in Hanover. No new localities are added in the supplement to this paper that appeared in 1885.[6]

[1] Fossile Fische, Krebse und Pflanzen aus dem Plattenkalk der jüngsten Kreide in Westphalen, von Dr. W. von der Marck: Palaeontographica, vol. 11, Cassel, 1863 pp. 1–83, pl. i–xiv.

[2] Note sur une collection de plantes fossiles provenant de la craie à Belemnites mucronatus de Haldem en Westphalie, par G. de Saporta: Bull. Soc. géol. France, vol. 24, Paris, 1867, pp. 33–36.

[3] Beiträge zur Geognosie Westfalens. Die in der westfälischen Kreideformation vorkommenden Pflanzenreste, von Dr. A. Hosius. Münster, 1869, pp. 1–34, 8°.

[4] Ueber einige Dicotyledonen der westfälischen Kreideformation, von A. Hosius: Palaeontographica, vol. 17, 1869, pp. 89–104, pl. xii–xvii.

[5] Die Flora der westphälischen Kreideformation, von A. Hosius and W. von der Marck: Palaeontographica, vol. 26, Cassel, 1880, pp. 125–236, pl. xxiv–xliv.

[6] Weitere Beiträge zur Kenntniss der fossilen Pflanzen und Fische, etc. Nachtrag zur Flora der westfälischen Kreideformation, von A. Hosius und W. von der Marck: Palaeontographica, vol. 31, Cassel, 1885, pp. 225–232, pl. xix–xx.

Rhenish Bavaria.—The coal mines of St. Ingbert were early known to furnish vegetable impressions, and some very good figures of these were made by Nau, in 1820,[1] when the tropical origin of fossil plants was still under discussion. These plants have been frequently mentioned by later authors.

The Saar-Rhein district (Carboniferous and Permian) extends far into Rhenish Bavaria, and is well developed, not only at St. Ingbert, but at Cusel,[2] Bedesbach, Carlingen near Homburg, and other points. It will therefore be necessary to consider them together, and owing to the greater prominence which these beds assume in Rhenish Prussia they can best be treated under that province, which next demands our attention.

Rhenish Prussia.—Five geological formations are represented in the fossil flora of Rhenish Prussia, namely, the Carboniferous and the Permian by the Saar-Rhine flora; the Buntersandstein by plant beds at Zülpich, on the Roer east of Aachen,[3] at Kreuznach, Beckingen and Rehlingen near Saarlouis, and at Mesenich and Wintersdorf near Trèves;[4] the Cretaceous (Senonian) of Aachen, and the Miocene of the Lower Rhine. The Triassic flora is not prominent, and need not be further mentioned.

Carboniferous and Permian.—The Saar-Rhine district has been the subject of investigation from the earliest times, but the first paper in the nature of a local monograph was Goldenberg's inaugural dissertation at the Royal Gymnasium of Saarbrücken in 1835,[5] though many of his specimens were from remote localities. In 1840 Steininger published an important geological account of the region between the Lower Saar and the Rhine,[6] in which he figured a number

[1] Pflanzenabdrücke und Versteinerungen aus dem Kohlenwerke zu St. Ingbert, im baierischen Rhein-Kreise, verglichen mit lebenden Pflanzen aus wärmeren Zonen, von Bernhard S. von Nau: Denkschr. k. bayer. Akad. Wiss., vol. 7, 1818–'20, München, 1821, pp. 283–288, pl. i–iv.

[2] Pflanzenreste in den Cuseler Schichten von Cusel, von C. E. Weiss: Zeitschr. deutsch. geol. Gesell., vol. 33, 1881, p. 704.

[3] Max Blanckenhorn: Die Trias am Nordrande der Eifel zwischen Commern, Zülpich und dem Roerthale. Abhandl. geol. Specialkarte Preuss. u. Thüring. Staaten, vol. 6, Heft 2, Berlin, 1885, pp. 134–269, 1–135, pl. i (map), ii (sect.), iii (invert.).

Die fossile Flora des Buntsandsteins und des Muschelkalks der umgegend von Commern. Palaeontographica, vol. 32, 1886, pp. 117–154, pl. xv–xxii.

[4] Ueber Voltzia und andere Pflanzen des bunten Sandsteins zwischen der untern Saar und dem Rheine, von. C. E. Weiss: Neues Jahrbuch für Mineral., 1864, pp. 279–294, pl. v.

[5] Grundzüge der geognostichen Verhältnisse und der vorweltlichen Flora in der nächsten Umgegend von Saarbrücken, von. Fr. Goldenberg. In Ottemann's öffentl. Prüfung d. k. Gymnasiums, Saarbrücken, 1835, pp. 1–32, 4°.

[6] Geognostische Beschreibung des Landes zwischen der untern Saar und dem Rheine. Ein Bericht an die Gesellschaft nützlicher Forschungen zu Trier, von J. Steininger. Trier, 1840, pp. 1–149, pl. i–v (geol.), 12 figs. (plates) fossil plants, 4°. Nachträge, 1841, pp. 1–49, figs. (plates) 13–18, 4°.

of plants and tried to identify them with Brongniart's species. The first part of Goldenberg's Flora Saræpontana Fossilis appeared in 1855, the second in 1857, and the third in 1862.[1] He here describes specimens obtained at Saarstollen, Fischbach, in the Holzhauerthal, at Völklingen, Auerswald, Neunkirchen, Altenwald, Duttweiler, Gersweiler, Hirshbach, Schnappbach, Friedrichsthal, Wellesweiler, Eschweiler, Essen, etc.

Weiss began his investigations into this flora in 1860,[2] completing them in 1868, and publishing a very full synopsis in that year.[3] His great work on the Fossil Flora of the Upper Carboniferous and the Permian (Rothliegende) in the Saar-Rhine district, appeared in 1869,[4] since which time no systematic works have been published on the region. Many new localities were then known, and we find that collections had been made from the Carboniferous at Heinitz, Gerhard, Reden, Steinbachstollen, Quierschied, Breitenbach, Hostenbach, Dilsburg, Labach, Jägersfreude, Ottenhausen, Russhütte near Reden, Ziehwald, Luise near Urexweiler, Hirtel, Krughütte, Bildstock, Hangard, between Rossberg and Adenbach, Spiemont, Münchwies, Katzenloch, Altenbamburg, Schiffweiler, Bettingen, Reisweiler, and Abtsweiler near Meisenheim, etc.; and from the Permian at Werschweiler, Leitersweiler, Carlstollen, Lebach, Steimel near Meisenheim, Berschweiler west of Kirn, Eichen opposite Kirn, Düppenweiler, Reifelbach, Niederhausen and Nordheim near Kreuznach, Feil-Bingert on the Kahleberg, Kirn, Marpingen, the tunnel between Staudernheim and Boos on the Nahe, Buchenberg, Alsweiler, Wadrill, and Saint Wendel.

In addition to the above localities in Rhenish Prussia, there occur many across the political boundaries in other States. Thus in Rhenish Bavaria plants are reported from the Carboniferous at Remigiusberg southeast of Cusel, Brücken, Oberweiler on the Lauter, St. Julian on the Glan, Bedesbach near Altenglan, Zweibrücken, and Rockenhausen; and from the Permian at Cusel, Altenwald near Quirnbach, Steckweiler in the Alsenz Valley, Danenfels near Bastenhaus, Medart on the Glan, Kronnenberg near Lauterecken, Falkenstein on the Donnersberg, Sitters near Obermoschel, Bledesbach, Münsterappel, between Nieder-Kirchen and Hefersweiler, Ebernburg,

[1] Flora Saræpontana fossilis. Die Pflanzenversteinerungen des Steinkohlengebirges von Saarbrücken abgebildet und beschrieben von Friedrich Goldenberg. Saarbrücken, 3 Hefte, 1855–'62. Text, 4°, plates folio.

[2] Ueber ein Megaphytum der Steinkohlen-Formation von Saarbrücken, von Ernst Weiss: Zeitschr. deutsch. geol. Gesell., vol. 12, Berlin, 1860, pp. 509–512.

[3] Begründung von fünf geognostischen Abtheilungen in den steinkohlenführenden Schichten des Saar-Rheingebirges, von Ch. Ernst Weiss: Verhandl. naturhist. Ver. preuss. Rheinl., Westfalens, 3d series, vol. 5, Jahrg. 1868, pp. 63–134.

[4] Fossile Flora der jüngsten Steinkohlenformation und des Rothliegenden im Saar-Rhein-Gebiete, von Ch. Ernst Weiss. Bonn, 1869–'72, pp. 1–250. pl. i–xx, 4°. Neues Jahrbuch für Mineral., 1870, pp. 373–375.

on the Bleckarsch southeast of Ulmet near Altenglan, Odenbach, Wolfstein, and Jacobsweiler. In the principality of Birkenfeld Carboniferous plants were obtained from Oberhausen on the Nahe, and Permian Plants from Berschweiler, Schwarzenbach, Veitsroth, Bergen, Buhlenberg, and Schonewald. In Hesse Nassau, Schwalbach, Niederwörresbach, and Wiesbach west of Hensweiler, all Carboniferous, are mentioned; and in Rhein-Hessen, Mauchenheim, Wendelsheim, and Flonheim, near Alzey, all Permian, occur. In Lorraine, Rosseln, Püttlingen near Völklingen, and l'Hôpital de St. Avold, yielded Carboniferous species, as did also Hilsbach in Baden. Finally, in the Netherlands, plant-bearing Carboniferous strata are indicated at Keutenberg near Wylré, and at Mt. St. Peter near Maestricht.

Cretaceous.—The Cretaceous flora of Aachen was first systematically studied by Göppert in 1841.[1] Debey commenced publishing upon it in 1848,[2] and, assisted by Ettingshausen in 1856 to 1859,[3] succeeded in placing the cryptogamous vegetation of that interesting deposit in a condition which made it available to students of paleobotany. It was not until 1877 that anything further was known of the Coniferæ of that flora,[4] and only one short paper, relating to the oak-like leaf prints,[5] has appeared upon the dicotyledons, although it is known that large collections have been made, which have been distributed since Debey's death.

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[1] Fossile Pflanzenreste des Eisensandes von Achen, als zweiter Beitrag zur flora der Tertiärgebilde, von H. R. Göppert: Nova Acta Acad. Leop.-Carol., vol. 19, pt. 2, 1841, pp. 139–160, pl. liv.

[2] M. H. Debey: Uebersicht der urweltlichen Pflanzen des Kreidegebirges überhaupt, und der Aachener Kreideschichten insbesondere. Verhandl. naturhist. Ver. preuss. Rheinl., Westfalens, vol. 5, Jahrg. 1848, pp. 113–125.

Ueber eine neue Gattung urweltlicher Coniferen aus dem Eisensand der Aachener Kreide. Ibid., pp. 126–142.

Entwurf zu einer geognostisch-geogenetischen Darstellung der Gegend von Aachen. Bericht 25. Versamml. deutsch. Naturf., 1849, pp. 269–328, pl. iv (sections).

Bemerkungen zu Debey's Entwurf einer geognostisch-geogenetischen Darstellung der Gegend von Aachen, von H. B. Geinitz: Neues Jahrbuch für mineral., 1850, pp. 289–301.

[3] Matthias Hubert Debey und Constantin von Ettingshausen: Ubersicht der gesammter Aachener und Maestrichter Kreideflora. Bericht 32. Versamml. deutsch. Naturf., 1856.

Die Urweltlichen Thallophyten des Kreidegebirges von Aachen und Maestricht. Denkschr. k. Akad. Wiss., Wien, math.-nat. Cl., vol. 16, 1859, pp. 131–214, pl. i–iii.

Die Urweltlichen Acrobryen des Kreidegebirges von Aachen und Maestricht. Ibid., vol. 17, 1859, pp. 183–248, pl. i–vii.

[4] Eine Uebersicht der fossilen Coniferen der Aachener Kreide, von M. Debey: Verhandl. naturhist. Ver. preuss. Rheinl. Westfalens, Corr.-Blatt., vol. 34, 1877, p. 110.

[5] Sur les feuilles querciformes des sables d' Aix-la-Chapelle, par M. Debey: Compte rendu du Congrès de botanique et d'horticulture, 1880, pt. 2, Bruxelles, 1881, pp. 1–16, 1 pl.

Tertiary.—Göppert called attention to Tertiary plants in the so-called "Schwerspath" of Kreuznach in 1848,[1] and Weber to those at Muffendorf, near Bonn, in 1850.[2] The researches of the latter author, assisted in part by Wessel, into the Tertiary flora of the lignites of the Lower Rhine, began about that time, and the first of the series of important memoirs published by him on that subject appeared in 1851.[3] The principal localities at which these remains were obtained were Rott, Stösschen, Orsberg, Friesdorf, Haardt, Liessem, Lieblar, Quegstein, Allrott, and Ofenkaule.

Weber has also shown the existence of a Tertiary plant bed at Pleidt, near Andernach, in the Saar-Rhine district.[4]

BELGIUM.

The earliest work relating to the paleontology of Belgium in which fossil plants received attention was Burtin's Oryctographia of Brussels, published in 1784.[5] His figures of fossil wood and fruits are often referred to by later authors.[6] Besides St. Gilles, Woluwe, Scharbeeck, Melsbroeck, and Everberg, in the close vicinity of Brussels, he mentions Alteren, farther to the westward and between Ghent and Bruges, as yielding these remains, upon the fossil wood of which place he had previously published a paper.[7]

In 1829 M. Jean Sauveur presented a paper to the Royal Academy of Belgium on the fossil plants of the Coal Measures of Belgium,[8]

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[1] Ueber fossile Pflanzen im Schwerspath, von H. R. Göppert: Uebersicht Arbeit. schles. Gesell., 1847, Breslau, 1848, pp. 71–73.

[2] Ueber die Süsswasserquarze von Muffendorf bei Bonn, von C. O. Weber: Haidinger Naturwiss. Abhandl., vol. 4, Abth. 2, 1850, pp. 19–45, pl. iii, iv.

[3] C. Otto Weber: Ueber die Tertiärflora der niederrheinischen Braunkohlenformation. Zeitschr. deutsch. geol. Gesell., vol. 3, Berlin, 1851, pp. 391–404.

Die Tertiärflora der niederrheinischen Braunkohlenformation. Palaeontographica, vol. 2, 1852, pp. 115–236, pl. xviii–xxv.

Philipp Wessel und C. Otto Weber: Neuer Beitrag zur Tertiärflora der niederrheinischen Braunkohlenformation. Ibid., vol. 4, 1856, pp. 111–168, pl. xx–xxx.

[4] C. O. Weber: Einige Pflanzen-Abdrücke im alten vulkanischen Tuffe von Plaidt bei Andernach. Verhandl. niederrhein Gesell., vol. 13, Bonn, 1856, No. 6, p. III.

Blattabdrücke im vulkanischen Tuffe von Plaidt bei Andernach. Ibid., vol. 18, 1861, pp. 19, 20.

[5] Oryctographie de Bruxelles, ou description des fossiles tant naturels qu' accidentels, découverts jusqu' à ce jour dans les environs de cette ville, par François-Xavier Burtin. Bruxelles, 1784, 152 pp., 32 pl. folio.

[6] On the Tertiary Strata of Belgium and French Flanders, by Charles Lyell: Pt. II, The Lower Tertiaries of Belgium. Quart. Jour. Geol. Soc. London, vol. 8, 1852, Proc. pp. 277–369, pl. xvii–xx. (The Schaerbeeck fruits are mentioned on pp. 343–351.)

Note sur le gisement des fruits et des bois fossiles recueillis dans les environs de Bruxelles, par Th. Lefèvre: Annales Soc. géol. Belgique, Mém., vol. 2, Liége, 1875, pp. 42–51.

[7] Verhandel. Hollandsche Maatschapp. Wettenschapp., vol. 21, p. 225.

[8] Mémoire contenant des recherches sur les végétaux fossiles des terrains houillers de la Belgique. Présenté à l'Académie [royale de Belgique] par M. [Jean] Sauveur, le 2 mai, 1829.

which, however, for some reason were not published until 1848, when they appeared in the form of a splendid atlas of sixty-nine plates, illustrating the Carboniferous flora of Belgium,[1] but no text accompanies it, and no intimation is given as to the localities from which the specimens came. The names given at the bottom of the plates do not state the authorities, and without a careful comparison of the figures it is in many cases impossible to say whether the species are the author's own or those of Brongniart and earlier writers. In fact, in the list published in J. J. d'Omalius d'Halloy's Éléments de géologie (Paris, 1831, pp. 302–305) which was furnished by M. D. Sauveur fils, the new species seem to be credited to him.

The Abbé Eugène Coemans studied the cones found at Baume (La Louvière) by Briart and Cornet in the Cretaceous of Hainaut and published them in 1867,[2] Kickx making a part at least of the drawings. The geologists named fixed the position of these beds at the base of the Gault.[3]

Crépin's investigations into the Carboniferous and Devonian flora of Belgium began in 1873, and the last of his notes that I have received is dated in 1881.[4] The Devonian plants treated by him were obtained from the "Psammites de Condroz" near Esneux and Comblain-la-Tour, in the valley of the Ourthe, and at Evieux, and in the "Pudding stone of Burnot" at Tilff, Angleur, Naninne, Fooz-Wépion, Rouveroy, etc. The Carboniferous plants were chiefly from the large collection made by the Abbe Coemans and generally without indica-

[1] Végétaux fossiles des terrains houillers de la Belgique, planches par Jean Sauveur. Bruxelles, 1848, 2 pp., 69 pl., 4°.

[2] Description de la flore fossile du premier étage du terrain crétacé du Hainaut, par Eugène Coemans et J. J. Kickx: Mém. Acad. Roy. de Belgique, vol. 36, No. 3, Bruxelles, 1867, pp. 1–21, pl. iii–v.

[3] Description minéralogique et stratigraphique de l'étage inférieur du terrain crétacé du Hainaut, par A. Briart et F. L. Cornet: Mém. cour. Acad. Roy. de Belgique, vol. 33, No. 2, Bruxelles, 1867, pp. 1–46. pl. i, iii.

[4] François Crépin: Note sur un Caulinites récemment découvert dans l'assise laekénienne. Bull. Acad. Roy. Belgique, 2d series, vol. 36, Bruxelles, 1873, pp. 170–172.

Description de quelques plantes fossiles de l'étage des psammites du Condroz (Devonien supérieur). Ibid., vol. 38, Bruxelles, 1874, pp. 356–366, pl. i–iii.

Fragments paléontologiques pour servir à la flore du terrain houiller de Belgique. Premier fragment. Ibid., pp. 568–577, pl. i, ii.

Observations sur quelques plantes fossiles des dépôts dévoniens rapportés par Dumont à l'étage quartzoschisteux inférieur de son système eifelien. Bull. Soc. roy. bot. Belgique, vol. 14, Gand, 1875, pp. 214–230, pl. i–vi.

Notes paléophytologiques. Première note: Observations sur les Sphenophyllum. Compte rendu Soc. roy. bot. Belgique, Bulletin, vol. 19, part 2, Gand, 1880, pp. 25–29.

Deuxième note: Observations sur quelques Sphenopteris et sur les côtes des Calamites. Ibid., pp. 49–55.

Troisième note: I. Révision de quelques espèces figurées dans l'ouvrage intitulé: Illustrations of Fossil Plants. II. Nouvelles observations sur le Sphenopteris Sauveurii. Ibid., vol. 20, pt. 2, Gand, 1881, pp. 42–50.

tion of the particular spot from which they came, but some were labeled Mariemont-St.-Catherine, Trazegnies, etc., and M. Crépin discovered others at Forchies, Levant du Flénu, Couchant de Mons, Belle et Bonne, Hornu, Wasmes, etc. The specimens described by Gilkinet in 1875[1] related to the same material as those discussed by Crépin.

The only other paper relating to Paleozoic plants in the vicinity known to me is that of Malaise, on an Oldhamia bed near Tubize, between Mont-St.-Guiber and Beaurieux, in Brabant, 1883.[2]

Many of the species figured in Zeiller's coal flora of Valenciennes (supra, p. 702) were obtained from adjacent Belgian territory, chiefly in the vicinity of Mons, at Levant du Flénu, Grand Buisson, Belle-et-Bonne, Produits, Crachet-Picquery, Bernissart, and Quaregnon.

Some of the Cretaceous plants of the Limburg deposits occur at Herve in Belgian Limburg. They will be noticed presently.

The Lower Eocene (Paleocene) deposits of Gelinden near Heers (Marnes Heersiennes) in Belgian Limburg, southeast of St. Trond, on the road to Liége have assumed extraordinary prominence in the history of paleobotany, partly in consequence of the number and the beauty of the specimens found there and partly from the interest attaching to a flora of about the same age as that of Sézanne, but also largely from the thorough and exhaustive treatment which they have received at the hands of the Marquis Saporta and Prof. A. F. Marion in the two memoirs that they have devoted to their elaboration.[3]

NETHERLANDS.

The Maestricht Cretaceous (Senonian) beds of Limburg at the same horizon as those of Aachen are the only ones in the Netherlands that have yielded any vegetable remains that have ever been reported upon. These were studied by Debey, in 1851,[4] together with those of the Aachen sands from specimens obtained at Vaels, Kunraed, and Maestricht.

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[1] Alfred Gilkinet: Sur quelques plantes fossiles de l'étage des Psammites du Condroz. Bull. Acad. roy. Belgique, 2d series, vol. 39, Bruxelles, 1875, No. 4, pp. 363–366, 384–398, 3 pl.

Sur quelques plantes fossiles de l'étage du poudingue de Burnot (dévonien inférieur). Ibid., vol. 40, Bruxelles, 1875, No. 8, pp. 70–74, 139–145, 3 pl.

[2] Sur un nouveau gisement de l'Oldhamia radiata, Forbes, dans le Brabant, par C. Malaise: Ibid., 3d series, vol. 5, Bruxelles, 1883, pp. 749–750.

[3] G. de Saporta et A.-F. Marion: Essai sur l'état de la végétation à l'époque des marnes heersiennes de Gelinden. Mem. cour. Acad. roy. Belgique, vol. 37, Bruxelles, 1873, No. 6, pp. 1–94, pl. i–xii.

Révision de la Flore Heersienne de Gelinden, etc. Ibid., vol. 41, Bruxelles, 1878, No. 3, pp. 1–112, pl. i–xiv.

[4] Beitrag zur fossilen Flora der holländischen Kreide (Vaels bei Aachen, Kunraed, Maestricht), von M. H. Debey: Verhandl. naturh. Ver. preuss. Rheinl., Westphalens, vol. 8, Jahrg. 1851, pp. 568–569.

In 1853 Miquel published the only good monograph of these plants.[1] His principal localities were Kunraed, Mt. St. Pieter, Maestricht, Schuller, and Keutenberg near Wilze. In 1861 Bosquet[2] enumerated one hundred species from Limburg, the names of which are given in his catalogue of the fauna and flora of the chalk of Limburg, in 1866.[3] His localities are Maestricht, Gulpen, and Herve, this last being in Belgian Limburg.

DENMARK.

No important plant beds have been developed in Denmark, but on the Island of Bornholm at Arnager occurs a Cretaceous (Cenomanian?) deposit, whose vegetable remains have attracted attention since Prince Christian of Denmark, sent specimens from that locality to Brongniart, who found a number of new species among them, which are described in his Histoire des végétaux fossiles (*Confervites fasciculatus, C. ægagropiloides, Fucoides Lyngbianus*).

Forchhammer also figures a number of these forms, together with animal remains, in his monograph of the coal formation of Bornholm, 1837.[4]

NORWAY.

Scarcely more can be said for Norway than for Denmark, but Brongniart described *Chondrites antiquus*, from the Lower Silurian of the island of Linoë, where Göppert afterwards rediscovered it in 1860,[5] along with another alga (*Dictyonema Hisingeri* Göpp.). Göppert also saw in Hausmann's collection from Idre and Sarnä, near the Swedish frontier, other undoubted vegetable remains resembling Sigillaria, which probably indicate a Devonian age for the rocks in which they occurred.

The only other locality is the little island of Andö, which properly belongs to the continent of Europe, and lies immediately off the northwest coast of Norway in latitude 68° 51″ N., and therefore only a little more than two degrees within the Arctic circle. The fossil plants from this locality were collected and described by Heer in

[1] De fossiele planten van het Krijt in het hertogdom Limburg, door F. A. W. Miquel: Verhandl. Geol. Kaart. Nederl., vol. 1, Haarlem, 1853, pp. 33–56, pl. i–vii.

[2] Coup d'œil sur la répartition géologique et géographique des espèces d'animaux et de végétaux citées dans le tableau des fossiles crétacés du Limbourg inséré dans la dernière livraison de l'ouvrage du Dr. W. C. H. Staring sur le sol de la Néerlande, par J. Bosquet. Verslag k. Akad. Wet., Naturk., vol. 11, Amsterdam, 1861, pp. 108–120.

[3] Fossiele fauna en flora van het Krijt van Limburg, door J. Bosquet. In Staring's Bodem van Nederland, vol. 2, Amsterdam, 1866, 60 pp., 8°.

[4] Om de Bornholmske Kulformationer, af Georg Forchhammer: Sel. Naturvid. og mathem. Afh., vol. 7, Kjöbenhavn, 1837, pp. 1–64, pl. i–iv.

[5] Bemerkungen über die Vegetations-Verhältnisse Norwegêns, von H. R. Göppert: 38. Jahresber. naturwiss. Section schles. Gesell., 1860, Breslau, 1861, pp. 36–50.

his Flora fossilis arctica in 1877.[1] Eight species were recognized, representing characteristic Lower Jurassic types, such as Baiera and Brachyphyllum. Both these and the animal remains point to the Rhetic formation as the most probable position of these beds.

SWEDEN.

The first to cultivate the science of paleobotany in Sweden was Sveno Nilsson, who, in 1820, and 1824,[2] figured and described numerous forms from the Rhetic beds of southern Sweden (Skåne), on lake Ringsjön at Hör and other places, and in 1831 he figured dicotyledonous leaves from a more recent formation at Köpinge.[3]

Brongniart visited these localities and made sketches of some forms, obtained others from Nilsson, and published a valuable paper upon that flora in 1825.[4] Agardh, in a special paper in 1823, determined some supposed fossil seaweeds from Höganäs, in the same section but on the coast,[5] and introduced these and others into the later parts of both his Species algarum, 1821–1828,[6] and his Systema algarum, 1824–1825.[7] Hisinger embodied the results of this work into his more general treatises, 1831–1840.[8]

Between these early investigations and those of the later and living students of the paleontology of Sweden, Linnarsson and Nathorst, a long period intervened. Linnarsson has confined his labors chiefly to the ancient formations, and necessarily, therefore, mostly dealt with animal remains; but at least one of his papers relates to sup-

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[1] Ueber die Pflanzen-Versteinerungen von Andö in Norwegen, von Oswald Heer. Flora fossilis arctica, vol. 4, pt. 3, Zürich, 1877, pp. 1–15, pl. i, ii.

[2] Sveno Nilsson: Om försteningar och aftryck af tropiska trädslag och deras blad, funne i ett sandstenslager i Skåne. Kongl. svensk. Vet.-Akad. Handl., 1820, pp. 108–122.

Om Försteningar och aftryck af tropiska trädslag, blad, ormbunkar och rörväxter m. m. samt trädkol, funna i ett sandstenslager i Skåne. Ibid., pp. 278–285, pl. iv, v.

Underrättelse om fossila landtväxter som finnas tillsammans med hafsmusslor, snäckor m. m. i den Skånska Grönsands-Kalken. Ibid., 1824, pp. 143–148, pl. iii.

[3] Fossila växter funna i Skåne och beskrifne, af S. Nilsson: Ibid., 1831, pp. 340–351, pl. i–iii; Första Stycket, pp. 340–347, pl. i, ii; Andra Stycket, Fossila växter i Skånes Stenkols-bildning, pp. 348–351, pl. iii.

[4] Observations sur les végétaux fossiles renfermés dans le grès de Hör en Scanie, par Adolph Brongniart: Ann. sci. nat., vol. 4, 1825, pp. 200–224, pl. xi, xii.

[5] Närmare bestämmande af några vextaftryck funne uti Höganäs Stenkolsgrufvor af Carl Adolph Agardh: Kongl. svensk. Vet.-Acad. Handl., 1823, pp. 107–111, pl. ii.

[6] Species algarum rite cognitæ, cum synonymis, differentiis specificis et descriptionibus succinatis. C. A. Agardh. Vol. 1, pt. 1, 1821, pt. 2, 1822; vol. 2, pt. 1, Gryphiæ, 1828, 8°.

[7] Systema algarum. C. A. Agardh. 3 Fasc., Lundiæ, 1825, Gryphiæ, Mauritius, 8°.

[8] Wilhelm von Hisinger: Esquisse d'un tableau des pétrifications de la Suède. Stockholm, 1823; nouvelle édit., Stockholm, 1831, 43 pp., 8°.

Lethæa suecica seu petrificata Sueciæ, iconibus et characteribus illustrata. Holmiæ, 1837, pp. 1–124, pl. i–xxxvi (xxxix); Supplementum secundum, Holmiæ, 1840, pp. 1–11, pl. xxxvii–xxxix.

posed plants (Cruziana, Fræna, Dictyonema, Eophyton, etc.) which he found at Lugnås, Kinnekulle near Råbäcks, Kållängen, Stolan, Mösseberg, Billingen, Presttorp, etc., in west Gothland.[1]

Nathorst's indefatigable labors began in 1870 and still continue, and it is to them chiefly that we owe our knowledge of the fossil plants of Sweden. He seems to have begun with the study of certain recent or glacial impressions that occur in considerable abundance near Alnarp, Nordanå, Klågerups, Hyby, Svedala, Snapparp, Hofgårds, Näsbyholmssjön, Gerdslöf, Börringe, Thorsjö, Bjersjöholm, Krageholm, Skegrie near Trelleborg, Benestad, Kan, Djurröd in Andrarum, between Greflunda and Bästekille, Lödahusen, Hörröd, Mamölla southeast of Gaddarōd, Slätteberga, Nöbbelöf, southeast of Halleröd in Onnestad, Träne, Linderöd, Gunnarp, Qvesarum east of Hör, Akarp, etc., all in Scania, or South Sweden.[2] His very interesting recent paper on the occurrence of the fruits of *Trapa natans* in Sweden in a subfossil state showing modifications of form should be mentioned here as belonging to this general class.[3]

His investigations into the Rhetic flora of Scania, which until his time was the only one known, have been very extensive. First appeared three short papers on the plants of Tinkarp north of Helsingborg, 1875,[4] of Pålsjö, 1875,[5] a collection from which place he sent to the Austrian Geological Survey,[6] and of Bjuf, 1876,[7] in which year the first part of his Swedish Fossil Flora[8] appeared, being a complete

[1] Geognostiska och Palæontologiska iakttagelser öfver Eophytonsandstenen i Vestergötland, af J. G. O. Linnarsson: Kongl. svensk. Vet.-Akad. Handl., vol. 9, No. 7, Stockholm, 1871, pp. 1–19, pl. i–iv.

[2] A. G. Nathorst: Om några arktiska växtlemningar i en sötvattenslera vid Alnarp i Skåne. Acta Univ. Lund., vol. 7, No. 9, 1870, pp. 1–18, 1 pl.

Om arktiska växtlemningar i Sknes sötvattens-bildningar. Öfversigt, Köngl. svensk. Vet.-Akad. Förhandl., No. 2, Stockholm, 1872, pp. 123–142.

Nya fyndorter för arktiska växtlemningar i Skåne. Geol. Förening. Stockholm, Förhandl., vol. 3, No. 10, 1877, pp. 293–319.

[3] Om de fruktformer af Trapa natans L., som fordom funnits i Sverige, af A. G. Nathorst: Bihang Kongl. svenska Vet.-Akad. Handl., vol. 13, pt. 3, No. 10, Stockholm, 1888, pp. 1–40, pl. i–iii.

[4] Om en cycadékotte från den rätiska formationens lager vid Tinkarp i Skåne, af A. G. Nathorst: Öfversigt Kongl. svensk. Vet.-Akad. Förhandl., vol. 32, No. 10, Stockholm, 1875, pp. 25–31, pl. xiii

[5] Fossila växter från den Stenkolsförande formationen vid Palsjö i Skåne, af A. G. Nathorst: Geol. Förening. Stockholm, Förhandl., vol. 2, No. 10, 1875, pp. 373–392.

[6] Pflanzenreste aus dem Rhät von Pälsjö in Schönen; ein Geschenk des Hrn. Dr. A. H. Nathorst. Von D. Stur: Verhandl. k.-k. geol. Reichansanstalt, Wien, 1877, pp. 35–38.

[7] Anmärkningar om den fossila floran vid Bjuf i Skåne, af A. G. Nathorst: Öfversigt Kongl. svensk. Vet.-Akad. Förhandl., vol. 33, No. 1, Stockholm, 1876, pp. 29–41.

[8] Bidrag till Sveriges fossila flora, af A. G. Nathorst: I, Växter från Rätiska formationen vid Pålsjö i Skåne. Köngl. svensk. Vet.-Akad. Handl., vol. 14, No. 3, Stockholm, 1876, pp. 1–82, pl. i–xvi. II, Floran vid Höganäs och Helsingborg. Ibid., vol. 16, No. 7, 1878, pp. 1–53, pl. i–viii.

monograph of the flora of Pålsjö, north of Helsingborg. The second part of this work came out two years later, and it is in like manner complete for the points in the neighborhood of Höganäs and of Helsingborg. This was followed almost immediately by his equally complete flora of Bjuf, the first part of which appeared in 1878[1] and the second in 1879, but the remainder was deferred, the third part not coming out till 1886.

From these works it appears that fossil plants have been obtained from the following Rhetic beds in south Sweden: Hör, Höganäs, Bjuf, Pålsjö, Helsingborg, Vallåkra, Sofiero, Bosarp, Billesholm, Stabbarp, Skromberga, besides minor points in the vicinity of these. A few other papers relating to this formation have since appeared.[2]

As regards the more ancient floras, Dr. Nathorst, as all geologists know, has taken strong ground against claiming the vegetable or even organic origin of many of the forms that have passed for plants,[3] but he has been careful not to deny the possibility of finding vegetable remains of a clearly distinguishable nature in Silurian or even Cambrian strata, and we have at least one paper[4] admitting the presence of a species of Sphenothallus resembling Hall's *S. angustifolius* in the Silurian of Vèstergötland.

RUSSIA.

In Russia much active work has been done. Following, and in part contemporary with, the life-long labors of Fischer de Waldheim,[5]

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[1] Om floran i Skånes kolförande bildningar, af A. G. Nathorst: vol. 1, Floran Vid Bjuf. Sveriges Geol. Undersökning, series C, Nos. 27, 33, 85, Stockholm, 1878, 1879, 1886, (3 Häfte), pp. 1-131, pl. i-xxvi, 4°.

[2] Alfred G. Nathorst: Om de växtförande lagren i Skånes kolförande bildningar och deras plats i lagerföljden. Geol. Förening. Stockholm, Förhandl., vol. 5, 1880, No. 6, pp. 276-284.

Nya fynd af fossila växter i undre delen af Stabbarps Kolgrufva. Geol. Förening. Stockholm, Förhandl., vol. 6, 1883, Heft 10, pp. 405-408.

[3] A. G. Nathorst: Om spår af några Evertebrerade djur M. M. och deras paleontogiska betydelse. Kongl. svensk. Vet.-Akad. Handl., vol. 18, No. 7, Stockholm, 1881, pp. 1-57, pl. i-xi.

Mémoire sur quelques traces d'animaux sans vertèbres, etc., et sur leur portée palèontologique. (Traduction abrégée par F. Schulthess.) Ibid., pp. 61-104, pl. i-xi.

Nouvelles observations sur des traces d'animaux et autres phénomènes d'origine purement mécanique décrits comme "Algues fossiles." Ibid., vol. 21, No. 14, Stockholm, 1886, pp. 1-58, pl. i-v.

[4] Om förekomsten af Sphenothallus cfr. angustifolius Hall, i silurisk skiffer i Vestergötland, af A. G. Nathorst: Geol. Förening. Stockholm, Förhandl., vol. 6, No. 8, 1883, pp. 315-319, pl. xv.

[5] Gotthelf Fischer de Waldheim: Naturhistorische Fragmente. Frankfurt, 1801, 5 pl., 4°.

Oryctographie du gouvernement de Moscou. Moscou, 1830-1837. See pl. xliii, xliv, folio.

Bois fossiles, in: Etudes paléontologiques sur les environs de Moscou, par Charles Rouillier: Jubilæum semisæcularem, Moscou, 1847, folio, pp. 20-24.

ranging from the early part of the century to 1847,[1] in the course of which he described plants from Moscow, from Petrofka in the government of Kharkow, Belebei, government of Orenburg, and from other localities, we have the important contributions of Eichwald, beginning in 1830 and not entirely closing until 1866;[2] the paleontology of Poland, in 1837,[3] by Pusch, who found plants in the Lias at Dziurow and Michalow in the Kamiona Valley, Modrzeowinà, Gromadzice, Walka, Grocholice, Porszów, Wirzbnik, Szewno, and Brody, all in the Sandomir district; in the Carboniferous at Niemce, Bendzin and Sielce; and in the Tertiary at Zwerzyniec and Lipowiec in the Lublin district, and at Borkow between Pinczow and Busko; several memoirs by Kutorga, treating the Permian plants of Belebey and Perm, Cretaceous wood from the Don, and fossil Confervæ from Tokarewo, near Porchow in the Government of Pskow

G. Fischer de Waldheim: Notice sur quelques plantes fossiles de la Russie. Bull. Soc. imp. des naturalistes Moscou, vol. 2, 1840, pp. 234–240.

Nachtrag zu Wangenheim von Qualen's geognostischen Beiträgen zur Kenntniss des westlichen Urals. Ibid., vol. 13, pt. 2, 1840, pp. 488-494; Neues Jahrbuch für Mineral., 1842, pp. 483, 484.

Zweiter Nachtrag zu den von Hrn. Major von Qualen am westlichen Abhange des Urals gesammelten Versteinerungen. Bull. Soc. imp. des naturalistes Moscou, vol. 15, 1842, pt. 1, pp. 462–467, pl. iv.

[1] Note sur les plantes fossiles du système Permien recueillies, etc., par Cap. Planer; par G. Fischer de Waldheim: Ibid., vol. 20, 1847, pt. 2, pp. 513–516, pl. x.

[2] Edourd d'Eichwald: Naturhistorische Skizze von Lithauen, Volhynien und Podolien, etc. Wilna, 1830, 3 pl., 4°; Nova Acta Acad. Leop.-Carol., vol. 16, p. 16.

Die Thier-und Pflanzenreste des alten rothen Sandsteins und Bergkalks im Novgorod'schen Government. Bull. sci. vol. 7, Acad. imp. sci. St. Petersburg, 1840, col. 78–91. Neues Jahrbuch für Mineral., 1840, pp. 620–629.

Die Urwelt Russland durch Abbildungen erläutert. Petersburg, Heft 1, 1840; Heft 2, 1842; Heft 3, 1845, 10 pl. In Baer's Beiträge zur Kenntniss des russichen Reiches.

Ueber einige fossile Pflanzen des Kupfer-führenden Sandsteins im Perm'schen und Orenburg'schen Govt. Neues Jahrbuch für Mineral., 1844, pp. 142–147.

Géognosie de Russie, 1846 (en langue russe).

Naturhistorische Bemerkungen, etc. Moskau, 1851, vi, 465 pp., 4 pl., 4°.

Einige paläontologische Bemerkengen über den Eisensand von Kursk. Bull. Soc. Imp. Nat. Moscou, vol. 26, 1853, pt. 1, pp. 209–231.

Lethæa Rossica ou Paléontologie de la Russie, décrite et figurée. Plantes fossiles: vol. 1, pt. 1, Stuttgart, 1860, pp. 33–268, 4°, Atlas vol. 1, pl. i–xxi, 4°, vol. 2, pt. 1, 1865–'68, pp. 1–71, Atlas vol. 2, pl. i–v.

Die vorweltliche Fauna und Flora des Grünsandes der Umgegend von Moskwa. Bull. Soc. Imp. Nat. Moscou, vol. 35, 1862, pt. 2, pp. 355–410.

Beitrag zur Geschichte der Geognosie und Paläontologie in Russland. Ibid., vol. 39, 1866, pt. 2, pp. 463–533.

[3] Polens Paläontologie, oder Abbildung und Beschreibung der vorzüglichsten und der noch unbeschriebenen Petrefakten aus den Gebirgs-Formationen in Polen, Volhynien und der Karpathen, von Georg Gottlieb Pusch. Stuttgart, 1836–'37, 218 pp., 16 pl., folio.

(1838–1842);[1] a few notes by Brongniart, 1842,[2] 1845,[3] in Demidoff and Murchison's voyages, relating to fossil plants from Kaffa in the Crimea, and from Nijni-Troïsk Bielebei, etc.; the work of John Morris, who named and figured many of the species of the Murchison expedition;[4] the report of Dr. Göppert in the Murchison expedition,[5] and minor contributions of his on the Carboniferous Flora of Malowka and Tawarkowa in the Government of Tula, central Russia;[6] the researches of Mercklin, chiefly relating to fossil wood, culminating in his Palæodendrologikon Rossicum, the most valuable work on the internal structure of the wood of recent formations, that had thus far appeared;[7] Ludwig's papers on the Carboniferous flora of the western slope of the Ural Mountains at Kiselowski-Rudnik, Iwanowka, Borowitschi on the Waldai, Nischni Parogi on the Uswa, Gubacha on

[1] Stephan Kutorga: Beiträge zur Kenntniss des Kupfersandsteins von Perm. St. Petersburg, 1838.

Beitrag zur Kenntniss der organischen Ueberreste des Kupfersandsteins am westlichen Abhange des Urals. Schrift. k. r. mineral. Gesell., St. Petersburg, 1838, pp. 1–38, pl. i–vii, 8°.

Beitrag zur Palæontologie Russlands. Verhandl. k. r. mineral. Gesell. St. Petersburg, 1842, pp. 1–34, pl. i–vi.

[2] Note sur des impressions des plantes reçue illies à Kaffa en Crimée par M. Huot par Adolphe Brongniart. Voyage dans la Russie méridionale et la Crimée . . . par Anat. de Demidoff. Paris, 1842, vol. 2, pp. 825–828, pl. vii.

[3] Géologie de la Russie d'Europe, et des montagues de l'Oural par R. I. Murchison, E. de Verneuil, et A. de Keyserling. Végétaux fossiles, par Ad. Brongniart, vol. 2, London-Paris, 1845, pp. 1–4, pl. A, B, C, E, F.

[Ad. Brongniart's letters.] Ibid., pp. 5–12, 503, 504, pl. A, B, C, D, F.

[4] [Description of Permian plants, by John Morris.] Ibid., vol. 1, 1845, pp. 78, 79, 113, 219, 240, pl. A, C, F.

[5] Lettre de M. Göppert à M. Murchison, par H. R. Göppert. Ibid., vol. 2, 1845, pp. 501–503, pl. ix.

[6] H. R. Göppert: Ueber die Kohlen Centralrusslands. In: Mehrere Beiträge zur fossilen Flora Russlands. 38. Jahresber. Schles. Gesell., 1860, pp. 33–36.

Bemerkungen über die Steinkohle zu Maliowka und Tawarkowa im Gouvernement Tula. Bull. Acad. imp. sci., St. Pétersbourg, vol. 3, 1861, col. 446–448.

Ueber die Kohlen von Malowka in Central-Russland. Sitzungsber. k. bayer. Gesell., München, 1861, math.-nat. Cl., pp. 199–209.

[7] C. E. von Mercklin: Prospectus der Paläontologischen Pflanzenüberreste in Russland, sowie ihrer Erforschung. Bull. Cl. phys.-math., Acad. imp. sci., St. Pétersbourg, vol. 10, 1852, col. 373–384.

Verzeichniss aller in Russland bis jetzt (November, 1852) aufgefundener, beschriebener, unbeschriebener oder zweifelhafter fossiler Pflanzen. Ibid., vol. 11, 1853, col. 300–305.

Palæodendrologikon Rossicum, Vergleichende anatomisch-mikroskopische Untersuchungen fossiler Hölzer aus Russland. Ein Beitrag zur vorweltlichen Flora. Eine von der kaiserlichen Akademie der Wissenschaften zu St. Petersburg des zweiten Demidowschen Preises gewürdigte Schrift. St. Petersburg, 1856; Text, 99 pp., 4°; Atlas, 20 pl., Abbildungen vom Verfasser n. d. N. gezeichnet., folio.

Sur un échantillon de bois pétrifié provenant du gouvernement de Rjäsan. Bull. Sci. Acad. imp. sci., St. Pétersbourg, vol. 29, 1884, pp. 243–250. Mélanges biol., vol. 12, 1884, pp. 1–11.

the Koswa, Malowka in the Government of Tula, Lithwinsk, etc., and the Permian flora of the Government of Perm at Kungur, Morgunowa, Janytschi, Poshwa on the Kama, and near Lithwinsk;[1] and on the Carboniferous flora of the province of the Don Cossacks at Petrowskaja near Izyum, Lissitschinskaja Balka near Privolnoi, Uspenskoi, Lugan above Luganskoi Sawod, Popopowskoi in the valley of Gruchewska, Krepenskoi, Zuwarewaja Balka near Ekaterinskoi, Nowo-Pawlowsk on the Mins, Krinitschenaja, Chrystalnoi, Dolschik, etc.;[2] the fine illustrated memoir of Trautschold on the flora of the Cretaceous (Neocomian?) sandstone of Klin,[3] at Klin, Taratowa, and Karrowa or Garjainowa, in the governments of Moscow, Vladimir, and Kaluga, respectively; a note by Stur[4] reporting upon Möller's collections from the Carboniferous deposits of Ukrainsk, and Petrowskoje, in Charkow, Uspenskoie, near Lugan, in the government of Ekaterinoslaw, and Gorodischte near Slavianoserbsk, and from the Culm (Subcarboniferous) strata of Ilinsk, the river Koswa, Gubaschinskaja Pristav, Utkinsk, the river Bulanasch, mouth of the Irbit, the river Bobrowka, etc.; the more important memoir of Schmalhausen[5] on the Eocene plants in the vicinity of Kiew, the Oligocene plants of Mogilno in Volhynia, and the fossil woods of the same and numerous other localities (e. g., Jekaterinopolje, Shurowka, Wyschgorod, Swenigorodka, Kremenez, Salesetz); and lastly the fine memoir by the last named author[6] in the Russian language, fortunately with a German résumé, on the "Permo-Carboniferous" (Artinskische) and Permian plants collected by Stoukenberg, Iwanow, and Krotow, in the governments of Perm and Kasan, at Kotlowka, Tschistopol, Kitjak, Konkino, Molebski-Sawod, Torgowskoje-Selo, Tass, Jugowski- and Moto-wilichinski-Sawod, Golubzow Mill between Krasnoufimsk and Atschit, Kotlowka, Kor-

[1] Zur Paläontologie des Urals, von Rudolph Ludwig: Palaeontographica, vol. 10, Cassel, 1861–63, pp. 17–36; 270–275, pl. iii–vi; xlvi. Pflanzenreste aus der Steinkohlen-Formation des Urals, pp. 27–36, pl. iv–vi. Pflanzen aus dem Rothliegenden im Governement Perm, pp. 270–275, pl. xlvi.

[2] Rudolph Ludwig: Die Steinkohlenformation im Lande der Don'schen Kosaken. Bull. Soc. imp. des naturalistes, Moscou, vol. 46, pt. 2, No. 4, 1873, pp. 290–331, pl. ii, iii. Fossile Pflanzen aus der Steinkohlenformation im Lande der Don'schen Kosaken. Ibid., vol. 51, pt. 1, No. 1, 1876, pp. 8–25, pl. i.

[3] Der klin'sche Sandstein, von H. Trautschold: Nouveaux Mém. Soc. imp. des naturalistes, Moscou, vol. 13 (livr. 3), 1871, pp. 189–236, pl. xviii–xxii.

[4] Ein Beitrag zur Kenntniss der Culm- und Carbon-Flora in Russland, von D. Stur: Verhandl. k.-k. geol. Reichsanstalt, Wien, 1878, pp. 219–224.

[5] Beiträge zur Tertiär-Flora Süd-west-Russlands, von J. Schmalhausen: Paläontologische Abhandlungen herausgegeben von W. Dames und E. Kaiser, vol. 1, Berlin, 1884, Heft 4, pp. 285–336 (1–58), pl. xxviii–xli (i–xiv).

[6] Die Pflanzenreste der Artinskischen und permischen Ablagerungen im Osten des europäischen Russlands, von J. Schmalhausen: Mém. Comité géol., vol. 2, No. 4, St. Petersburg, 1887, pp. 1–30 (Russian); followed by a "Beschreibung der Pflanzenreste," pp. 31–42 (German), pl. i–vii.

gala near Orenburg, Tetenina on the Koswa, Krasnoufimsk, mouth of the Bojak, on the Bardyn River, at Kitjak, Podbelskoje, Kamskaja, Urma, and Swinogorje.

The following are a few of the localities given by Eichwald which have not hitherto been mentioned:

Devonian.—Tschoudowo, government of St. Petersburg, Logozawitsche, government of Pskow, banks of the Sjass.

Subcarboniferous.—Roodsikülle on the island of Oesel, Erras and Haljal near Wesenberg in Esthonia, Nouveau-Kuigaugh, island of Nuck near Lyckholm, Sutlep in Esthonia, Pawlowsk, Fockenhof near Narva, Reval, Kirrimäggi, Kirna, banks of the Slawänska, Oranienbaum and Zarskoje Selo, near St. Petersburg.

Carboniferous.—Mount Kaschkabasch, river Mjous near Krasnykoute, Donetz Mountains, rivers Prikscha and Msta (Novgorod), Kamenskaja near Jekaterinebourg, Artinsk, Välino Sloboda (Toula), Isjoume (Kharkoff), Jegorgiewsk on the Occa (Kalouga), Zoubarawaja (Jekaterinoslaw).

Permian.—Kamskowotkinsk (Wjatka), copper mines of Kloutschewsk and Dourassow on the Dioma, Kargala, Novoberschetzk near Yougowsk, Novosyränowsk near Motawillisch (Perm), Préobragensk, Stepanova, Santogoulowsk, Blagovetschensk, Pyskorsk (Orenberg).

Cretaceous.—(Grès vert, Neocomian) Berezow ravine, district of Sysran, Troitzkoyé Kouroyedowo (Simbirsk), Kaloughino, Kirssanow (Tambow), Tim (Kursk), Klenowka and Lytkarino, near Klin, Kotelniki, Tatarowa (Moscow), Karowa, banks of the Oka (Kalouga), Novgorod Sewersk, Ossinowa (Tschernigow), Biassala (Crimea).

Jurassic (Lias).—Kamenka near Izoume, Petrowskaya, district of Izoume, Dziurow, Miktzailow, valley of the Kamiona near Sandomir (Poland), Iletzkaya-Zaschtschita (Orenberg).

Oolite (Oxfordian).—Khoroschówo, Mucowniki, Schtschoukino near Moscow, Soudagh, Katarasse (Crimea), Petschora River, Iletzkaya, near Orenberg, Popiljani (Wilna).

The numerous specimens of petrified wood which found their way into Merklin's hands were collected in various parts of the empire, and represent several horizons. The following are some of the localities given in his Palæodendrologikon Rossicum:

Permian.—A few points in the government of Perm.

Jurassic—Popiljani (Wilna), Windau River (Curlandia), Moscow.

Cretaceous (Greensand, properly Neocomian).—Durasovka (Saratov.)

Tertiary.—Podkumok River near Pjatigorsk, Alexandoovsk (Ekaterinoslaw), Kursk, Kamischin (Saratow), Stalipino, Goroditsche (Pensa), Szysran (Simbirsk), Podolia on the river Dniester near Mogilev.

ASIA.

SIBERIA.

Beginning with Siberia, we find that *Calamites nodosus* from the banks of the Yenesei, at Krasnojarsk, was known as early as 1834,[1] but systematic research practically began with Tchihatcheff's voyage, during which he collected fossil plants from Carboniferous strata at the village of Afonino and on the banks of the Inia, which were studied and described by Göppert, and published in Tchihatcheff's "Voyage scientifique dans l'Altai oriental et les parties adjacentes de la frontière de la Chine," 1845 (pp. 345–390, pl. xxv–xxxv).

Göppert also worked up the fossil wood of Middendorf's Siberian voyage, found at Túndra, on the river Boganida, 71° north latitude, and on the banks of the Taimyr, 74–75° north latitude,[2] and Merklin described other fossil wood from Gishiginsk in Kamtschatka collected by Brevarn, and published in 1852.[3]

Geinitz worked up the plant-remains obtained by Cotta in 1866 from the Carboniferous strata of the Altai Mountains at Meretskaja, Sokolowa, Monastyrskaja, Salair Range and Inja district,[4] and a year later Trautschold mentioned the locality on the Angara, near Ust-Balei, below Irkutsk, from which so many species were subsequently described by Heer.[5]

But the principal works in this line have been by Heer and Schmalhausen. The former published, in 1876, the first of his important "Beiträge zur Jura-Flora Sibiriens," the second in 1878,[6] and his final Nachträge to the same in 1880.[7]

The plants described in the first of these memoirs were collected by Czekanowski. Those from Siberia were found at Ust-Balei on the Angara, about forty miles north of Irkutsk, in latitude 51° north, at the mouth of the Kaja River, and on the Tapka. The Amoor plants

[1] Notice sur la localité du Calamites nodosus, par Kaspar Sternberg: Bull. Soc. imp. des naturalistes Moscou, vol. 7, 1834, pp. 412–419.

[2] Fossile Hölzer, von H. R. Göppert. Middendorf's Reise in dem äussersten Norden und Osten Sibiriens während der Jahre 1843 und 1844, etc., vol. 1, Theil I, St. Petersburg, 1848, pp. 225–234, pl. vii–x.

[3] Ueber fossiles Holz und Bernstein in Braunkohle aus Gishiginsk, von C. von Merklin: Bull. Classe phys.-math. Acad., imp. sci. St. Pétersbourg, vol. 11, Nos. 6, 7, 1852, col. 81–93, 1 pl.

[4] Ueber fossile Pflanzen aus der Steinkohlenformation am Altai, von H. B. Geinitz: Neues Jahrbuch für Mineral., 1869, pp. 462-465, pl. vi, fig. 4, 5; and in a more extended form with two plates as a Separatabdruck aus B. v. Cotta's: Der Altai, sein geologischer Bau und seine Erzlagerstätten, Leipzig, 1871, 15 pp., pl. ii, iii.

[5] Fossile Pflanzen von der Angara, von Oswald Heer: Neues Jahrbuch für Mineral., 1870, pp. 589, 590.

[6] Mém. Acad. Imp. Sci. St. Pétersbourg, 7th series, vol. 22, No. 12, 1876, pp. 1–122, pl. i–xxxi, and vol. 25, No. 6, 1878, pp. 1–58, pl. i–xv.

[7] Ibid., vol. 27, No. 10, 1880, pp. 1–34, pl. i–ix.

were found on the Upper Amoor River and at Bureja. The second memoir describes plants collected by Hartung and others from Ust-Balei and the Tapka, from Mount Petruschina near Irkutsk; by Czekanowski from the district of the Lena at Naschim, Ajakit, Bulun, Tumul Kaja, mouth of the Olenek, Yngyr Kaja, on the Buotar; also in the Túndra on the Atyrkan (Cretaceous ?), Tertiary plants at Tschirimyi on the Lena, from Simonowa in the western part of eastern Siberia, latitude 56° north, 20 miles below Atschinsk in the Government of Jenisseisk, and from the lower Bureja; also from Possiet Bay and Kengka Lake in Mantschooria.

The plants described in the Supplement to the Jurassic Flora of eastern Siberia were all from Ust-Balei, collected by Richard Maack in the summer of 1878.

Here should also belong two important papers on the fossil flora of the island of Sachalin, off the east coast of Siberia.[1] The plants described in the first of these memoirs were collected by Schmidt, Glehn, and Koppen, at the Russian post Dui on Cape Dui, at Sertunai between Sachkoran and Najassi, and at Mgratsch farther to the northwest, and above the fifty-first parallel of north latitude. The smaller collection described in the second paper was made by Furuhjelm in 1860, and although the labels did not indicate the locality with precision, Heer presumes from the character of the rock and the nature of the plants that it was made at Dui.

All these papers were afterwards incorporated into his great work entitled "Flora fossilis arctica,"[2] which will receive special treatment when we come to consider the more strictly Arctic fossil floras.

Schmalhausen commenced his investigations into the Siberian fossil floras by a study of the so-called Ursa-Stufe, on the River Ogur,[3] and probably of Subcarboniferous age. He had also begun his study of the Jurassic flora of Lower Tunguska and Kusnezk before the date of Heer's first publication, and in 1879 appeared his Beiträge zur Jura-Flora Russlands,[4] read before the Imperial Academy at St. Petersburg, which was followed in March, 1883, by a supplementary paper in the Bulletin[5] of the same society. In the same year he pub-

[1] Primitiæ floræ fossilis Sachalinensis. Ibid., vol. 25, No. 7, 1878, pp. 1-61, pl. i-xv. Beiträge zur miocenen Flora von Sachalin. Kongl. svenska Vet.-Akad. Handlingar, vol. 15, No. 4, 1878, pp. 1-11, pl. i-iv.

[2] Cf. vol. 4, pt. 2; vol. 5, parts 2, 3, 4; vol. 6, pt. 1.

[3] J. Schmalhausen: Die Pflanzenreste aus der Ursa-Stufe im Flussgeschiebe des Ogur in Ost-Siberien. Mélanges phys. et chim. tirés du Bull. Acad. imp. sci. St.-Pétersbourg, vol. 9, 1876, pp. 625-645, pl. i-iv; Bulletin, vol. 17, pp. 227-291, 4 pl.

Ein fernerer Beitrag zur Kenntniss der Ursastufe Ost-Sibiriens. Mélanges phys. et chim. tirés du Bull. Acad. imp. sci. St.-Pétersbourg, vol. 10, 1877, pp. 733-756, pl. i, ii; Bulletin, vol. 25, pp. 1-17, 2 pl.

[4] Mém. Acad. imp. sci. St.-Pétersbourg, 7th series, vol. 27, No. 4, 95 pp., 16 pl.

[5] Pflanzenpaläontologische Beiträge, von J. Schmalhausen: I, Nachträge zur Jura-Flora des Kohlenbassins von Kusnezk am Altai. Mélanges biol. tirés du Bull. Acad. imp. sci. St.-Pétersbourg, vol. 11, 1883, pp. 545-552, pl. i.

lished a paper illustrated by four plates on some Carboniferous plants from the eastern slope of the Ural Mountains,[1] and in 1887[2] an excellent contribution in Palaeontographica on the Tertiary (Pliocene) plants of the valley of the Buchtorma River.

JAPAN.

The fossil flora of Japan, after Geyler broke the way by his short memoir in Palaeontographica (1877)[3] describing the vegetable remains collected by Rein in the valley of the Tetorigawa, on the island of Niphon, apparently of Jurassic age, first began to be well known through the collections of that indefatigable traveler, Baron Nordenskiöld, which have been elaborated by Dr. A. G. Nathorst, of Stockholm.

But two other references to the fossil flora of Japan seem to have been made[4] before the earliest paper resulting from Nathorst's researches appeared in 1881,[5] and Nordenskiöld was able to use some of the results reached at the time of the publication of his Voyage of the Vega.[6]

In the second volume of the Vega-Expeditionens Vetenskapliga Arbeten (Stockholm, 1883), occurs Nathorst's first important descriptive paper on the flora of Mogi, near Nangasaki. The horizon is upper Tertiary or perhaps Quaternary.[7] A French translation of this paper appeared in the Memoirs of the Swedish Academy of Science of the same year.[8]

Baron von Ettingshausen's strictures upon some of Nathorst's determinations[9] and the reply of the latter thereto[10] throw further

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[1] Mém. Acad. imp. sci. St.-Pétersbourg, 7th series, vol. 31, No. 13, 20 pp., 4 pl.

[2] Ueber tertiäre Pflanzen aus dem Thale des Flusses Buchtorma am Fusse des Altaigebirges, von J. Schmalhausen: Palaeontographica, vol. 33, 1887, Lief. 4–5, pp. 181–216, pl. xviii–xxii.

[3] Ueber fossile Pflanzen aus der Juraformation Japans, von H. T. Geyler: Palaeontographica, vol. 24, Cassel, 1877, pp. 221–232, pl. xxx–xxxiv.

[4] Botanische Mittheilung, von H. Th. Geyler. Carpinus grandis Ung. in der Tertiärformation Japans. Frankfurt a. M., 1880, pp. 16, 17, pl. ii, 4°.

Vorläufige Notizen über Vorkommnisse der Jura-Formation in Japan, 1880, von D. Brauns.

[5] Förutskickadt meddelande om tertiärfloran vid Nangasaki på Japan af A. G. Nathorst: Geol. Förening. Stockholm, Förhandl., vol. 5, 1881, No. 12, pp. 539–551.

[6] See English edition, New York, 1882, pp. 690–693, 4 figs.

[7] Bidrag till Japans fossila Flora, pp. 119–225, pl. iv–xix.

[8] Contributions à la flore fossile du Japon, par A. G. Nathorst: Kongl. svensk. Vet.-Akad. Handl., vol. 20, No. 2, 1883, 92 pp., 16 pl.

[9] Zur Tertiärflora Japans, von C. von Ettingshausen: Sitzungsber. k. Akad. Wiss., Wien, math.-nat. Cl., vol. 88, Abth. I, 1883, pp. 851–864.

[10] Bemerkungen über Herrn v. Ettingshausen's Aufsatz zur Tertiärflora Japans, von A. G. Nathorst: Bihang till Kongl. svensk. Vet.-Akad. Handl., vol. 9, 1884, Heft 2, No. 18.

light upon the general subject, as does also the somewhat elaborate criticism of the Marquis Saporta.[1]

A later contribution has come to hand by a native Japanese,[2] Mr. Matajiro Yokoyama, who has obtained twenty-four species of Jurassic plants from the following localities: Shimamura, Yanagidani, and Ōzo, in the province of Kaga; Hakogase and Tanimura, in that of Echizen; Okamigo and Ushimaru, in that of Hida.

Relative to the geological formation it may be remarked that inasmuch as some of the supposed Jurassic plants determined by Geyler appear to be related to forms found by Professor Fontaine in the Potomac formation of Virginia, supposed to be of Lower Cretaceous age, there is at least a possibility not only that Godfrey[3] was right in assigning the leaf-bed of Kiushiu to the Cretaceous, but that those beds are of the same age as those of Kaga, where Rein obtained his specimens.

Material for the preparation of a monograph of the pre-Pliocene and post-Miocene flora of Japan began to reach Dr. Nathorst soon after the appearance of his Flora of Mogi. A collection made by Mr. Yokoyama in the northern and central portions of the empire was sent to him in 1883 by Dr. Edmund Naumann, of the Japanese Geological Survey, of which he gave a preliminary account in the following year.[4] This was followed by a second collection made during Dr. Naumann's journey through southern Japan from the middle and southern portions of the principal island (Hondo), and also from the more southern islands of Sikoku and Kiushiu. In 1887 Mr. Yokoyama sent still a third collection, this from Shiobara, in central Japan; and, in addition to this, certain material of the same nature, which had been sent to the Berlin museum, was placed in Dr. Nathorst's hands for identification. Putting all these collections with the excellent ones which Messrs. Julius Petersen and J. C. Smith at Nagasaki had presented to the University of Upsala, he found himself in possession of fossil plants from no less than thirty-two localities in Japan. His able monograph of this flora, which appeared in 1888,[5] leaves little to be desired. It is especially satisfactory for our present purpose on account of the extreme care and

[1] Nouvelles observations sur la flore fossile de Mogi dans le Japon méridional, par G. de Saporta: Annales sci. nat., botanique, 6th series, vol. 17, 1884, pp. 73–106, pl. vi–ix.

[2] On the Jurassic plants of Kaga, Hida, and Echizen, by Matajiro Yokoyama: Bull. geol. Soc. Japan, vol. 1, pt. 1, Tokio, 1886, pp. 1–10, 8°.

[3] Notes on the geology of Japan, by J. G. H. Godfrey: Quart. Jour. Geol. Soc. London, vol. 34, 1878, pp. 542–555, with map.

[4] Beiträge No. 2 zur Tertiärflora Japan's, von A. G. Nathorst: Botanisches Centralblatt, vol. 19, Cassel, 1884, No. 29.

[5] Zur fossilen Flora Japan's, von A. G. Nathorst: Palæont. Abhändl., herausgegeb. von Dames u. Kayser, vol. 4, Heft 3, Berlin, 1888, pp. 197–250 (1–56), pl. xvii–xxx (i–xiv).

attention given to the geographical part. We will follow him in classifying the localities under the two geological horizons, which he calls respectively Prepliocene and Postmiocene, by which terms he aims to denote a considerable difference of age without committing himself further than to claim that the former lies below the Pliocene, while the latter can not be Miocene, and may be Quaternary. To the lower of these horizons belong, according to him, the following localities: Moriyoshi, Kayakusa, and Shimohinokinai, in the province of Ugo; Aburado, province of Uzen; Yamakumada, in the province of Yechigo; Koya, in the province of Jwaki; Kamikanazawa, in the province of Hitachi; Kita-Aiki, in the province of Shinano; Todohara and Jtsukaichi, in the province of Musashi; Kongōdji, in the province of Yetchin; Otsuchi and Ogoya, in the province of Kaga; Ama-no-hashidate, in the province of Tango; Azano, in the province of Shinano; Ōya, in the province of Kii; the above all on the island of Hondo; Mioga and Kamibayashi, in the province of Iyo, and an unknown locality on the island of Sikoku; Nobata and Mori, in the province of Bungo; Kagokinzan, in the province of Satsuma; Yamantsuri, in the province of Buzen; Nakano, in the province of Higo; Takashima and Jwojima, in the province of Hizen; all on the island of Kiushiu. To the Postmiocene belong, besides Mogi, province of Hizen, on the island of Kiushiu (which has yielded by far the largest representation of fossil plants of all the localities in Japan), Nogami, province of Bungo, on the same island; Kwannonsaka (Sekimura), on the small island of Sado; Ushigatani, province of Yechizen; Shiobara, province of Shimozuke; and Yokohama Bluff, near the city of Yokohama, on the main island.

COREA.

Gottsche, in his geological sketch of the Corea (1886),[1] mentions the occurrence of plant remains in the Carboniferous of Kyöngsangdo, Mungyöng, and Udong, and silicified wood in a supposed Tertiary bed on the base of the hill upon which Phyöngyang stands.

CHINA.

The fossil plants of China have chiefly been investigated by Newberry and Schenk, from the collections of Pumpelly and Baron Richthofen. Professor Pumpelly's well known expedition through various parts of China was made during the years 1862–'64, and the results were published in 1867[2] as one of the Smithsonian Contributions to Knowledge. Dr. Newberry's report upon the fossil plants

[1] Geologische Skizze von Korea, von C. Gottsche: Sitzungsber. k. preuss. Akad. Wiss. zu Berlin, 1886, No. 39, pp. 857–873, pl. viii (map).

[2] Geological researches in China, Mongolia, and Japan, during the years 1862 to 1865, by Raphael Pumpelly: Smithsonian Contributions to Knowledge, No. 202, 1866 (vol. 15, art. 4, 1867), pp. 1–161, pl. i–ix. (pl. i–viii, maps and sections.)

collected forms the first appendix to that article. Only seven species of plants are described, but these all point to a Mesozoic age for the beds of the Kwei basin and of Pyünsz, where these remains were obtained. One of the species was the widely diffused *Podozamites lanceolatus* (LH) Brongn., found in the Jurassic of England, Siberia, Japan, Spitzbergen, India, in the Rhetic of Sweden, and even in Neocomian strata of Kootanie Pass, British America, according to Dr. J. W. Dawson; but this may prove to be lower than he supposes. Another was identified with the plant found in North Carolina by Dr. Emmons, and published as *P. lanceolatus*, but which differs from the former, and was named *P. Emmonsii* by Dr. Newberry.

The fossil plants of Tinkiako collected by the Abbe David showed, when determined by Brongniart in 1874,[1] that the coal mines of southern Shensi were not of Carboniferous age, as had been supposed, but Jurassic allied to the Oolite beds of England and the Rhetic of Bavaria.

In 1883 Dr. Newberry published in the American Journal of Science[2] a list of ten species of Carboniferous fossil plants obtained by Mr. Arnold Hague in the coal basin of the Pin-hsu-hoo, in the southern peninsula of Mantchuria, on the east side of the gulf of Liantung, and about one hundred miles northeast of Niuchwang. All but two of these (*Lonchopteris Hagueana*, n. sp., and *Archæopteris spatula*, n. sp.) were European forms.

The great expedition of Baron von Richthofen has undoubtedly done more to reveal to the western world the subterranean treasures of China than all others combined. The vegetable remains collected from a large number of points throughout the country, including some from Mongolia, were placed for determination in the hands of the distinguished paleobotanist, Dr. August Schenk, professor of botany at the University of Leipzig, who elaborated them and prepared a report, which was published in the fourth volume of Richthofen's "China," 1883.[3] Both the localities which furnished plant remains to the Pumpelly expedition were represented in the Richthofen collections, and in addition numerous others of Jurassic age. But the most important result was the first scientific investigation of the extensive beds of productive coal measures, and the discovery in these of a large number of characteristic species of Carboniferous plants. Of the forty-one species of these latter described by Schenk, twenty-five are either themselves found or have near analogues in the coal beds of other parts of the world. A few are of

[1] Note sur les Plantes fossiles de Tinkiako (Schensi méridional) envoyés en 1875, par M. l'abbé A. David, par Ad. Brongniart: Bull. Soc. Géol. France, 3d series, vol. 3, 1874, p. 408, pl. ii.

[2] Notes on some Fossil Plants from Northern China, by J. S. Newberry: Am. Jour. Sci., 3d series, vol. 26, 1883, pp. 123–127.

[3] Pp. 211–269, pl. xxx–liv.

Subcarboniferous affinities, and quite a large number range upward into the Permian. The collection is furthermore interesting from the number of Cordaitean and Taxinean forms which it embraces. Included among the Gymnospermous remains are two specimens which Schenk referred to the Cycadaceæ, and described under the name of *Pterophyllum carbonicum* Schenk.[1] Such a reference would be prima facie questionable, and the Geological Survey is so fortunate as to have come into the possession of the late Dr. H. R. Göppert's private copy of Schenk's contribution, in which the above name is stricken out and in its stead is written in Dr. Göppert's characteristic hand "Cordaites spec. ramulus." I am not aware that Göppert published anything on this point.

Besides the Carboniferous and Jurassic plants, Baron von Richthofen collected one fossil plant from Tertiary strata, the only Tertiary fossil obtained. Schenk refers it without hesitation to the genus Rhus, and describes it as *Rhus atavia* Schenk, illustrating it by two very good figures (pl. i, figs. 9, 10).

The fossil plants collected by Lóczy, geologist of Count Széchényi's expedition, which were also elaborated by Schenk, 1885,[2] possess a special interest, not only from the large number of localities not hitherto represented, but also from their geological range from the Carboniferous to the Tertiary. Twenty-three forms are enumerated, of which two are Carboniferous, fifteen Jurassic, two Eocene (Flysch), two "Tertiary," and the remaining two (fruits) from Schantschou, province of Schen-si, probably Carboniferous. The recognized Carboniferous deposits are at Teng-tjan-tsching, Wu-so-ling, Lun-kuan-pu, and Lo-pan-san, in the province of Kansu, and Youngssho-Shien, in the province of Schen-si. Ni-tou-and Lin-tschinshien, in the province of Se-tschuen are put down as Lias, Quan-juönshien, and Hoa-ni-pu, in the same province as "Jura." The localities yielding forms characteristic of the Flysch (Palæodictyon and Caulerpites) are Ton-go-lo and Schin-go-lo, in the last-named province, while the dicotyledonous leaves referred to in the Tertiary came from Kjän-tschuen-tschou, and Lan-tjen, province of Yunan. The latter forms were not generically, and many of the others were not specifically determinable.

COCHIN-CHINA.

The French expedition to Tong-King made by Fuchs and Saladin during December, 1881, and January to March, 1882, for the purpose of investigating the coal and metalliferous deposits at that place, resulted in the collection of upwards of twenty species of

[1] Ibid., p. 214, pl. xliv, figs. 4, 5.

[2] Die während der Reise des Grafen Bela Széchenyi in China gesammelten fossilen Pflanzen, von A. Schenk: Palaeontographica, vol. 31, Cassel, 1885, pp. 163–182 (1–19), pl. xiii–xv.

fossil plants. These were elaborated by M. R. Zeiller, of the School of Mines of Paris, and the results were published in the Annales des Mines in 1882.[1] They bear a lower Jurassic facies, many of them being identical with the forms found in the Rhetic beds of Franconia and Scania, but upon the whole this flora is most nearly allied to that of the Lower Gondwánas of India. Similar forms are also found in Australia and South Africa, pointing to wide-spread homotaxis in the principal plant-bearing beds of the land areas of the southern portion of the eastern hemisphere.

Four years later two additional collections from the same general localities were made by MM. Jourdy and Sarran, and also studied by M. Zeiller.[2] By these collections the number of species is raised to thirty, of which eight are found in the Rhetic of Europe, five in the Gondwána system of India, and the remainder thus far peculiar to Tong-king.

BURMAH.

Among the fossils and other objects brought by Mr. J. Crawfurd from Farther India, which he collected on his embassy to Ava in the years 1826 and 1827, were pieces of silicified wood in a fine state of preservation. According to Buckland, who published an account of that expedition in 1828,[3] they occurred along the course of the Irawadi from its mouth, near Rangoon, up to Ava, but principally in a new tract of country extending over a square of more than twenty miles on the east bank of the Irawadi, near the town of Wetmasut, about half way between Ava and Prome, between latitude 20° and 21° north.

Buckland states that the structure of this wood indicates that the trees were in part dicotyledonous and in part monocotyledonous, and that some of it resembles the tamarind wood, although no figures are given and it is not distinctly stated that it had been subjected to microscopic investigation.

INDIA.

The extensive plant beds of India have been the subject of scientific investigation for many years. Specimens collected by Voisey were in the hands of Brongniart in 1828, and are described in his Histoire des végétaux fossiles (pp. 223, 224). In 1839 Royle[4] described

[1] Examen de la flore fossile des couches de charbon du Tong-King, par R. Zeiller: Annales des Mines, 8th series, vol. 2, livraison 5, 1882, pp. 299–352, pl. x–xii.

[2] Bull. Soc. Géol. France, 3d ser., vol. 14, 1886, pp. 454-463, 575-581, pl. xxiv, xxv.

[3] Geological Account of a Series of Animal and Vegetable Remains and of Rocks, collected by J. Crawfurd, esq., on a voyage up the Irawadi to Ava, in 1826 and 1827, by W. Buckland: Trans. Geol. Soc. London, vol. 2, 1828, pp. 377-392, pl. xxxvi-xlv.

[4] J. Forbes Royle: Illustrations of the Botany, etc., of the Himalaya Mountains, London, 1839, vol. 1, p. xxix*, vol. 2, pl. ii.

four species from the Burdwan Coal, and in 1849 McClelland[1] figured some of these same forms and some new ones.

A somewhat more extensive paper was published by Sir Charles Bunbury[2] in 1861, entitled, "Notes on a collection of fossil plants from Nágpur, Central India." Seventeen forms are enumerated and figured, but about half of these were regarded as too uncertain to be specifically designated.

In 1862 appeared the first important systematic contribution to the flora of India, which was the product of the joint labors of Dr. Thomas Oldham, Superintendent of the Geological Survey of India, and Prof. John Morris, of University College, London.[3] Though published separately, this paper now forms the first of that important series of memoirs on the fossil flora of the Gondwána system.[4] This was an exclusively descriptive paper and formed a substantial basis for the subsequent voluminous reports of that indefatigable paleobotanist Dr. Ottokar Feistmantel.

These plants were collected at Bindrabun, Ghutiari, Jamkoondih, Soorujbera, Onthea, near Salempur, Shahabad, Amrapara, Murrero, Burio, Moorcha Pass, etc., in the Rajmahal Hills.

Feistmantel's minor contribution to the fossil flora of India, in the Records of the Geological Survey of India,[5] in the Journal of the Asiatic Society of Bengal,[6] in Palaeontographica,[7] and in other scientific periodicals, are far too numerous to be mentioned here in detail, and it must therefore suffice to speak briefly of the important series already referred to as continued by him.

The first of these in order of date is his "Jurassic (Oolitic) Flora of Kach," which was published separately in 1876, but for some reason found its way into the second volume of the Fossil Flora of the Gondwána System[8] instead of the first. It is a thorough and systematic paper with excellent illustrations, and describes a number of new species. As the title indicates, the plant-bearing strata of Cutch are regarded as of Oolitic age, and Feistmantel would assign

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[1] Rept. Geol. Survey India, 1848-'49, pl. xv.

[2] Quart. Jour. Geol. Soc. London, vol. 17, 1861, pp. 325–346, pl. viii–xii.

[3] The Fossil Flora of the Rajmahal Series, in the Rajmahal Hills, Bengal, by Thomas Oldham and John Morris: Mem. Geol. Survey India, Palæontologia Indica, series 2, vol. 1, pt. 1, Calcutta, 1862, 52 pp., 35 pl.

[4] Mem. Geol. Survey India, Palæontologia Indica, series 2, 11, 12, vols. 1–4.

[5] Notes on the age of some fossil floras of India, Nos. 1–19, by Ottokar Feistmantel: Records Geol. Survey India, vols. 9, 10, Calcutta, 1876, 1877.

[6] Ottokar Feistmantel: Contributions towards the knowledge of the fossil flora in India. Jour. Asiatic Soc. Bengal, vol. 45, pt. 2, No. 4, 1876, pp. 329–382, pl. xv–xxi.

A sketch of the history of the fossils of the Indian Gondwána System. Ibid., vol. 50, pt. 2, 1881, pp. 168–219.

[7] Paläontologische Beiträge, von Ottokar Feistmantel: Palaeontographica, Supplement 3, Lieferung 3, Heft 1, Cassel, 1876, pp. 1–24, pl. i–vi; Heft 2, 1877, pp. 25–51, pl. i–iii.

[8] Palæontologica Indica, series 11, vol. 2, pt. 1, 1876, pp. 1–80, pl. i–xii.

them to the Lower Oolite and correlate them most nearly with the Yorkshire deposits. The localities for plants are Goonari, Thrombow, Kukurbit, Boojooree, Doodaee, and Loharia.

Three memoirs are dated 1877, viz: (1) Flora of the Jabalpur Group (Upper Gondwanas) in the Son-Narbada region (Jabalpur, Sher in the Sátpura Basin, South Rewah, Naogaon, Upper Godavari district), which forms the second part of the same volume; (2) Jurassic (Liassic) Flora of the Rajmahal Group in the Rajmahal Hills, forming the second part of volume 1, and in which only one locality (Buskoghât) is added to the number given by Oldham and Morris; and (3) Jurassic (Liassic) Flora of the Rajmahal Group from Golapili (near Ellore), South Godavari district, forming the third part of the same volume.

Two papers bear date 1879, viz: (1) Upper Gondwána Flora of the Outliers of the Madras Coast, forming part 4 of volume 1, embracing the Ragavapuram shales near Ellore, the Sripermatur area; Budavada, Vemavaram, Deronadula, Idupulapadu, and Punur, in the Nellore-Kistna district; Naicolum, Utatúr, Terany, Kari, Kullpaudy, and Maravatur, in the Trichinopoly district; and Chirakunt and Naogaon in the Middle Gondavari Basin. (2) The Flora of the Talchir-Karharbári Beds, forming part 1 of volume 3, and describing the plants from Passarabhia, Buriadi, Karaon, Káranpura, Máthadi, Mohpáni, Kotmi in the Shalpur area, Dolári, Deoghur, Domahni, Jogitand, Chunka, Lumki (Komaljore) Hill, and Bhuddua Hill.

The Flora of the Damuda and Panchet divisions, which forms the second part of volume 3, bears date 1880, a conclusion to it forming part 3 of the same volume, being dated 1881. This extensive paper covers much of the area of several previous ones, but the following additional localities may be noted: Raniganj, Jharia, Hurdeeamo, Sarun, Bokáro coal field, Nala field, Garjan hills, Raigarh coal field, Bajbai east of Gopat River, Chanduidol, Mahau River near Minarra, and Gajar, Baricondam, Harapala, Maitur, northwest of Assensole, northwest branch of Nunia River, Bharatwáda, Dubrajpur, Gopicandar area, Layeo, Auranga coal field west of Murup, Pachmari, Upper Donwa Valley, Sikkim, Mussinia, Burgo, Kumerdhubi, Sendur River west of Mitgain, Ledho Nala near Karamdiha, Majurdaki, Suknai Nala north of Sarsera, Gopálprasád, Mardaupur, Umret coal field (Barkoi), Gouri, Ghui, Morne River, Parasdiha, Sohágpur, Sone River, Garara, Tansar, Kámthi, Tondakheri, Hingir coal field, Girundla, Kodaloi and on the Bilpahari, Wardha Valley coal field (Kawársa), Kulti, Guráru, Aráhura south of Chepa-Jugra, Isápur near Chanda, Silewáda, Latiahar Hill, Lohundia, Kunlácheru.

The first part of the fourth volume is the fossil flora of the South Rewa Gondwána Basin, and appeared in 1882. Most of the localities given in this paper have already been recorded, but the following appear here for the first time: Son River opposite Sarsi, Chota Chauri on the Son, Kunuk, Kurabar east of Páli, Hardi, Dhobgata near Khodargaon, Behia Bargaon, northeast of Anukpur, Umrar, Parsora, Beli, hill between Karkote and Malhadu, Son River near its junction with the Murna, Bansa on the Machrar River, small stream south of Chandia, Kurabar, Ghogri, Kachodhar, Simaria, Harri, Kedoundi, Kichri, Dumarkachar, Khaira, Umeria-Kaleshar, Daigaon, Chiriapani, Kachodhar, Chatan, Sandabah River, and Barwar.

The second part of this volume did not appear until 1886. It treats of the fossil flora of some of the coal fields of western Bengal, the principal localities being Karanpura, Auranga, Hutár, Daltonganj, Sukri River west of Gurtur, Garhi River southeast of Tandwa, Naikori River near Jainagar, Ganespur River west of Burgaon, Singra, Rikba in the Chano Basin, Rájhera, Nowadih, Bishanpur River, Daigaon on the Johilla, and Jaguldagga. Many of the minor points of occurrence had been enumerated in the preceding memoirs.

These several contributions of Feistmantel taken together make 617 pages of text, and contain 176 plates, filling three ponderous (folio) volumes and part of a fourth. One marvels at the seemingly inexhaustible resources from which he is able to draw, not less than at the powers of application and endurance displayed in the prosecution of so great a work.

From the titles given to these several papers it is seen that all this vast flora and the extensive geographical range of the beds are embraced within the lower portion of the Jurassic formation, no species being regarded as necessarily lower than the Lias or higher than the Middle Oolite. There are, however, Tertiary plant-bearing beds in India and in Burmah, but thus far very little has been done in the direction of making them known to science.[1]

TURKESTAN.

Fossil plants have been discovered in Turkestan by Milaschewitsch,[2] and by Mushenkoff[3] on the Yagna River, seven versts north of the station Sarvada, and by Mushketoff in the Kuldja district[4] from the Karatau Mountains, Buguni, and other localities.

To these works may be added the chapter devoted to fossil plants

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[1] See Feistmantel's "Note on remains of palm leaves from the (Tertiary) Murree and Kasauli beds in India:" Records Geol. Survey India, vol. 15, pt. 1, 1882, pp. 50–53, pl. xv.

[2] Nachrichten d. Gesell. für Naturgesch. Anthropol. u. Ethnograph., vol. 8, Lief. 1, Moskau, 1869, p. 378.

[3] Геологическія Набліоденія во Бремя Заравшанской Экспедиціи.—Д. К. Мышенкова: Записки Императорскаго Русскаго Географическаго общества, St. Pétersbourg, Vol. 4, 1871, pp. 265–287. Краткій отчеь о Геологическомь Путешествіи по Туркестану въ 1875 голу.—И. Мушкетова.

[4] Verhandl. russ. k. Mineral. Gesell. zu St. Petersburg, 2d series, vol. 12, 1877, pp. 117–224, pl. x–xiii.

in Romanowski's Geologie von Turkestan,[1] in which are described and figured some very interesting vegetable remains from a formation corresponding to the Rhetic of Europe, and to the older Mesozoic of Virginia and North Carolina.

The plants are found in the vicinity of Wernoie in the Semiretschinsk country; at Iliisk and Kuldscha and on the River Pilitschi in the Chodschend district; in the Syr-Darja country; northeast from Taschkend; in the Karschanyn-Tau Mountains. Most of the species come from the Kara-Tau Mountains, the Tatarinowschen mine being the chief locality, though they are also found at the Uigam mine and Isyndy-Bulak, in the eastern border of the same range.

PERSIA.

The earliest fossil plants collected in Persia were those which Dr. Göbel obtained from the southeastern shore of the Caspian Sea, in the province of Astrabad, east of the village of Tasch, in the Alborus chain, which he sent to Dr. Göppert at Breslau for determination. The latter regarded them as indicating the Liassic age of that formation, and included them with some other forms from the Caucasus, presently to be mentioned, in a short report published in 1861.[2]

Later Tietze, and after him Pohlig, visited this same general region and made collections at Schachrud, near Tasch, at Hif, near Kaswin, and at Ah on Mount Siodsher, all of which, as well as those of Göbel which remained at the University of Breslau after Göppert's death, found their way into the hands of Schenk, who prepared a valuable monograph of that flora and published it in Palaeontographica in 1887.[3] He distinguished twenty-seven different forms, most of which were specifically determinable; all but four were referable to species already known from Jurassic or still older strata of Europe and other countries, and Schenk concludes that this flora is practically one with that of Tong-king, and referable to the Rhetic age.

The fossil plants brought from Persia by Dr. Wähner in 1886[4] came from the Carboniferous strata at Rudbar and Sapuhin.

[1] Materialien zur Geologie von Turkestan. I. Lieferung: Geologische und paläontologische Uebersicht des nordwestlichen Thian-Schan und des südöstlichen Theiles der Niederung von Turan, von G. Romanowski. St. Petersburg, 1880 (Fossil Plants, pp. 126–137, pl. xxii–xxix).

[2] Ueber das Vorkommen von Lias-Pflanzen im Kaukasus und der Alborus-Kette, von H. R. Göppert: Abhandl. Schles. Gesell., Breslau, 1861, pp. 189–194. Verhandl. Russ. k. Akad., 1861, pp. 657–666.

[3] Fossile Pflanzen aus der Albourskette gesammelt von E. Tietze, besprochen von A. Schenk: Bibliotheca Botanica, Abhandl. aus dem Gesammtgebiete der Botanik von Dr. Oscar Uhlworm und Dr. F. H. Haemlein in Cassel, Heft No. 6, Cassel, 1887, 4°, pp. 1–12, pl. i–ix.

[4] Vorlage der von Dr. Wähner aus Persien mitgebrachten fossilen Pflanzen, von D. Stur: Verhandl. k.-k. geol. Reichsanstalt, Wien, No. 16, 1886, pp. 431–436.

TRANSCAUCASIA.

In 1860 Göppert determined as of Liassic age the plants sent him by Abich in 1845 from Tquirbul in Okriba north of Kutais, in Imerthien on the Asiatic side of the Caucasian Mountains, which received brief mention in the paper considered on the preceding page.

More recently Georg Gürich,[1] in Breslau, has described a new species of fossil wood collected in the Cretaceous at Pechthòr Arwák, near the village of Saglik, in the province Gaudschak (Elisabethpol). A more definite geological age is not stated.

Abich in two of his papers[2] has mentioned the existence of well preserved dicotyledonous leaves and reed-like grasses of apparently about the age of the Oeningen beds (Miocene), at the foot of Mount Ararat.

ASIA MINOR.

The first important mention of fossil plants from Asia Minor seems to be that of Schlehan, in 1852,[3] of those found in the Carboniferous deposits at Amasry, and Tyrla-asy.

In 1853 Theodor Kotschy traveled through parts of Asia Minor and brought a few specimens of fossil plants from the southern slope of the Cilician Taurus near the village of Nimrum, on the estate of Emir Hassen Aga Kalch Agassi. They were intrusted to Dr. Unger for determination and proved to be of Tertiary age.[4]

Foetterle[5] speaks of plant remains from beds of red sandstone interstratified with quartz conglomerate between Eregli and Amasoora, in the coal-bearing rocks of Paphlagonia, on the northeast coast of Asia Minor, which he regards as of Permian (Rothliegende) age. Tchihatcheff, during his expedition into Asia Minor, had visited this locality, and the fossil plants which were regarded as Carboniferous were elaborated by Brongniart and published in Tchihatcheff's Asie Mineure.[6] The species, so far as determinable, were the same as are found in European strata.

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[1] Ein neues fossiles Holz aus der Kreide Armeniens nebst Bemerkungen über Paläozoische Hölzer, von Georg Gürich: Zeitschr. deutsch. geol. Gesell., vol. 37, 1885, Heft 2, pp. 433–440.

[2] Ueber das Steinsalz und seine geologische Stellung im Russischen Armenien, von H. Abich: Mem. Acad. imp. Sci., St. Pétersbourg, 6th series, vol. 7, 1857, pp. 61–150, 9 pl.

Ueber Dumount's neue geologische Karte von Europa, soweit vie den Kaukasus betrifft, von H. Abich. (Auszug aus einem bei der Naturforscher-Versammlung in Bonn, 1857, gehaltenen Vortrage.) Neues Jahrbuch für Mineral., 1857, pp. 769–774.

[3] Versuch einer geognostischen Beschreibung der Gegend zwischen Amasry und Tyrla-asy, aus der Nordkuste von Klein-Asien, von Herrn Schlehan: Zeitschr. deutsch. geol. Gesell., vol. v, 1852, pp. 96–142, pl. i–iii.

[4] Notiz über ein Lager Tertiarpflanzen im Taurus, von Franz Unger: Sitzungsber. k. Akad. Wiss., Wien, math.-nat. Cl., vol. 11, 1853, pp. 1076, 1077.

[5] Jahrbuch k.-k. geol. Reichsanstalt, Wien, vol. 9, 1858, (verhandl.) p. 86.

[6] Asie Mineure, Paris, 1866–'69, Palæontologie, pp. 75–81.

The Tertiary plants collected on the same expedition at Boulgardagh, in Cilicia, were described by Unger.[1] The plate is devoted to the illustration of his two new genera of fossil wood, Constantinium and Tchihatcheffites, founded on their internal structure, the first of which presented so close an analogy to the wood of the Proteaceæ that the author felt safe in referring it to that order. Both these forms, however, and two of the others, were collected in Thrace, and not in Asia Minor, and were mentioned while treating the fossil plants of Europe under the title *Roumelia.*

In the same work[2] Tchihatcheff gives a list of fossils sent him by Mr. Barkley, from Kosloo, 30 miles east of the town of Erekli, the site of ancient Heraclea, which is probably the same locality as that mentioned by Foetterle.

In 1877 Rear-Admiral Spratt of the British navy, read a paper before the Geological Society on his visit to the last-named place, made in 1854,[3] where he obtained a number of plant remains. Appended to this paper, as published in the Quarterly Journal of the society, is a list of the species contained in his collection, which were determined by Mr. R. Etheridge. The formation is Carboniferous.

ARABIA.

A specimen of Lepidodendron, received by Sir Roderick Murchison from an officer traveling in Arabia, which the latter had picked up in the desert of Sinai, formed the subject of a paper by Mr. J. W. Salter, read before the Geological Society of London on June 17, 1868.[4] Unable to identify it with any known species, he gave it the appropriate name of *L. Mosaicum.*

AFRICA.

SOUTH AFRICA.

Sir J. D. Hooker figured a plant in 1845[5] that Bain had discovered in the Roggeveld (Fish River), and he mentioned in a note a collection made by Rubidge at Smithfield, Orange River Sovereignty. These plants were of Lower Jurassic age.

On June 17, 1851, Dr. Adamson exhibited to the Linnæan Society[6]

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[1] Asie Mineure, Paris, 1866–'69, Paleontologie, pp. 319–325, atlas pl. xvii.

[2] Ibid., IV[e] Partie. Géologie. I. Paris, 1869, pp. 709, 710.

[3] Remarks on the Coal-bearing Deposits near Erekli, (the ancient Heraclea Pontica, Bithynia), by T. Spratt: Quart. Jour. Geol. Soc. London, vol. 33, 1877, pp. 524–533.

[4] On a true coal-plant (Lepidodendron) from Sinai, by J. W. Salter: Ibid., vol. 24, 1868, pp. 509, 510.

[5] Note on a Fossil Plant from the Fish River, South Africa, by J. D. Hooker: Trans. Geol. Soc. London, 2d series, vol. 7, 1845–'46, p. 227, pl. xxviii, fig. 1.

[6] Notice of several Vegetable Fossils from South Africa, by Dr. Adamson: Proc. Linn. Soc. London, vol. 2, 1851, pp. 145, 146.

several vegetable fossils from South Africa, in the neighborhood of the Cape of Good Hope, near Wynberg, in the sandstone district. They were described as of two kinds, "one occurring as upright cylindrical bodies, and the other in the form of spreading aloe-like groups of fleshy leaves."

Among the fossil remains collected by Atherstone and Bain from the Sunday River and Zwartkop, South Africa, and described by Sharpe,[1] occurred fucoidal remains, calcareous wood, and lignite (p. 202), and at Roggeveld, on Fish River, in the Karoo Desert,[2] was found, besides fossil wood, a very remarkable fossil plant resembling a Williamsonia, described by Dr. Hooker (p. 227) and figured in the transactions of the Geological Society (pl. xxviii, fig. 1).

In 1867 Mr. Ralph Tate communicated to the Geological Society an important paper "On Some Secondary Fossils from South Africa."[3] In this paper are enumerated the fossil plants, so far as known, from the Karoo beds, the Geelhoutboom series, and the wood-bed series. These three deposits represent considerable vertical thickness of strata, but from their organic remains (especially the vegetable) they seem to agree in homotaxy with the Secondary (Jurassic) deposits of India.

Mr. George Grey, in a communication to the Geological Society of London on December 7, 1870,[4] mentions the discovery of Carboniferous plants in the Karoo district on the northeast margin of the Stormberg Range, from the Lower Albany, and at Port Alfred. In the region of the Zambezi River, plants have been found at Moatise in Tete, among which Zeiller[5] has identified eleven species common to the Carboniferous of France and other countries.

EGYPT.

The fossil forests of the Libyan deserts have been made historic by tourists and travelers from very early times, and numerous descriptions of the objects observed have been published, a few of which have some scientific value. The names of Nicol, Russegger, Monro, Nasq, Lefèvre, Hericourt, Holroyd, Wilkinson, Murray, and numerous others have become associated with them in this way. Holroyd

[1] Description of Fossils from the Secondary Rocks of Sunday River and Zwartkop River, South Africa, collected by Dr. Atherstone and A. G. Bain, esq., by D. Sharpe: Trans. Geol. Soc. London, 2d series, vol. 7, 1852, pp. 193–203, pl. xxii, xxiii, xxviii.

[2] Notes on some Fossils from the Karoo Desert and its vicinity, by Daniel Sharpe, Dr. Hooker, and Sir P. D. M. Egerton: Ibid., p. 225, pl. xxviii.

[3] Quart. Jour. Geol. Soc. London, vol. 23, 1867, pp. 139-175, pl. v–ix.

[4] Remarks on some specimens from South Africa, by George Grey: vol. 27, Ibid., 1871, pp. 49–51.

[5] Note sur la Flore du bassin houiller de Tete (Région du Zambèze), par R. Zeiller: Annales des Mines, 8th series, vol. 4, 1883, livr. 6, pp. 594–598.

supposed the trunks he saw to belong to the Doom-Palm (*Hyphæne Thebaica*), and prior to 1848 they were commonly regarded as palm wood. But Newbold[1] submitted specimens to Robert Brown, who pronounced them dicotyledonous. Unger as early as 1843[2] had examined specimens and named the species *Nicolia Ægyptiaca* Ung. In 1845[3] he published a description and a figure of a cross-section which was infested by a fungus (*Nyctomyces entoxylinus* Ung.), but classed it among his "Ligna." In his Genera et Species, published in 1850, he repeats the description (p. 523) but still places the plant in his "Plantæ incertæ sedis."

The first systematic attempt to make known the character of this material was also made by Unger in 1858.[4] In this, besides giving a very good historical account of the whole subject, he describes the Nicolia anew, and illustrates it with two figures, a transverse and a longitudinal tangential section showing the spiral vessels, wood cells, and medullary rays to good advantage. In addition to this he describes three coniferous species, *Dadoxylon Ægyptiacum*, *D. Rollei*, and *Taxoxylon cretaceum*, all of which are shown in radial section.

Carruthers in 1870 reviewed the subject of Nicolia[5] from abundant material in the British Museum, and established a second species, *N. Owenii*. This same genus, and probably the original species also, were collected in Abyssinia in 1862 by Dr. Th. von Heuglin, an account of which was published by Unger in 1866.[6]

Prior to 1874 no other vegetable remains than the silicified trunks of trees had been discovered in the Libyan deserts, but during that year Dr. Georg Schweinfurth obtained certain fruits from the oasis of Chargeh, west of Thebes, in about latitude 25° north. These he afterwards placed in the hands of Dr. Oswald Heer for identification, and as might have been expected a valuable paper was the result.[7]

Of these fossil fruits Heer distinguished two ebenaceous genera, Diospyros and Royena. He also found palm-like fruit which he called *Palmacites rimosus*. Ten figures of *Diospyros Schweinfurthi* and six of *Royena desertorum* are given.

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[1] On the geological position of the silicified wood of the Egyptian and Libyan Deserts, etc., by Lieut. Newbold: Quart. Jour. Geol. Soc. London, vol. 4, 1848, pp. 349–352.

[2] In Endlicher's Genera Plantarum, Supplement 2, p. 102.

[3] Synopsis plantarum fossilium, p. 262; Chloris protogæa, p. 89, pl. i, fig. 7.

[4] Der versteinte Wald bei Cairo und einige andere Lager verkieselten Holzes in Ägypten, von Franz Unger: Sitzungsber. k. Akad. Wiss., Wien, math.-nat. Cl., vol. 33, 1858, pp. 209–233, pl. i–iii.

[5] On the petrified forest near Cairo, by W. Carruthers: Geol. Mag., London, vol. 7, 1870, pp. 306–310, pl. xiv.

[6] Notiz über fossile Hölzer aus Abyssineen, von F. Unger: Sitzungsber. k. Akad. Wiss., Wien, math-nat. Cl., vol. 54, 1866, Abth. 1, pp. 289–297, pl. i.

[7] Ueber fossile Früchte der Oase Chargeh, von Oswald Heer: Neue Denkschr. Schweiz. Gesell. gesammt. Naturwiss., vol. 27, Abth. 1, Article 2, Zürich, 1876, 11 pp., 1 pl.

The celebrated expedition made by Rohlfs in 1873 and 1874[1] formed the basis for renewed investigation.

The first part of Zittel's exhaustive investigation of the Libyan deserts as a result of Rohlfs's expedition (1874?) occupies the whole of volume 30 of Palaeontographica, 1883. In the geological part mention is made (page 141) of some vegetable remains found in the calcareous tufa beds around certain springs in the oasis of Chargeh. The remains were studied by the Marquis Saporta, who detected, besides stems of an Arundo, fragments of a dicotyledonous leaf which he pronounces to be *Quercus Ilex* L., of the living flora. One of these fragments he figures with a restoration of the leaf.

The report upon the fossil wood for this treatise was made by Dr. August Schenk. Thirty-nine specimens were submitted to him for investigation, eighteen of which were found to belong to *Nicolia Ægyptiaca,* and six others to as many other dicotyledonous genera, each representing, as the author believes, a different natural order of plants. His new genus Jordania[2] is believed by him to belong to the Ebenaceæ and agrees quite closely with Royena in internal structure. As this is the genus whose fruits were discovered by Schweinfurth at the oasis of Chargeh, it seems not improbable that Jordania may be the same. Besides these Dicotyledons there were one coniferous species (*Araucarioxylon Ægyptiacum* Kraus), and two species of palm wood (*Palmoxylon Zitteli* and *P. Aschersoni*), both new.

As to the geological age of these remains, it is generally believed by geologists that they belong to the Upper Cretaceous, although it must be confessed that if the genera have been correctly determined the internal evidence points to a more recent date.

Dr. G. Schweinfurth[3] found at the Wady Arabah, in what he supposes to be a Carboniferous limestone, specimens of fossil wood belonging to the genus Araucarioxylon.

NUBIA.

The fossil wood of the Libyan Desert extends southward into Nubia, and as early as 1839 Lefèvre gave an account of its discovery at the well of the Bayondeh desert.[4]

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[1] Reisebericht: "Bermerkungen," [following Jordan's account of Rohlfs's Expedition in the Libyan Desert] von George Rohlfs: Petermann's geogr. Mittheilungen, vol. 21, 1875, pp. 211–214.

[2] The name is pre-occupied by Bossier's caryophyllaceous herb (Diagn. viii, 93) of the present flora of central Asia, which, however, is united with Acanthophyllum by modern botanists.

[3] Sur une récente exploration géologique de l'Ouady Arabah, par G. Schweinfurth: Bull. de l'Inst. Égyptien, 2d series, Année 1887, No. 8, Cairo, 1888, pp. 146–162.

[4] Lettre addressee á M. Cordier, par M. Lefèvre: Bull. Soc. géol. France, vol. 10, 1839, pp. 144–148.

ABYSSINIA.

The specimens collected by Heuglin and described by Unger (supra, p. 801) were found in the high lands around the Djidda and the Baschilo, in Wadla, and especially in Woro-Heimano, near the fortress of Magdala, north of Schoa, and the Wollo-Galla land, at an altitude of 9,000 to 11,000 feet.

WESTERN AFRICA AND ALGERIA.

Advices from West Africa (Benito),[1] and also from Algeria (Beledboufrour, near Oréleanville),[2] though thus far indicating small results, give hopeful signs that other sections of the "Dark Continent" will yet reveal to us the nature of its primeval vegetation.

SUNDA ISLANDS.

Fossil plants have been found on all of the three principal islands of this group, Borneo, Sumatra, and Java. In all these cases most of them seem to have come from substantially the same geological horizon, namely, the Lower Tertiary or Eocene formation. Though few in number thus far, their comparatively recent geologic age renders them more interesting to the student of geographical distribution, since from their greater similarity they admit of more satisfactory comparison with the living flora of the same and other regions of the globe.

JAVA.

Perhaps the earliest mention of vegetable remains in Java was that in 1839[3] by Horner, who saw petrified wood scattered over the whole extent of the tufa formation in Bantam, near Lebak (see p. 47); and Rigg, the same year,[4] and Hasskarl, 1841,[5] speak of fossil wood in South Bantam and Jasinga.

The fossil plants collected by Junghuhn during his stay in Java were elaborated by Dr. H. R. Göppert, and published in a very exhaustive paper in 1854.[6] They were derived from three localities:

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[1] Eine Anzahl Gesteine aus Westafrika gesammelt von Capitain Rudolph Rabenhorst, von H. B. Geinitz: Sitzungsber. Gesell., Isis, Dresden, 1886, p. 28.

[2] Lignites d'Algérie, par C. T. Gaudin: Bull. Soc. Vaud. Sci. Nat., vol. 6, Lausanne, 1859, pp. 255–257.

[3] Verslag van eene mineralogische reis in de residentie Bantam op Java, L. Horner: Verhand. Batav. Genootsch. Kunst. Wetensch., vol. 17, 1839, pp. 29–57.

[4] Sketch of the Geology of Jasinga, by J. Rigg: Ibid., vol. 17, 1839, p. 133.

[5] Bijdragen tot de kennis van Zuid-Bantam, J. K. Hasskarl: Tijdschr. voor Neêrl. Indie, Jaarg. 4, Batavia, 1841–'42, p. 227.

[6] Die Tertiärflora auf der Insel Java nach den Entdeckungen des Herrn Fr. Junghuhn beschrieben und erörtert in ihrem Verhältnisse zur Gesammtflora der Tertiärperiode, von Heinrich Robert Göppert. Mit vierzehn farbig gedruckten Tafeln. Herausgegeben auf Veranlassung und mit Unterstützung des Ministerium's der Kolonien. S'Gravenhage, 1854, 169 pp., 14 pl., 4°.

(1) The left, or southeast side of the Tji-Buni Valley, district of Djampang; (2) near the village of Pesawahan, in the interior of the same district; (3) the upper Tji-Tjolang Valley, near the village of Selo. In the first two of these localities remains of leaves were found. The entire flora, as described by Göppert, consisted of thirty-nine species, all but eight of which were dicotyledonous, and no coniferous forms occurred. There were one fungus (*Xylomites stigmariæformis* Göpp.), five palmaceous plants, all but one of which were referred to the genus Amesoneuron, one Canna-like plant (*Cannophyllites Vrieseanus* Göpp.) represented by leaves and a stem, and fragments of a banana-like leaf (*Musophyllum truncatum* Göpp.).

Aside from the three new genera (Junghuhnites, Bredæa, and Miquelites) founded on fragments of wood, all the remaining dicotyledonous forms were referred either to living genera or to extinct genera allied to living ones, and classified in their proper botanical families. Thus, according to Göppert, there occur three species of Piperites, three of Quercus, two of Ficus, two of Daphnogene, two of Laurophyllum, one of Diospyros, two of Apocynophyllum, one of Cornus, three of Magnoliastrum, one of Malpighiastrum, one of Ceanothus, one of Rhamnus, and five of Celastrophyllum.

In 1883 Baron von Ettingshausen revised Göppert's work on the fossil flora of Java,[1] and made a few changes in the above determinations, altering some of the genera, but not seriously affecting the family relationships.

The geological age of the beds yielding these fossils was originally regarded as Eocene, and there is nothing in the flora that indicates a different age, while the strong representation of palms seems rather to confirm this determination. More recent stratigraphical evidence, however, has led the Dutch geologists, especially K. Martin, director of the geological museum of Leyden, to regard them as Miocene.

Another plant-bearing deposit has more recently been discovered by Engineer Delprat while tunneling through the Goenoeng Kendang Mountain, situated to the east of Soekaboemi and southeast of Tjiandjoer, in the Preanger Regentschappen. A fairly representative suite of specimens collected in this tunnel was sent to the Leyden museum and referred by Director Martin to Professor Crié for determination. Nine species are described in the paper by Crié, which appeared in 1888,[2] consisting of two glumaceous species, one palm and six dicotyledons, five of which were founded on leaves, the other one on spec-

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[1] Beitrag zur Kenntniss der Tertiärflora der Insel Java, von C. von Ettingshausen: Sitzungsber. k. Akad. Wiss., Wien, math.-nat. Cl., vol. 87, Abth. I, 1883, pp. 175–193, pl. i–v.

[2] Recherches sur la flore pliocène de Java, par M. L. Crié: Samml. geol. Reichs-Mus. Leiden, No. 17. I, Beitr. Geol. Ost-Asiens u. Australiens, herausgegeb. von K. Martin u. A. Wichmann; vol. 5, Heft I, pp. 1–22, pl. i–viii.

imens of silicified wood. This wood, however, was obtained from a different locality, in the western part of the province of Buitenzorg, and sent to the museum of Leyden by M. Musschenbroek. These deposits are regarded as more recent than those last mentioned, and are placed by the geologists who have studied them in the Pliocene.

SUMATRA.

Two collections of fossil plants made by Verbeek in Sumatra were sent to Dr. Oswald Heer in 1874 and 1875. The first lot was reported upon promptly.[1]

The report upon the second lot was deferred until the year 1881.[2] The plants were all obtained from clay shales on the west coast of the island, in the so-called Padang Bovenland, the high land of Sumatra. The first collection came from two localities not more definitely indicated, the second and much richer one from the river Sangkarewang, six kilometers from Telaweh and three kilometers west of Kollok, in the Tamah-Datar division, and the beds were of the same age. Thirteen species were described from the first installment and nineteen additional ones in the second, making the total flora, so far as known, to consist of thirty-two species. They consisted chiefly of leaves, many of which were well preserved, and their character made it quickly apparent that the beds were of Tertiary age. They bear a close general resemblance to the flora of Java, last described, and two of the species (*Xylomites stigmariæformis* Göpp., and *Daphnophyllum*[3] *Beilschmiedioides* Göpp.) are common to the two islands. Besides these two plants, three other genera, Ficus, Diospyros, and Apocynophyllum, occur in both floras; and Heer's *Piper antiquum* bears sufficient resemblance to Göppert's *Piperites Miquelianus*, whose affinities to Piper Baron von Ettingshausen questions, to suggest the probability that they both belong at least to the same family. But the presence of a Casuarina and a Eucalyptus in the Sumatran flora distinguishes it sharply from that of Java as made known by Göppert.

The other genera not occurring in the Java flora are the following: Bambusium, Caulinites, Sapotacites, Dombeyopsis, Dipterocarpus, Sapindus, Rhus, Dalbergia, and Cassia. Especially noticeable is the absence of palms, which, so far as it goes, is favorable to Heer's earlier view that the beds of Sumatra that yielded these plants were Miocene and not Eocene. This view, however, he distinctly with-

[1] Ueber fossile Pflanzen von Sumatra, von Oswald Heer: Abhandl. schweiz. paläont. Gesell., vol. 1, Basel, 1874, No. 2, 26 pp., 3 pl.

[2] Beiträge zur fossilen Flora von Sumatra, von Oswald Heer: Neue Denkschr. schweiz. Gesell. gesammt. Naturwiss. vol. 28, Abth. I, Zürich, 1881, No. 1, 22 pp., 6 pl.

[3] Laurophyllum of Göppert.

drew in his second paper (p. 4) in favor of their Eocene age, as indicated by animal remains.

In Ettingshausen's short paper[1] on the subject, Heer's *Rhus bidens* is regarded as an oak, and Göppert's *Laurophyllum Beilschmiedioides*, referred to Daphnophyllum by Heer, becomes *Bombax Heeri* Ett. These changes, however, do not materially change the general character of the flora.

BORNEO.

The small collection of fossil plants made by Verbeek at Pengaron was elaborated by Geyler, and the results were published in 1875. The material was scanty and poorly preserved, and only thirteen distinct forms were recognized. All but three (*Litsœa Boettgeri, Entoneuron melastomaceum,* and *Nephelium Verbeekianum,* all new species) were too obscure to be definitely named and classified, and were thrown into Phyllites, Carpites, and Leguminosites, with an indication of their apparent generic relationship.

Geyler's work on these specimens was revised in 1883[2] by Baron von Ettingshausen, and the following changes were indicated: *Phyllites* (*Hopea*) *prœcursor* becomes *Alnus prœcursor*, Phyllites (*Grumilea*) *mephitioides* becomes *Castanopsis mephitioides, Phyllites* (*Pterospermum*) *gracile* becomes *Cinnamomum gracile,* and *Nephelium Verbeekianum* becomes *Phyllites Geyleri* Ett. This last case is in the direction of greater indefiniteness, but the other three, if correct, add considerable character to this small fossil flora.

The question asked, whether this and the other floras last considered belong to the Eocene or to the Miocene age, could not, it must be confessed, be determined by the evidence afforded by the plant remains alone, although this evidence would be sufficient to indicate with certainty that all the beds are of Tertiary age and that they do not probably differ greatly from one another in stratigraphical position.

In all of Ettingshausen's papers above cited relative to the fossil floras of the Sunda Islands, he has taken special pains to correct the impression naturally made upon those who have studied them that they were essentially Indian in their character, and to point out their resemblance to the Tertiary flora of Europe. He maintains that the facts sustain the general proposition that the Tertiary flora of the globe was far more uniform than its present flora, a proposition which may be said to be now established.

[1] Beitrag zur Kenntniss der Tertiärflora von Sumatra, von C. von Ettingshausen: Sitzungsber. k. Akad. Wiss., Wien, math.-nat. Cl., vol. 87, Abth. I, 1883, pp. 395–403, 1 pl.

[2] Zur Tertiärflora von Borneo, von C. von Ettingshausen: Sitzungsber. k. Akad. Wiss., Wien, math.-nat. Cl., vol. 88, Abth. I, 1883, pp. 372–384, 1 pl.

Labuan may be regarded as a part of Borneo. In 1853 Mr. J. Motley, who had visited the island and found vegetable remains as well as other fossils, made a communication to the Geological Society of London describing its geology.[1] In this paper he stated that he had procured identifiable specimens of nine species of dicotyledons, two or three species of ferns, a large flag-shaped leaf like a crinum, and something closely resembling a large thick-stemmed usnea or confervoid alga, also four or perhaps five species of palms.

These statements of the occurrence of plant remains on the island of Labuan were abundantly confirmed by Nordenskiöld's visit, that traveler having brought back from there a considerable collection of them. These were deposited in the museum at Stockholm in charge of Dr. Nathorst, who subsequently sent them to Dr. Geyler for determination. The report of the latter has just come to hand[2] and possesses a special interest for our present subject. The material was very fragmentary, but yielded thirty-four distinct forms, nearly all impressions of leaves, all but seven dicotyledonous. In naming these plants the author has adopted Dr. Nathorst's system of affixing the ending "phyllum" to the supposed nearest living genus. Upon analysis he concludes that there is no reason to regard this Labuan flora as distinct in geologic age from the Tertiary flora of Borneo and the other islands of the Sunda group.

AUSTRALASIA.

Fossil plants have been found in Australia, New Zealand, Van Diemen's Land, and New Guinea, representing the Carboniferous, the Mesozoic, and the Tertiary formations.

AUSTRALIA.

Perhaps the earliest mention of vegetable petrifactions in Australia is that made by Niemeyer in 1821[3] of silicified trees or forests in the sand dunes of Decrès Island, on the north coast, the formation and process of petrifaction of which he offers a theory to explain.

Brongniart was acquainted with two species of Carboniferous plants from the Hawkesbury River, 10 miles north of Port Jackson, New South Wales (*Glossopteris Browniana*, var. *australasica*, and *Phyllotheca australis*, cf. Prodrome, pp. 169, 175; Hist., vol. 1, p. 223).

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[1] On the Geology of Labuan, by J. Motley: Quart. Jour. Geol. Soc. London, vol. 9, 1853, pp. 54–57.

[2] Ueber fossile Pflanzen von Labuan, von H. Th. Geyler. Vega-Expeditionens Vetenskapaliga Jakttagelser, af Nordenskiöld, vol. 4, Stockholm, 1887, pp. 473–507, pl. xxxii-xxxix.

[3] Geologische und andere naturhistorische Bemerkungen über Australien, von Chr. Niemeyer: Ballenstedt und Krüger's Archiv., vol. 2, Heft 2, 1821, pp. 249–258.

Specimens of fossil wood collected by Wilton and Burnet at Castle Hill and in the sandstone on the coast in the vicinity of Newcastle, New South Wales, were studied microscopically by Nicol in 1833,[1] and found to be coniferous.

The earliest paper on the fossil flora proper of Australia is contained in Strzelecki's Physical Description of New South Wales and Van Diemen's Land, 1845, and was prepared by Mr. John Morris.[2]

Four of the eight species described in this work from the Carboniferous formation came from the Newcastle coal mines of New South Wales. They embrace two species of Sphenopteris, one of Pecopteris, and one of Phyllotheca; the remainder are from Van Diemen's Land and will be mentioned later.

The Rev. William Branwhite Clarke discovered a fossil pine forest at Kurrurkurran, in the inlet of Awaaba, on the east coast of Australia, which he made the subject of a short communication to the Geological Society of London, in 1846.[3]

A year later Mr. Frederick McCoy made a report upon the fossil plants collected by Mr. Clarke and sent to Professor Sedgwick, who intrusted the elaboration of the fossil remains, both animal and vegetable, to Mr. McCoy.[4]

The plant remains occurred in the shales and clays of Mulubimba, the sandstone of Clarke's Hill, the siliceous flags of Arowa, and in the gray shale of Guntawang in New South Wales. They consist chiefly of ferns, but one species of Vertebraria and three of Phyllotheca are also described.

Twenty genera of alleged Carboniferous plants, said to embrace about sixty species, are enumerated by Mr. Clarke in his paper On the Genera and Distribution of Plants in the Carboniferous System of New South Wales,[5] 1848, but a number of these most probably belong to the Mesozoic system.

Prof. J. D. Dana, in the first appendix to his report on the Geology of Wilkes' Exploring Expedition, 1849 (pp. 714–720), describes a considerable number of species, three of which are referred to Noeggerathia, but the most of them are of Mesozoic type. The new species are figured on pl. xii–xiv of the atlas. They were collected at Illawarra and Newcastle, near the mouth of Hunter River.

In 1871 Baron von Mueller commenced describing the fossil plants

[1] On fossil woods from Newcastle, New South Wales; with a plate. In a letter to Professor Jameson, by William Nicol: Edinburgh New Philos. Jour., vol. 14 No. 27, 1833, pp. 155–158, pl. iii.

[2] Fossil flora, pp. 245–254, pl. vi–viii.

[3] Proc. Geol. Soc. London, vol. 4, 1846, pp. 161–164.

[4] On the fossil botany and zoölogy of the rocks associated with the coal of Australia, by Frederick McCoy: Annals Mag. Nat. Hist., vol. 20, London, 1847, pp. 145–157; 226–236; 298–312; pl. ix–xvii; fossil plants, pp. 145–157, 308–312, pl. ix–xi.

[5] Quart. Jour. Geol. Soc. London, vol. 4, 1848, pp. 60–63.

of the Auriferous Drifts,[1] supposed by him to be of early Pliocene age, which work he has continued down to quite a recent date.[2] The principal localities are: Smythe's Creek, Nintingbool, and Haddon, in the Haddon gold field, Victoria; on the Tanjil, at Orange, Beneree, Carcoar, Gulgong, and Eldorado near Beechworth, New South Wales; and on a branch of the Tamar opposite Georgetown; also on Geilston Bay, Tasmania.

The number of the fruits made known by Baron von Mueller in these important contributions is very large, and their character is of extraordinary interest. The forms are so anomalous as to shed comparatively little light upon the age of this formation, and upon the relations that subsist between its flora and that of the present day. It is to be regretted that the eminent author of these researches has nowhere given us such a careful discussion and comparison of his results as their importance demands, and as he is alone qualified to prepare.

In 1872 Mr. R. Daintree published some important Notes on the Geology of the Colony of Queensland, with an appendix containing descriptions of the fossils by R. Etheridge and William Carruthers.[3] The last-named author described the fossil plants.[4] *Lepidodendron nothum* Ung. is here described from the Devonian formation. It has been found at Mount Wyatt, Ryedale, and in the Mount Lambie Range.

From Mesozoic strata five species are described from the Tivoli coal mine, including the well known *Tæniopteris Daintreei* McCoy, about whose affinities so much discussion has taken place.

In 1874 Mr. McCoy commenced publishing his important Prodromus of the Palæontology of Victorian Organic Remains, in which the fossil flora of Victoria is carefully revised and much new material added.

Decade II (1875) contains a description of a number of Mesozoic plants (*Gangamopteris angustifolia* McCoy, *Tæniopteris Daintreei* McCoy, and *Pecopteris australis* Morr.), from Cape Peterson, the Barabool hills, Murundal, the Wannon River, and Belerine, near Geelong, all of which are more carefully figured than in any previous work.

Decade IV (1876) deals with some Devonian forms (*Archæopteris Howitti* McCoy, *Sphenopteris Iguanensis* McCoy, and *Cordaites australis* McCoy) from Iguana Creek. Here is also described and

[1] New Vegetable Fossils of Victoria, described by Baron Ferdinand von Müller: Reports of the Mining Surveyors and Registrars for quarters ending 30th of June, 1871; 30th September, 1871; 30th September, 1873; 31st December, 1873; 30th September, 1874; 30th June, 1875; 30th September, 1876.

[2] Observations on New Vegetable Fossils of the Auriferous Drifts, by Baron Ferdinand von Mueller, Melbourne and London, 1874; second decade, 1883.

[3] Quart. Jour. Geol. Soc. London., vol. 28, 1872, pp. 271-360, pl. ix-xxvii.

[4] Ibid., pp. 350-356, pl. xxvi-xxvii.

figured an extremely interesting fossil species of Eucalyptus (*E. Pluti* McCoy) from Pliocene strata at Daylesford, and two Miocene species (*Cinnamomum polymorphoides* McCoy and *Laurus Werribeensis* McCoy) from near the junction of the Werribee and Lyell's Creek.

Feistmantel's extensive study of the flora of eastern Australia, which appeared in 1878 and 1879,[1] next demands our attention.

The work was the result of his careful elaboration of an extensive series of fossils, sent to him by Mr. W. B. Clarke, at Sidney, New South Wales, at the beginning of the year 1876, which included fishes and other animal remains and represented the Upper Devonian, the Carboniferous, and the Mesozoic formations. The material is treated in the geological order above named; we are concerned only with the fossil plants. The work consists of two parts, the second part being of a supplementary character,[2] but containing many additional data. In the first part sixty distinct forms are enumerated, only one of which (*Cyclostigma australe* Feistm.) is from the lowest or Upper Devonian formation; seventeen are from Carboniferous strata, and the remainder from four distinct beds of Mesozoic age.

The second part is devoted to the elaboration of another collection which the author received from Mr. Clarke shortly before his death, in June, 1878. It was found to contain a large number of the forms already described, but in addition to these occurred several new species not found in the other collection. Prominent among these latter may be mentioned *Lepidodendron nothum* (Ung.) Carr., early reported by Carruthers. This lowest formation, which was represented by only one species in the first collection, is here represented by six species, and the Mesozoic forms are proportionally less numerous. In this entire work the new species and the more interesting specimens of the many previously known species are fully described and thoroughly illustrated in thirty plates.

According to Feistmantel, as set forth in this elaborate memoir, there are in Australia below the Cretaceous the following plant-bearing formations and localities:

Devonian.—Goonoo-Goonoo on Peel River, Back Creek diggings on Barrington River, in New South Wales; Iguana Creek on Mitchell River, in Victoria; and Mount Wyatt, Canoona River, and Broken River, in Queensland.

Lower Carboniferous.—Port Stephen, Smith's Creek, near Stroud, Greta, Stony Creek, Anvil Creek, Rix's Creek, Raymond Terrace, Arowa, most of which are near Newcastle, in New South Wales; Avon River and Rouchel River (district of Durham), in Victoria.

Trias (Newcastle, Wianamatta, and Hawkesbury beds).—New-

[1] Palaeontologische Beiträge. III, Palaeozoische und Mesozoische Flora des östlichen Australiens, von Ottokar Feistmantel: Palaeontographica, Supplement 3, Lieferung 3, Hefte 2–4, Cassel, 1878–'79, pp. 1-195, pl. i–xxx.

[2] Ibid., Heft 4, "Nachtrag zur erstern Abhandlung, 1879."

castle, Mulubimba, Bowenfels, Wallongong, Illawara, Blackman Swamp, Guntawang-Mudgee, Cockatoo Island, and Mount Victoria, on the Hawkesbury River, Wianamatta, Paramatta, Clark's Hill, in New South Wales; and Bacchus Marsh, northwest of Melbourne, Victoria.

Jurassic.—Southgate on the Clarence River, New South Wales; Cape Patterson, Barabool Hills, Coleraine, on the Wannoon River, Belerine near Geelong, in Victoria; Talgai, on the Condamine River, the Ipswich and Tivoli mines, near Brisbane, in Queensland; and Springs Hill, in the Jerusalem Basin, Tasmania.

On December 6, 1882, Mr. J. E. Tenison-Woods read before the Royal Society of New South Wales a paper describing A Fossil Plant Formation in Central Queensland.[1] This locality is situated on the central line of railway which runs westward from Rockhampton to the Drummond Range, 235 miles from the former place, 1,840 feet above sea level. Four species are described (*Lepidodendron Velthemianum* Sternb., *Cyclostigma australe* Feistm., *Calamites radiatus* Brongn., and *Calamites varians* Sternb., the character of which indicates a position for this bed at the base of the Carboniferous formation (Subcarboniferous) or possibly the Devonian. The figures are mere photographs and not sufficiently clear to enable paleobotanists to recognize the species without the specimens.

On February 28, 1883, Mr. Tenison-Woods read another paper before the same society.[2] In this the plant-bearing deposits of Australia are again reviewed in the light of previous literature, and the following geological formations are indicated with their characteristic species: Upper Devonian (Victoria), Lower Carboniferous (Queensland, New South Wales, Victoria, also Tasmania), Newer Coal, Trias? (Queensland, Victoria, also Tasmania), Rhetic or Lower Lias (Queensland), Jurassic (Queensland, New South Wales, also Tasmania). The following localities were not mentioned by Feistmantel: Lower Carboniferous: Canowindra and Cowra in New South Wales; Medway River and Bobuntangen in Queensland; Trias: Dawson River basin, and Comet River in Queensland; Rhetic or Lower Lias: Talbragar River, Ballinore near Dubbo, Clifton, and Darling Downs, in New South Wales, and Burnett River in Queensland; Upper Lias: Burrum River near Maryborough. This classification is exclusive of the beds at Rosewood west of Rockhampton, yielding Ptilophyllum, Vertebraria, Sequoiites, Pecopteris and Equisetum, the geological age of which is regarded as uncertain. The remainder and principal part of the paper is devoted to the description of nearly a hundred forms from the above-mentioned deposits which he had examined.

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[1] Jour. Royal Soc. New South Wales, vol. 16, 1882, pp. 179–193, pl. xi, xii.

[2] On the fossil flora of the coal deposits of Australia, by J. E. Tennison-Woods: Proc. Linn. Soc. New South Wales, vol. 8, part 1, Sydney, 1883, pp. 37–167, pl. i–xA.

A paper by Milne Curran on the fossil plants of Ballinore and Dubbo (probably Permian),[1] 1885, and another by Woodward on Australian Mesozoic plants[2] which appeared in the same year, may be mentioned in passing.

It remains to consider the important contributions of Baron von Ettingshausen to the fossil flora of Australia.[3]

The Tertiary flora of Australia, as distinguished from that of the Auriferous Drifts, had received very little attention prior to the date of these papers. Prof. A. Liversidge, of the University of Sydney, sent a large collection of fossil plants, the property of that university, to the British Museum for investigation and determination. Mr. C. F. Wilkinson, State geologist of New South Wales, sent another collection, made by Mr. J. K. Hume, for the same object. These collections were turned over to Baron von Ettingshausen to be examined and reported upon, and the first of the papers above quoted is the result.

Five distinct localities are represented as follows: (1) Dalton near Gunning in New South Wales; (2) Wallerawang, New South Wales; (3) near Hobart Town, Tasmania; (4) Nintingbool, Haddon, Tangil, Smythe Creek, Eldorado, etc., in Victoria; (5) Gulgong, Bathurst, and Lumpy Swamp, in New South Wales. The last two groups belong to the Pliocene formation and represent the same horizon from which Baron von Mueller obtained the fruits and seeds mentioned above. The first-named locality is regarded as of Eocene age, and the remaining four are considered as Miocene.

Sixty-one species are described in this paper, all new to science. It would be interesting to discuss the elements of this extensive flora, but this can be more profitably done in connection with the other species of the Tertiary formation which have been made known by other authors, and Baron von Ettingshausen has rendered this task easy by the preparation of a table of distribution of the entire Tertiary flora of Australia. From this it appears that ninety-eight species of Tertiary plants had been described at that date. Of these but a single cryptogamous species occurs (*Pteris Humei* Ett.), from the Eocene of Dalton, New South Wales, a form which he compares with *P. inæqualis* Heer, from the Tertiary flora of Europe, and with *P. tremula* L., from the living flora. Almost as remarkable is it that only two coniferous species occur (*Spondylostrobus*

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[1] On some fossil plants from Dubbo, New South Wales, by J. Milne-Curran: Proc. Linn. Soc. New South Wales, vol. 9, 1884, Sydney, 1885, pp. 250–254, pl. ix.

[2] Notes on some Mesozoic Plant-Remains from South Australia, by Henry Woodward: Geol. Mag., 3d series, vol. 2, London, 1885, pp. 289–292, pl. vii.

[3] Beiträge zur Kenntniss der Tertiärflora Australiens, von C. von Ettingshausen: Denkschr. k. Akad. Wiss., Wien, math.-nat. Cl., vol. 47, Abth. I, 1883, pp. 101–148, pl. i–vii. Zweite Folge. Ibid., vol. 53, Abth. I, 1886, pp. 81–142, pl. viii–xv.

Smythii F. v. M., and *Araucaria Johnstonii* F. v. M.), and scarcely less so that only one monocotyledonous species (*Microrrhagion Liversidgei* Ett.) appears. The Tertiary flora of Australia is seen to consist chiefly of dicotyledonous plants. Of these thirty-one are placed under apetalous genera, thirty-six under polypetalous, and eleven under gamopetalous; besides these there are seventeen whose systematic position is uncertain. Of the apetalous genera Quercus has five species, Cinnamomum four, Laurus three, Betula, Fagus, and Conchotheca two each. The Proteaceæ, however, to which the last genus belongs, are represented by eight species. We find also the genera Myrica, Alnus, Castanopsis, Salix, Ficonium, and Artocarpidium. The other proteaceous genera are Lomatia, Knightia, Banksia, Conchocaryon, Celyphina, and Dryandroides. The largest polypetalous genus is von Mueller's Penteune, which he places in the Sapindaceæ, and of which there are four species of polypetalous orders; the order Sapindaceæ is the best represented, embracing with Penteune ten species, one of which is a true Sapindus (*S. Tasmanicus* Ett.). Of other orders the Cappariden are represented by four genera and five species, the Myrtaceæ by three species of Eucalyptus, the Cæsalpinieæ by two species of Cassia and one Leguminosites, the Magnoliaceæ by two species of Magnolia, the Saxifragaceæ by two of Bombax. The following orders are each represented by one species: Menispermaceæ, Tiliaceæ, Olacineæ, Pittosporeæ, Celastrineæ, Rhamneæ, Calycifloræ, and Papilionaceæ.

The Gamopetalæ embrace plants of the Rubiaceæ, one species; Apocynaceæ, five species; Boragineæ, one species; Verbenaceæ, two species; and Sapotaceæ, two species.

From the comparatively small number of myrtaceous, proteaceous, and leguminous plants, together with the considerable sprinkling of cupuliferous species, it is obvious that the author of this paper has good ground for maintaining that the Tertiary flora of Australia is analogous to other well known Tertiary floras rather than to the living flora of Australia, and he regards these facts as furnishing an important confirmation of his views on this general question. It is true, however, as Dr. Nathorst has pointed out,[1] that the specimens figured by Ettingshausen are too fragmentary to render his determinations a sufficiently safe guide for deducing such important conclusions.

The second contribution is the result of the elaboration of a fine collection sent by Mr. C. S. Wilkinson, chiefly from Vegetable Creek, near Emmaville, but also from Rocky Creek, Tingha, and Elsmore, in New South Wales. From this material the baron has obtained one hundred and twenty-eight additional species, the character of which, compared with other floras of known age, would place them in the Lower Eocene. An analysis of the results shows a quite dif-

[1] Botanisches Centralblatt, vol. 25, Cassel, 1886.

ferent character from the Miocene flora. It contained but two cryptogamous and one cycadaceous species, but the Coniferæ are here represented by eleven species belonging to almost as many genera. The largest dicotyledonous orders are the Proteaceæ (20 species), Cupuliferæ (14) Myrtaceæ (10), and Laurineæ (7). The largest genera are Quercus (9 species), Banksia (7), Ficus (5), Lomatia (5), Fagus, Apocynophyllum, Aralia, Eucalyptus, and Callistemophyllum (4 each).

The preponderance in this collection of elements related to the present flora of Australia is difficult to explain, in view of their meager representation in the previous one. On any theory of the development of the present flora out of these past ones the living elements should increase in relative prominence as the geologic antiquity diminishes. This is the reverse of the present case. It must therefore be assumed that as we come to know the later extinct floras better we shall find these elements to increase in importance.

The illustrations are much better and the specimens more perfect than in the first collections, so that whatever objections may be raised to the baron's conclusions, he has furnished satisfactory data for his critics to proceed upon.

In a letter dated November 2, 1887, Mr. I. C. Russell informs me that when in Australia he obtained good specimens of Glossopteris and other Jurassic plants from blocks of light-colored calcareous rock that had been detached from the sea-cliff on the coast at the mouth of the harbor of Sydney, New South Wales.

TASMANIA.

In the foregoing attempt to treat the fossil flora of Australia as distinct from that of Tasmania, mention has been unavoidably made of the latter colony. In the earliest paper to which reference was made, viz, Morris's contribution to Strzelecki's Physical Description of New South Wales and Van Diemen's Land, half of the species enumerated were from the Jerusalem basin of Van Diemen's Land, which were referred to the Rhetic or Lower Lias. They embrace *Pecopteris australis* Morr., *P.* (*Thinnfeldia*) *odontopteroides* Morr., *Zeugophyllites elongatus* Morr., and one species of Sphenopteris belonging to the section of *S. linearis* Sternb.

In Tenison-Woods's enumeration of localities for fossil plants the following points in Tasmania are mentioned, with the characteristic species found at each: The Mersey coal-field, Don River, Spring Bay, and the valley of the Derwent, yielding Glossopteris, Phyllotheca, and Vertebraria doubtfully referred to the Permian formation; Jerusalem Basin and Spring Hill yielding the forms mentioned by Morris from the first of these localities.

It was also seen in Baron von Ettingshausen's work just considered that one of the prominent localities for Tertiary plants was near Hobart Town in Tasmania, where Darwin examined them in

1836.[1] A large number of species were obtained from the following points in this vicinity: Risdon, Shoebridge's lime kiln, Geilston, Pipeclay Bluff, Cornelian Bay, Sandy Bay, One Tree Point. Ettingshausen refers these beds to the Miocene formation, and the species were unavoidably included in the discussion of that paper.

More recently Mr. R. M. Johnston has reported Jurassic plants from Adventure Bay on Bruni Island,[2] Compton, Old Beach,[3] in the Longford Coal basin at Norwich,[4] and at Lord's Hill, New Town;[5] as also of Tertiary plants at Table Cape.[6] He has also prepared a valuable Reference List[7] of all the Cenozoic species described down to 1886, in which it appears that, in addition to the localities already mentioned, Tertiary plants have been found at Stevenson's Bend, Launceston, Breadalbane, Waratah, and Macquarie Harbor, and Pliocene fruits at Beaconsfield, Muddy Creek, and Launceston.

In the large and admirable work by this author on the Geology of Tasmania,[8] which has reached me too late to receive adequate treatment, the fossil plants have received special attention. The following localities are either new or are more definitely stated than in earlier papers: Cambro-Silurian: Cabbage-Tree Hill, Beaconsfield; Mesozoic: Mount Nicholas, Mount Cygnet, Campania, Spring Hill, Mount Wellington, Richmond, Okehampton, Ben Lomond; Tertiary: Mount Bischoff near The Forest, Glenora, Wallerwang, Beaconsfield Deep Lead, Corra Lynn, Wind Mill Hill (Launceston).

NEW ZEALAND.

The first plant remains that were described from New Zealand were those collected by Hochstetter and elaborated by Unger in the report of the Novara expedition, 1864.[9]

The plants of this collection belong to two horizons, Mesozoic and

[1] Journal of Researches, etc., New York, 1871, p. 448.

[2] Notes on the geology of Bruni Island, by R. M. Johnston: Papers and Proc. Roy. Soc. Tasmania, 1886, pp. iv, 18–26, with sections (geologic).

[3] Remarks regarding coal seam opened out by Mr. Brock at Compton, Old Beach, by R. M. Johnston: Ibid., pp. 155, 156.

[4] Remarks on the Longford Coal Basin, by R. M. Johnston: Ibid., pp. 156–160.

[5] Fresh contribution to our knowledge of the plants of Mesozoic age in Tasmania, by R. M. Johnston: Ibid., pp. 160–182, 1 chart.

[6] Note on the discovery of plant remains in the Tertiary Marine Beds at Table Cape, Tasmania, by R. M. Johnston: Ibid., pp. xx, xxi.

[7] Reference List of the Tertiary Fossils of Tasmania, by R. M. Johnston: Ibid., pp. 124–140.

[8] Systematic account of the Geology of Tasmania, by Robert M. Johnston, Tasmania, 1888, xxii, 408 pp., lvii pl., 4°.

[9] Reise der Österreichischen Fregatte Novara um die Erde in den Jahren 1857, 1858, 1859, etc. Wien, 1864. Geologischer Theil, vol. 1, Abth. II, Paläontologie von Neu-Seeland; I, Fossile Pflanzenreste aus Neu-Seeland, beschrieben von Dr. Franz Unger, pp. 3–13, pl. iv.

Tertiary; from the former only two recognizable species are described (*Asplenium palæopteris* Ung. and *Polypodium Hochstetteri* Ung.), from a point between the mouth of the Waikato and Whaingaroa on the west coast of New Zealand, in the province of Auckland, regarded by Unger as probably in the Wealden formation. Fragments of a palm (Phœnicites), of an equisetaceous plant (Equisetites), and of a fern (Neuropteris?) were also found in the coal-bearing strata of Pakawau on Massacre Bay, province of Nelson, South Island, also regarded as of Mesozoic age.

Thirteen species of dicotyledonous plants are described from the Tertiary strata of New Zealand, chiefly from a coal bed at Drury near Auckland, and another near Nelson; only four of these were sufficiently well preserved to be referred to their proper genera. One of these was a beech (*Fagus Ninnisiana* Ung.); two are referred to Loranthophyllum (*L. Griselinia* Ung. and *L. dubium* Ung.); the remaining species is his *Myrtifolium Lingua,* which he doubtfully refers to the Myrtaceæ. The nine species of Phyllites are supposed to represent the orders Urticaceæ (Artocarpeæ), Laurineæ, Leguminosæ (Myrtaceæ), Cupuliferæ, and perhaps some other orders.

Three species are described from silicified trunks, one of which is a new species of Nicolia (*N. Zelandica* Ung.), from the Drift at Mutere Hills near Nelson, and from Hunua Range near Drury. Another is a Dammara (*D. fossilis* Ung.), from fossiliferous sandstone near Richmond, which was scarcely distinguishable in its internal structure from the living species *D. australis,* and the age of which is not further indicated. The remaining species is *Podocarpium dacrydioides* Ung., from the trachyte of Great Barrier Island and from the River Waiau, the structure of which is intermediate between that of Podocarpus and that of Dacrydium.

Quite recently Baron von Ettingshausen has published the results of his investigation of a fine collection of fossil plants which Dr. J. Haast and Prof. T. J. Parker have sent him from fifteen distinct localities in New Zealand,[1] and which represent the Triassic (Rhetic?), the Cretaceous (Senonian?), and the Tertiary (Eocene) formations. The Triassic plants are from Mt. Potts, Haast Gully, Malvern Hills, Mataura, and Waikawa, and number twenty-three species. The Cretaceous plants were collected from Pakawau, Grey River, Wangapeka, and Reefton, and embrace thirty-seven species. The Tertiary plants were found at Shag Point, Dunstan, Landslip Hill, Malvern Hills (at a higher horizon), Roca Cliff Gully, Weka Pass, and Murderer's Creek, and have yielded fifty-one species.

In the memoir which has just reached me from the author the Eocene and the Cretaceous plants alone are described, the Triassic

[1] Beiträge zur Kenntniss der fossilen Flora Neuseelands, von Constantin von Ettingshausen: Denkschr. k. Akad. Wiss., Wien, math.-nat. Cl., vol. 53, Abth. I, 1887, pp. 141–192 (1–52), pl. i–ix.

forms being reserved for a second part. The Eocene flora here portrayed consists of fifty-two species, including one problematical fruit whose botanical position is uncertain. The remaining fifty-one species are distributed through the system as follows: cryptogams (ferns), 3; Cycadaceæ, 1 (Zamites sp. indet.); Coniferæ, 10; monocotyledons, 2 (one a palm); apetalous dicotyledons, 22; gamopetalous dicotyledons, 3; polypetalous dicotyledons, 10. The largest genus is Quercus, with four species; Myrica and Fagus have each three species, and Aspidium, Araucaria, Dammara, Podocarpus, Apocynophyllum, and Cassia have two each. No other genus is represented by more than one species. Among these are to be observed many which are still living in Australia.

The Cretaceous flora consists of four ferns, eight Coniferæ, four monocotyledons (one a palm), thirteen apetalous dicotyledons, and seven polypetalous dicotyledons, making a total of thirty-six species. The genera Podocarpium and Quercus have each three species, while Fagus, Ulmophylon, and Dalbergiophyllum have each two, the remainder being represented by only a single species each.

In this paper the author has not entered into a discussion of the elements of these floras, as he will probably do at a subsequent time. They certainly are not less remarkable from the point of view of the origin and geographical distribution of plant life than others which he has discussed.

NEW GUINEA.

Hardly anything is yet known of the fossil flora of New Guinea, the only mention of which occurs in some notes on rocks and minerals from that island, read before the Royal Society of New South Wales, by Rev. A. Liversidge.[1] He found there numerous specimens of fossil wood, chiefly silicified, with the vegetable structure well preserved. They were only seen in the natives' fire-places, and their source was not discovered; no attempt was made to identify the genera or species, nor any suggestion given as to their geological age.

KERGUELEN LAND.

It is an interesting fact that silicified wood has been discovered on Kerguelen Land. Specimens were first observed during the Antarctic voyage of Her Majesty's discovery ships *Erebus* and *Terror*, 1839–1843, and received mention by Dr. Hooker in Part II of his Flora Antartica[2] (p. 219), published in 1847.[3]

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[1] Notes on some rocks and minerals from New Guinea, etc., by A. Liversidge: Jour. and Proc. Roy. Soc. New South Wales, vol. 20, 1886, Sydney, 1887, pp., 227–230.

[2] Flora Antarctica. Part II: The Botany of Feugia, the Falklands, Kerguelen's Land, etc. Under the general title, "The Botany of the Antarctic Voyage of *Erebus* and *Terror*, 1839–1843;" London, 1847, 4°, pp. 219, 220.

[3] See J. N. Mosely: Notes by a Naturalist on the *Challenger*. London, 1879, p. 195.

Collections were also made by Baron von Schleinitz. The specimens were found in Tertiary strata permeated by veins of basalt. They were examined by Dr. Göppert,[1] and two species, *Araucarites Schleinitzii* Göpp. and *A. Hookeri* Göpp., were distinguished.

MADEIRA.

The existence of lignite in the valley of St. Jorge, on the north coast of Madeira, was first made known by Mr. James Smith[2] in 1841, and formed the basis of Professor Johnston's opinion that they had been formed by the deposition of peat, which argued for the existence of a colder climate at that period. Subsequently Prof. Oswald Heer visited the place in hope of finding the remains of fossil plants associated with the lignite, but the excavations necessary were too great for the facilities he possessed and his efforts were unsuccessful. Still later Sir Charles Lyell, accompanied by Mr. (later Sir) Charles J. F. Bunbury, spent considerable time among the Madeira Islands and made special efforts to investigate the lignite bed of St. Jorge, which were rewarded by the verification of Heer's prediction that recognizable plant remains would be found. In a paper, consisting of extracts of letters of Sir Charles Lyell to Mr. L. Horner, communicated to the Geological Society of London on March 22, 1854,[3] an account is given of the geology of the Madeiras, and special mention is made of the plant remains discovered. The material was examined by Mr. Bunbury, who was an authority on Carboniferous plants, and who supposed he recognized the genera Pecopteris, Sphenopteris, Adiantum, and Woodwardia, but he seems not to have realized how recent the deposit was. Specimens collected in this bed by Hartung and Ziegler-Steiner were forwarded to Heer, who gave them a thorough investigation, figuring the principal specimens. An important monograph published in the memoirs of the Swiss Natural History Society in 1855 was the result.[4] Twenty-five species are described, a large proportion of which belong to the living flora of Madeira and the adjacent parts of Africa and Europe, but seven species were regarded as extinct. The collections by Lyell and Bunbury were elaborated by the latter, and his report was communicated to the Geological Society of London on April 28, 1858.[5]

[1] Revision meiner Arbeiten uber die Stämme der fossilen Coniferen, von H. R. Göppert: Botanisches Centralblatt, vol. 6, Cassel, 1881, pp. 27–30, 98–101, 170–174, 207–212.

[2] On the Geology of the Island of Madeira, by James Smith: Proc. Geol. Soc. London, vol. 3, 1841, pp. 351–855.

[3] On the Geology of some parts of Madeira, by Chas. Lyell: Quart. Jour. Geol. Soc. London, vol. 10, 1854, pp. 325–328.

[4] Ueber die fossilen Pflanzen von St. Jorge in Madeira, von Oswald Heer: Denkschr. schweiz. Gesell. gesammt. Naturwiss., vol. 15, 1885, No. 2, 40 pp., 3 pl.

[5] On some vegetable remains from Madeira, by Charles J. F. Bunbury: Quart. Jour. Geol. Soc. London, vol. 15, 1859, pp. 50–59.

He was then acquainted with Heer's paper, and his material for the most part agreed with that of the Swiss author, but he distinguished a few additional species of ferns and dicotyledons, the latter of which he referred to Phyllites. No figures accompany his paper.

WEST INDIES.

The only one of the West Indies from which fossil plants have been reported is the island of Antigua, one of the lesser Antilles. This bed, containing silicified wood, seems to have been discovered very early in the history of the country. Scheuchzer[1] speaks of it as a fact long known and refers it to Lhwyd's genus Lithoxylon. Since that time specimens have been distributed quite generally throughout Europe. In 1818 some specimens came to the hands of Benj. Silliman[2] and formed the basis of a notice in the American Journal of Science. Mr. William Nicol stated in 1833[3] that he had examined upwards of a hundred specimens from the island of Antigua and found them chiefly dicotyledonous, but a few monocotyledonous, and no Coniferæ.

Prof. S. Hovey gives an interesting account of this locality in the American Journal of Science and Arts for January, 1839,[4] founded partly on personal observation, but also drawn largely from the papers of Dr. Nicholas Nugent[5] and those of Dr. Thomas Nicholson.[6]

He states that in addition to the silicified wood, or chert, so common on the island, petrified leaves have been found in the clay formation near its junction with the trap at Drew's Hill, and that these leaves belong to trees of the dicotyledonous class, among which Dr. Nicholson thought he recognized those of *Ficus pertusa* Nich. and a species of Melastoma. Professor Hovey gives a glowing description of the silicified remains, among which he imagined to occur petrifactions of *Pisonia subcordata* Nich. and of the cocoanut tree.

Not to mention numerous other allusions to this deposit, the recent elaborate paper of Dr. J. Felix, of Leipzig, on the fossil wood of the West Indies,[7] demands special mention. This paper is chiefly devoted to the wood of this locality, sixteen species being described from Antigua, five of which are palms, the remainder being dicotyledonous species. Dr. Felix has carefully studied these forms, and

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[1] Herbarium Diluvianum, ed. nov., 1723, p. 102.

[2] Petrified wood from Antigua, by B. Silliman: Am. Jour. Sci., vol. 1, 1818, pp. 56, 57.

[3] Observations on the structure of Recent and Fossil Coniferæ, by William Nicol: Edinburgh New Philos. Jour., vol. 16, 1834, pp. 137-158, 310-314. (See p. 155.)

[4] Geology of Antigua, by S. Hovey: Am. Jour. Sci., vol. 35, 1839, pp. 75-85.

[5] A sketch of the geology of the Island of Antigua, by Nicholas Nugent: Trans. Geol. Soc. London, vol. 5, 1821, pp. 459-475.

[6] Antigua Almanac and Register.

[7] Die Fossilen Hölzer Westindiens, von J. Felix: Sammlung palaeontologischer Abhandlungen, series 1, Heft 1, Cassel, 1883, pp. 1-29, pl. i-v.

establishes a number of new genera founded upon them. His genus Tænioxylon, which he places in the order of Leguminosæ, near to Cæsalpinia and Mimosa, receives three of these species; his Zittelia, having a somewhat similar structure and probably belonging to the same family, furnishes one species (*Z. elegans* Fel.); and his Cassioxylon one (*C. anomalum*), making seven species of that family. The Sapindaceæ are represented by *Schmideliopsis Zirkelii* Fel., the Anacardiceæ by *Anacardioxylon spondiaeforme* Fel., and the Ebenaceæ by *Ebenoxylon diospyroides*; besides these are described three species of his genus Helictoxylon, founded in 1883,[1] having numerous and very sinuous medullary rays indicating its relation to the lianes of the tropics.

The palms are all placed under the unnatural genus Palmoxylon.

SOUTH AMERICA.

Vegetable remains have been discovered in Chili, the Argentine Republic, Bolivia, and Brazil.

CHILI.

In 1835 Mr. Charles Darwin found "great prostrate silicified trunks of trees embedded in a conglomerate" near the house of his host, Don Benito, above Potrero Seco, west of the Upsallata Pass of the Cordilleras, the structure of which, he says, was perfectly preserved, and one of which measured 15 feet in circumference.[2]

Mr. Darwin, in his celebrated voyage round the world in Her Majesty's steamship *Beagle*, noted "fragments of wood" and "leaves of trees" on the eastern coast of Terra del Fuego on Sebastian Bay,[3] now absorbed in Chili. Dr. Hooker informed him that some of the latter belonged "to three species of deciduous beech, different from the two species which compose the great proportion of trees in this forest-clad land."[4]

Messrs. Mallard and Fuchs brought from Ternera, Chili, in the district of Atakama, some specimens of fossil plant of Jurassic age[5] which were determined by Messrs. Zeiller[6] and Schimper. The impressions occur in fine-grained grayish-blue sandstone schists, and are referred by the geologists above named to the base of the Jurassic or Rhetic formation. The only species described is *Pecop-*

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[1] Untersuchungen über fossile Hölzer, von J. Felix: Zeitschr. deutsch. geol. Gesell., vol. 35, Berlin, 1883, pp. 59–91, pl. ii–iv. (See page 66.)

[2] Journal of Researches, New York, 1871, p. 353.

[3] Geological Observations on South America, London, 1851, p. 118.

[4] J. D. Hooker: Botany of the Antarctic Voyage, H. M. S. Erebus and Terror, 1839–1843, vol. 2, London, 1847, p. 212.

[5] Bull. Soc. Géol. France, 3d series, vol. 3, 7 Dec., 1874, pp. 56.

[6] Note sur les Plantes fossiles de la Ternera (Chili), par R. Zeiller: Ibid., 1875, pp. 572–574, pl. xvii.

teris Fuchsi Schimp., but fragments determinable as *Jeanpaulia Münsteriana* Presl, *Angiopteridium Münsteri* (Göpp.) Schimp., *Pecopteris Göppertiana* (Münst.) Schimp., *Dictyophyllum acutilobum* Fr. Br., *Podozamites distáns* Presl., and *Palissya Braunii* Endl., accompanied the collection.

Consul Ochsenius discovered at Coronel, in southern Chili, latitude 36° south, in a lignite deposit probably of Miocene age, some interesting plant remains, which were elaborated by Dr. F. Kurtz and found to embrace one species of Sequoia allied to *S. Tournalii* Sap., a fern related to *Pteris eocenica* Ett. & Gard., and numerous dicotyledonous leaves resembling those of Nectandra and Tetranthera in the Laurineæ.[1]

ARGENTINE REPUBLIC.

Mr. Darwin seems to have been the first to discover vegetable remains in the Argentine Republic. While on his return from Mendoza to Valparaiso through Upsallata Pass, on March 29, 1835, he observed a veritable silicified forest, which is described on page 332 of the New York edition of his Journal of Researches. From the fact that it was on the next day that the party reached the custom-house, which must have been on the line between Chili and the Argentine Republic, it seems a safe inference that this region was within the territory of the latter country.

Alfred Steltzner, of Freiberg, while professor at the University of Cordoba, Argentine Republic, made in the years 1871-'73 two geological excursions, the one to the provinces of Catamarca and La Rioja, the other to the provinces of San Juan and Mendoza. The general results of the expeditions were published in the Neues Jahrbuch für Mineralogie, etc. (1872, pp. 630-636; 1873, pp. 726-744), and the more special results form Supplement 3 to Palaeontographica, 1876. Fossil plants were collected from five distinct localities: (1) Las Gredas on the eastern slope of the Sierra Famatina, province of La Rioja; (2) Las Mareyes in the province of San Juan, in the Sierra de la Huerta; (3) Punta de la Laja; (4) Challao (the last two on the eastern slope of Sierra Mendoza); (5) Cuesta Colorado, province of La Rioja. Most of the plants are found in the bituminous shale of Mendoza. At Agua de la Zorra occur numerous silicified trunks of trees standing erect, which did not escape the keen eye of Mr. Darwin[2] when in that country. The latter traveler submitted specimens of this wood to Mr. Robert Brown, the eminent botanist, who examined it microscopically and pronounced it coniferous, "partaking of the character of the Araucarian tribe, with some curious points of affinity with the yew."

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[1] Cf. Engler's Versuch einer Entwicklungsgeschichte der Pflanzenwelt, Theil 2, p. 11.

[2] Geological Observations on South America, London, 1851, p. 202.

The fossil plants and a few animal remains obtained on this expedition were investigated by Dr. Hanns Bruno Geinitz.[1] Seventeen different forms are distinguished, ten of which are from the coaly sandstone shales of Mareyes, in the province of San Juan. The plants all belong to the ferns, cycads, and Coniferæ, and include such characteristic Mesozoic genera as Thinnfeldia, Pachypteris, Pterophyllum, Otopteris, Baiera, and Palissya, which point to the base of the Jurassic, or Rhetic formation, as the probable age of these beds.

An apparently new locality, viz, at Cacheuta, south of Mendoza, but obviously of the same age as the beds last mentioned, has recently been brought to light by Dr. R. Zuber, fossil plants from which are described by Dr. Ladislaus Szajnocha of Cracow, to whom they were sent.[2] The forms present a remarkable resemblance to those of the Jerusalem beds of Tasmania and of the Tivoli and Ipswich mines of Queensland, classed as upper Trias, and even the supposed exceptional paleozoic type, *Cardiopteris Zuberi* Szajnocha, is pronounced by Nathorst to belong to the Rhetic genus Ptilozamites.[3]

In 1879 General Roca, of the Argentine army, conducted an expedition to the Rio Negro. On the south bank of that river Captain Rhode, of that expedition, collected eighteen specimens of silicified wood, which were subsequently sent to Dr. Hugo Conwentz, of Danzig, so well known for his researches into the amber inclusions of north Prussia and into the minute histology of fossil plants. His paper describing the forms detected in this collection was published by the Argentine Government in 1885.[4] The particular localities were west of Fresno-Menoco, Picu-Pren-Leuvú, and Katapuliche, in a formation believed to correspond to the Lower Oligocene of Europe. Dr. Conwentz found in this collection six distinct forms, to four of which he gives specific names, regarding them as distinct from any species hitherto described. Three of these forms were referable to the genus Cupressinoxylon, one to Glyptostroboxylon, and one to Araucaryoxylon. It is to be regretted that these structures are not figured in the report.

[1] Ueber Rhätische Pflanzen- und Thierreste in den Argentinischen Provinzen La Rioja, San Juan, und Mendoza, von Hanns Bruno Geinitz. Beiträge zur Geologie und Palaeontologie der Argentinischen Republik. II, Palaeontologischer Theil: Abtheilung II. Palaeontographica, Supplement III, Cassel, 1876, pp. 1–14, pl. i, ii.

[2] Ladislaus Szajnocha: Ueber die von Dr. Rudolf Zuber in Süd-Argentina und Patagonien gesammelten Fossilien. Verhandl. k.-k. geol. Reichsanstalt, Wien, 1888, No. 6, pp. 146–151. Sitzungsber. k. Akad. Wiss., Wien, math.-nat. Cl., vol. 97, Abth. 1, 1888, 27 pp., 2 pl.

[3] Neues Jahrbuch für Mineral., 1889, vol. 1, Heft 2, p. 202.

[4] Sobre Algunos Árboles Fósiles del Rio Negro, por el Dr. H. Conwentz: Boletin de la Academia Nacional de ciencias en Córdoba (República Argentina), vol. 8, Entrega 4ª Buenos Aires, 1885, pp. 435–456.

BOLIVIA.

M. Alcide D'Orbigny, in the paleontological part of the third volume of the report of his voyage in South America,[1] described and figured two species of Cruziana from the Upper Silurian of Bolivia. Both were found between Cotani and Sacava, in the province of Cochabamba, at Tiquipaya and Quillacollo, and to the east of Yamparaes, in the department of Chuquisaca.

A few vegetable remains of Tertiary age have recently been obtained by Dr. Ochsenius[2] at Cerro de Potosi, in Bolivia, which have been studied by Dr. Engelhardt.[3]

In the latter of these papers he describes and figures six new species founded on small but tolerably well preserved leaves, which he refers to Myrica, Cassia, Sweetia, and Phyllites.

BRAZIL.

Although the coal beds of the southern provinces of Brazil have long been known, no fossil plants were reported from them prior to 1869. The Geological Magazine for April of that year contains a short paper by Mr. Nathaniel Plant On the Brazilian coal fields, giving some account of these beds, which is followed by Mr. Carruthers's description of some specimens placed in his hands for identification.[4] The specimens came from the shales above the coal in the province of Rio Grande do Sul, and consist of one species of Noeggerathia (*N. obovata* Carr.), one of Odontopteris (*O. Plantiana* Carr.), and one of Mr. Carruthers's genus Flemingites (*F. Pedroanus* Carr.), founded on its peculiar strobilus, which differs from that of Lepidostrobus in having a double row of sporangia under each scale. The character of these remains places the Carboniferous age of the Brazilian coal fields out of question.

Prof. Orville Derby, of the Brazilian Geological Survey, collected at Rio Trombetos and Rio Curuà some specimens showing peculiar

[1] Voyage dans l'Amérique Méridionale (le Brésil, la république orientale de l'Uruguay, la république Argentine, la Patagonie, la république du Chili, la république de Bolivia, la république du Pérou), exécuté pendant les années 1826, 1827, 1828, 1829, 1830, 1831, 1832 et 1833 [Publié sous les auspices de M. le Ministre de l'Instruction publique], par Alcide D'Orbigny. Vol. 3, Géologie; 4e partie, Paléontologie, Paris et Strasbourg, 1842, pp. 1–188, pl. i–xxii. (Foss. plants, pp. 30, 31, pl. i.)

[2] Ueber das Alter einiger Theile des Südamericanischen Anden, II, von Carl Ochsenius: Zeitschr. deutsch. geol. Gesell., vol. 39, Heft 2, 1887, pp. 301–313.

[3] Ueber fossile Blattreste vom Cerro de Potosi in Bolivia, von H. Engelhardt: Sitzungsber. naturwiss. Gesell. Isis in Dresden, 1887, Abh. V, pp. 36–38, pl. i, fig. 10–16.

[4] On the Plant Remains from the Brazilian Coal Beds, with Remarks on the Genus Flemingites, by William Carruthers: Geol. Mag., vol. 6, London, 1869, pp. 151–156, pl. v, vi.

spores, which he brought to Washington and submitted to me for examination in 1882 or 1883. With them were other specimens exhibiting fragments of Lepidodendron or Sigillaria embedded in quartz. The latter were too imperfect for identification, but the former interested me greatly; and knowing that Dr. J. W. (now Sir William) Dawson, had been making investigations of similar spores, I suggested that these be sent to him for determination. The results of his study of these objects were laid before the geological section of the American Association for the Advancement of Science at its thirty-second meeting, in Minneapolis, August, 1883. In his paper he described them as *Sporangites* (*Protosalvinia*) *Braziliensis*, and *S.* (*P.*) *bilobatus*, from their analogy to forms found in the Devonian in Canada. The supposition that the Brazilian beds belong to that age is natural, though it is, of course, merely a supposition.

While investigating these specimens Dr. Dawson discovered that he was already in possession of certain other spore cases, collected by the late Professor Hartt at Rio Tapagos above Haituba, in Brazil, and that he had prepared, but not yet published, a brief description of them under the name of Sporangites.[1]

Dr. Dawson also states[2] that Professor Hartt had found plants belonging to the genus Spirophyton of Hall in beds referred to the Carboniferous period on the Rio Tapajos, in Brazil, and that he had described the species as *S. Braziliense* and sent the manuscript to Professor Hartt for publication in his reports.

HONDURAS.

The only report that has reached me of the discovery of fossil plants in any part of Central America is contained in two recent papers by Dr. J. S. Newberry[3] giving an account of material sent him by Messrs. Chas. M. Rolker and T. H. Leggett, mining engineers, from San Juancito, Honduras, from which he has described fourteen species of cycads and ferns, the characters of which point to an upper Triassic (Rhetic) age for the bed that yielded them, apparently contemporaneous with that on the Yaki River, Sonora, Mexico, presently to be considered, and also probably with the one in the vicinity of the city of Mexico made known by Señor Barcena.

[1] On Rhizocarps in the Palæozoic Period, by J. W. Dawson: Canadian Record of Science, vol. 1, Montreal, 1885, pp. 19–27.

[2] Quart. Jour. Geol. Soc. London, vol. 37, 1880, p. 303.

[3] J. S. Newberry: Triassic plants from Honduras. Trans. N. Y. Acad. Sci., vol. 7, Jan. 30, 1888, pp. 113–115.

Rhætic Plants from Honduras. Am. Jour. Sci., 3d series, vol. 36, November, 1888, pp. 342–351, pl. viii.

MEXICO.

Dr. J. S. Newberry, in his report on the Geology of the Macomb Expedition,[1] made in 1859, described thirteen species of fossil plants from the Trias of Los Bronces and the Yaki River in Sonora, Mexico, collected by Messrs. Remond and Hartley. They represent the genera Otozamites, Pterophyllum, Jeanpaulia (Baiera), Tæniopteris, Camptopteris, Pecopteris, and Alethopteris.

In the National Museum collection there are a few specimens collected by Mr. Ellis Clarke at the city of Mexico. These specimens were recently sent to Prof. Leo Lesquereux, at Columbus, Ohio, for identification, and have since been returned. Professor Lesquereux describes them in a contribution to the Proceedings of the United States National Museum.[2] One of these specimens (Museum No. 2151) is *Calamites approximatus* Schloth., var. *cruciatus* Lx. (p. 22); another (No. 2202) is a new species of Pecopteris (*P. Powellii*, p. 26, pl. i, fig. 1 1*a*); the third (No. 2270) is a species of Cordaites (p. 31) not sufficiently definite to be named.

Señor Mariano Barcena, professor of geology in the preparatory school, City of Mexico, brought to Washington in 1884 a few specimens of fossil plants collected in the vicinity of the City of Mexico, which he had provisionally named, and which were referred to me for verification. The forms indicated such a decided Jurassic facies that I decided to send them to Prof. William M. Fontaine, at the University of Virginia, author of the Older Mesozoic Flora of Virginia, who, I was sure, would be able to express an opinion as to their age. The specimens were shortly after returned with a letter, which, as it has not been published, I introduce here.

UNIVERSITY OF VIRGINIA, VA.,
November 11, 1884.

DEAR SIR: I must ask your pardon for not having replied sooner concerning the plants sent by Mr. M. Barcena.

I should say that these plants indicate positively that the age of the beds containing them is Rhætic, and not Triassic. The fern marked No. 4 belongs to the Jurassic type of which *Pecopteris Whitbiensis* is the most widely spread form. Heer considers these plants to be Asplenium; I think that this fern may be considered a new species. In the absence of fructification, it seems to me to be better to retain the name Cladophlebis, which Schimper gave to the group of which

[1] Report of the Exploring Expedition from Santa Fé, New Mexico, to the Junction of the Grand and Green Rivers of the Great Colorado of the West, in 1859, under the command of Capt. J. N. Macomb: with a Geological Report by Prof. J. S. Newberry, Geologist of the Expedition. Washington, 1876, 152 pp., 8 pl., 4°. (Foss. pl., pp. 141–148, pl. iv–viii.)

[2] List of recently identified fossil plants belonging to the United States National Museum, with descriptions of several new species, by Leo Lesquereux: Proc. U. S. Nat. Mus., vol. 10, 1887, pp. 21–46, pl. i–iv.

Pecopteris Whitbiensis is the type. I would then regard this plant as most probably a new species of Cladophlebis. It is a good deal like some of the narrow sterile forms of my *Mertensides bullatus*, Bunbury's *Pecopteris bullatus*.

On the specimen marked No. 3, there are probably two distinct cycadaceous plants, viz, the one with larger and wider leaves, marked "*Ptilophyllum Herraræ*," and a plant with smaller and shorter leaves, which is of the same type with the larger. This smaller plant, probably considered by Mr. Barcena to be the same as the larger and hence unmarked, is, I think, distinct. It belongs to the type *Ctenophyllum Braunianum*, so characteristic of the Rhætic. It is, I think, the same with the plant from the North Carolina Rhætic that Emmons called *Pterozamites obtusus*, and which I have called *Ctenophyllum Emmonsi*. The larger plant, marked No. 3, and called by Mr. Barcena *Ptilophyllum Herraræ*, is not inserted by the lower part of the bases of the leaflets, as Ptilophyllum is. The tips of the leaflets are narrowed after the peculiar fashion of *Ctenophyllum Braunianum* ; it is not identical with any plant known to me. It is something like the *Podozamites longifolius* of Emmons, from the North Carolina Rhætic, which I have called *Dioonites longifolius*. It is, however, a different species, and being probably a new one, I would suggest the name *Ctenophyllum Herraræ*.

The plant marked No. 1, and called *Ptilophyllum ? rigidum*, is the same, I think, with *Ctenophyllum Emmonsi*, being simply a larger specimen of the same species.

The very large leaflets, marked No. 2, and called *Pterophyllum ? Ferrarii*, belong certainly to my *Ctenophyllum grandifolium* from the Virginia Rhætic.

The plants are decidedly Rhætic.

Yours truly,

WM. M. FONTAINE.

Prof. LESTER F. WARD.

ARCTIC REGIONS.

Probably the most important result of paleobotanical science is the light it has shed upon the geologic and the climatic history of the Arctic regions. The numerous Arctic expeditions which have been sent out for various objects in most cases have brought back valuable scientific material of different kinds. But especially within the last forty years the records and collections of Inglefield, McClintock, Richardson, Steenstrup, Nordenskiöld, Blomstrand, and others, whose attention has been particularly directed into scientific channels, have furnished a basis for a correct solution of most of the problems of Arctic research.

By far the greater part of the fossil plants from these regions were placed in the hands of Prof. Oswald Heer, whose published reports upon them form an enduring monument to his indefatigable zeal and scientific ability. No less than twenty-three distinct papers, some of them quite extended, were published by him on this subject between the years 1868 and the year of his death, 1883. His first report, which he seems at the time to have regarded as complete, appeared in 1868 as the "Flora Fossilis Arctica : Die fossile Flora der Polarländer" (Zürich, 1868) and forms volume 1 of the complete work. The remainder appeared at intervals as contributions to the Memoirs of the Swedish Academy of Sciences, the Philosophical Transactions of the Royal Society of London, Memoirs of the Imperial Academy of Sciences at St. Petersburg, and other scientific serials. These papers were collected into volumes of convenient size and published as the continuation of the Flora Fossilis Arctica, which now consists of seven volumes. The last of these bears date 1883.

NOVA ZEMBLA.

In the summer of 1875 Nordenskiöld collected a number of fossil plants at Goose Cape, in Nova Zembla, which were sent to Heer and described in the memoirs of the Swedish Academy of Science, vol. 15, No. 3. The paper now forms part 5 of the fifth volume of the Flora Fossilis Arctica. All the plants belonged to the genus Cordaites, of which there were four species, exclusive of a fruit which was called Rhabdocarpus, but was probably the fruit of a Cordaites; the formation is therefore no doubt Carboniferous, although Heer seems to suppose that it may be at the base of the Permian.

BEAR ISLAND.

This small island, which lies between Lapland and Spitzbergen, in latitude 74° 30′ N., has been frequently visited by scientific expeditions, beginning with those of Sir Edward Perry and B. M. Keilhau, in 1827, and followed by those of Lovén (1837), Robert (1838), Lamont (1858), and the Swedish expeditions of 1858, 1861, 1864, and 1868. It was during the last named of the above voyages that Nordenskiöld and Malmgren made a collection of some three hundred and sixty specimens of fossil plants. Heer's determinations of these specimens were published in the Memoirs of the Stockholm Academy (vol. 9, No. 5, 1871) and now form the first part of the second volume of his Flora Fossilis Arctica. The plant remains confirm the views of the geologists who had studied this formation, according to which it represents the Bergkalk of Europe, which underlies the productive coal measures.

Of the eighteen species occurring in this collection only four were new, the remainder being all old, well-known species, found in the Ursa-Stufe, Bergkalk, and Culm, of Europe. Among them are the wide-spread *Lepidodendron Veltheimianum* Sternb., *Knorria imbricata* Sternb., and *Stigmaria ficoides* (Sternb.) Brongn. *Cyclostigma Kiltorkense,* and *C. minutum* of Haughton, from the Devonian of Ireland, also occur.

SPITZBERGEN.

The first installment of fossil plants from Spitzbergen that Heer elaborated was collected by Nordenskiöld and Blomstrand in their several expeditions of 1858, 1861, and 1864. According to Heer's geological conceptions, they were of Miocene age, and consisted chiefly of conifers and dicotyledons. Besides these, two ferns and two monocotyledonous plants are described. The conifers embrace two species of Taxodium and one of Pinus; also three species of Pinites, described by Cramer in the appendix to Heer's paper (ibid., pp. 175–177). Among the dicotyledons we find the well known *Alnus Kefersteinii* Göpp., *Corylus McQuarrii* (Forbes) Heer, *Fagus Deucalionis* Ung., and *Platanus aceroides* Göpp., of European Miocene strata. The remainder of the species were new to science, and of these *Populus Richardsoni*, *P. arctica*, and *Tilia Malmgreni* have since played an important rôle in the fossil floras of the polar districts and of America.

The most of these forms were collected at Bell Sound and King's Bay, but the fossil wood came from Green Harbor.

This small collection was supplemented in 1868 by a much larger one made by Nordenskiöld, Malmgren, and Nauckhoff, consisting of some seventeen hundred specimens, five hundred of which were from King's Bay, the remaining twelve hundred from a new locality on Cape Staratschin. This last locality appears to be of the same age as the others, but on Advent Bay was found a much more recent bed containing *Mytilus edulus* L. and other recent shells, which also yielded thirty-one species of plants, chiefly mosses, that were determined by Professor Schimper, at Strasburg. Besides mosses occurred *Fucus canaliculatus*, a species of Laminaria, and *Equisetum variegatum* Schloth. This bed is of Quaternary age.

The entire collection of plants formed the subject of a memoir by Heer, read before the Swedish Academy of Sciences on December 30, 1869, and published in vol. 8, No. 7, of its transactions. It was ultimately incorporated into the Flora Fossilis Arctica (vol. 2, pt. 3).

The Miocene flora of Spitzbergen had now assumed considerable prominence, numbering one hundred and thirty-two species, divided as to the larger systematic groups as follows: cryptogams, 8; gymnosperms, 26; monocotyledons, 33; apetalous dicotyledons, 16; polypetalous dicotyledons, 22; gamopetalous dicotyledons, 6. The remaining 21 are fruits (Carpolithus) which, if distributed among these groups, would somewhat increase these figures.

In the summer of 1870 Nathorst and Wilander visited Spitzbergen and found at Klaas Billen-Bai a Subcarboniferous deposit containing fossil plants, and from materials collected there and submitted to Heer five species were identified, three of which were the same as those found on Bear Island, but one new species (*Cyclostigma Nathorsti* Heer) was described in his memoir presented to the Swedish Academy on July 16, 1873 (Handlingar, vol. 12).

Two years later (August, 1872) Nordenskiöld again visited Spitzbergen and re-investigated the geology of Cape Staratschin. This time he found another bed of fossil plants lying some two or three thousand feet below the Miocene shales. This proved to be of Lower Cretaceous age, probably equivalent to the Gault or the Urgonian, and to the Kome beds of Greenland. The fossil plants were described in Heer's Kreide-Flora der Arctischen Zone,[1] which is now incorporated in his Flora Fossilis Arctica, vol. 3, pt. 2. Fifteen species are enumerated in this report, five of which are ferns and eight Coniferæ. There were no dicotyledons and only one monocotyledon, described as *Hypoglossidium antiquum*, a small elliptical leaf with longitudinal nervation.

In the Robert Valley, north latitude 77° 33′, Nordenskiöld discovered fossil plants lying in a black carbonaceous shale, favorable for their preservation; they proved to be of Carboniferous age, somewhat more recent than the Bergkalk of Klaas Billen-Bai and of Bear Island. Twenty-six species from this locality are described in the first part of Heer's memoir presented to the Swedish Academy on the 23d of August, 1875 (Handlingar, vol. 14, No. 5, Stockholm, 1876), which forms part 1 of the fourth volume of the Flora Fossilis Arctica. A considerable number of these are new species, but we still find such common forms as *Lepidodendron Sternbergii* Brongn. and *Cordaites borassifolius* (Sternb.) Ung. One species of Walchia (*W. linearifolia* Göpp.) serves to indicate that the deposit occupies the upper portion of the Carboniferous formation.

In the year 1872 there were collected at Cape Boheman (latitude 78° 22′ N.), by Nordenskiöld and Oberg, certain plant remains which proved upon investigation to belong to the Jurassic formation. Among them occurred numerous cycadaceous forms, chiefly of the genus Podozamites. The Coniferæ were represented by several exceedingly interesting species of Ginkgo, two of which had long been known, from Oolite of Scarborough, England. Thirty-two species were enumerated in the second part of Heer's memoir last referred to (pp. 26–47, pl. vi–x).

In the third part of the same paper several additional species of Cretaceous plants collected by Nordenskiöld in 1873, at the same locality on Cape Staratschin where the principal collection was made the previous year, are enumerated, and a few new species are described.

Finally, a large addition was made to the Miocene flora of Spitzbergen by Nordenskiöld's discoveries, in 1863, at Cape Lyell, entrance to Bell Sound (lat. 77° 50′ N.), at the Scott Glacier on Recherche Bay (lat. 77° 30′ N.), and at Cape Heer, Grünhafen (lat. 78° 5′ N.). These plants were described in the fourth part of the same memoir (pp. 51–93, pl. xi–xxxii). Seventy-one species are enumerated in this paper, a large number of which are new to science, but the general facies of these three floras is essentially the same as that of King's Bay and Bell Sound, described in a former paper.

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[1] Kongl. svensk. Vet.-Akad. Handl., vol. 12, No. 6, Stockholm, 1874.

ICELAND.

Although Iceland lies entirely outside the Arctic Circle, still it naturally belongs to the general group of localities now under consideration, and can be better treated here than elsewhere.

Professor Steenstrup, in 1838 and 1839, obtained fossil plants at Brjamslaek, Hredavatn, Laugavatsdlr, and Tindarfell, and brought them to Copenhagen. In 1857 Dr. Winkler, of Munich, visited Iceland and collected fossil plants at Husavik, Gaulthvamr, Sandafell, and Tindarfell. Both these collections found their way into Professor Heer's hands, and the plants are described in the first volume of the Flora Fossilis Arctica (pp. 139–155, pl. xxiv–xxviii). The deposits belong to Heer's Arctic Miocene, and forty-two species were distinguished; nevertheless, a comparatively small number are specifically identical with those found at localities within the Arctic Circle, and most of the species are new. The Coniferæ and the apetalous dicotyledons are the groups best represented, the genus Pinus furnishing seven species, and the Betulaceæ four species.

In 1886 Paul Windisch made the Tertiary flora of Iceland the subject of his inaugural dissertation for the degree of doctor of philosophy at the University at Leipzig.[1] Besides furnishing a valuable historical account of antecedent discoveries, he undertook the elaboration of a collection which Dr. C. W. Smith, of Berlin, had brought from Iceland in 1883. The collection contained petrified wood from Husavik and Bödvarsdalr, lignite from the Surturbrand, and other determinable remains from Tröllatunga, Brianslaekr, Husavik, and Vindfell.

GREENLAND.

Of all the lands belonging to the Arctic regions none has furnished so extensive, so rich, or so varied plant-bearing deposits as Greenland. Captain Inglefield, in his third Arctic voyage in 1854 in company with Lieutenant Colomb, visited the petrified forest of Atanekerdluk, opposite Disco Island, on the west coast of Greenland, and collected fossil plants there. Those obtained by Inglefield were turned over to the British Geological Survey at London, and those obtained by Colomb to the Museum of the Royal Society of Dublin. Olrik, on his return trip in 1859, touched at the Greenland locality and brought from the same beds another rich collection of these fossils, which were also sent to the Dublin Museum after passing through the hands of Sir Leopold MacClintock. Whether the specimens brought by Dr. Torrell, of Stockholm, were from the same locality is somewhat doubtful, though Heer inclines to think they were. Those collected by Dr. Lyall and placed in the museum at

[1] Beiträge zur Kenntniss der Tertiärflora von Island (Inaugural-dissertation), von Paul Windisch. Halle, 1886, 52 pp., 8°.

Kew were obtained on the east side of Disco Island, near sea level. Besides these localities yielding fossil plants, that of Kome, in the bay of Omenak at the north of Greenland, had been visited by Rink and others, and a few fossil plants had been obtained.

All this material was eventually intrusted to Heer for determination, and its description formed a large part of volume 1 of the Flora Fossilis Arctica (pp. 78–129, pl. i–xix; xlii–l).

The plants from Kome, of which sixteen species are described. indicate a Lower Cretaceous age, which has been correlated with the Urgonian or next lowest member of the Cretaceous. They consist chiefly of ferns and Coniferæ, but one cycadaceous species (*Zamites arcticus* Göpp.) and one supposed monocotyledon (*Fasciculites Grœnlandicus* Heer) occur. The bed at Atanekerdluk is placed in the Miocene, though a large proportion of the forms are new. It shows the usual preponderance of apetalous dicotyledons, characteristic of the Arctic Tertiary flora.

A large collection made by Mr. Edward Whymper in 1867, at Ujararsusuk and Kudliset, on the island of Disco, and at Atanekerdluk (chiefly from the last named place), furnished the subject of an important memoir of Heer, communicated by Professor Stokes to the Royal Society of London.[1]

Of the seventy-three species from Atanekerdluk forty-eight had been previously described, leaving twenty-nine new to science. Fourteen species were obtained from Disco Island, two of which (*Sequoia Couttsiæ* Heer and *Platanus Guillelmæ* Göpp.) appear to have been very abundant. "It appears, therefore," says Professor Heer, "that at the Miocene epoch the woods of this part of Disco Island were chiefly composed of Planes and Sequoias." These important additions to the Miocene flora of Greenland do not materially alter its general relationship to that of Europe.

In 1871 Freis and Nauckhoff brought to Stockholm some fossil plants which they collected at Ujararsusuk. Upon examination by Heer, to his great surprise, they were found to represent, besides the Miocene as in former cases, the Carboniferous and the Cretaceous formations. From the Carboniferous one species (*Protopteris punctata* (Sternb.) Presl., is represented by seven specimens, which agreed so completely with the European forms that he found it impossible to separate them from it. Cretaceous forms (two species of Gleichenia and two of Sequoia) were found,[2] all of which were new.

In his Kreide-Flora der Arctischen Zone (Flora Fossilis Arctica, vol. 3, pt. 2; Kongl. svenska Vet.-Akad. Handl., vol. 12, No. 6, Stock-

[1] Contributions to the Fossil Flora of North Greenland, being a Description of the Plants collected by Mr. Edward Whymper during the summer of 1867, by Oswald Heer: Philos. Trans. Royal Soc. London, vol. 159, 1869, pp. 445–488, pl. xxxix–lvi; Flora Fossilis Arctica, vol. 2, pt. 4.

[2] Flora Fossilis Arctica, vol. 3, pt. 1, p. 7; pt. 2, p. 90.

holm, 1874) both the Upper and the Lower Cretaceous floras of Greenland are treated systematically; the material for the report was obtained by the Swedish expeditions of 1870 and 1872. The Lower Cretaceous or Urgonian deposits lie on the north side of the peninsula of Noursoak at Kome, on Kook River (lat. 70° 37′ N.), at Pattorfik (lat. 70° 42′ N.), at Karsok (lat. 70° 43′ N.), at Avkrusak and at Ekkorfat in the same vicinity. Seventy-five species are enumerated from these places, thirty-four of which (excluding the two species of Jeanpaulia, then regarded as ferns) were ferns, nine species were cycads, and nineteen (including the Jeanpaulias) were conifers, but the most notable fossil plant discovered was his *Populus primæva*, described on page 88 (pl. xxiv, fig. 6), which remains to this day the most ancient dicotyledonous plant thus far published.[1]

The Middle Cretaceous flora of Greenland, which Heer correlates with the Cenomanian of Europe, is represented by the now celebrated Atane beds, which lie at the base of the same eminence in which, at the height of 1,200 feet above sea level, the rich "Miocene" deposits occur. Sixty-two species are given in this report from that locality; the proportion of ferns is somewhat smaller and that of conifers much less than in the Kome beds; but on the other hand the dicotyledonous flora now forms a prominent feature, furnishing more than half of the forms enumerated. Among these are represented the genera Populus, Myrica, Ficus, Sassafras, Proteoides, Credneria, Andromeda, Diospyros, Magnolia, Sapindus, and Rhus.

A short supplement to this report was published in 1882 and forms the second part of the sixth volume of the Flora Fossilis Arctica. Nine species of Lower Cretaceous plants from Pattorfik and thirty-one Miocene species are added in this supplement.

But these numerous and important memoirs were destined to form merely a beginning of Heer's researches into the fossil flora of Greenland. The Danish commission for the geological and geographical investigation of that country sent able explorers, geologists and collectors, to all the principal points of scientific interest, who returned to Copenhagen during the years 1878, 1879, and 1880 with a much larger mass of material than had been previously obtained. Steenstrup, Pfaff, Jörgensen, and Krarup Smith not only re-investigated the old localities but discovered new ones. Especially important were the beds on Upernavik Island, Umenak Fiord, and at Patoot. At the last named place a formation occurs in which fossil plants had not been found before, being more recent than the Atane beds. Heer correlates this formation with the Fox Hills group of the western United States and the Senonian of Europe.

[1] The name first appears in a paper entitled: Förutskickade anmärkningar öfver Nordgrönlands Kritflora, grundade frå den svenska expeditionens upptäckter 1870, af Osw. Heer: Öfversigt af Kongl. sevensk. Vet.-Akad. Förhandl., No. 10, Stockholm, 1871, p. 1182.

These collections were turned over in 1880, like the preceding, to Professor Heer, in twenty-five large boxes, and although then seventy years old he undertook, not without serious misgivings, the formidable task of their elaboration. Some idea of his remarkable industry may be gained when we are told that on the first day of July, 1883, the last of the one hundred and nine plates which it required to figure these plants was received by the commission for publication. These illustrations were primarily published as an atlas to the fifth part of the commissioners' report on Greenland.[1] An elaborate report by Dr. Heer accompanying the plates was published in the text of the fifth volume of the Meddelelser om Grønland, after having been translated into the Danish language (pp. 79–202) but in it the species are not described. This latter work was reserved for the Flora Fossilis Arctica, in which the plates of the Danish commission are reproduced, accompanying an elaborate descriptive text, the whole constituting a second Abtheilung of the sixth and the whole of the seventh volume of that work.

It would carry us quite too far to undertake an extended review of this important contribution, and we shall be obliged to confine ourselves to a brief résumé. Beginning with the lowest or Kome beds (Urgonian) we find them to have yielded 88 species from six localities, namely: Kome, 38; Kaersuarsuk, 11; Pagtorfik, 32; Kaersut, 12; Slibestensfield, 44; and Ekorgfat, 33. It will be seen that 92 species were common to two or more of these localities. The additions made to this flora did not appreciably affect the systematic relations as already given above, and no other dicotyledons than the one species there mentioned have yet been found.

The Middle Cretaceous or Atane beds had now furnished 177 species from seventeen distinct localities, the most productive of which was the Liriodendron bed at Atanekerdluk, with 96 species; the other rich deposits being Igdlokunguak with 44 species, Kitdlusat with 24 species, Upernavik with 17 species, Kardlok, Isunguak, and the fern bed at Atanekerdluk each with 16 species, and Ivnanguit with 15 species. The other and less productive localities are: Lower Atanekerdluk (11 species), Atane and Ritenbenk's coal mine (9 each), Alianaitsunguak (8), Lower Patoot sandstone (7), Asuk (5), Ujaragsugsuk and Skandsen (4 each), and Kook angnertunek (3). In this large flora the dicotyledons, conifers, and ferns about hold their own, while the Cycadaceæ and the monocotyledons are somewhat increased.

The Upper Cretaceous or Patoot deposits here treated for the first time have a more special interest. The flora amounts in all to 118 species, 21 of which are cryptogams, all but two (*Sphæria Cretacea*

[1] Meddelelser om Grønland, udgivne af Commissionen for Ledelsen af de geologiske og geographiske Undersøgelser i Grønland. Tillæg til Femte Hefte, Flora fossilis Grønlandica. Afbildninger af Grønlands fossile Flora, ved Dr. Oswald Heer. Kiobenhavn, 1883, 27 pp., 109 pl., map, and landscapes, 4°.

Heer and *Equisetum amissum* Heer) being ferns. There are no cycads, only 11 conifers, 5 of which belong to Sequoia, and 5 monocotyledons, leaving 75 dicotyledons, or about five-eighths of the species.

In addition to these Cretaceous forms the later collections contained a very large number of specimens from the Miocene deposit, bringing the total number up to 282 species. The following are the Tertiary localities with the number of species yielded by each: Upper Atanekerdluk, lower siderite bed, 143, upper marl bed, 78; Haseninsel (Hare Island), 53; Naujat, 33; Puilasok, 30; Ritenbenk's coal mine, 29; Kugisnek, 21; Kardlunguak and Sinigfik, 20 each; Isunguak, 19; Ifsorisok and Igdlokunguak, 15 each; Ujaragsugsuk, 12; Ingnerit and Unartok, 11 each; Asakak, 9; Schanze, 6; Kangiusak, 5; Marrak and Kitingusait, 4; and Flakkerhuk, 4; with 256 species common to two or more of these localities.

We thus have a general summary of the flora of Greenland at that date: One Carboniferous species; 335 Cretaceous species, of which latter 88 belong to the Lower, 177 to the Middle, and 118 to the Upper Cretaceous, 38 overlapping; and 282 Tertiary species; making 618 fossil plants from Greenland.

GRINNELL LAND.

The highest latitude on the globe at which fossil plant remains have been discovered is near Water Course Bay, on the north side of Grinnell Land (lat. 81° 46′ N.), where, on the 16th and 17th of August, 1876, Captain Feilden and Dr. Moss, of the English expedition commanded by Captain Sir G. Nares, after nearly a year's stay in the vicinity, in ignorance of their existence and only two days previous to their final departure, discovered them and made a small but valuable collection. They found them in a gulch four miles north of Discovery Bay, in the vicinity of Cape Murchison, at an altitude of about two hundred feet above the sea level and one mile from the coast. They were in a bed of coal which, had it been previously known, might have furnished abundant fuel during the long arctic winter which was passed at Discovery Bay.

This material upon examination yielded 30 species, and proved that the coal-bed was of Tertiary age, similar to other Arctic Tertiary beds. The Coniferæ were well represented, furnishing 11 species, 5 of which belonged to Pinus, and 5 to the new genus Feildenia. There were 12 dicotyledons, including 2 species of Populus, 2 of Betula, and 2 of Corylus, all of which occur in other localities of the Arctic regions. Only 7 of the species are new, and several of them are well known European Miocene forms.

BATHURST ISLAND.

Taking up the islands of the Arctic American Archipelago that have yielded plant remains, from east to west, we meet first with

Bathurst Island, where a single species (*Pinus Bathursti* Heer) was collected by Sir L. MacClintock in the coal of Graham Moore Bay, which is probably of the same age as the other Arctic Tertiaries.

MELVILLE ISLAND.

The same explorer discovered a Subcarboniferous deposit on Melville Island, in Skene Bay near the promontory of Bridport, and at Cape Dundas, which yielded ten species, all but one of which were new, but several were too fragmentary for specific determination. The coal bed at Village Point, from which he obtained the coniferous species *Thuyites Parryanus*, is probably of Mesozoic age, perhaps Jurassic.

BANKS'S LAND.

Finally, six species were obtained on Banks's Land by MacClintock and MacClure, two of which (*Pinus MacClurei* Heer, and *P. Armstrongi* Heer), were represented by cones; those of the first-named species were in a fine state of preservation. This, together with three species of Cupressinoxylon and one of Betula (*B. MacClintockii* Cram.), were represented by stems and trunks, which, together with other fossil wood from Greenland and Spitzbergen, were studied by Cramer and published in the first volume of the Flora Fossilis Arctica.[1]

NORTH AMERICA.

MACKENZIE RIVER.

We may commence our description of North American localities for fossil plants, with the interesting bed discovered on the Mackenzie River (lat. 65° N., or 3° outside of the Arctic Circle) by Dr. Richardson, and brought to London in 1848. This collection forms an integral part of the Arctic flora as described by Heer, and the species were named in the Flora Fossilis Arctica.[2]

Seventeen species are there enumerated, ten of which are new. All but six were dicotyledons, and among these occur the wide-spread Miocene species, *Corylus McQuarrii* (Forbes) Heer and *Platanus aceroides* Göpp., while among the Coniferæ we find *Glyptostrobus Europæus* (Brongn.) Heer and *Sequoia Langsdorfii* Brongn. The deposit appears, therefore, clearly to be of Tertiary age, and is probably the same as the other Arctic Tertiary flora.

Many efforts were subsequently made to obtain additional material from this locality, and the Hudson Bay Company several times col-

[1] Heer's treatment of the American archipelago occupies pp. 131–135 of the first volume of the Flora Fossilis Arctica, and Cramer's description of the fossil wood of the Arctic regions, pp. 167–180, pl. xxxiv–xlii of the same volume.

[2] Flora Fossilis Arctica, vol. 1, pp. 135–139, pl. xxi–xxiii.

lected fossil plants there; but, with the exception of one box, all these specimens were lost on their way to London. This box contained fourteen species, seven of which had already been described in the above mentioned report. The total flora, therefore, of the Mackenzie River region, so far as known, now amounts to twenty-three species, the later collections having added *Xylomites borealis* Heer, *Taxodium distichum miocenum* Heer, *Juglans acuminata* Al. Braun, *Viburnum Nordenskiöldi* Heer, *Magnolia Nordenskiöldi* Heer, *Pterospermites spectabilis* Heer, and *Tilia Malmgreni* Heer.

The report upon this new material forms the third part of the first Abtheilung of the sixth volume of the Flora Fossilis Arctica, in which the author enters into a somewhat lengthy discussion of the probable age of these beds, defending his views, so persistently adhered to. that the Arctic Tertiary flora is Miocene.

BRITISH COLUMBIA.

The earliest mention of fossil plants in British Columbia is contained in the geological volume of the report on the Wilkes Exploring Expedition, by Prof. J. D. Dana, published in 1849. At the mouth of Frazier River there was picked up by that expedition a slab containing the imprint of a number of leaves, stems, etc. This slab is figured in the atlas accompanying that volume (pl. xxi, fig. 10), and a brief account of its discovery is given in Appendix I (pp. 729–730) of that report. One of the specimens figured was regarded by Professor Dana as belonging to Smilax, but the dicotyledonous leaves, though tolerably well preserved, are pronounced uncertain. The figures are not sufficiently clear to render their determination safe without access to the specimens, but the genera Carpinus, Rhamnus, and perhaps Berchemia appear to be represented. The Taxodium is the common Tertiary form (*T. distichum miocenum* Heer) and the other coniferous branch is doubtless *Glyptostrobus Europæus* or *G. Ungeri*. The cone belongs to Taxodium, and the reed-like stems represent either Phragmites or Arundo.

The next report from this district that we have in order of date is contained in a paper contributed by Prof. Leo Lesquereux to the American Journal of Science in 1859[1] (report upon a collection made by Dr. John Evans, United States geologist of the Territory of Oregon, at Nanaimo, on Vancouver Island), in which six species are described from that point along with a number from Bellingham Bay, Washington Territory. Although the formation yielding these plants was supposed at the time to be Miocene, it is now known to be Upper Cretaceous.

[1] On some Fossil Plants of Recent Formations, by Leo Lesquereux. I, Species of Fossil Plants collected by Dr. John Evans at Nanaimo (Vancouver Island), and at Bellingham Bay, Washington Territory: Am. Jour. Sci., 2d series, vol. 27, 1859, pp. 360-363.

In 1863 Dr. J. S. Newberry published a report upon another collection made at the same place by Mr. George Gibbs,[1] but consisting of only four species, which are described, along with a number of others, from Orcas Island, Bellingham Bay, and Birch Bay, in Washington Territory.

A third collection was made in 1859 by Dr. C. D. Wood, not only at Nanaimo but also at Burrard Inlet and Lea Beach, British Columbia, and sent to Sir J. D. Hooker, at London, who turned it over to Heer for determination. It forms the subject of a valuable memoir published in 1865.[2] Seven species are described, chiefly from Burrard Inlet, though *Sequoia Langsdorfii* occurred from Nanaimo. The most abundant species was *Diospyros lancifolia* Lx., first noted at Bellingham Bay. Very fine specimens of that species are figured.

In the Report of Progress of the Geological Survey of Canada, 1871–'72 (Montreal, 1872, pp. 58, 59), Dr. A. R. C. Selwyn gave an account of some lignite beds on the Pacific coast, near Kamloops Lake and Quesnel Mouth, from which were obtained a few plant remains. Among them Dr. Dawson recognized *Taxodium cuneatum* Newb., and fragments of Quercus, Platanus, Pterospermites, Acer, and Populus.

On pages 87 and 88 of the same volume Mr. James Richardson speaks of certain fragments of tree-stems and well-formed broad leaves, discovered by him at Nanaimo and North Saanich, Vancouver Island. These were also examined by Dr. J. W. Dawson, and a list of them is given on page 98. Twelve distinct forms were found, three of which were specifically determinable as *Taxodium cuneatum* Newb., *Sequoia Langsdorfii* (Brongn.) Heer, and *Cinnamomum Heerii* Lx. There also occurred two palm leaves and fragments of the leaves of Populus, Quercus, and Platanus.

During the explorations of 1877–'78 collections were made from three points on the northwest coast in deposits regarded as Miocene. The species determined from these beds were described by Dr. Dawson, in Appendix B (p. 186 B) of the Report of Progress for that year (Montreal, 1879). The localities are (1) Coal Brook on the Indian Reserve, North Thompson River, from which three species of Populus were obtained; (2) Vermilion Cliff, three miles up the Tulameen, or North Fork of the Similkameen River, where *Taxodium distichum miocenum* Heer, *Myrica partita* Lx., and a leaf

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[1] Descriptions of the Fossil Plants collected by Mr. George Gibbs, geologist to the United States Northwest Boundary Commission, under Mr. Archibald Campbell, United States Commissioner, by Dr. J. S. Newberry: Boston Jour. Nat. Hist., vol. 7, 1863, pp. 506–524.

[2] Ueber einige fossile Pflanzen von Vancouver und Britisch-Columbien, von Oswald Heer: Neue Denkschr. schweiz. Ges ll. gesammt. Naturwiss., vol. 21, 1865, No. 3, pp. 1–10, pl. i, ii.

of Paliurus were found; and (3) Nine Mile Creek, where were collected different forms, mostly in a fragmentary state. Among these was one new species (*Equisetum Similkamense*). Besides conifers there were represented the genera Platanus, Myrica, Populus, Corylus, Betula, Juglans, Sapindus, Carpinus, and Nelumbium, but in many cases the species are not determinable.

The above seem to be all the data obtained from this district prior to the appearance of Dr. J. W. Dawson's paper on the Cretaceous and Tertiary Floras of British Columbia and the Northwest Territory.[1] This paper was founded upon collections that had been previously made by Dr. G. M. Dawson and Mr. J. Richardson, a considerable part of which were from the Pacific coast, and represented several localities, Beaver Harbor, Baynes' Sound, Protection Island, and Nanaimo. Thirty-three species from these points, more than half of which are dicotyledons, are named in the comparative table of Cretaceous rocks given on page 19 of this report. These beds are correlated with the Fox Hills group of Hayden, the Maestricht and Foxoe beds, or Danian of western Europe.

Other Tertiary beds were found in the interior of British Columbia, on Quesnel, Blackwater, and Similkameen Rivers, the Indian Reserve and North Thompson River, which were also mentioned by Dr. J. W. Dawson on pages 33 and 34 of the memoir last considered.

There are in the National Museum collection two specimens of fossil wood, marked "Jurassic," from Skoomei, and Port Massett, British Columbia; and three from Susk, Graham Island, British Columbia, collected by James G. Swan, none of which have as yet been prepared for microscopic study.

In 1885 a collection of fossil plants was made by Dr. George M. Dawson, on the northeast coast of Vancouver Island on the north shore of Port McNeill. They were reported upon by Sir William Dawson in 1888, who regards them as indicating a Cretaceous age somewhat more recent than the Nanaimo beds, and nearly equivalent to those of Protection Island.[2]

BRITISH NORTHWEST TERRITORY.

The recent extensive geological explorations made by the Canadian government in the Rocky Mountain region of British America have demonstrated the existence of a series of plant-bearing beds in that section, extending from near the base of the Cretaceous upward to include a considerable portion of the Tertiary formation. The first report upon the flora of these formations appears to have been made by Dr. J. W. Dawson, in Appendix A to the Report on the Ge-

[1] Proc. Trans. Royal Soc. Canada, vol. 1, 1883, section iv, pp. 15–34, pl. i–viii.

[2] On Cretaceous Plants from Port McNeill, Vancouver Island, by Sir W. Dawson and Dr. G. M. Dawson: Ibid., vol. 6, 1888, section iv, pp. 71, 72.

ology and Resources of the region in the vicinity of the forty-ninth parallel, by Dr. G. M. Dawson (Montreal, 1875). The plants which form the subject of this report were collected on the Souris and in the Great Valley. They occurred in connection with beds of lignite, and though their age was very little known at the time, it is now tolerably well settled that at least the bed on the Souris River corresponds to the Fort Union group of Dakota and Montana. The other may have been somewhat higher, agreeing perhaps with our Green River group. The species found by Dr. Newberry on the Yellowstone and Upper Missouri Rivers, such as *Corylus Americana* (Walt.) Newb., *C. rostrata* (Ait.) Newb., *Sapindus affinis*, and *Carya antiquorum* figure prominently in this report. Besides eight or ten species founded upon internal structure of silicified wood that was found scattered over the plains, twenty-five distinct forms are here enumerated, only seventeen of which are assigned specific names, and of this latter only two (*Lemna scutata* and *Æsculus antiqua*) were new. The fossil wood is figured on pl. xv, and the more interesting forms and new species on pl. xvi.

In the Report of Progress of the Geological Survey of Canada for 1879–'80 (Montreal, 1881) five species of fossil plants are described by Dr. J. W. Dawson in a note which forms Appendix II. The specimens were collected in the same formation last considered at Roche Percée. Besides one new species (*Sassafras Selwyni*) there occurred in this collection *Platanus nobilis* Newberry, *Taxites occidentalis* Newberry, and *T. Olriki* Heer; also an unnamed species of Quercus.

The recent report upon the flora of these formations occurs in the paper above mentioned in the transactions of the Royal Society of Canada, presented May 23, 1883, which, in addition to the enumeration of the fossil plants from the Pacific coast, also embraces an account of the flora of the Peace and Pine Rivers, on the eastern slope of the Rocky Mountains, correlated in the section above referred to with the Niobrara of Hayden and the Senonian of western Europe. Twenty-two species from this formation are described in this report, two of which belong to the Cycadaceæ and three to the genus Protophyllum, hitherto confined to the Dakota group. Other forms, such as the *Populites cyclophylla* Heer, serve to give this flora a decidedly Mesozoic facies.

The Laramie group was also represented in these collections, and a list of thirty-seven species is given on page 32, without description. These plants were collected on Porcupine Creek and Souris River. As this flora is treated more at length in a later paper we need not consider it further in this place.

The second of this series of papers, presented to the Royal Society of Canada on May 2, 1885,[1] describes further additions to the Cretaceous flora of the interior of British Columbia, the most important

[1] On the Mesozoic Floras of the Rocky Mountain Region of Canada, by Sir J. W. Dawson: Proc. Trans. Royal Soc. Canada, vol. 3, 1885, section iv, pp. 1–22, pl. i–iv.

part of which treats of three successive deposits not hitherto known to hold vegetable remains. These are—

(1) The Kootanie series, which is correlated with the Neocomian and furnishes twenty-two species. No dicotyledons occur in these beds, but seven species of Cycadaceæ and Cretaceous forms of Ginkgo give to the flora a strong Mesozoic aspect. The localities for these beds are situated in the Rocky Mountains at Martin Creek, North Fork of Old Man River, Canmore, Coal Creek, Crow's Nest Pass, and Kootanie Pass.

(2) The intermediate series. Above the Kootanie beds and apparently separated by a considerable interval of barren strata there occurs on the midddle branch of the North Fork of Old Man River another deposit, yielding two species of dicotyledonous plants (*Sterculia vetustula* Dawson, n. sp., and *Laurus crassinervis* Dawson), which are supposed also to belong to the Lower Cretaceous, and are correlated with the Urgonian. Should this conclusion be sustained we have in these two species the second case on record of dicotyledons at that horizon.

(3) The Mill Creek series. On Mill Creek, a tributary of the south branch of Old Man River, occurs another plant-bearing bed, which is regarded as higher than the last named but older than the Peace and Pine River series described in a previous paper. This the author correlates with the Cenomanian of Europe, the Dakota group of the United States, and the Atane beds of Greenland. Twenty-three species are described from this place, the great majority of which (seventeen species) are dicotyledons. There were four ferns and one supposed cycadaceous form, his *Williamsonia recentior*. Among the dicotyledons occur a large proportion of the lobed and digitate leaves belonging to the alleged genera Platanus, Aralia, and Sterculia, one of which (his *Sterculia vetustula*, pl. iii, fig. 2) resembles very closely some of the forms found by Professor Fontaine in the younger Mesozoic clays of Virginia.

(4) The Belly River series, correlated by the author with the Fort Pierre group of Hayden, or Senonian of Europe. These beds are located at a point called Medicine Hat, on the Belly River, and from them three species of plants were collected by Mr. T. C. Weston, of the Canadian Geological Survey, namely, *Brasenia antiqua, Populus latidentata* and *Acer Saskatchewense*, all new to science. The first of these, which is carefully figured on page 15, is an especially interesting form.

Above all these beds was found a group which is regarded as Lower Laramie and from which ten species were obtained. From the occurrence of *Platanus nobilis* Newberry, and *P. Raynoldsii* Newberry, which are characteristic of our Fort Union group, there seems no reason to suppose that these beds are lower than those of Dakota, and therefore are rather Upper than Lower Laramie.

The third of this series of papers is On the fossil plants of the Laramie formation of Canada.[1] This paper includes a revision of work done on this horizon as noted in the treatment of the several foregoing papers, and the study of new material collected principally by Mr. J. B. Tyrrell and Mr. T. C. Weston, in the more westerly section of the Laramie district of British America. It may, therefore, be regarded as embodying all the information relative to the Laramie flora of that region, in possession of the author at the date of its publication.

It is here confessed that little distinction can be detected between the Lower and the Upper Laramie, as they have been separated in this and the previous paper, and also that the Belly River series mentioned in the last paper, possesses a flora that may practically be regarded as Laramie. Only eight species were found in the lower division of the Laramie, and all but two of these occurred also in the upper division, while of the nine species now known from the Belly River series four are also found in the true Laramie. If then we include, as we probably should, the Belly River in the Laramie series we find the total number of fossil plants thus far known in that series to amount to fifty-six. Among these there are only two ferns (*Onoclea sensibilis* L. and *Davallia tenuifolia* Sw.), both of which, singularly enough, agree so closely with living species, that they have been regarded as such. There are six coniferous plants, most of them widely distributed species, and four monocotyledonous species, only one of which (*Lemna scutata* Dawson) was in a sufficiently good state of preservation to be specifically determined. The remainder are dicotyledons. Judging from the figures given in this report, the material for it must have been quite fragmentary and the determinations are therefore correspondingly unsatisfactory. Many are allowed to go without specific names, and those referred to species already known are not refigured. Nearly all of these latter cases are Fort Union species, but some of them belong to Heer's Arctic Miocene. It is of special interest to observe that among the platanoid leaves found in this district there occur some with a well defined basal lobe, such as I have described from the Lower Yellowstone Valley, under the name of *Platanus basilobata*.[2] There is no doubt that Sir J. W. Dawson's fig. 7 of pl. i represents the same species as figured by me and described more than a year before I became acquainted with the memoir here under consideration, but whether it should be regarded as a lobed form of *Platanus nobilis*, as he supposes, or as a new species, can not be decided until we have sufficient material to demonstrate the variability or constancy of this character. After what was said in the paper last quoted, not only

[1] Proc. Trans. Royal Soc. Canada, vol. 4, 1886, section iv, pp. 19-34, pl. i, ii.

[2] Types of the Laramie flora, by Lester F. Ward: Bull. U. S. Geol. Survey, No. 37, 1887, p. 35, pl. xvii-xix; Sixth Ann. Rept. U. S. Geol. Survey, 1884-'85, pl. xlii, xliii.

under this species but also under *Aralia notata* (pp. 60, 61), it is scarcely necessary to add that I regard his two species of Sassafras figured on pl. ii, if not his *Viburnum oxycoccoides* on the same plate, as belonging to the general platanoid group.[1] His *Symphorocarpophyllum* (pl. ii, fig. 17, 18) seems to have much the same nervation as my *Populus craspedodroma* (Types, etc., pl. viii, fig. 3), though the general outline is quite different, and is scarcely distinguishable from that of his *Populus arctica*, var., figured on the preceding plate.

The last of this series of papers to reach my hands treats of the fossil wood of the Cretaceous and Laramie formations of the western territories of Canada.[2] Sections from about sixty distinct trees are here described, which had been collected in the Belly River and Fort Pierre series at Ribstone Creek, Vermilion River, Medicine Hat, Twenty Mile Creek, South Saskatchewan, Swift Current, and at points on the Bow, Belly, and Saskatchewan Rivers ; from the Lower Laramie series at Antler Hill, Edmonton, and Scabby Creek ; from the Upper Laramie series at Wood End Depot, Côteau, Turtle Mountain, Souris Valley, Edmonton, McKenzie River, Red Deer River, Middle Fork, Old Man River, Swift Current, Rocky Mountain House, and North Saskatchewan.

A still later and doubtless very important contribution to this series is announced,[3] which unfortunately has not reached me. It promises to add many localities for fossil plants in this part of Canada, and greatly to increase our knowledge of the flora of the Cretaceous deposits of the Northwest Territories, especially of the Kootanie series at their base, the interest in which is so much increased by the nearly equivalent flora of the Potomac formation, which Professor Fontaine's Monograph, now in press, will soon bring prominently into view.

CANADA.

Although Brongniart had received one species (*Fucoides serra* Brongn.) from Point Levi, near Quebec, collected by Mr. Stockes,[4] and Dr. Harlan in 1825 stated that *F. Brongniartii* Harlan was said to abound on the Welland Canal,[5] nevertheless science is almost exclu-

[1] See my paper on The Paleontologic History of the Genus Platanus: Proc. U. S. Nat. Mus., vol. 11, 1888, pp. 39–42, pl. xvii–xxii.

[2] Notes on Fossil Woods and other Plant Remains, from the Cretaceous and Laramie Formations of the Western Territories of Canada, by William Dawson: Proc. Trans. Royal Soc. Canada, vol. 5, 1887, sec. iv, pp. 31–37.

[3] Cretaceous Floras of the Northwest Territories of Canada, by William Dawson: American Naturalist, vol. 22, November, 1888, p. 953–959. See foot-note to p. 953.

[4] Prodrome, p. 165; Histoire des vég. foss., vol. 1, p. 71.

[5] Description of a new extinct Fossil Vegetable, of the Family Fucoides, by Richard Harlan: Med. and Phys. Researches, or Original Memoirs, etc., Philadelphia, 1835, pp. 398, 399, 1 pl.

sively indebted to Sir William Dawson, of Montreal, for the development of the fossil flora of Canada and the other British provinces on the Atlantic. His investigations into this subject date back to a very early period. In 1859 he made a communication to the Geological Society of London On Fossil Plants from the Devonian rocks of Canada,[1] in which he described some vegetable remains from the peninsula of Gaspé Bay, Lower Canada. The genera Psilophyton and Prototaxites (Nematophyton)[2] were established in this paper, and numerous forms figured in the text. It was reprinted in the Canadian Naturalist, vol. 5, pp. 1–14.

In 1861 he read a paper before the Natural History Society of Montreal On the Precarboniferous flora of New Brunswick, Maine, and eastern Canada.[3] This paper is chiefly devoted to describing plants from the first named localities, but two species (*Selaginites formosus* and *Psilophyton princeps*) were collected in the Gaspé sandstones, and are figured on page 176.

In the summer of 1862 Mr. R. Bell made further collections at this point and added the two species *Leptophlœum rhombicum* and *Didymophyllum reniforme*, and also two species of a peculiar kind of fossil wood forming Dawson's new genus Nematoxylon. These are described in the Quarterly Journal of the Geological Society of London.[4]

In his important paper On the flora of the Devonian period in northeastern America,[5] which will be further treated later on, Devonian beds holding fossil plants are noticed at Kettle Point on Lake Huron, as well as at Gaspé; eight species are reported from the more western locality.

The Gaspé beds are further treated in his report on The fossil plants of the Devonian and Upper Silurian formations of Canada, made to the Director of the Geological Survey of Canada in 1871, and in the supplement to this paper published in 1882. Between the dates of these two papers other deposits were found at Scaumenac Bay on the Restigouche River opposite Dalhousie, and also in the vicinity of Campbellton on the same river.

Besides these Devonian and Silurian beds, higher ones occur in

[1] Quart. Jour. Geol. Soc. London, vol. 15, 1859, pp. 477–488.

[2] For his reasons for preferring the name Nematophyton to Prototaxites see his Geological History of Plants, New York, 1888, p. 21. For an exhaustive study of this and allied forms, see a paper entitled: On Nematophyton and Allied Forms from the Devonian (Erian) of Gaspé and Bay des Chaleurs, by D. P. Penhallow (with Introductory Notes by Sir William Dawson): Proc. Trans. Royal Soc. Canada, vol. 6, 1888, Montreal, 1889, section iv, pp. 27–47, pl. i, ii.

[3] Canadian Naturalist, vol. 6, 1861, pp. 161–180.

[4] Further Observations on the Devonian Plants of Maine, Gaspé, and New York, by J. W. Dawson: Quart. Jour. Geol. Soc. London, vol. 19, 1863, pp. 458–469, pl. xvii–xix.

[5] Quart. Jour. Geol. Soc. London, vol. 18, 1862, pp. 296–330, pl. xii–xvii.

Gaspé and on the Bay of Chaleurs, which are referred to the Lower Carboniferous, and treated in a report of the fossil land plants of the Lower Carboniferous and Millstone Grit formations of Canada, made in 1873.

Other collections made by Mr. A. H. Ford at Scaumenac, opposite Dalhausie, and by Mr. Weston near Campbellton, are treated in a short paper on New Devonian plants from the Bay de Chaleur, in 1883.[1]

The Post-pliocene deposits in the vicinity of Montreal received early attention, the first mention of plant remains from them having been made in 1857 in a paper On the Newer Pliocene and Post-pliocene deposits of the vicinity of Montreal,[2] with notices of fossils recently discovered in them, three recognizable species of living plants (*Populus balsamifera* L., *Potentilla Norvegica* L., and *Thuya occidentalis* L.) being enumerated, besides the remains of Algæ.

In a later paper[3] mention is made of "leaves and stems of grasses, needles of pines and a moss," also a well preserved small dicotyledonous leaf.

Having received additional material from other beds of this age, Dr. J. W. Dawson, in a paper published in 1866,[4] reviews this flora, enumerating twelve distinct forms, making several specific changes, and figuring some of the best preserved specimens. From the data thus got together he draws certain conclusions both as to the climate indicated and the age of the deposits. He thinks that the summer of that period must have been colder than at present to an extent equal to about 5° of latitude. The plants are chiefly found in the bowlder drift associated with *Leda truncata*, deposits of which extend along the St. Lawrence River, sometimes at a height of 500 feet, and also on the Ottawa River at Green's Creek, where the best specimens are obtained.

In an elaborate paper on the Post-pliocene geology of Canada, published in 1872,[5] the author gives a list of the plants chiefly from Green's Creek (p. 99), and states that no additional material has been obtained since the appearance of the paper last treated.

Much interest has recently attached to certain spore cases found associated with fragments of Calamites and Lepidodendron, in the coal bed at Kettle Point, which is of Upper Devonian age. The first

[1] Canadian Naturalist, vol. 10, 1883, pp. 8–11.

[2] Canadian Naturalist and Geologist, vol. 2, 1857, pp. 401–426. (Plants, p. 422.)

[3] Additional Notes on the Post-pliocene deposit of the St. Lawrence Valley, by J. W. Dawson: Ibid., vol. 4, 1859, pp. 23–39 (see p. 37).

[4] The Evidence of Fossil Plants as to the Climate of the Post-pliocene Period in Canada, by J. W. Dawson: Canadian Naturalist, new series, vol. 3, 1866, pp. 69–76.

[5] Notes on the Post-pliocene Geology of Canada, with especial reference to the Conditions of Accumulation of the Deposits and the Marine Life of the Period, by J. W. Dawson: Canadian Naturalist, new series, vol. 6, 1872, pp. 1–112, pl. vii.

paper on this subject was published by Dr. J. W. Dawson, in the American Journal of Science for April, 1871.[1] One species of Sporangites (*S. Huronensis*), a name proposed by him in 1866, is here figured. In a paper read before the American Association for the Advancement of Science, at Minneapolis (1883), previously quoted (supra, p. 824), in which he described some Brazilian forms, he gives his reasons for supposing that these spore cases represent fossil Rhizocarps.

Most of the objects of problematical character, regarded by some authors as fucoids, that have been found in the Silurian rocks of Canada are described in Mr. E. Billings's contributions to the Geological Survey of Canada on Paleozoic fossils.[2] Such objects were found in the Potsdam group at Anse au Loup on the north shore of the straits of Belle Isle, in the township of Landsowne, near Beverly, in the township of Bastard, near Ste. Anne, and at Ste. Geneviève; in the Calciferous at Beauharnois, Edwardstown, near Norton's Creek Mill, county of Napierville, and at L'Original, county of Prescott; in the Chazy group at the head of the Grenville canal; in the Black River group and base of the Trenton near Hilton village, and on the island of St. Joseph in Lake Huron; in the Trenton group at Belleville, Peterborough, and the city of Ottawa; and in the Hudson River group on Manitouwaning Bay, Lake Huron.

NEW BRUNSWICK.

This province has proved very rich in Paleozoic plants. In the paper already quoted on the Pre-carboniferous flora of New Brunswick, etc., 1861, seven species, six of which were new, are described from the Devonian beds in the vicinity of St. John, and in the more extended paper also previously quoted, on the flora of the Devonian Period in Northeastern America, 1862, thirty-nine of the sixty-nine species given in the list, on page 327, were from this locality.

In his Synopsis of the Flora of the Carboniferous Period in Nova Scotia, 1862, presently to be more fully treated, Dr. Dawson reported Carboniferous plants from Dorchester, Miramichi, Coal Creek, Grand Lake, and Bathurst, in New Brunswick.

Most of the plants enumerated in his Descriptive list of Carboniferous Plants found in Nova Scotia and New Brunswick,[3] were

[1] On spore-cases in Coals, by J. W. Dawson: Am. Jour. Sci., 3d series, vol. 1, 1871, pp. 256–263. Canadian Naturalist, n. s., vol. 5, 1870, pp. 369–377.

[2] E. Billings: New species of Lower Silurian fossils. I, On some new or little known species of Lower Silurian Fossils from the Potsdam Group (Primordial Zone). Geol. Survey Canada, Montreal, 1861, 24 pp., 8°.

Palæozoic fossils, vol. 1, containing descriptions and figures of new or little known species of organic remains from the Silurian rocks. Geol. Survey Canada, Montreal, 1861–1865, 426 pp., 8°.

[3] Appendix to his memoir "On the Conditions of the Deposition of Coal, etc." Quart. Jour. Geol. Soc. London, vol. 22, 1866, pp. 145–166, pl. v–xiii.

from Nova Scotia and Cape Breton, but a few were collected on the Bay de Chaleurs and Norton Creek, in New Brunswick.

In the careful revision of this flora published by the Geological Survey of Canada in 1871,[1] much new material was found to have accumulated, and seventy Middle Devonian species from St. John and Lepreau, New Brunswick, are given in the list on pages 85 and 86, and in the supplement to this paper, published by the Canadian Survey in 1882,[2] several new species of ferns previously described in the Quarterly Journal of the Geological Society of London (vol. 37, 1881, pp. 303–306), are added to this number.

In his report of the fossil land plants of the Lower Carboniferous and Millstone Grit, 1873, to which reference has already been made, a few species from Norton Creek and Hillsborough, New Brunswick, are described.

PRINCE EDWARD ISLAND.

The first mention of fossil plants from Prince Edward Island was made by Dr. J. W. Dawson in 1854, in a short paper On fossil coniferous wood from Prince Edward Island.[3]

The localities from which these specimens were taken were on the south shore of the island at Gallows Point, Des Sables, and Crapaud.

In 1871 appeared the Report on the Geological Structure and Mineral resources of Prince Edward Island, by J. W. Dawson and B. J. Harrington (Montreal, 1871, 8°), in which are described all the fossil plants of the island known at that time. They represent the Upper Carboniferous with sixteen species, and the Trias with five species. The Carboniferous species are from Gallows Point, Miminigash, and Campbellton, and the Triassic species from Indian River and from a bed on Gallows Point belonging to that age, also from Murray Harbor and near Penn Point. Two new species are found in this formation (*Dadoxylon Edvardianum* and *Cycadeoidea Abequidensis*). Besides these are figured forms of Knorria and of Sternbergia, which, if correctly determined, would indicate a lower horizon. The paper is illustrated by three plates.

In a paper On the Upper Coal-formation of Eastern Nova Scotia and Prince Edward Island, in its relation to the Permian,[4] Dr. J. W. Dawson enumerates the fossil plants from the Upper Coal Formation of Prince Edward Island known at that date, which, it appears, had not been increased since the date of the report last quoted.

An enumeration of the Permo-carboniferous plants of Prince Ed-

[1] The Fossil Plants of the Devonian and Upper Silurian of Canada, Part 1, pp. 11–86.

[2] The Fossil Plants of the Erian (Devonian) and Upper Silurian formations of Canada, pt. 2, pp. 114–118.

[3] Proc. Philadelphia Acad. Sci., vol. 7, 1854, pp. 62–64.

[4] Quart. Jour. Geol. Soc. London, vol. 30, 1874, pp. 209–218.

ward Island, amounting to fourteen species, was embodied by Dr. J. W. Dawson in his remarks on the paper presented to the Royal Society of Canada by Francis Bain, and published in the Canadian Record of Science (vol. 1, pp. 154–161) for 1884 and 1885 (page 158), and in the same connection some interesting forms from the so-called Trias of that island are commented upon and figured. *Walchia imbricatula* is here for the first time made known (page 161, fig. 2).

NOVA SCOTIA.

The formation from which fossil plants have chiefly been obtained in Nova Scotia is the Carboniferous. Lyell refers to them in his travels (vol. 2, p. 195), and a large number of papers—principally geological, but containing allusions to this flora and descriptions of some species, especially accounts of remarkable erect fossil trees from these beds—appeared from time to time in the Quarterly Journal of the Geological Society of London,[1] in the Canadian Naturalist, and in other scientific periodicals. Teschemacher in 1846 had also received some material from Pictou which he mentions in his Fossil Vegetation of America.[2] But prior to the year 1863 no systematic summary of the paleobotanical results had been published.

The Canadian Naturalist for that year[3] contains Dr. Dawson's Synopsis of the Flora of the Carboniferous Period in Nova Scotia, which is a catalogue of the plants in his collection and in the collections made by Bunbury, Lyell, and Brown. In this list of nearly two hundred species from the Lower, Middle, and Upper Carboniferous occur a large number not hitherto known, and these are for the most part briefly described. The following are the localities enumerated in this paper: Joggins, Malagash, Pictou, Horton, Tatamagouche, Parrsboro', and Salmon River. This enumeration is exclusive of points in Cape Breton and New Brunswick.

In his illustrated paper On the conditions of the deposition of coal,[4] a large number of these species are figured and many new ones added.

Again, in 1873, in the Reports of the Geological Survey of Canada,[5] the plants of the Lower Carboniferous and Millstone Grit, as they occur at Horton Bluff, Pictou, Windsor, etc., are systematically treated and carefully figured in ten plates.

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[1] Vol. 1, 1845, pp. 322–330; vol. 2, 1846, pp. 132–136, pl. viii; vol. 7, 1851, pp. 194–196; vol. 9, 1853, pp. 58–63; vol. 10, 1854, pp. 1–42, 42–51; vol. 17, 1861, pp. 522–524, proceedings, p. 5.

[2] Boston Jour. Nat. Hist., vol. 5, pt. 3, 1846, pp. 370–385; pl. xxxiii–xxxvi.

[3] Vol. 8, 1863, pp. 431–457.

[4] Quart. Jour. Geol. Soc. London, vol. 22, 1866, pp. 95–169, pl. v–xiii.

[5] Report on the Fossil Plants of the Lower Carboniferous and Millstone Grit Formations of Canada, Montreal, 1873.

A list of the plants of the Upper Coal Formation known in 1874 to occur in Nova Scotia, is given on page 216 of volume 30 of the Quarterly Journal of the Geological Society of London, and contains forty-two species.

CAPE BRETON.

Although, in treating Dr. J. W. Dawson's papers on Nova Scotia, Cape Breton was necessarily included, it seems proper to give special recognition to an important paper by Bunbury[1] antedating most of Dawson's work and based on collections made in the Sidney coal field by Mr. Richard Brown. In this paper forty-eight distinct forms are recognized, of which seven are new species. The latter are very well figured on the four accompanying plates.

In another paper[2] the same author treats an additional and remarkable specimen, apparently from the same collection.

Besides the principal beds at Sidney, Dawson in his synopsis notes the occurrence of Carboniferous plants at Port Hood, Glace Bay, and Mabou on Cape Breton Island.

NEWFOUNDLAND.

Carboniferous fossil plants have been collected on St. George's Bay, Newfoundland, and four species also common to other beds of the British provinces are mentioned in the Geological Survey Report on the fossil plants of the Lower Carboniferous and Millstone Grit formations of Canada, 1873, already several times quoted (pp. 29, 32, and 34).

It is proper to state that the entire subject of the paleobotany of eastern British America was carefully reviewed in the first edition of the Acadian Geology, published in 1857, and the work accomplished between that time and the appearance of the second edition in 1868 was revised and brought down to that date, and also that the supplement, which was appended to the second to make the third edition, and published in 1878, embodies the results of the author's labors during the preceding decade.

UNITED STATES.

In harmony with the general plan thus far pursued, which contemplates the subject primarily from a geographical stand-point, I shall consider the various deposits in the United States that have yielded fossil plants in the usual geographical order of States, with the exception that the Territories will be arranged in a single series along with the States, and not separated from them as is customary

[1] On Fossil Plants from the Coal Formation of Cape Breton, by C. J. F. Bunbury: Quart. Jour. Geol. Soc. London, vol. 3, 1847, pp. 423–438, pl. xxi–xxiv.

[2] Description of a peculiar Fossil Fern from the Sidney Coal Field, Cape Breton, by C. J. F. Bunbury: Quart. Jour. Geol. Soc. London, vol. 8, 1852, pp. 31–35, pl. i.

in official reports. Subordinate to the geographical order the information that is obtainable in reference to the fossil flora of each State will be treated in the chronological order of its discovery and of publication. While it will, of course, be impossible in some of the States whose floras have long been known and studied, such as New York and Pennsylvania, to mention every minute locality from which vegetable remains have been taken, or to refer to every individual publication, great and small, that has ever appeared, still it is hoped that the data here collected will be sufficient to afford a fairly correct idea of the extent and value to science of the fossil flora of the United States, and of the history and progress of its discovery and development.

Maine.—In 1846 Dr. Ebenezer Emmons, while writing the first volume of the Agriculture of New York,[1] described *Nereites Jacksoni*, *N. pugnus*, *N. Loomisi*, and *N. lanceolata*, from the Taconic (Cambrian) slate of Waterville, Me.

The town of Perry, on Passamaquoddy Bay, opposite Deer Island, has yielded a number of species of plants of Devonian age, which were first noticed in a paper, to which reference has already been made, On the Pre-carboniferous flora of New Brunswick, Maine, and eastern Canada, by J. W. Dawson,[2] where eight different forms are mentioned, four of which were specifically determinable, two of them (*Cyclopteris Jacksoni* and *Lepidostrobus Richardsoni*) being in a very good state of preservation, as shown by figures on pages 173 and 174.

In 1862, in another paper by the same author,[3] this flora is revised along with those of Canada, two new species (*Cyclopteris Brownii* and *C. Hitchcockiana*) are added, and the affinities of some of the former doubtful ones are worked out. In the appendix to the paper (opposite page 329) a short account is given of a visit made by the author to this locality and of several additional forms discovered by him.

On the 3d of March of the same year C. H. Hitchcock[4] read a paper before the Portland Society of Natural History, in which the same new species from Perry are described and illustrated from notes and drawings by J. W. Dawson.

Still a third paper by Dawson relating to this flora was published

[1] Agriculture of New York: Comprising an account of the classification, composition, and distribution of the soils and rocks, and the natural waters of the different geological formations; together with a condensed view of the climate and the agricultural productions of the State, by Ebenezer Emmons: Nat. Hist. of N. Y., pt. 5, Agriculture, vol. 1, pp. i–xi, 1–370, pl. i–xx (see pp. 68, 69, 365, pl. xv, xvi).

[2] Canadian Naturalist and Geologist, vol. 6, 1861, pp. 161–180. (See pp. 172–175.)

[3] On the Flora of the Devonian Period in Northeastern America, by J. W. Dawson: Quart. Jour. Geol. Soc. London, vol. 18, 1862, pp. 296–330, pl. xii–xvii (pl. xvii).

[4] Notes on the Geology of Maine, by C. H. Hitchcock: Proc. Portland Soc. Nat. Hist., vol. 1, pt. 1, 1862, pp. 72–85, pl. i.

in the Quarterly Journal of the Geological Society of London, for 1863,[1] in which the number of distinct forms is increased to eighteen and fuller descriptions are given.

These plants are also included in his report on the fossil plants of the Devonian and Upper Silurian formations of Canada, published by the Geological Survey of Canada (Montreal, 1871).

Vermont.—The fossil fruits of Brandon have been known since 1854, in which year Dr. Edward Hitchcock published a description of them with good figures,[2] but without attempting to correlate them with similar objects previously found, or to assign them a place in the vegetable kingdom.

In 1861 this paper was published in an enlarged form, with many additional figures, in the Report on the Geology of Vermont.[3]

The task of identifying these fossils was undertaken the same year by Professor Lesquereux, who made his report on the fossil fruits found in connection with the Lignites of Brandon, which appeared both in the American Journal of Science[4] and in the Report of the Geology of Vermont.[5] He distinguishes twenty-three species of plants, the most abundant of which are referred to the genus Carya and regarded as lignitized hickory-nuts. In addition to these he finds one species of Fagus or beech-nut, two of Apeibopsis, three of Aristolochia, one of Sapindus, one of Illicium, one of Carpinus, and three of Nyssa, besides eight other forms not distinctly referable to any known genus, most of which he classes under Carpolithes, though several of them may belong to Carya.

There is no doubt that these lignite beds of Brandon are of Tertiary age, and Dr. Hitchcock regards them as belonging to the Pliocene. Professor Lesquereux compares the fossils with some obtained from Kentucky and other Southern States, and his view that this formation is the same as the so-called Eocene lignite beds, and once had an extensive development in the United States, has been strengthened by later discoveries.[6]

Certain forms of doubtful affinity (*Palæophycus incipiens*, *P. congregatus* and *Scolithus Canadensis*) were described by Billings[7] in

[1] Further Observations on the Devonian Plants of Maine, Gaspé, and New York, by J. W. Dawson: Quart. Jour. Geol. Soc. London, vol. 19, 1863, pp. 458–469, pl. xvii–xix.

[2] Description of a Brown Coal Deposit in Brandon, Vermont, with an attempt to determine the geological age of the principal Hematite Ore Beds in the United States, by Edward Hitchcock: Am. Jour. Sci., 2d series, vol. 15, 1853, pp. 95–104.

[3] Rept. Geol. Vermont, vol. 1, 1861, pp. 226–234.

[4] Am. Jour. Sci., 2d series, vol. 32, 1861, pp. 355–363.

[5] Rept. Geol. Vermont, vol. 2, 1861, pp. 712–718.

[6] See Dana's Manual of Geology, 2d ed., 1875, pp. 494, 498, 774.

[7] E. Billings: On some new or little known species of Silurian Fossils from the Potsdam Group (Primordial Zone). Appendix to the Report on the Geology of Vermont, vol. 2, 1861, pp. 942, 960. Palæozoic Fossils, vol. 1, Montreal, 1865, pp. 2, 3, 96.

an appendix to the Report on the Geology of Vermont, above referred to, and enumerated in his catalogue of Paleozoic fossils as having been found in the Lower Silurian. The first and third were from the Cambrian at Swanton; the other was found in the same formation one mile south of the boundary line, between Moor's Corners and Saxe's Mills in Highgate.

Massachusetts.—As early as 1823 Dr. Edward Hitchcock[1] noted the presence of vegetable remains in the valley of the Connecticut in Massachusetts, some of which he figured without names, in rock probably of Triassic age found at Gill, Sunderland, and Newgate.

In the Trias of the Connecticut Valley the remains of plants are in most cases fragmentary. All those figured by Dr. Hitchcock in his Final Report on the Geology of Massachusetts, vol. II, 1841, whether in the text (pp. 451–457) or on pl. xxviii (described as pl. xxix), are so imperfect as to remain problematical. They were found on an island at Turner's Falls, on Agawam River in West Springfield, in Sunderland and Northampton on the Connecticut River, on the Chicopee River at Chicopee Factory Village, in Springfield, at Hoyt's quarries in Deerfield, and near the county jail in Greenfield.

In 1843 Dr. Hitchcock[2] gave an account of several fossil plants discovered in a large bowlder of dark gray sandstone on Mount Holyoke, Massachusetts, among which he recognized *Tæniopteris vittata* Brongn., which he figured on plate xiii (fig. 2). In the same paper he figures (pl. xiii, figs. 3–5) a second species, which he refers to the genus Voltzia, from that formation found at Montague in Massachusetts.

During the summer of 1854 a specimen of fossil fern (*Clathropteris rectiuscula* Hitch.) was found in the sandstone of Mt. Tom in East Hampton, which was described by Edward Hitchcock, jr., in the American Journal of Science (2d series, vol. 20, 1855, pp. 22–25). The plant is figured on page 24; the geological age is the same as in former cases.

Further details in regard to this species were presented by the elder Hitchcock to the American Association for the Advancement of Science, at its Newport meeting in 1860.[3]

Dr. J. S. Newberry, in an important work just published,[4] con-

[1] A Sketch of the Geology, Mineralogy, and Scenery of the Regions contiguous to the River Connecticut; with a Geological Map and Drawings of Organic Remains; and occasional Botanical Notices, by Edward Hitchcock: Am. Jour. Sci., vol. 6, 1823, pp. 1–86, 201–236, pl. ix; vol. 7, 1824, pp. 1–30.

[2] Description of several species of Fossil Plants, from the New Red Sandstone formation of Connecticut and Massachusetts, by Prof. Edward Hitchcock: Philadelphia Assoc. Am. Geol. and Nat., 1843, pp. 294–296, pl. xiii.

[3] Proc. Am. Assoc. Adv. Sci., 14th (Newport) meeting, 1860 (1861), pp. 158, 159.

[4] Fossil Fishes and Fossil Plants of the Triassic Rocks of New Jersey and the Connecticut Valley, by John S. Newberry: Monogr. U. S. Geol. Survey, vol. 14, Washington, 1888, 152 pp., 26 pl. (Part III, Fossil Plants, pp. 77–95, pl. xxi–xxvi.)

siders the Connecticut Valley Trias as equivalent in age to the Rhetic beds of Germany and to the older Mesozoic of Virginia. The localities in Massachusetts at which his specimens of fossil plants were obtained were Turner's Falls, Sunderland, Westfield, and Easthampton.

Vegetable remains from Wrentham and Mansfield have also been mentioned by Dr. C. T. Jackson.[1] Teschemacher, in his paper on the fossil vegetation of America,[2] enumerated quite a list of ferns from the Carboniferous of the latter place, some of which he figured.

The coal plants figured by Dr. Hitchcock are all referred by him to the Graywacke. They were chiefly obtained from the Hardon coal mine at Mansfield, from an excavation for coal in the southern part of Wrentham and from stone walls in Norton.

The discovery in 1885 of specimens of Lepidodendron (*L. acuminatum* Göpp.) by Mr. Joseph H. Perry in the graphite beds of Worcester,[3] seems to prove that these beds are much less ancient than was formerly supposed, and perhaps not older than Subcarboniferous.

One of the localities for *Scolithus linearis* Hald., as given by Hall,[4] is Adams, Mass.

Dr. Edward Hitchcock, in the Final Report on the Geology of Massachusetts, vol. 2, 1841, mentions the occurrence of vegetable remains at a number of points within the State. The submarine forests of the alluvium are noted in the harbor of Nantucket, at Holmes's Hole, and also at the southwestern extremity of Martha's Vineyard, on the north side of Cape Cod opposite Yarmouth on Barnstable Bay, and at Provincetown. In the lignite bed at Gay Head were found leaves that are almost certainly dicotyledonous, but the figures given of them on pl. xix are not sufficiently distinct to indicate with certainty their generic affinities. Some of them seem to belong to the genus Rhamnus or Berchemia. This formation is Tertiary, and is placed in the Eocene by Dr. Hitchcock.

Prof. N. S. Shaler, who has been investigating the coast geology of southeastern Massachusetts, in a letter to me dated February 28, 1888, expresses the opinion that the formations at Nantucket Harbor, Holmes's Hole, and Martha's Vineyard, as well as at Barnstable Bay and Provincetown, are of post-glacial age, and that the deposit at Gay Head is pre-glacial and probably Pliocene. Professor Shaler also notes the presence of a submerged forest at a point on Cape Ann, about midway between Gloucester Harbor and Rockport, show-

[1] Geology of Rhode Island, 1840, p. 12, pl. iii, v, vi.

[2] Boston Jour. Nat. Hist., vol. 5, No. 3, 1846 (1847), pp. 370–385, pl. xxxiii–xxxvi.

[3] Note on a Fossil Coal Plant found at the Graphite deposit in mica schist, at Worcester, Mass., by Joseph H. Perry: Am. Jour. Sci., 3d series, vol. 29, 1885, pp. 157, 158.

[4] Natural History of New York, Palæontology, vol. 1, 1847, p. 3.

ing the roots in normal position below high-water mark and extending downward below tide level. In Boston Harbor, in Lynn Bay, and on Nantucket, peat-bog material containing abundant vegetable impressions occurs below high tide.

Rhode Island.—The first mention of fossil plants from Rhode Island was made by Dr. C. T. Jackson, who published a report in 1840,[1] in which some dozen species are figured from Portsmouth, Warren, Bristol Neck, Warwick Neck, and Newport Neck. They include the genera Pecopteris, Neuropteris, Asterophylites, etc.

Teschemacher, in the paper already mentioned (supra, p. 852), figures three species (*Pecopteris longifolia* Brongn., *Cyatheites Schlotheimii* (Sternb.) Göpp., and *Odontopteris Brardii* (Brongn.) Sternb.) from the same locality.

Between this date and 1884, however, considerable collections had accumulated, especially from the Newport and Mt. Hope coal mines, from Valley Falls, and from Cranston. Those from the Newport and Mt. Hope coal mines, amounting to sixty-nine species, are described by Professor Lesquereux in his Coal Flora of Pennsylvania, where figures of most of them may be found.

In the American Naturalist for September, 1884,[2] Professor Lesquereux published a list of eighty-eight species of which fifty-six are ferns. They were collected at Valley Falls, near Portsmouth, and at Cranston. A second collection from Pawtucket, Valley Falls, and Bristol was reported on by him in the American Journal of Science for March, 1889 (3d series, vol. 37, pp. 229-230). It contains twenty-four species, only seven of which occurred in the previous list. These lists and the one published in the Coal Flora include all the fossil plants thus far known from Rhode Island, amounting to one hundred and five species, only three of those of the earlier lists not appearing in the later ones. Two new species (*Sphenopteris fuciformis* and *Callipteridium* sp.) are described in the earlier of the two last named papers. Substantially the same list as that which appeared in the American Naturalist is included in a report of a committee of the Franklin Society of Providence on the Geology of Rhode Island, published in 1887.[3] Besides containing descriptions and figures of the two last named species, a new one, *Sphenopteris Salisburyi* is described and illustrated from manuscript furnished by Professor Lesquereux. Among the localities given in this list are found the names Pawtucket, Sachuest Point, Providence, and East Providence.

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[1] Report on the Geological and Agricultural Survey of the State of Rhode Island, by Charles T. Jackson. Providence, 1840, pp. 1–312, pl. i–vi, 8°.

[2] The Carboniferous Flora of Rhode Island, by Leo Lesqeureux: Am. Naturalist, vol. 18, pp. 921–923.

[3] Report on the Geology of Rhode Island. Providence Franklin Society, Providence, 1887, pp. 1–128, pl. i–iii, 8°. ("Carboniferous Flora of Rhode Island," pp. 68–79, pl. ii, iii.)

Connecticut.—A brief list of miscellaneous localities of minerals, contributed to the American Journal of Science by J. P. Brace,[1] contains a notice of the occurrence of "agatized wood" in the south part of the town of Southbury.

In an extended paper by Dr. Edward Hitchcock, published in 1828,[2] mention is made of "a siliceous petrifaction of a trunk of a tree eight or ten inches in diameter," discovered at Southbury, which he found in the possession of Dr. Smith, of that place. The Report on the Geological Survey of Connecticut, by Charles Upham Shepard,[3] 1837, refers to the occurrence of vegetable remains in the red sandstone at Middletown, and in the cupriferous sandstone-slate at Enfield Falls, in Suffield, and at Southington and Durham. In 1843 Dr. Hitchcock gave a fuller account of the Southbury specimen in the proceedings of the Philadelphia Association of American Geologists and Naturalists,[4] embracing the report made upon it by Prof. J. W. Bailey, of West Point, who had subjected it to a microscopic examination and pronounced it coniferous.

Most of the Triassic (Rhetic) plants described from Connecticut by Dr. Newberry in the work quoted above were from Durham, but he states that some were collected at Middletown, and his *Dendrophycus Triassicus* was obtained at Portland.

New York.—The earliest account that I have met with of vegetable remains in New York State is Prof. Jacob Green's Notice of a Mineralized Tree, etc., found near the village of "Chitteningo," in Sullivan County, in 1822.[5] Aside from its early date this discovery is of comparatively small importance.

In view of the recent discussions relative to the problematical organism that goes by the names of Bilobites, Cruziana, etc., the vegetable nature of which has been so strongly claimed by certain paleobotanists, it may be appropriate to mention that the first paper on this subject was written by Dr. J. E. Dekay in 1823,[6] and contains descriptions of certain of these forms in the cabinet of the Lyceum, which were

[1] Miscellaneous Localities of Minerals, communicated by various persons. No. 6, by J. P. Brace: Am. Jour. Sci., vol. 6, 1823, pp. 250, 251.

[2] Miscellaneous Notices of Mineral Localities, with Geological Remarks, by Edward Hitchcock: Am. Jour. Sci., vol. 14, 1828, pp. 215–230. See especially page 228. Also mentioned in Final Rept. Geology Mass., vol. 2, 1841, p. 456.

[3] A Report on the Geological Survey of Connecticut, by Charles Upham Shepard. New Haven, 1837, pp. 1–188, 8°. (See pp. 62, 166.)

[4] Description of several species of Fossil Plants from the New Red Sandstone Formation of Connecticut and Massachusetts, by Edward Hitchcock: Philadelphia Assoc. Am. Geol. and Nat., 1843, pp. 294–296, pl. xiii, fig. 1.

[5] Am. Jour. Sci., vol. 5, 1822, pp. 251–253. Chittenango is in Madison County, and it remains doubtful as to where this locality is.

[6] Note on the Organic Remains termed Bilobites, from the Catskill Mountains, by J. E. Dekay: Annals Lyceum Nat. Hist. N. Y., vol. 1, 1823, pp. 45–49, 1 pl.

collected by Mr. James Pierce at Cairo, in the Catskills, and in the Totoway Mountain in New Jersey. This paper establishes the priority of the name Bilobites, which will have to be credited to Dekay, although he states that the specimens were labelled "under the name of Bilobite." Dr. Dekay did not regard them as plants, but inclined to the belief that they might be molds or casts of an extinct species of Cardium, though he also quoted from a report by Mr. Say the opinion of that author that they belong to the genus Productus, a brachiopod.

Dr. Richard Harlan in describing his *Fucoides Brongniartii*,[1] 1835, mentions the western part of the State of New York as one of the localities at which it has been collected.

Mr. T. A. Conrad, in the first annual report of the Geological Survey of New York, 1837, mentions the occurrence of vegetable remains in the Third District at various localities (pp. 167, 168, 169, and 171), chiefly of the different fucoids (*F. Brongniartii* and *F. Alleghaniensis*), and in the second report of the same survey (Report of T. A. Conrad on the Paleontological Department of the Survey, pp. 107–119), he enumerates the fossil plants along with the other fossils under the different geological groups. In the sixth group, or Black Limestone of Trenton Falls, or Grauwacke Slate of the Hudson River, eight species of fucoids are named. In the same volume Mr. Lardner Vanuxem calls attention to these same forms in the Third District (p. 283), and Prof. James Hall in the Fourth District (pp. 357, 358).

In 1840 Professor Haldeman founded the genus Skolithus,[2] which he regarded as a fucoid from the Potsdam sandstone of Pennsylvania. It also occurs in the valley of Lake Champlain, and has since been found to have a wide distribution.[3]

Dr. Ebenezer Emmons (Nat. Hist. of New York, Agriculture, vol. 1, 1846, pp. 68, 69, pl. xiv–xvii) mentions *Gordia marina*, numerous fucoids, and a number of species of Nereites and Myrianites from the Taconic at McArthur's Quarry, in Jackson, Washington County.

Vanuxem's final report of the Geology of the Third District of New York[4] contains figures of a large number of fucoidal remains and other vegetable fossils. Good figures of *Fucoides Harlani* Conr., from the Medina sandstone, are given on page 71, and *Spirophyton velum*, from the Hamilton group at Lewis's Quarry, near Solsville, Madison County, is figured on page 160 (Fig. 39). Here, too

[1] Medical and Physical Researches, etc., by Richard Harlan. Philadelphia, 1835, p. 398, fig. 2. See also Trans. Geol. Soc. Pa., vol. 1, 1835, p. 110.

[2] Supplement to Number One of a Monograph of the Limnaides, etc., by S. S. Haldeman, 1840.

[3] Natural History of New York, Palæontology, vol. 1, 1847, p. 3.

[4] Natural History of New York, Geology of New York, pt. 3, Albany, 1842; 4°.

(p. 175), occurs the first figure of the now well known form *Ptilophyton Vanuxemi* Dawson from the Ithaca shales, about whose vegetable origin he was not less doubtful than are many at the present time, and *Sigillaria Vanuxemi* Göpp., from the Chemung at Owego, which, following a mistake initiated by Göppert, is commonly quoted as Oswego. From the Catskill group (pp. 190, 191) are figured a number of other plants (*Sigillaria simplicitas* Vanux., from Mt. Upton and North Bainbridge, *Lepidodendron Gaspianum* Dawson, etc.).

These researches were continued by Prof. James Hall in the subsequent reports on the Natural History of New York. In part 4 of the Geology of New York, comprising the survey of the Fourth Geological District (Albany, 1843), a number of Vanuxem's figures are reproduced, many others added, and names and descriptions given to many pre-Carboniferous forms,[1] among which were *Sphenopteris laxa* from Pine Valley, Chemung County, and *Sigillaria Chemungensis* from Black Creek and Wisner's Quarry, near Elmira, both from the Chemung.

In the Paleontology of New York, volume 1 (1857), some attempts at systematic descriptions were made. Thus, on page 2 we have a description of *Scolithus linearis* figured on pl. i, from the valley of Lake Champlain and the base of the Green Mountains; on pages 7 and 8, two new species of Palæophycus and one of Buthotrephis from the Calciferous Sandstone of various parts of the State (Mohawk Valley, Amsterdam, Fort Plain, Canajoharie, Chazy, Keeseville, etc.); on pages 38–40, two species of Phytopsis from the Birds-eye Limestone of the same and some other localities; on pages 62, 63, two species of Buthotrephis and two of Palæophycus from the Trenton limestone of Jacksonburgh, Middleville, West Canada Creek, Glens Falls, and Prospect Hill; on pages 261–264, two species of Sphenothallus, two of Buthotrephis, and two of Palæophycus, from the Utica slate and Hudson River group, from the Mohawk Valley, Schoharie, Turin, Martinsburgh, Loraine, Pulaski, Jackson, Union Village, Salem, and Rome. *Gordia marina* of Emmons, from McArthur's Quarry, Jackson, Washington County, is also figured here (pl. lxxi). In the tabular list, pp. 322–330, the number of species referred to the vegetable kingdom, including the genera Gordia and Phytopsis, amounts to seventeen, representing six genera, and distributed geologically as follow:

Potsdam Sandstone, 1 (*Scolithus linearis* Hald.).
Calciferous Sandstone, 3 (Palæophycus and Buthotrephis).
Birdseye Limestone, 2 (Phytopsis).
Trenton Limestone, 4 (Palæophycus and Buthotrephis).
Hudson River Group, 6 (four genera).

[1] Pages 28, 46, 47, 68, 69, 77, 241, 273, 275, pl. i.

Dr. Asa Fitch in 1849[1] enumerated five species of Palæophycus and one of Phytopsis from the Potsdam and Calciferous on the west side of Skene's Mountain, at Fort Ann, in the slates of Greenwich and Salem, at Hartford, and below the last falls of the Mettowee, near East Fort Ann.

In the second volume of the Paleontology of New York, 1852, fossil plants are described from the Medina sandstone (pp. 4–7) and from the Clinton group (pp. 18–26). These consist for the former horizon of about eight species of Arthrophycus, Scolithus, Palæophycus, Dictuolites, and other problematical forms, from the Oswego River, Rochester, Lockport, Medina, etc., and for the latter horizon of twice as large a number representing the genera Buthotrephis (six species), Palæophycus, Rusophycus (Cruziana), and Ichnophycus. These forms are all carefully figured in the plates (pl. i–iii, v–x). This is not the place to enter into any discussion as to the vegetable nature of any of these remains. Many of these species are found in the Taconic system of Emmons, and are described from the same localities in the American Geology of that author.[2]

In his description of the Paleozoic Basin of New York, Bigsby,[3] in 1858, mentions Smyrna and De Ruyter among the localities in the Chemung at which fossil plants are found.

In one of the more important papers by Dr. J. W. Dawson, which has been referred to when treating of his Canadian researches,[4] occurs his report upon the collections of Devonian plants from the State of New York which were intrusted to him by Professor Hall. From this material he identified seven species from the Catskill group, ten from the Chemung group, and seventeen from the Hamilton group; in all, thirty-four species, fifteen of which were here described for the first time. Among those from the last named group was mentioned somewhat doubtfully the Silurian species *Cordaites Robbii* occurring perhaps at Cazenovia.

In reviewing this paper by Dr. Dawson in the sixteenth annual report of the New York State Museum of Natural History, 1863 (pp. 108, 109), Professor Hall has changed the geological arrangement so as to refer the supposed Catskill species to the Chemung and Portage groups. He also here reproduces, on pages 79–82 and 110–117, a

[1] A historical, topographical, and agricultural survey of the county of Washington, by Asa Fitch: Trans. N. Y. State Agricultural Soc., vol. 9, Albany, 1850, pp. 753–944. (Fossil plants of Washington County, p. 862.)

[2] American Geology, containing a Statement of the Principles of the Science, with full illustrations of the characteristic American fossils, with an atlas and a geological map of the United States, by Ebenezer Emmons. Vol. 1, Albany, 1855, 8°; pt. 1, pp. i–xvi, 1–194, pl. i; pt. 2, The Taconic System, pp. 1–251, pl. i–xviii.

[3] On the Paleozoic Basin of the State of New York, etc., by J. J. Bigsby: Quart. Jour. Geol. Soc. London, vol. 14, 1858, pp. 335–452. (See p. 391.)

[4] On the Flora of the Devonian Period in Northeastern America, by J. W. Dawson: Quart. Jour. Geol. Soc. London, vol. 18, 1862, pp. 296–330, pl. xii–xvii.

number of the figures that had previously appeared in the large works above mentioned, and gives a more thorough and systematic account of them, with important changes in nomenclature. He also (pp. 84–91) describes the genera Uphantænia and Dictyophyton from the Chemung group of Steuben, Allegany, and Cattaraugus Counties. Good figures of these species are found not only in the text, but on the plates ii–v, of that report.

In 1870 excavations in Schoharie County revealed the presence of certain trunks, which Dr. Dawson referred to the genus Psaronius. This formed the subject of a paper by Professor Hall before the British Association.[1]

In 1872 Hall and Whitfield[2] published the new genus and species *Hippodophycus Cowlesi*, from the Chemung of Cattaraugus County. They were found at Salamanca, Randolph, and South Valley.

In 1879 Professor Hall published a brief paper on the genus Plumalina, with excellent figures, in which he proposes to refer the *Ptilophyton Vanuxemi* of Dawson to the family Plumularidæ (Hydrozoa) under the name of Plumalina and of which he thinks he detects two species (*P. plumaria* Hall and *P. densa.*)[3]

In Dr. Dawson's Notes on New Erian (Devonian) Plants,[4] a number of new forms from the Devonian of New York are described: *Asteropteris noveboracensis* Dawson, n. g. and sp. n., from the Portage group of Milo, *Equisetites Wrightiana* Dawson and *Cyclostigma affinis* from that of Italy, and *Celluloxylon primævum* Dawson, n. g. and sp. n., from the Hamilton of Canandaigua.

The same year Mr. C. D. Walcott published his Fossils of the Utica Slate,[5] in which are described two species of Cyathophycus and one of Discophycus, two new genera from Trenton, Oneida County. They are illustrated in figures 16–18 of plate ii, and were believed by him to be algæ.

In 1881 Prof. H. S. Williams defended the vegetable origin of Ptilophyton from the Devonian shales of Ithaca,[6] and in 1882 Dr. J. W. Dawson published a paper[7] in the first part of which he treated the subject of The Nature and Affinities of Ptilophyton, giving his views

[1] On the occurrence of trunks of Psaronius in an erect position resting on their original bed, in rocks of Devonian age in the State of New York; etc., by James Hall: Rept. Brit. Assoc., 42d (Brighton) meeting, 1872, trans., p. 103.

[2] Remarks on some peculiar impressions in Sandstone of the Chemung group, New York, by James Hall and R. P. Whitfield: 24th Ann. Rept. N. Y. State Mus. Nat. Hist., Albany, 1872, pp. 201–207, 1 text-fig.

[3] 30th Ann. Rep. N. Y. State Mus. Nat. Hist., Albany, 1879, pp. 255–256, 4 pl.

[4] Quart. Jour. Geol. Soc. London, vol. 37, 1881, pp. 299–308, pl. xii, xiii.

[5] Trans. Albany Inst., vol. 10, 1883, pp. 18–38, pl. ii (printed in advance, June, 1879).

[6] Proc. Am. Assoc. Adv. Sci., 30th (Cincinnati) meeting, 1881 (1882), p. 204.

[7] Recent Discoveries in the Erian (Devonian) Flora of the United States, by J. W. Dawson: Am. Jour. Sci., 3d series, vol. 24, 1882, pp. 338–345.

upon the relations of the Ithaca forms to those of Scotland and of Pennsylvania, and re-affirming his opinion that they are of vegetable origin. The second part of this paper relates to some specimens of silicified trunks found by Professor Hall in the Hamilton group of New York, which he recognizes as belonging to his genus Dadoxylon. The third part discusses some forms referable to Cladoxylon and to Celluloxylon, discovered by Prof. J. M. Clarke in the Hamilton group, and certain cryptogamous plants (Asteropteris, Equisetites and Cyclostigma) collected by Mr. B. H. Wright, of Penn Yan, N. Y., in the Portage and Chemung groups. The fourth and last part of this paper merely calls attention to the presence of Rhodea in the Ithaca shales associated with the Ptilophyton.

In 1883 Dr. J. S. Newberry founded his new genus Spiraxis, upon specimens collected in the Chemung rocks of southern New York and northern Pennsylvania, and described two species.[1]

In some Notes on the Geology of Yates County, New York,[2] Prof. Berlin H. Wright reproduces Dawson's descriptions and figures of the three species (*Equisetites Wrightiana, Cyclostigma affinis*, and *Asteropteris noveboracensis*) from the Chemung of Italy and the Portage of Milo, New York, and mentions the occurrence of other forms in the Genesee shale.

In a paper On Devonian spores[3] Prof. J. M. Clarke announces the discovery of spores, similar to those described by Dr. J. W. Dawson, in the Marcellus beds of Ontario County and in the Genesee shales, especially in Canandaigua, East Bloomfield, and at Padelford's, on the New York Central Railroad. He distinguishes the species *Sporangites Huronensis* and *S. bilobatus* in New York strata. Bodies of this nature had already been mentioned as occurring in New York,[4] but they had not hitherto been correlated with the Canadian and Brazilian forms.

In 1885 Clarke[5] published a paper in which fossil plants are mentioned as occurring in the Genesee shales at Naples, Bristol Centre, and Black Point on Canandaigua Lake; in the Naples shales (Portage) at Naples and at Sparta (Livingston County); and in the Portage at Naples and High Point.

Mr. N. H. Darton is authority for the occurrence of Devonian plants near Monroe and Woodbury Falls, Orange County.[6]

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[1] Descriptions of some Peculiar Screw-like Fossils, from the Chemung Rocks, by J. S. Newberry: Annals N. Y. Acad. Sci., vol. 3, No. 7, 1883, pp. 217–220, pl. xviii.

[2] 35th Ann. Rept. N. Y. State Mus. Nat. Hist., Albany, 1884, pp. 195-206, pl. xv.

[3] Am. Jour. Sci., 3d series, 1885, vol. 29, pp. 284–289.

[4] See Dawson's paper on Rhizocarps in the Paleozoic Period. Proc. Am. Assoc. Adv. Sci., 32d (Minneapolis) meeting, 1883 (1884), pp. 260–264.

[5] On the higher Devonian Faunas of Ontario County, N. Y., by John M. Clarke: Bulletin U. S. Geol. Survey, No. 16, 1885, pp. 1–86, pl. i–iii.

[6] In a letter from Mr. I. C. Russell, dated November 2, 1887.

New Jersey.—The forms of Bilobites from the Totoway Mountains described by Dekay in 1823 have already been referred to (supra, p. 855), but it is only within the past eight years that the most important plant beds of New Jersey have been discovered.

In his "Notes on Later Extinct Floras of North America," read before the Lyceum of Natural History of New York April 22, 1867, Dr. J. S. Newberry placed his *Cupressites Cookii* and *Salix membranacea* in his preliminary list (p. 9), but described only the latter (p. 19) as from Lower Cretaceous strata, Raritan River, New Jersey.

In 1879 Prof. H. Carvill Lewis found a fossil fucoid at Milford, N. J., a photograph of which he sent to Professor Lesquereux, who pronounced it a Palæophycus. This figure was published in the proceedings of the Philadelphia Academy of Sciences[1] as *Palæophycus limaciformis* Lewis. The principal interest that attaches to this discovery is its occurrence in so recent a formation, which is supposed to be a fresh water deposit, the genus Palæophycus being a very ancient (Devonian or Silurian) type.

The first authentic announcement we have of the existence of a Cretaceous flora in New Jersey was made by Dr. J. S. Newberry in the columns of Nature for June 30, 1881.[2] Between this date and November 10, 1885, there appeared occasional indications that this flora was being thoroughly elaborated at the School of Mines, Columbia College, New York, and Dr. Newberry was able at the meeting of the Torrey Botanical Club of that date to give a further account of it.[3] He also read a paper on the subject before the National Academy of Sciences, at Albany, the same year (Transactions, vol. 5, 1885, p. 18).

Progress in making this flora known has been exceedingly slow, and the first published indication of its character appeared in the Transactions of the New York Academy of Sciences for January, 1886.[4] The plants occur in what have long been known as the Raritan or Amboy clays, and are accompanied by lignite. They were first found along the Raritan River, but owing to the perishable nature of the impressions little could be done with them. More recently better material has been obtained at Woodbridge and South Amboy, also in the Kreischerville fire-clay, in which the leaf-prints are permanent. In this paper we have the first intimation of the botanical relations of this flora. At that time "about a dozen species of conifers, as many ferns, two or three cycads, fifty to sixty angiosperms (dicotyledons), with many fruits and some flowers" had

[1] A new Fucoidal Plant from the Trias., by Henry Carvill Lewis: Proc. Acad. Nat. Sci. Phila., vol. 32, 1880, pp. 293, 294. (Read Nov. 24, 1879.)

[2] American Cretaceous Flora, Nature, vol. 24, London, 1881, pp. 191, 192.

[3] On the fossil plants of the New Jersey Cretaceous, by J. S. Newberry: Bulletin of the Torrey Botanical Club, vol. 12, 1885, p. 124.

[4] The Cretaceous Flora of North America, by Dr. J. S. Newberry: Trans. New York Acad. Sci., vol. 5, 1886, pp. 133–137.

been identified. Among the conifers, there were represented the genera Pinus, Brachyphyllum, Moriconia, Sequoia, Juniperus, Thuya, and Dammara. Species of Gleichenia, Dicksonia, and Aspidium were detected among the ferns, while the cycads resembled Podozamites as found in the Cretaceous of Greenland. The dicotyledons embraced the genera Liriodendron, Magnolia, Sassafras, Aralia, Celastrus, Celastrophyllum, Salix, Hedera, Ficus, Diospyros, Juglans, Bauhinia, and Hymenæa.

With the exception of the last two genera, this flora is not widely different from what might have been expected in Middle Cretaceous strata of North America, corresponding in horizon with the Dakota group of the west. The "Helianthoid composite flower" may represent a later modified form of the group of plants found in Lower Mesozoic strata which have gone by the name of Williamsonia. Two specimens of this last named type have been discovered in the Potomac formation on the James River, which is supposed to be of Cretaceous age, though of course much older than the Raritan clays.

In the abstract of his paper before the Torrey Botanical club on The Flora of the Amboy clays, published in the Bulletin of that club for March, 1886, Dr. Newberry enters somewhat more fully into the character of this flora.[1]

In the same publication for May of that year[2] he gives a Description of a species of Bauhinia from the Cretaceous clays of New Jersey, with figures of the fossil species and of three living species, which appear to leave no doubt that the impressions belonged to that genus.

Another still more important contribution has since been made by Dr. Newberry to the same subject.[3] Three new species of Liriodendron (*L. oblongifolium*, *L. quercifolium* and *L. simplex*) are here described and figured from the New Jersey Cretaceous. They represent the extremes in the matter of lobation, *L. simplex* being less lobed than *L. Meekii* Heer, of the Dakota group, while the other two species are more lobed, one of them much more so than our living *L. Tulipifera*.

It is known that Dr. Newberry has prepared an extensive series of drawings of the plants of this formation, and it is greatly to be desired that he may soon publish a final monograph on this subject.

In 1884 Mr. J. B. Marcou made a small collection of leaf prints from a bed of Pleistocene or Quaternary age at Bridgeton, N. J. Professor Lesquereux[4] finds among them the shingle oak (*Quercus*

[1] Bull. of the Torrey Botanical Club, vol. 13, 1886, No. 3, pp. 33–37.

[2] Ibid., No. 5, pp. 77, 78, pl. lvi.

[3] The Ancestors to the Tulip Tree, by J. S. Newberry: Ibid., vol. 14, 1887, No. 1, pp. 1–7, pl. lxi. lxii.

[4] Proc. U. S. Nat. Mus., vol. 10, 1887, pp. 39–46.

imbricaria, Michx.), and other forms that he fails to identify with any known genus (*Phyllites fraxineus* and *P. mimusopsoideus*).

Later collections made by Mr. Frank Burns and Mr. John I. Northrop, from the same deposit, are now in process of elaboration by the latter gentleman at the School of Mines, Columbia College, New York.

In the graphite found in the white crystalline (Archæan) limestone of Sussex County, Dr. N. L. Britton[1] has discerned certain forms which he has figured and described as *Archæophyton Newberryanum*, representing a new genus, whose affinity he assumes as perhaps nearest the algæ. That it is highly problematical needs scarcely to be stated.

From the sandstone quarries near Newark, Dr. Newberry, in his Monograph above quoted, describes *Equisetum Meriani* Brongn., *Dioonites longifolius* (Emm.) Font., and a species of Palissya. He also reports *Cheirolepis Münsteri* from Milford. These, with *Palæophycus limacifolius* mentioned above, constitute the present known Triassic flora of New Jersey.

Pennsylvania.—The general impression prevails among paleobotanists that the paper published in the first volume of the Transactions of the American Philosophical Society at Philadelphia in 1818, by the Rev. Henry Steinhaue. On Fossil Reliquia of unknown Vegetables in the Coal Strata, which was the first paper containing descriptions and figures of fossil plants with generic and specific names attached, related to the Pennsylvania deposits and the plants found in them. I examined the paper several years ago and could find no reference to American localities.[2] A second careful examination of this paper confirms all that was then ascertained relative to it,[3] and I mention it here only because some might be surprised at its omission from the literature of the fossil plants of Pennsylvania.

The earliest collector of vegetable remains in the coal regions of that State was Mr. Zachariah Cist, who published several papers in the American Journal of Science[4] relative to the coal, incidentally mentioned the impressions associated with it, and sent invoices of these specimens to Adolphe Brongniart in Paris for determination.

The plants thus sent are enumerated in Brongniart's Prodrome, 1828, and described and illustrated in his Histoire des Végétaux Fossiles, 1828. The principal species are *Calamites Cistii, C. Suckowii, Neuropteris Cistii, Pecopteris polymorpha, P. gigantea, P. punctu-*

[1] On an Archæan Plant from the White Crystalline Limestone of Sussex County, N. J., by N. L. Britton: Annals N. Y. Acad. Sciences, vol. 4, 1888, No. 7, pp. 123–124, pl. vii.

[2] Fifth Ann. Rept. U. S. Geol. Survey, 1883–'84, Washington, 1885, p. 403.

[3] See H. C. Wood's Catalogue of Carboniferous Plants in the Museum of the Academy of Natural Sciences, with corrections in Synonomy, descriptions of new Species, etc., in Proc. Acad. Nat. Sci. Philadelphia, vol. 12, 1860, pp. 436–443.

[4] Vol. 4, 1822, pp. 1–16; vol. 9, 1825, pp. 165, 166.

lata, Sigillaria Sillimani, S. obliqua, Sphenophyllum emarginatum, Lepidodendron mamillare, L. varians, L. aculeatum, L. Cistii, Stigmaria intermedia, S. tuberculosa, Annularia fertilis, and *A. longifolia,* all from the Wilkes Barre coal beds.

On March 8, 1831, Dr. Richard Harlan read before the Academy of Natural Sciences of Philadelphia a Description of an Extinct Species of Fossil Vegetable of the family Fucoides.[1] The species described in this paper was his *F. Alleghaniensis,* which had been collected from the Alleghany Mountains near Lewistown, on the north side of the Juniata River, in Mifflin County.

This plant was also figured by Richard C. Taylor in Loudon's Magazine of Natural History, 1834 (p. 29),[2] and in the Transactions of the Geological Society of Pennsylvania (vol. 1, pt. 1, Philadelphia, 1834), in his paper On the Geological Position of certain Beds which contain numerous fossil Marine Plants of the family Fucoides, near Lewistown, Mifflin County, Pennsylvania, he goes quite extensively into the subject, describing his journey through that region and giving figures of this plant and other organic remains.

In the same volume Dr. Richard Harlan mentions the occurrence of "dicotyledonous lignite" in the deep cut of the Chesapeake and Delaware Canal, and enumerates (pages 107, 108) most of the fossil plants from the coal measures of Wilkes Barre, which had been described by Brongniart, certain fucoids and ferns (*Pecopteris obsoleta, P. Milleri,* and a Neuropteris), also *Equisetum stellifolium,* all of which were from different localities in the Lehigh and Schuylkill coal mines.[3]

In 1831 Prof. Benjamin Silliman mentioned the existence of vegetable remains at Mauch Chunk,[4] seen by him on his visit to that place on May 13, 1830. A year later Maximilian, Prinz zu Neuwied, also visited these coal mines and noted their presence in his Journey into the interior of North America.[5] He carried away with him specimens of these plants, which he submitted to Dr. Göppert for identification. The latter prepared a systematic paper upon them, which was published as an appendix to that volume.[6] They included species of Odontopteris, Calamites, and Sagenaria.

[1] Jour. Acad. Nat. Sci. Phila., vol. 6, 1831, pp. 289-295, pl. xv.

[2] A description of a Fossil Vegetable of the Family Fucoïdes in the Transition Rocks of North America, etc., by R. C. Taylor: Mag. Nat. Hist., vol. 7, London, 1834, pp. 27-32.

[3] Trans. Geol. Soc. Pennsylvania, vol. 1, pt. 1, Philadelphia, 1834, pp. 46-112; pt. 2, 1835, 256-262, pl. xiv.

[4] Notes on a Journey from New Haven, Conn., to Mauch Chunk and other Anthracite regions of Pennsylvania, by Benjamin Silliman: Am. Jour. Sci., vol. 19, 1831, pp. 1-21. (See p. 17.)

[5] Reise in das Innere Nord-America in den Jahren 1832, bis 1834, von Maximilian, Prinz zu Wied, vol. 1, Coblenz, 1839, p. 1-653, 4°. (See p. 111.)

[6] Ibid., Beilage, A. A., pp. 636-642.

The much discussed fossil, *Scolithus linearis*, was first discovered by Haldeman at a point south of Reading and north of Columbia, in 1835, and described by him as *Skolithos linearis*, but his description does not seem to have been published till 1840,[1] when he had changed it to "Fucoides."

On May 30, 1843, Mr. Richard C. Taylor communicated to the American Philosophical Society a Notice of fossil Arborescent Ferns, of the Family of Sigillaria, and other Coal Plants exhibited in the Roof and Floor of a Coal Seam in Dauphin County, Pennsylvania,[2] at the close of which he gives a list of the plants found at that place, amounting to twenty species.

Mr. J. E. Teschemacher made a second communication On the fossil vegetation of America in 1847,[3] in which he described some coal plants from Carbondale, Pa., accompanied by a few wood cuts. About sixteen different forms are enumerated which are either identified with European species or are not specifically determined. His note in the twelfth volume of the same periodical[4] does not add anything to this number, but merely discusses some questions raised by Göppert as to the method of the formation of coal plants, based on material in his collection, and he further strengthened the views there expressed in a subsequent paper read before the Boston Society of Natural History on April 7, 1852.[5]

In the last named publication for April, 1854, Dr. Alfred T. King, of Greensburgh, Pa., published two short communications describing certain petrified trunks and fruits in Westmoreland and Beaver Counties.[6]

In 1851 Prof. Leo Lesquereux commenced his important researches upon the coal flora of Pennsylvania. His first paper appeared in 1854.[7] This paper, which is preceded by some introductory observations by Prof. Henry Darwin Rogers, director of the Pennsylvania Geological Survey, describes one hundred and ten species, a very large percentage of which were here first made known to science.

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[1] Supplement to Number One of "A Monograph of the Limniades, or Freshwater Univalve Shells of North America," containing descriptions of apparently new animals in different classes and the names and characters of the subgenera in Paludina and Anculosa, by S. S. Haldeman. Published October, 1840, for gratuitous distribution. (See p. 3).

[2] Trans. Am. Philos. Soc., vol. 9, Philadelphia, 1843, pp. 219–227.

[3] Am. Jour. Sci., 2d series, vol. 3, 1847, pp. 86–90.

[4] Note on the Vegetation of the Coal Period, by J. E. Teschemacher: Am. Jour. Sci., 2d series, vol. 12, 1851, pp. 438, 439.

[5] Proc. Boston Soc. Nat. Hist., vol. 4, 1851–1854, pp. 199–202.

[6] Description of Fossil Trees in the Coal Rocks near Greensburgh, Westmoreland County, Pennsylvania, by Alfred T. King: Proc. Acad. Nat. Sci. Phila., vol. 7, 1854, pp. 64, 65. (Description of Fossil Fruit found in the Carboniferous Rocks of Beaver County, Pa.; Ibid., p. 66.)

[7] New species of Fossil Plants from the Anthracite and Bituminous Coal-fields of Pennsylvania, by Leo Lesquereux: Boston Jour. Nat. Hist., vol. 6, 1854, pp. 414–431.

The inaugural dissertation of Mr. James P. Kimball, of Salem, Mass., prepared for the degree of doctor of philosophy of the University of Göttingen, in 1857, entitled "Flora from the Appalachian Coal Fields," is devoted to a systematic description of a number of fossil vegetable impressions collected by Prof. Ferdinand Roemer when in North America, chiefly from the Appalachian region in Pennsylvania and Ohio. It embraces twenty-two species, two of which (*Neuropteris Rogersi* Lx. and *Lepidodendron Beyrichii*) were new. The remainder are correlated with species already known, chiefly from European strata, and a full bibliography and synonymy accompanies the descriptions. The work contains three plates, on which the new species and other forms are figured with great care and fidelity. All but three of the species here described were found in the coal formations of Pennsylvania, but the exact localities are not stated.

Professor Lesquereux's second paper appeared in 1858.[1] This paper, as the title implies, consists of a catalogue of the fossil plants in the cabinet of the Pottsville Scientific Association, which had been studied and identified by Professor Lesquereux, but among which there were found to occur quite a number not previously described. At the close of the paper is a summary of the data made by a committee on publication that had analyzed its contents, from which it appears that thirty-five genera and three hundred species were contained in the collection.

Mr. Samuel Lewis's paper on Impressions of Vegetables on Coal, which immediately follows the one last considered (page 24), mentions three species identified by Professor Lesquereux, from Pennsylvania coal mines, in which the imprints of the plants were recognizable upon the surface of pieces of coal.

But it was in the reports of the Pennsylvania Geological Survey that the great results of these and subsequent investigations were laid before the public, and these may be found in the second volume, part 2, of the Geology of Pennsylvania, under the direction of Prof. Henry Darwin Rogers, State geologist, published in Philadelphia in 1858. With the exception of the naming of one species (*Lepidodendron primævis*, page 828, Fig. 675), by Professor Rogers himself, and the figuring of a few others, the work on the fossil plants was performed exclusively by Professor Lesquereux. His contributions to this volume consist first of some "General Remarks on the Distribution of the Coal Plants in Pennsylvania and on the formation of the Coal" (pp. 837–847); second, "Description of the Fossil Plants found in the Anthracite and Bituminous Coal Measures of Pennsylvania" (pp. 847–878, pl. i–xxiii); and third, "Catalogue

[1] The Fossil Plants of the Coal Measures of the United States, with descriptions of the New Species in the Cabinet of the Pottsville Scientific Association, by Leo Lesquereux: [Read before the Pottsville Sci. Assoc., Feb. 13, 1858.] Pottsville, 1858, 22 pp., pl. i, ii. 8°.

of the Fossil Plants which have been named or described from the Coal Measures of North America" (pp. 878–884). Under the second of these titles a very large number of hitherto unknown coal plants are described. It will thus appear that this volume contains a complete account not only of the coal flora of Pennsylvania as known at that time, but of the Carboniferous flora of the United States. The localities are, of course, carefully given, but to avoid duplication it seems best to postpone their enumeration until his later final reports, published by the Second Geological Survey of the State, are considered.

In 1860 Dr. Horatio C. Wood, jr., published his Contributions to the Carboniferous Flora of the United States,[1] in which he describes thirty new species found in the cabinet of the Academy, chiefly from the Pennsylvania coal measures. The localities were generally unknown, but Shæver's Drift, East Norwegia, Milnes Mine, St. Clair, Broad Top Coal Region, and Mine Hill in the Black Heath Colliery, Ashland, and the Hazleton Mines are mentioned.

In Dr. J. W. Dawson's important paper On the Flora of the Devonian Period in Northeastern America, which has been so often referred to (supra, page 843), the Devonian species mentioned by Rogers in the Geology of Pennsylvania (vol. 2, pt. 2, 1858, pp. 828–830) are taken up and more accurately determined. The form figured on page 829, fig. 677, is identified as *Lepidodendron Gaspianum* Dawson. *L. primævis* is believed to be identical with *Sagenaria Veltheimiana* Presl., and Lesquereux's *Noeggerathia obtusa* is referred to Cyclopteris. This appears to be the same as Rogers's "Ponent Fern" (p. 830, fig. 684).

On May 18, 1866, Professor Lesquereux made a communication to the American Philosophical Society on Fucoides in the coal formation,[2] in which he describes a new species of Caulerpites (*C. marginatus*) found on Slippery Rock Creek, opposite Wurtemburgh, Lawrence County, Pa., which was regarded as belonging to the lower portion of the Carboniferous formation, although the form considered in itself would indicate a lower horizon.

The same volume[3] contains Dr. Horatio C. Wood's Contribution to the Knowledge of the Flora of the Coal Period in the United States, which is a review of the previous papers presented by him to the Philadelphia Academy of Sciences, as a result of his studies of the material in the cabinet of the Academy. About fifteen new species are added to the original lists. The illustrations are excellent.

The two papers by Prof. Herman L. Fairchild on the structure of Lepidodendron and Sigillaria and on the variations of the leaf-scars of *Lepidodendron aculeatum* Sternb., published in the An-

[1] Proc. Acad. Nat. Sci. Phila., vol. 12, 1860, pp. 236–240; 519–522.
[2] Trans. Am. Philos. Soc., vol. 13, Philadelphia, 1869, pp. 313–328, pl. vii.
[3] Ibid., pp. 341–349, pl. viii–ix.

nals of the New York Academy of Sciences, vol. 1, Nos. 2 and 3, were based upon material from the Carboniferous strata of Wilkes Barre, Scranton, Lackawanna Valley, and Nanticoke, in Pennsylvania.

On January 5, 1877, Professor Lesquereux read a paper before the American Philosophical Society On the progress of the North American Carboniferous Flora, in preparation for the Second Geological Survey of Pennsylvania,[1] in which he indicates the nature of the important work already undertaken and which we shall presently have occasion to consider.

As a second precursor of this great work, Professor Lesquereux published in the same society a revision of the American species of Cordaites[2] in which he refers to the plates already prepared for the forthcoming monograph. Some of these species were especially interesting in showing the inflorescence and fructification of that ancient type of vegetation. A case of this kind received special treatment in a second short paper read before the same society on April 4, 1879,[3] in which we have, as it were, an immature Rhabdocarpus bearing the remains of the male inflorescence upon its summit, which certainly throws a flood of light upon the nature of this form of vegetable life.

The first two volumes of the Coal Flora of Pennsylvania,[4] bound in one, appeared in 1880, and embodied the results of all previous investigations into the Carboniferous flora, not only of the State of Pennsylvania but of the entire United States, with complete descriptions and synonymy, and accompanied by an atlas of eighty-five double lithographic plates.

The third and last volume of this work appeared in 1884, and consists of a systematic revision of the previous volumes and the embodiment of the information from all sources in the possession of the author at that date. This work is unquestionably the most important contribution to the Paleozoic flora of the United States that has been produced, and it constitutes a complete manual of the same for the entire country. The total number of species embraced in the work amounts to eight hundred and thirty-five, from fifteen States of the Union, and ranging from the Devonian to the top of the productive coal measures.

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[1] Proc. Am. Philos. Soc., vol. 16, Philadelphia, 1877, pp. 397–416.

[2] On the Cordaites and their related generic divisions in the Carboniferous formation of the United States, by Leo Lesquereux: Ibid., vol. 17, 1878, pp. 315–335.

[3] On a Branch of Cordaites, bearing Fruit, by Leo Lesquereux: Ibid., vol. 18, 1879, pp. 222–223, pl. iii.

[4] Second Geological Survey of Pennsylvania, Report of Progress P: Description of the Coal Flora of the Carboniferous Formation in Pennsylvania, and throughout the United States, by Leo Lesquereux: Vol. 1 (1) Cellular Cryptogamous Plants, Fungi, Thalassophytes; (2) Vascular Cryptogamous Plants, Calamariæ, Filicaceæ (Ferns); Vol. 2 (1) Lycopodiaceæ; (2) Sigillariæ; (3) Gymnosperms, 2 vols. in one, Harrisburg, 1880, i–xvi, 1–694, i–lxiii, map, and pl. lxxxvi, lxxxvii; with atlas, 18 pp., pl. A. B., i–lxxxv, 8°. Vol. 3, Harrisburg, 1884, pp. 695–977, pl. lxxxviii–cxi, 8°.

The following are the localities arranged according to horizons in the ascending scale, from the Middle Devonian to the bituminous coal beds:

Middle Devonian:
- Huntingdon, Huntingdon County, 1 species.

Chemung group:
- Vergent series, perhaps on the Juniata River, locality not stated (see p. 396; also Rogers's Geol. Pennsylvania, 1858, pp. 829–756), 1 species.

Catskill group:
- Meshoppen, Wyoming County, 6 species.
- Coxton Narrows, 5 species.
- Montrose, Susquehanna County, 1 species.
- Tioga County, 2 species.

Pocono Sandstone:
- Mauch Chunk, 3 species.
- Pottsville, 2 species.
- Sideling Hill, Huntingdon County, 7 species.

Subconglomerate:
- Mauch Chunk, 1 species.
- Pottsville, 4 species.

Interconglomerate:
- Campbell's Ledge, near Pittston, 101 species.
- West Pittston, Brewery Cut, 4 species.
- Slippery Rock Creek, Lawrence County, 1 species.
- Venango County, near Oil City, 1 species.

Middle or Productive Coal Measures:
- Shamokin, Northumberland County, 22 species.
- Lehigh Summit, 6 species.
- Trevorton (Low Coal) Northumberland County, 12 species.
- Coxton and Everhart Creek, 8 species.
- Johnstown, Cambria County (Low Coal), 3 species.
- Gaines, Tioga County, 2 species.
- Broad Top, Huntingdon County, 1 species.
- Archbald, Lackawanna County, 13 species.
- Carbondale, Lackawanna County, 20 species.
- Boston Mine, Pittston, 18 species.
- Ontario Colliery, Pittston, 18 species.
- "Butler Dam," Pittston, 9 species.
- Hughestown Deep Shaft, Pittston, 6 species.
- Brown Colliery, Pittston, 48 species.
- Butler Mine, Pittston, 57 species.
- Pennsylvania Coal Company (Shaft No. 6), Pittston, 11 species.
- Port Griffith Railroad Cut, below Pittston, 33 species.
- Seneca Mine, Pittston, 12 species.
- Pittston, not further defined, 5 species.

Carbon Hill Shaft, Old Forge, Lackawanna County, 2 species.
Carbon Hill Tunnel, Old Forge, 13 species.
Tompkins Mine, Pittston, 12 species.
Wilkes Barre, not further defined, 34 species.
Oakwood Colliery, Wilkes Barre, 32 species.
Stanton and Empire Mines, Wilkes Barre, 53 species.
Connell's Mine, Minooka, Lackawanna County, 2 species.
Taylorville, Bucks County, 6 species.
Susquehanna Anthracite Coal Company Mine, 1 species.
Rausch Gap, 7 species.
Pottsville (Mammoth Vein), 6 species.
Yatesville (railroad cut), 17 species.
Port Griffith, Switch-back, 15 species.
Kingston, Luzerne County, 3 species.
Plymouth, 27 species.
Orchard Mine Vein, 28 species.
Maltby, 9 species.
Olyphant, Lackawanna County, 92 species.
Enterprise Colliery, Plainsville, Luzerne County, 5 species.
Gate and Salem Vein, Pottsville, 49 species.
South Salem Vein, Pottsville, 8 species.
Gate Vein, New Philadelphia, 17 species.
Salem Vein, Port Carbon, 7 species.
Salem Vein, Tremont, 7 species.

Localities of uncertain horizon:
Tremont, New Vein, Schuylkill County, 3 species.
Pottsville and vicinity, 11 species.

Bituminous coal region:
Cannelton, Beaver County, 241 species.
Beaver County, 1 species.

Almost simultaneously with the appearance of the first two volumes of the work last mentioned, there issued from the same press another work, second only to this in importance, namely, The Permian or Upper Carboniferous Flora of West Virginia and Southwestern Pennsylvania, by Wm. M. Fontaine and I. C. White.[1]

The greater part of the plants described in this work are from West Virginia and will be considered in treating that State. The following occur in Pennsylvania: Little Washington, *Annularia minuta* Brongn.; Carmichael's, Greene County, *Pecopteris Miltoni* Artis, *P. Merianiopteroides* F. & W., *Rhacophyllum lactuca* (Sternb.) Schimp., and *R. speciocissimum* Schimp.; Jollytown, Greene County, *Neuropteris* sp.?; Greene County not more definitely stated, *Odontopteris pachyderma* F. & W.; near Washington, Washington County, *Sigillaria Brardii* Brongn.

[1] Second Geological Survey Pennsylvania, Report of Progress P P, Harrisburg, 1880, ix, 143 pp., 38 pl., 8°.

Professor Lesquereux's Report on the recent additions of fossil plants to the Museum collections of Harvard College[1] mentions the accession to that museum of a considerable number of Carboniferous plants collected by Mr. I. C. Mansfield, of Cannelton, Pa. From the list given it appears that they add nothing to the flora as published in the report of the Second Geological Survey.

In mentioning under New York Dr. Newberry's paper on Spiraxis (supra, p. 859) it was stated that specimens of this form occurred in northern Pennsylvania. One of the species there described (*S. Randalli*) was collected at Warren, Pa., by Mr. F. A. Randall.

In 1883 Dr. James Hall figured in the Transactions of the American Institute of Mining Engineers Some new plant forms lately found in the Peach Bottom slates of southeastern York and southern Lancaster counties, doubtfully referable to Halymenites and Buthotrephis.[2] The horizon is Lower Silurian, and Dr. Hall believes it to lie in either the Hudson or the Quebec group.

Among the miscellaneous collections that have recently been sent from the National Museum to Professor Lesquereux for identification, and which were published in the proceedings of the Museum,[3] the following were from Pennsylvania: *Calamites Cistii* Brongn., locality not definitely stated; *Archæopteris minor* Lx., Towanda, Bradford County; *Neuropteris Carrii* Lx., *N. cordata* Brongn., *Pseudopecopteris anceps* Lx., *P. Plukenetii* (Schloth.)Lx., *Sigillaria monostigma* Lx., *Cordaites borassifolius* (Sternb.)Ung., *C. costatus* Lx., and *C. Mansfieldi* Lx., Cannelton, Beaver County; *N. hirsuta* Lx., and *N. Loshii* Brongn., Saint Clair, Schuylkill County; also *N. obscura* Lx., *N. rarinervis* Bunb., *Pecopteris dentata* Brongn., and *P. villosa* Brongn. var. *microphylla* Lx., Greene County.

Maryland.—The only locality in Maryland from which Carboniferous plants have been reported is at Frostburgh, Allegany County, in the Cumberland coal mining region. Lyell passed through this place during his travels in the United States,[4] and collected a number of specimens, which he submitted to Bunbury for determination. Bunbury's report on the material was published in the Journal of the Geological Society of London.[5] Twenty-one species are described in this report, a few of which were new at the time.

In the first report of the State agricultural chemist to the House

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[1] Bull. Mus. Comp. Zoöl. Harvard Coll., vol. 6, No. 6, Oct., 1881, pp. 225–230.

[2] Vol. 12, Easton, 1883, pp. 357–358, pl. A, B, C.

[3] List of recently identified Fossil Plants belonging to the U. S. Nat. Mus., with descriptions of several new species, by Leo Lesquereux: Proc. U. S. Nat. Mus., vol. 10, 1887, pp. 21–46, pl. i–iv.

[4] Travels in North America, with Geological Observations on the United States, Canada, and Nova Scotia, by Charles Lyell. Vol. 2, London, 1845, 8°. (See pp. 8–22.)

[5] On some remarkable Fossil Ferns from Frostburgh, Maryland, collected by Mr. Lyell, by Chas. J. F. Bunbury: Quart. Jour. Geol. Soc. London, vol. 2, 1845, pp. 82–91, pl. vi, vii.

of Delegates of Maryland in 1860, Tyson[1] mentions the occurrence of coniferous plants in the Cretaceous, and silicified coniferous wood and remains of cycads in the iron-ore clays (Potomac) of the same formation.

In the early part of July, 1887, Mr. W J McGee discovered a bed of fossil leaves at Grove Point, on the eastern shore of the Chesapeake Bay near its head, and brought specimens for my inspection. He stated that they came from undoubted Potomac strata. The impressions were very indistinct and easily effaced, and few of them gave any certain characters. They were chiefly dicotyledonous and seemed to present a very different appearance from any other plant remains that I had seen from that formation. I did not hesitate to say that they indicated a more recent geologic age than do those of the localities in Virginia visited by me. This collection was also seen a few days later by Dr. Newberry, who confirmed my opinion and thought he could detect some of the forms that he was then studying from the Raritan clays of New Jersey.

On the 22d of October of that year, I visited the locality myself in company with Mr. McGee, but failed to discover any strata in which the impressions were better preserved. I made another small collection which I brought safely to Washington, and which still awaits a careful study. As all the plant remains previously found in Potomac strata are believed to have come from the lower member of that formation, only silicified wood and lignite having been known from the upper member, it is probable that this bed belongs to the latter member, which would sufficiently account for the difference in the floras.

Prof. P. R. Uhler has very thoroughly explored the country in the vicinity of Baltimore, and finds many plant beds in the Potomac clays. Exceptional facilities were afforded him by the excavations made within the city limits and he was thus able to examine many beds which were soon afterward destroyed. Lignite is abundant at nearly all points and silicified wood is also found. But in addition to these he has met with several localities where ferns, conifers, and even dicotyledons occurred. In October, 1886, I not only had the pleasure of examining his collection, but also, under his guidance, of visiting one of these last named beds on Covington street, Baltimore, at the foot of Federal Hill, where grading was still going on. I obtained quite a collection of recognizable impressions which I sent to Professor Fontaine to be incorporated in his flora of the Potomac formation. It should also be publicly stated that Professor Uhler has generously placed his collection at Professor Fontaine's disposal for the same purpose.

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[1] First Report of Philip T. Tyson, State Agricultural Chemist, to the House of Delegates of Maryland. Annapolis, 1860, pp. 1–145; Appendix, pp. 1–20, 8°. (See p. 42.)

Much lignite and silicified wood is to be seen among the iron mines to the west of Baltimore, and in railroad cuts between Baltimore and Washington, particularly on Deep Run, near Hanover station, on the Baltimore and Ohio Railroad. Some remarkable cycadean trunks were also found in Maryland by Dr. Tyson, Professor Uhler, and others.

In a letter dated January 28, 1888, Professor Uhler gives the precise localities for these discoveries as follows: "Only one specimen (a broken piece) of cycad was found on the surface. That piece came from the iron-clay on the south shore of the 'Middle Branch,' of the Patapsco River, opposite South Baltimore. One large (almost complete) specimen was dug out of the iron-clay several feet beneath the surface on property of Mr. Emack, near Beltsville. The other (nearly complete) one was dug seven feet beneath the surface, together with a fragment of some type of cycad, from the iron-ore bed of Mr. Latchford, situated half a mile south of the sixteenth milestone beyond Washington. A small piece of cycad was dug out of the iron-ore clays on the property of Dr. J. D. Jenkins, near Latchford's. These clays seem to lie above those of our iron-ore series around Baltimore, and may turn out to be equivalent to those immediately next beneath my Albirupean formation. I have provisionally classed them with the Baltimorean, but they seem to lie next beneath the Cretaceous near Washington, D. C."

In a paper by Professor Uhler, published since the above-named letter was written,[1] he has repeated these statements and given additional information respecting these remains.

Quite recently (December, 1887) Mr. J. B. Hatcher has found at Coffin's Engine Mine, near Beltsville, in typical Potomac iron-ore shales, beautifully preserved Sequoia cones in considerable abundance. This is an exceedingly important discovery as confirming in a most satisfactory manner the determinations made by Prof. F. H. Knowlton, of the silicified wood and lignite of the Potomac formation,[2] most of which he refers to the genus Cupressinoxylon of Göppert, the internal structure of which differs only slightly from that of the living Sequoias. Associated with these cones Mr. Hatcher found the osseous remains of vertebrates which Prof. Marsh does not hesitate to pronounce Jurassic types.

District of Columbia.—All the higher portions of the city of Washington rest upon the Potomac formation, and it extends over all the eastern portions of the District of Columbia, passing under the

[1] Sketch of the History of the Maryland Academy of Sciences, by P. R. Uhler: Trans. Md. Acad. Sci., vol. 1, Dec. 19, 1888, pp. 1–10. (See pp. 7, 8.)

[2] The fossil wood and lignites of the Potomac Formation, by F. H. Knowlton: Bull. U. S. Geol. Survey, No. 56; Proc. Am. Assoc. Adv. Sci., 37th (Cleveland) meeting, 1888, pp. 207, 208; Am. Geologist, vol. 3, No. 2, 1889, pp. 99–106.

Eocene to the southeastward and capping the hills to the northwestward, where it rests upon the Archæan gneisses of the Potomac Valley. No impressions of leaves, fronds, or recognizable stems have thus far been detected within the District, but silicified wood and lignite are common, and some of the former has been found to show structure admirably and has been referred by Professor Knowlton to its proper genus.

Virginia.—Dr. Thomas Nuttall appears to have been the first to draw attention to the existence of vegetable remains in the Richmond coal fields,[1] where in 1821 he observed impressions of ferns, Equisetum, and a broad-leafed plant, which he supposed to belong to the Canna family; also palms and cycadaceous plants.

Brongniart, in his Prodrome and Histoire, gives Richmond, Virginia, as the locality for *Calamites Suckowii*, var. δ, which he must have received from some of his American correspondents (Silliman, Cist, Wickham, or Granger), and Harlan states that his *Fucoides Brongniartii*[2] occurs in the mountains of western Virginia, although this may have been in what is now West Virginia.

The same volume in which the paper last mentioned[3] was published contains Mr. Richard C. Taylor's Review of Geological Phenomena and the deductions derivable therefrom, in 250 miles of sections in parts of Virginia and Maryland; also notice of certain Fossil Acotyledonous Plants in the secondary strata of Fredericksburgh. In the plate accompanying this paper are figured a number of plants from the Fredericksburgh strata, which were collected by Mr. F. Sheppard. They consist chiefly of ferns, and were referred by Mr. Taylor to the genera Sphenopteris and Pecopteris, but figures 1 and 5 are evidently remains of some coniferous plant, as indeed the author surmised with regard to figure 5, which he thought might belong to the genus Thuyites. The particular interest attaching to this paper arises from its being the first mention of fossil plants from the Younger Mesozoic of Virginia, which has since been so thoroughly studied by Professor Fontaine.

Prof. W. B. Roger's paper on the age of the Coal Rocks of Eastern Virginia,[4] gives the names of quite a number of species from this same formation and compares the flora to that of the Oolite of Yorkshire, England. He had previously designated the formation as the "Upper Secondary Strata," and in the paper immediately following this on Fossil Plants of the Oolite Coal Rocks of Eastern Virginia, he enumerates and discusses somewhat at length

[1] Observations on the Geological Structure of the Valley of the Mississippi. Jour. Acad. Nat. Sci., Phila., vol. 2, pt. 1, 1821, pp. 14–52. (See pp. 35, 36).

[2] Trans. Geol. Soc. Pennsylvania, vol. 1, pt. 1, 1834, p. 110.

[3] Ibid., pt. 2, 1835, pp. 314–325, pl. xix.

[4] Philadelphia Assoc. Am. Geol. and Nat., 1843, pp. 298–301.

twelve species from his Lower Oolite, figuring three of them in an accompanying plate.

These coal beds were visited by Lyell, and a paper describing their geological character was published by him in 1847.[1] He here treats (p. 278) the fossil plants and arrives at the conclusion that "the coal measures are probably of the age of the inferior Oolite and Lias." The plants collected by him were described by Bunbury, in a paper immediately following that of Lyell.[2] Some dozen different forms are characterized in this paper, including two new species, *Neuropteris linnææfolia* and *Pecopteris* (*Aspidites*) *bullata*.

Hitchcock, in his paper on the fossil fruits of Brandon, Vt. (supra, p. 850), quotes a statement of Prof. Jeffries Wyman (pp. 101, 102) relative to the discovery by him at Richmond of similar fruits in the Tertiaries of that place, probably in the Eocene.

The only other vegetable fossil reported from the Eocene formation of Virginia of which I have seen any account is the supposed nut, described by Mr. Edmund Ruffin, of Marlbourne [perhaps Marlborough], Virginia, in 1850.[3] The figures given are too indefinite to base any conjecture upon them as to the real nature of the object.

On June 15, 1872, Mr. F. B. Meek read before the Philosophical Society of Washington a paper giving Descriptions of New Species of Fossil Plants from Alleghany County, Virginia, with some Remarks on the Rock seen along the Chesapeake and Ohio Railroad, near the White Sulphur Springs of Greenbrier County, West Virginia, which was not published until 1876.[4] The six species here treated are of Carboniferous age and are thoroughly illustrated in the two accompanying plates. The types are now in the Museum collection.

In 1883 Mr. Benjamin Miller, of Georgetown, D. C., communicated two specimens of *Sphenopteris flaccida* Crépin to the National Museum (No. 2223) from Rawley Springs, Rockingham County, and Mr. H. R. Geiger, in 1884, collected six specimens of *Triphyllopteris Lescuriana* Meek at Whetstone Hill, Augusta County. Specimens of *Ostrya Walkeri?* Heer, and *Acer vitifolium* Al. Br., obtained by Mr. Howard Shrive, at Wytheville, Wythe County, reveal the presence there of a Tertiary bed that calls for closer investigation.[5]

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[1] On the Structure and Probable Age of the Coal-Field of the James River, near Richmond, Virginia, by Charles Lyell: Quart. Jour. Geol. Soc. London, vol. 3, 1847, pp. 261–280.

[2] Descriptions of Fossil Plants from the Coal Field near Richmond, Virginia, by C. J. F. Bunbury: Ibid., pp. 281–288, pl. x, xi.

[3] Description of a Nut found in Eocene marl, by Edmund Ruffin: Am. Jour. Sci., 2d series, vol. 9, 1850, pp. 127–129.

[4] Bull. Philos. Soc. Washington, vol. 2, 1874–1878, Appendix; Art. viii, pp. 26–44, pl. i, ii.

[5] The four species last named are published in Professor Lesquereux's List of Recently identified fossil plants belonging to the U. S. National Museum, etc. Proc. U. S. Nat. Mus., vol. 10, 1887, pp. 23, 25, 38, 44.

According to Mr. Darton, Carboniferous plants also occur on Price's Mountain 6 miles west of Christiansburgh, Montgomery County, on Brushy Mountain in the same county, and on Cloyd's Mountain in Pulaski County.

In 1879 Prof. William M. Fontaine, of the University of Virginia, published a continued article[1] giving the results of his studies into the geology and paleontology of the Mesozoic strata of the State, and indicating in advance the nature of the flora that he was then engaged in elaborating.

His Contribution to the Knowledge of the Older Mesozoic Flora of Virginia[2] contains the results of many years of study in this field. The first part of it (pp. 1–96) is devoted to the systematic description of the plants found in Virginia, of which forty-two different species are distinguished. A comparison of these species with those of the Old World leads the author to the conclusion that the formation is more or less homotaxial with the plant-bearing beds of Franconia, Scania, and other European localities, which have been regarded as of Rhetic age, and with this conclusion any one who carefully studies this subject will be likely to agree,[3] the views of Dr. Stur (see supra, p. 734) to the contrary notwithstanding.

The principal locality for these plants was at Clover Hill, but many were found at Carbon Hill, Midlothian (Gowry shaft), Manakin (Aspinwall shaft), Deep Run, Black Heath mines, and in the Cumberland area. A few also came from near Hanover Junction in Hanover County. Plants of the same geological age have also been found one-half mile southeast of Dover, in the Norwood mines on the James River, and at a point one mile southwest of the Norwood mines (see Mr. Russell's letter above cited).

In view of what has already been said[4] respecting this flora, it may not be premature to call attention to the work upon which Professor Fontaine is now engaged, in further making known the fossil floras of his State; but it is already well known to some, and can not but be of interest to all paleobotanists, that he has now completed a large and important monograph, to be published by the U. S. Geological Survey, on what he denominated the "Younger Mesozoic Flora of Virginia," which is the same that Rogers called the Upper Oolite. Mr. W J McGee, in view of the doubts that still exist with regard to the age of these beds, has proposed for them the name of Potomac Formation, which name

[1] Notes on the Mesozoic Strata of Virginia, by William M. Fontaine: Am. Jour. Sci., 3d series, vol. 17, 1879, pp. 25–39; 151–157; 229–239.

[2] Mon. U. S. Geol. Survey, vol. 6, 1883.

[3] See Science, vol. 5, 1885, pp. 280, 281.

[4] Evidence of the Fossil Plants as to the Age of the Potomac Formation, by Lester F. Ward: Am. Jour. Sci., 3d series, vol. 36, 1888, pp. 119–131.

has been adopted by the U. S. Geological Survey. It extends from Baltimore to the Roanoke, and fossil plants have been found in the clay beds of Baltimore, White House Landing, Telegraph Station and Brooke on the Atlantic Coast Line Railroad, Potomac Run, Acquia Creek, Fredericksburgh, and along the James River, in the vicinity of the Dutch Gap Canal.

West Virginia.—Professor Fontaine, in an article on The "Great Conglomerate" on New River, West Virginia,[1] mentions a number of species of fossil plants as occurring in the roof deposits of the lower coal rocks in this vicinity (p. 574), which would, therefore, be of Subcarboniferous age. The Devonian plants (Chemung or Catskill) mentioned by him in the same article (p. 578) at the Lewis Tunnel, six miles east of White Sulphur Springs, lie outside the limits of this State, in Alleghany County, Virginia.

Professors Fontaine and White, in the introduction to their valuable monograph on The Permian or Upper Carboniferous Flora of West Virginia and Southwestern Pennsylvania,[2] give a sketch of the geology of the Carboniferous formation in West Virginia, from the Vespertine group to their supposed Permian, with a list of the plants that have been found in each group. Eight species are thus credited to the Vespertine group, consisting of two species of Lepidodendron, two of Triphyllopteris, and four of Archæopteris, but the chief locality for these is said to be Lewis Tunnel, which, as stated above, is in Alleghany County, Virginia, though near the State line. The Umbral or Lower Carboniferous limestone and the Umbral Shale group are without plant remains, but the Conglomerate group, described in Professor Fontaine's article above mentioned, has yielded eighteen species, chiefly on New River at Quinnimont and at Sewell Depot.

The lower productive coal measures have furnished fourteen species, namely, five from the Kittanning coal seam, four from the upper Freeport, and five others common to both these horizons, representing altogether the genera Neuropteris, Odontopteris, Pecopteris, Asterophyllites, Sphenophyllum, Lepidodendron, Lepidostrobus, and Lepidophyllum. Most of the species were named by Brongniart.

The flora of the lower barren coal measures consists of twenty-eight species, all of which were obtained in the vicinity of Wheeling; of these six belong to Neuropteris and seven to Pecopteris.

The upper barren coal measures of West Virginia constitute the so-called Permian of the monograph, the plant-bearing shale lying at the very base of the section. One hundred and seven species are described

[1] Am. Jour. Sci., 3d series, vol. 7, 1874, pp. 459–465; 573–579.

[2] Second Geol. Survey Pennsylvania, Report of Progress, PP, 1880.

from this horizon; a few of which, as already stated, occur within the limits of Pennsylvania, but these are for the most part also found in West Virginia. The principal locality for these plants is the roof shales of the Waynesburgh coal at West Union, Doddridge County, and Cassville, Monongalia County, but the following additional localities are noted: Brown's Bridge and Arnettsville between Fairmont and Morgantown, Monongalia County; Bellton and Moundsville, Marshall County; and near Wheeling.

North Carolina.—Dr. Ebenezer Emmons, in his Geological Report of the Midland Counties of North Carolina (New York and Raleigh, 1856), chapter xxxix, describes a number of vegetable remains which are figured on plates i–iv. They were from his Permian and Triassic formations. The Permian forms embraced, according to him, Chondrites, Gymnocaulus, Equisetum, Cheilanthites, and Dyctuocaulus; and the Triassic forms, which were much more numerous, were referred to Acrostichites, Pecopteris, Neuropteris, Tæniopteris, Cyclopteris, Calamites, Equisetum, Stangerites, Zamites, Pterozamites, Podozamites, Cycadites, Lepacyclotes, and Walchia, while from the Keuper sandstone and marls he obtained his *Sphenoglossum quadrifolium* and a species of Pecopteris. Several of these genera were his own and have not been accepted by paleobotanists.

In the sixth part of his American Geology,[1] Dr. Emmons reviews these floras, giving fuller descriptions, introducing numerous figures in the text, and adding one plate. He thus brings the flora up to about forty species; but not having devoted himself especially to paleobotany, many errors occur in both his descriptions and his delineations, and the entire work upon the fossil plants of this State was long in great need of thorough revision.

Such a revision was undertaken by Professor Fontaine, in the third part of his admirable monograph of the U. S. Geological Survey, published in 1883.[2] It was based, however, entirely upon the figures and descriptions of Emmons, the specimens themselves having been dedestroyed during the war, but it was sufficiently complete to make it altogether probable that the North Carolina Trias of Emmons is the same as the Virginia Trias of Rogers, or the Richmond coal field, which, as we have seen, bears a close relation in its plant remains to the Rhetic beds of Europe. Professor Fontaine has already succeeded in identifying the greater part of Emmons's figures with Virginia species studied by him. He thus recognizes forty-one species of Mesozoic plants from North Carolina, sixteen of which are also

[1] American Geology, containing a statement of the principles of the science, with full illustrations of the characteristic American fossils, etc., by Ebenezer Emmons: pt. 6, Albany, 1857. (See chapter xv, pp. 99–134, pl. iii, iv, iv*a*, v, vi.)

[2] Contributions to the Knowledge of the Older Mesozoic Flora of Virginia, by Wm. M. Fontaine: Mon. U. S. Geol. Survey, No. 6, 1883, pp. 97–128, pl. xlviii–lii.

found in the Virginia Mesozoic, and fifteen in the Rhetic formations of other countries; eight are common to the Jurassic plants of other countries, and nine peculiar to North Carolina.

The principal localities for these beds are at Haywood, Egypt, Lockville, and Ellington's, Chatham County; Madison, Stokes County; and Farmville, Pitt County.

With the exception of the discovery by Mr. W. C. Kerr, State geologist of North Carolina, of petrified wood at a place locally known as Paint Hill, in Moore County,[1] and by Prof. J. A. Holmes, of the University of North Carolina, of petrified remains of the bald cypress (*Taxodium distichum* Rich.) beneath a Quaternary shell deposit in Craven County, on the Neuse River below New Berne,[2] no other vegetable remains have, to my knowledge, been recorded in the State.

Georgia.—Professor Lesquereux in the third volume of his Coal Flora enumerates some thirty species of Subconglomerate fossil plants from Dade County, Georgia, in the collection of Mr. R. D. Lacoe. I learn from Mr. Lacoe that they were collected by Messrs. Daniel M. and John R. Evans from mines near Cole City.

Alabama.—Mr. Charles Lyell observed in the coal fields of Alabama several plant-bearing strata, and in a letter to Professor Silliman dated at Mobile, February 19, 1846, he called attention to the presence of species of Calamites, Pecopteris, Neuropteris, Sigillaria, and Lepidodendron, which he saw at Tuscaloosa, collected by Professor Brumby on the Warrior River, a tributary of the Tombigbee, which he afterwards visited and observed for himself. He gave the locality as in latitude 33° 10′ north, which he said constituted "the extreme southern limit to which the peculiar vegetation of the ancient Carboniferous era has yet been traced (in the northern hemisphere) whether on the western or eastern side of the Atlantic."[3] A little later the same author again calls attention to the plants of this locality,[4] having previously submitted the specimens collected there to Mr. C. J. F. Bunbury, who identified the species and whose report accompanies this paper.

Other collections seem to have been made from time to time in the coal beds of Alabama, and in 1875, Prof. Eugene A. Smith, at that time State geologist, sent these specimens to Professor Les-

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[1] Distribution and character of the Eocene deposits in eastern North Carolina, by W. C. Kerr: Jour. Elisha Mitchell Sci. Soc. for the year 1884-'85, Raleigh, 1885, pp. 79-84. (See p. 80.)

[2] Taxodium (Cypress) in North Carolina Quaternary, by J. A. Holmes: Ibid., pp. 92, 93.

[3] Coal field of Tuscaloosa, Ala., being an extract of a letter to Prof. Silliman from Charles Lyell: Am. Jour. Sci., 2d series, vol. 1, 1846, pp. 371-376.

[4] Observations on the Fossil Plants of the coal field of Tuscaloosa, Ala., by C. Lyell, esq., with a description of some species by C. J. F. Bunbury: Ibid., 2d series, vol. 2, 1846, pp. 228-233.

quereux at Columbus, Ohio, for determination. According to the latter's statement, published in 1876,[1] some of these specimens were without labels to show localities, while others were from Helena, Shelby County, from Finley's Mine, Tuscaloosa, from the Warrior vein, from Montevallo, also in Shelby County, Black Lick seam, Jefferson County, etc. The list contains seventy-eight species, none of which are described, although ten of them are set down as new. They are all of Carboniferous age, and many of them had been previously observed by him in the coal formations of other States, while an equally large number are common to the coal flora of the Old World.

In the Coal Flora of Pennsylvania Professor Lesquereux revises this list and describes and figures all the plants known to him from the Carboniferous formation in Alabama, the principal formation in that State which yields fossil plants.

A large number of the specimens enumerated by Professor Lesquereux in the Proceedings of the U. S. National Museum for 1887 (vol. 10, pp. 21–46) were collected by Mr. Frank Burns on Warrior Creek, Jefferson County, also at Blount Springs, Blount County. They are of Carboniferous age and for the most part well known species. The U. S. National Museum collection contains other specimens, labeled La Grange, Colbert County (B. Paybos), Baugh Bend, Walker County, also Saint Clair County (C. McKinley).

Mr. I. C. Russell, in the letter above quoted, reports Carboniferous plants from the south end of Lookout Mountain, along the borders of Black Creek, and about one mile northwest of Gadsden.

His collection was subsequently sent to Prof. Lesquereux and reported upon in 1888.[2] It embraced twenty-seven species, two of which (*Rhabdocarpus Russellii* and *Stigmaria Russellii*) were new, and forms of Neuropteris and Sphenopteris furnished important characters not usually preserved in a fossil state.

During the summer of 1887, Prof. William M. Fontaine visited Tuscaloosa, and with his practiced eye discovered fossil plants agreeing with those of the Potomac formation in the vicinity of that place. My information is derived from letters from him giving an account of his reconnoissance.

Mississippi.—Dr. Eugene W. Hilgard, state geologist of Mississippi, published in 1860, in his Report on the Geology and Agri-

[1] Partial list of coal plants from the Alabama fields, and discussion of the Geological positions of several coal seams, by Prof. Leo Lesquereux. Geol. Survey Alabama, Rept. Prog., 1875, pp. 75–82.

[2] List of fossil plants collected by Mr. I. C. Russell, at Black Creek, near Gadsden, Ala., with descriptions of several new species, by Leo Lesquereux, compiled and prepared for publication by F. H. Knowlton: Proc. U. S. Nat. Mus., vol. 11, 1888, pp. 83–87, pl. xix.

culture of the State of Mississippi (p. 108), the names of a few fossil plants that had been found in the gray clays and sands of Tippah, Lafayette, Calhoun, and Winston Counties, as furnished him by Professor Lesquereux, to whom the specimens had been submitted. They all belong to the so-called lignite of Mississippi, now commonly regarded as Eocene, and the genera Quercus, Carya, Populus, Morus, Ficus, Laurus, Persea, Cornus, Olea, Rhamnus, Terminalia, Magnolia, Dryandroides, Rhus, Cinnamomum, Smilax, and Cycas, were supposed to be represented.

Professor Lesquereux in submitting these determinations had only made a preliminary investigation of the material in hand. In subsequent years, however, he found time to elaborate it very thoroughly, and in 1869 published in the Transactions of the American Philosophical Society his important paper On species of fossil plants from the Tertiary of the State of Mississippi.[1] In this paper thirty species were described, most of them being new to science. The cycadaceous species previously reported is eliminated. Two species of palm occur. *Salisburia binervata* Lx. is the only coniferous plant; the remainder are all dicotyledonous, and include, in addition to the genera mentioned in the previous report, Salix, Banksia, Ceanothus, Sapindus, Juglans, and Asimina. On the other hand eight of the genera previously mentioned are eliminated as follows: Carya, Morus, Cornus, Olea, Terminalia, Dryandroides, Rhus, and Smilax. The following four species, as I have before stated,[2] have since been found in the Laramie group, and show the close relationship of this flora to the Laramie flora: *Sabal Grayana* Lx., *Populus monodon* Lx., *Magnolia Hilgardiana* Lx., and *M. Lesleyana* Lx. The full discussions and the well executed figures of this paper render it one of the most important of the lesser contributions to North American paleobotany.

Professor Lesquereux, who has always insisted upon the Eocene age of the Laramie group, in Hayden's Annual Report of the U. S. Geological and Geographical Survey of Colorado for 1873 (page 379) included all these Mississippi plants in his list of the species of the first group of that formation which comprised the principal Laramie localities in Wyoming and Colorado.

Louisiana.—In a recent letter to Science[3] Prof. E. W. Hilgard mentions a collection of "well preserved leaves and fruits" made by him in 1869 on the Upper Red River in Louisiana and deposited at the University of Mississippi at Oxford. So far as I am aware this collection has not been studied. Still more recently Mr. Lawrence Johnson, of the U. S. Geological Survey, has made quite extensive

[1] Trans. Am. Philos. Soc., vol. 13, 1869, pp. 411–430, pl. xiv–xxii.

[2] Sixth Ann. Rept. U. S. Geol. Survey, 1884–'85 (1886), p. 529.

[3] The Equivalence in Time of American Marine and Intracontinental Tertiaries, by E. W. Hilgard: Science, vol. 9, 1887, pp. 535, 536.

collections from various points in Louisiana, especially from Campbell's quarry, Cross Lake near Shreveport, and at McLee's, two miles north of Mansfield, De Soto County. The beds are of Tertiary age and probably Eocene. These collections were reported upon by Prof. Lesquereux in 1888,[1] and assuming the identity in age of these beds with those of Mississippi called Eocene, they are remarkable in adding four species to the four above enumerated as being original Laramie plants. These are the following: *Sapindus caudatus* Lx., *Laurus socialis* Lx., *Rhamnus Cleburni* Lx., and *Ficus spectabilis* Lx. There are also several others found in the Laramie group but also occurring elsewhere, such as *Quercus angustiloba* Al. Br., *Phragmites Oeningensis* Al. Br., and *Platanus Guillelmæ* Göpp.

The same collector obtained in 1886 several specimens of palm stems or wood in a silicified state in Rapides Parish which have recently been studied by Prof. F. H. Knowlton and referred to two species of Palmoxylon (*P. Quenstedti* Felix, and *P. cellulosum*, n. sp.)[2]

Tennessee.—Near Somerville, Fayette County, occurs a bed of fossil plants of Tertiary age, probably Eocene, from which Prof. J. M. Safford, State geologist of Tennessee, collected numerous specimens. This material was submitted to Professor Lesquereux and the plants were named in 1869.[3]

Two species (*Rhamnus marginatus* Lx. and *Quercus Saffordii* Lx.) from the red shales of Tennessee, collected by Professor Safford, were first described in 1860 in the Geological Report of Arkansas (p. 319, pl. vi).[4]

Another list from the same locality, consisting to a considerable extent of the same species, but including also three species from La Grange, is given in Professor Safford's Geology of Tennessee (1869, pp. 425–428), and here the most characteristic of them are figured on pl. vii (K).

Carboniferous plant beds are also found in the State, especially at Tracy City, and a list of the plants from this locality as determined

[1] Recent determinations of fossil plants from Kentucky, Louisiana, Oregon, California, Alaska, Greenland, etc., with descriptions of new species, by Leo Lesquereux. Compiled and prepared for publication by F. H. Knowlton: Proc. U. S. Nat. Mus., vol. 11, 1888, pp. 11–38, pl. iv–xvi. (Plants from Louisiana, pp. 24–25.)

[2] Description of two species of Palmoxylon—one new—from Louisiana, by F. H. Knowlton: Ibid., pp. 89–91, pl. xxx.

[3] Species of Fossil Plants collected near Sommerville, Fayette Co., Tenn., by Prof. J. M. Safford, State geologist of Tennessee (Fossil Plants of Recent Formations), Am. Jour. Sci., 2d series, vol. 27, 1859, p. 364.

[4] Second Report of a Geological Reconnoissance of the middle and southern counties of Arkansas, made during the years 1859 and 1860, by David Dale Owen. Philadelphia, 1860. Botanical and Palæontological Report, by Leo Lesquereux, pp. 295–319, pl. i–vi.

by Professor Lesquereux was published in 1869.[1] Thirty-two species are contained in this list, five of which came from the Ætna mines, and the remainder from the Main Sewanee and Jackson coal horizon. The most of them are old species described by Brongniart, Sternberg, and Lindley and Hutton.

In his Coal Flora of Pennsylvania the only localities in Tennessee mentioned are Tracy City, in Grundy County; Sewanee, in Franklin County; and Rockwood, in Roane County. Much additional material must have accumulated in the interval between the publication of Professor Safford's report in 1869 and the completion of the coal flora in 1880. Over sixty species are described in the latter work that are not enumerated in the former, the most of these being from the Subconglomerate of Tracy City, Lower Sewanee, and Rockwood. The total coal flora of the State, according to this report, was eighty-four species.

Mr. Ira Sayles has recently discovered another locality in the vicinity of Centerville, Hickman County, from which he has sent a number of specimens to the U. S. Geological Survey. These have been investigated by Professor Lesquereux and two species identified, namely: *Annularia sphenophylloides* (Zenk) Gutb. and *Rhabdocarpus multistriatus* (Presl) Lx. Fragments of Stigmaria, Sigillaria, and Cordaites also accompany this collection. They are published in the Proceedings of the U. S. National Museum for 1887, pp. 23–33.

Kentucky.—At the fourth meeting of the American Association for the Advancement of Science, held at New Haven in August, 1850, Prof. George C. Schaeffer read a paper on Fossil Coniferous Wood from the Lower Devonian strata, Lebanon, Marion County, Kentucky.[2] He states that this "wood is found in very large quantities between Lebanon and the foot of the 'Knobs,' at a distance of about three or four miles from the latter."

The first serious study of the coal measures of Kentucky from the point of view of vegetable paleontology, was made by Professor Lesquereux during the years 1856 and 1857, and the results were published in the Third Report of the Geological Survey in Kentucky.[3] During three explorations Professor Lesquereux found fossil plants at many of the horizons, particularly at Bell's mine in Crittenden County, Casey's mine on the west side of Trade Water River, near Caseyville; at Union mines, Crittenden County, 20 miles below Casey-

[1] Geology of Tennessee, by James M. Safford, State geologist, Nashville, 1869, pp. 408, 409.

[2] Proc. Am. Assoc. Adv. Sci., 4th (New Haven) meeting, 1850 (1851), pp. 193, 194.

[3] Palæontological Report of the Fossil Flora of the Coal Measures of the western Kentucky Coal Field, by Leo Lesquereux, palæontologist. In Third Rept. Geol. Survey Kentucky, made during the years 1856 and 1857, by David Dale Owen. Frankfort, 1857, pp. 499–556, pl. vi, vii.

ville; at Hawesville, Hancock County; at Giger's Hill, Union County; in the Curlew & Mulford mine, Union County; and at Airdrie, Muhlenberg County. In this report about a dozen species are figured, with brief descriptions accompanying the explanation of the plates (p. 556). Only one of these species (*Lepidodendron politum*) was new. In the same report (p. 122) Owen records the presence of *Spirophyton velum* (Vanux.) Hall, at Rockport, Lewis County, in rock probably of Subcarboniferous age.

The fourth volume of the Kentucky Geological Survey contains another and still more elaborate paper by the same author.[1] This paper is chiefly geological, but closes with a description of about twenty species, which are figured in the atlas; they are from the Union mines, Livingston County; West Liberty and Hazel Green, Morgan County, etc. The Coal Flora of Pennsylvania contains a description of seventy-three species; eight of which are from Crittenden County, twenty-six from Union County, fourteen from Greenup and Carter Counties, and twenty-six from Hopkins and Christian Counties.

Besides this large coal flora there is at least one bed of much more recent vegetable remains in the State; this is located on the Mississippi River, near Columbus, and was mentioned by Dr. David Dale Owen in the first volume of the Geological Survey of Kentucky (p. 22). It is probably of Pliocene age. A small collection from this place was examined by Professor Lesquereux in 1859, and ten species were enumerated in his paper On some fossil plants of recent formations, already referred to.[2] The plants, so far as determinable, belong to species still living, and include the live oak, the pecan, the honey locust, the winged elm, the chinquapin, etc.

From the Niagara limestone near Louisville, Hall and Whitfield[3] described *Dictyonema pergracilis* in 1872.

Rev. H. Herzer, of Louisville, has collected specimens of *Asterophycus Coxii* Lx., at Rock Castle, Trigg County, in the Carboniferous formation,[4] and the same gentleman communicated to Professor Lesquereux a specimen of *Psilophytum gracillimum* Lx., found by Mr.

[1] Report of the Fossil Flora and of the Stratigraphical Distribution of coal in the Kentucky Coal Fields, by Leo Lesquereux. Fourth Rept. Geol. Survey of Kentucky, made during the years 1858 and 1859, by David Dale Owen. Frankfort, 1861, pp. 333–437, pl. i–iv.

[2] Fossil leaves collected in the chalky banks of the Mississippi River near Columbus, Ky., by Dr. David Dale Owen and Leo Lesquereux: Am. Jour. Sci., 2d series, vol. 27, 1859, pp. 364–366.

[3] Description of new species of fossils from the vicinity of Louisville, Kentucky, and the Falls of the Ohio, by James Hall and R. P. Whitfield: 24th Rept. N. Y. State Cabinet of Nat. Hist., Albany, 1872, pp. 181–196.

[4] Species of fossil marine plants from the Carboniferous Measures, by Leo Lesquereux: Seventh Ann. Rept. Geol. Survey Indiana, 1876, 8°. (See p. 142.)

Edward Ulrich in the bed of Licking River, near Covington, opposite Cincinnati, in the Cincinnati group.[1]

Mr. M. P. Lightfoot has collected two specimens of *Calamites Suckowii* Brongn., at Commercial Summit, Whitley County, which were identified by Professor Lesquereux[2] and are deposited in the National Museum (No. 2154).

A small collection of fossil plants made by Prof. R. H. Loughridge from the Eocene, or Lignite group, at Wickliffe, in Ballard County, and from a much higher horizon (Upper Tertiary or Quaternary) at Boaz, in Graves County, has recently been determined by Professor Lesquereux, whose report has been published in the proceedings of the U. S. National Museum (vol. 11, pp. 12, 13, pl. iv, v). One of the species, *Juglans rugosa* Lx., is a Laramie type. There were eight others, one of which was new.

Ohio.—Next to Pennsylvania, Ohio possesses the most extensive deposits both of coal and of fossil plants. The latter have been long known, and as early as 1820 we find that Mr. Ebenezer Granger had undertaken their investigation. In that year he wrote to the editor of the American Journal of Science a Notice of Vegetable impressions on the rocks connected with the coal formation of Zanesville, Ohio, which was published with comments by the editor.[3] The figures accompanying this notice are very clear, and especially interesting in view of their early date.

About the same time Dr. S. P. Hildreth commenced to investigate the geology of Ohio, and some of his letters to Mr. Caleb Atwater contained allusions to the discovery of fossil plants. In one of these, speaking of the petrifactions in the neighborhood of Zanesville and of Marietta,[4] he says: "Vegetable productions are also found in a petrified state. I have in my possession a petrifaction which appears once to have been a large poke-root (*Phytolacca decandra*) . . . I have discovered at two different places, within a few miles of Marietta, some very curious impressions of vegetables in a loose slaty stone, and in a red ocherous earth that was in a middle state between ocher and slate. The impressions in the first resembled the leaves of white clover, and were very perfect. They appeared to be distributed through the whole mass of stone, which easily separated into thin layers, and between the contiguous layers was to be seen the perfect impression of clover leaves. Those in the ocherous bed were the perfect impressions of fern leaves. They were to be

[1] Land plants recently discovered in the Silurian rocks of the United States, by Leo Lesquereux: Proc. Am. Philos. Soc., vol. 17, 1877, pp. 163–175, pl. iv. (See p. 165.)

[2] Proc. U. S. Nat. Mus., vol. 10, 1887, p. 23.

[3] Am. Jour. Sci., vol. 3, 1821, pp. 5–7, pl. i–ii.

[4] Facts relating to certain parts of the State of Ohio, by Dr. S. P. Hildreth: Ibid., vol. 10, 1826, pp. 1–8.

found in almost every place that I examined, and what is a little curious, the impressions were all of the same kind of leaf, and as perfect and fair as if made but yesterday." Hildreth seems at this time not to have been acquainted with the works on fossil plants that had already been published by Steinhauer, Sternberg, and Brongniart; but Granger, in the paper just referred to, quotes the first of these works, and it was he, as is known, who sent Brongniart many of the American specimens which he described in his Histoire des Végétaux Fossiles.

In the twelfth volume of the same journal Hildreth called attention to certain fossil trees observed by him about two miles above Gallipolis, near the Ohio River.[1]

In a letter to Professor Silliman, dated Cincinnati, April 30, 1833, Rev. Sayles Gazlay gave an account of the discovery of pieces of fossil wood at a number of points in the State of Ohio, especially near Palmyra, Springfield, and Cincinnati. These specimens were chiefly found while digging wells, but from the descriptions given it is difficult to judge of their nature.

The first important paper on the geology and paleontology of Ohio was published by Hildreth in 1836,[2] with an appendix by Dr. Samuel George Morton,[3] who elaborated the organic remains collected on Hildreth's expeditions. Twenty-five of the thirty-six plates by which this paper is illustrated are devoted chiefly to fossil plants, and a more or less successful attempt was made by Dr. Morton to identify them with species figured by Brongniart and Steinhauer. They all appear to be of Carboniferous age, but the exact locality at which each of the specimens was found is nowhere clearly set forth.

The thirty-first volume of the same journal contains a long anonymous article[4] of a similar character to the one last considered and which is known to have been also from the pen of Dr. Hildreth. In this paper he figures a number of vegetable impressions obtained on the expedition at Mariner's Mills and on the Mahoning River. Among these were his *Carpolithus trilocularis*, *Syringodendron Kirtlandium*, *Sigillaria marineria*, and *Ficoidites scabrosus*.

Mr. John Locke's Notice of a prostrate Forest under the Diluvium

[1] Notice of Fossil Trees near Gallipolis, Ohio, by S. P. Hildreth: Am. Jour. Sci., vol. 12, 1827, pp. 205, 206.

[2] Observations on the Bituminous Coal deposits of the valley of the Ohio and the accompanying rock strata; with notices of the fossil organic remains and the relics of vegetable and animal bodies, illustrated by a geological map, by numerous drawings of plants and shells, and by views of interesting scenery, by S. P. Hildreth: Am. Jour. Sci., vol. 29, 1836, pp. 1–148.

[3] Appendix. Being a Notice and description of the Organic Remains embraced in the preceding paper, by Samuel George Morton: Ibid., pp. 149–154, pl. i–xxxvi.

[4] Miscellaneous observations made during a tour in May, 1835, to the Falls of the Cuyahoga, near Lake Erie; extracted from the Diary of a Naturalist [by S. P. Hildreth]: Am. Jour. Sci., vol. 31, 1827, pp. 1–84.

of Ohio,[1] and Mr. Charles Whittlesey's Description of a Plant supposed to be new,[2] constitute about the only other papers relating to the fossil plants of Ohio that appeared prior to the earliest contributions to the subject by Prof. Lesquereux and Dr. Newberry.

On January 7, 1852, Professor Rogers presented to the Boston Society of Natural History, in the name of Prof. Leo Lesquereux, some observations on the coal measures of Ohio. In the notes thus communicated Professor Lesquereux refers to fossil plants found by him in the coal bed of Zanesville; on the Ohio River, three miles west of Marietta; at Barlow, ten miles west of Marietta; and at Cuyahoga Falls, of which latter point Dr. Newberry had furnished him with a section. The species were of course Carboniferous, and, for the most part, were recognized by him as the same that he had met with in Pennsylvania.

A number of very important papers relating to the coal flora of Ohio, chiefly by Dr. Newberry, appeared in 1853 and 1854 in a publication entitled "The Annals of Science; being a record of the Inventions and Improvements in applied Science; including the Transactions of the American Association for the Advancement of Science," conducted by Hamilton L. Smith, Cleveland, 1853 and 1854, of which one volume and a part of the second only are extant. These papers were evidently the result of prolonged research, and were presented to the American Association for the Advancement of Science. The first was entitled "Fossil Plants from the Ohio coal basin,"[3] which consists of a catalogue of nineteen species, with remarks on some of the more important ones. No figures accompany this paper.

Then follows a series of four papers, entitled, "New [species of] Fossil Plants from Ohio."[4] These new species are illustrated by wood-cuts. The first describes a plant collected by Mr. Charles Whittlesey from a coal mine two miles southeast of Cuyahoga Falls, a notice of which was published in the American Journal of Science, as mentioned above, and gives it the name of *Whittleseya elegans*. The second is important in being the first attempt made in this country to characterize the fruits of the coal measures. Eight species of Cardiocarpus are here made known, from the coal measures at Cuyahoga Falls, Summit County, and at Youngstown, Mahoning County. The third describes four species of Sigillaria from the same localities and from Coshocton. The fourth, which comes in the second volume (pp. 2, 3) under the name of Antholites, gives figures of the inflorescence of Cordaites found in Mahoning

[1] Philadelphia Assoc. Am. Geol. and Nat., 1843, pp. 240, 241.
[2] Am. Jour. Sci., 2d series, vol. 8, 1849, pp. 375-377.
[3] Annals of Science, vol. 1, 1853, pp. 95-97; 106-108.
[4] Ibid., pp. 116, 117; 152, 153.

County associated with the lowest stratum of coal in the coal basin of Ohio.

Between the first and second of these papers, and apparently forming a part of them, is another bearing the same title but credited to Mr. J. W. Foster,[1] in which three Carboniferous fruits, one species of Sphenophyllum, and one of Sigillaria, from Guernsey County, and from Zanesville, Muskingum County, are figured and discussed.

Volume 1 of the Annals of Science contains two other papers by Dr. Newberry on the Structure and affinities of certain fossil plants of the Carboniferous era (pp. 268–270), and on the Characteristics of the Carboniferous flora of Ohio, with descriptions of fifty new species of fossil plants (pp. 280, 281). The first of these contains figures of a Trigonocarpus, of a species of Asterophyllites, and of Sphenophyllum, with remarks upon these and other forms. The second does not give the descriptions of the fifty species, but merely an account of them, with a list of the genera and a number of species belonging to each genus.

The second volume of the Annals of Science contains another short illustrated paper by Dr. Newberry.

In the Sixteenth Annual Report of the Regents of the University of the State of New York, 1863 (pp. 84–91, pl. iii–v), Prof. James Hall describes some vegetable fossil remains from the Waverly Sandstone (Devonian) at Cuyahoga Falls, Richfield, Summit County, and Harrisville, Medina County, which are referred to the genus Dictyophyton (*D. Newberryi* Hall and *D. Redfieldi* Hall): This genus, although the name signifies a plant, seems now to be definitively relegated to the sponges.

In several catalogues and in the various issues of his little publication called The Paleontologist, Mr. U. P. James, of Cincinnati, between the years 1871 and 1881, published a considerable number of species of so-called plants from the Cincinnati group found at Cincinnati, or within a range of forty or fifty miles of that city.[2] Among

[1] Annals of Science, vol. 1, 1853, pp. 128, 129.

[2] U. P. James: Palaeontology. Catalogue of the Lower Silurian Fossils, Cincinnati Group, found at Cincinnati and vicinity, within a range of forty or fifty miles. Cincinnati, 1871, 14 pp., 8°. "Additions" to the same publ. at Cincinnati, 1873, pp. 15–17.

The same, new edition, much enlarged, with Descriptions of some New Species of Corals and Polyzoa, Cincinnati, 1875, pp. 1–12, 8°.

Descriptions of newly-discovered species of fossils and remarks on others, from the lower and upper Silurian rocks of Ohio. The Paleontologist, No. 2, Sept. 14, 1878, pp. 9–13; No. 3, Jan. 15, 1879, pp. 17–23.

Supplement to Catalogue of Lower Silurian Fossils of the Cincinnati Group, etc., Ibid., No. 4, July 10, 1879, pp. 29–32.

Contributions to Paleontology: Fossils of the Lower Silurian Formation: Ohio, Indiana, and Kentucky. Ibid., No. 5, June 10, 1881, pp. 33–44.

the special localities for these plants he enumerates Lebanon, Obanon Creek, Clermont County, and Crawford Run, in the eastern part of Cincinnati, as well as a point in Kentucky opposite that city, and another in Dearborn County, Indiana, but for the most part they are entered on his lists without any local designations.

The work of Dr. J. S. Newberry, thus far outlined, was all preliminary to the important contribution which he made in 1873, to the Report of the Geological Survey of Ohio, vol. 1, pt. 2, Paleontology, Columbus, 1873 (pp. 359–385, pl. xli–xlviii). This paper shows the result of mature study, and although only a small part of the material in hand was here published, the descriptions and delineations, so far as they go, are careful and thorough. All but five of the twenty-nine species relate to fruits, and the figures, which are well drawn and engraved, are constantly referred to as the best that had appeared prior to Brongniart's latest investigations. These fruits, as well as the five ferns described, were taken from the vicinity of coal seams at Tallmadge, Summit County; at Youngstown, Mahoning County; at Zanesville, Muskingum County, and at Massillon, Stark County.

The second volume of the paleontological report of the Geological Survey of Ohio contains a paper by Mr. E. B. Andrews.[1] This paper is confined to a collection made by himself at a point two miles east of Rushville, in Perry County. Seventeen species, representing the genera Megalopteris, Archæopteris, Orthogoniopteris, Alethopteris, Hymenophyllites, Eremopteris, Lepidophloios, Lepidodendron, Asterophyllites, and Cardiocarpon are described. All the species, as also his genus Orthogoniopteris, were new. In the preliminary notice of this discovery presented to the Detroit meeting of the American Association, 1875,[2] Mr. Andrews was disposed to regard these plants as of Devonian age, but in the geological report he is inclined to place them at the base of the coal measures.

In 1874 Professor Lesquereux offered the first evidence of the existence of well defined vegetable remains in the Silurian formation of Ohio.[3] It is here stated that the "two specimens representing branches or small stems of a species referable to Sigillaria," were reported to have been found by Dr. S. S. Scoville on Longstreet Creek, near Lebanon, Ohio, in the Cincinnati group. This report was subsequently confirmed, and Professor Lesquereux identified the species as closely allied to *S. Serlii* Brongn., and also to *S. Menardi* Brongn. Speaking of the age of this deposit he says that "with the exception

[1] Descriptions of Fossil Plants from the coal measures of Ohio, by E. B. Andrews: Rept. Geol. Survey Ohio, vol. 2, Geology and Palæontology, pt. 2, Columbus, 1875, pp. 413–426, pl. xlvi–liii.

[2] Notice of New and Interesting Coal Plants, by E. B. Andrews: Am. Jour. Sci., 3d series, vol. 10, 1875, pp. 462–466.

[3] On remains of Land Plants in the Lower Silurian, by Leo Lesquereux: Ibid., vol. 7, 1874, pp. 31–34.

of the Lebanon specimen the geological formations of the United States have not afforded as yet any records of land plants earlier than those of the Lower Devonian."

Notwithstanding the opinion of Professor Lesquereux so confidently expressed as to the character of these remains, Dr. Newberry, in a paper read before the National Academy of Sciences in April of that year, after careful study of the same specimens, figures of which he had prepared, did not hesitate to pronounce them of doubtful affinity, and he strongly questioned their reference to land plants,[1] regarding them rather as fucoidal remains.

The interest aroused by these two papers led Professor Lesquereux not only to investigate the specimens found by Dr. Scoville, and to make drawings of them for himself, which were submitted to several eminent geologists and botanists, but also to collate and publish a systematic monograph of all the land plants that had been reported from strata below the Devonian.[2] Such plants are here shown to have been met with in Kentucky, Michigan, and Ohio, as well as in Nova Scotia and some parts of Europe. An additional specimen of the same nature as those previously considered had been found near Cincinnati, in the Cincinnati group, and this presented better characters than any hitherto found. Upon it he founded the new genus Protostigma, considered as related to Sigillaria, and he applied to these fossils the name *Protostigma sigillarioides.*

In July, 1877, Professor Claypole discovered in the vicinity of Eaton, Preble County, Ohio, a vegetable impression bearing marks or scars similar to those of Lepidodendron. After studying this carefully he described it in the American Journal of Science[3] as *Glyptodendron Eatonense.* In the expanded form in which this paper appeared in the Geological Magazine, a figure of this impression is introduced.[4]

In the third number of the Cincinnati Quarterly Journal of Science, for July, 1871 (vol. 1, pp. 235, 236), Mr. S. A. Miller described his *Buthrotrephis ramulosa* from the banks of the Ohio River, in the first ward of Cincinnati, which he also found on the opposite shore in Kentucky, and among the twelve new species which he described in the same journal for July 1879 (vol. 2, pp. 104–118), is one *Trichophycus venosus* (pp. 112, 113, pl. ix, fig. 5, 5*a*), which

[1] On the so-called Land Plants from the Lower Silurian of Ohio, by J. S. Newberry: Ibid., vol. 8, 1874, pp. 110–113, two wood-cuts.

[2] Land Plants recently discovered in the Silurian Rocks of the United States, by Leo Lesquereux: Proc. Am. Philos. Soc., vol. 17, 1877, pp. 163–173, pl. iv.

[3] On the occurrence of a tree-like fossil plant, Glyptodendron, in the Upper Silurian (Clinton) Rocks of Ohio, by E. W. Claypole: Am. Jour. Sci., 3d series, vol. 15, 1878, pp. 302–304.

[4] On the occurrence of a fossil tree (Glyptodendron) in the Clinton limestone (base of Upper Silurian) of Ohio, U.S., by E. W. Claypole: Geol. Mag., decade 2, vol. 5, London, 1878, pp. 558–564.

he regarded as a plant from the Hudson River group, also at Cincinnati.

Messrs. S. A. Miller and C. B. Dyer, in 1878[1] described a number of the so-called fucoids of the Cincinnati group, collected at Cincinnati, near Lebanon and Morrow, Warren County, and at Bantam, Clermont County.

Mr. James Geikie states[2] that Mr. Hinde has discovered plant remains in Newberry's "laminated clay series" (Quaternary ?) at Cleveland, but no further details are given.

Mr. Edward Orton, of Columbus, Ohio, has discovered that the bituminous matter in the black shales of Ohio, which are equivalent to the Hamilton, contains vast numbers of yellow translucent disks ranging from $\frac{1}{200}$ to $\frac{1}{100}$ of an inch in diameter, and presenting the appearance of empty and flattened spherical sacs.[3] They were believed by him to be the empty envelopes of Lycopodiaceous spores, probably *Sporangites Huronensis* Dn., or such as have been described by Williamson and Binney in the British fire-clays, iron-ore, and Boghead cannel-coal of Great Britain, and he thinks that they may make up a large proportion of these beds hitherto regarded as barren of fossils. One of the principal localities for these spores is at Kingsville, Ashtabula County.

This would be the proper place to notice these perplexing little objects from the Devonian of the Falls of the Ohio, resembling Chara fruits, which have been several times independently described under different names, and whose history was for the first time written by Prof. F. H. Knowlton in 1889.[4] His name, *Calcisphæra Lemoni*, is, however, anticipated by Ulrich's name, *Mœllerina Greenei*, 1886,[5] who treated them as Foraminifera, which, indeed, they may be.

Prof. E. W. Claypole has commenced the study of certain silicified trunks found in Holmes and Highland Counties. He read a preliminary paper on the subject before the American Association for the Advancement of Science, at its Buffalo meeting, in 1886.[6] In that paper he identifies two species of Dadoxylon (*D. antiquius* Dawson,

[1] Contributions to Palæontology, by S. A. Miller and C. B. Dyer. No. 1. Jour. Cincinnati Soc. Nat. Hist., vol. 1, 1878, pp. 24–39, pl. i–ii; No. 2 [published separately], Cincinnati, 1878, 11 pp., pl. iii–iv, 8°.

[2] Geol. Mag., decade 2, vol. 5, 1878, p. 78.

[3] A source of the bituminous matter in the Devonian and Sub-carboniferous black shales of Ohio, by Edward Orton: Am. Jour. Sci., 3d series, vol. 24, 1882, pp. 171–174.

[4] Description of a problematical organism from the Devonian at the Falls of the Ohio, by F. H. Knowlton: Ibid., vol. 37, 1889, pp. 202–209, 3 figures on p. 203.

[5] Descriptions of New Silurian and Devonian Fossils, by E. O. Ulrich: Contributions to American Palæontology, vol. 1, Cincinnati, May 1, 1886, pp. 3–35, pl. i–iii. (See pp. 34–35, pl. iii, figs. 8–8*e*.)

[6] Preliminary note on some fossil wood from the Carboniferous Rocks of Ohio, by E. W. Claypole: Proc. Am. Assoc. Adv. Sci., 35th (Salem) meeting, 1886, pp. 219–220.

and *D. Newberryi* Dawson). No figures accompany this paper, which is only an abstract of the one presented.

The coal flora of Pennsylvania, which is claimed to embrace all the paleozoic fossil plants of Ohio, contains descriptions of one hundred and thirty-two species, derived as follows as to geological horizon and geographical location, which includes twenty duplications:

Waverly Sandstone (Subconglomerate or Subcarboniferous):
- Newark, Licking County, 3.
- Rushville, Fairfield County, 29.

Interconglomerate:
- Youngstown, Mahoning County, 12.
- Cuyahoga Falls, Summit County, 15.
- Tallmadge, Summit County, 9.
- Jackson's Shaft, Perry County, 3.

Bituminous coal region (Carboniferous):
- Massillon, Stark County, 6.
- Buchtel, Athens County, 9.
- Nelsonville, Athens County, 11.
- Shawnee, Perry County, 1.
- Coshocton, Coshocton County, 3.
- Pomeroy, Meigs County, 8.
- Barnesville, Belmont County, 3.
- Saint Clairsville, Belmont County, 21.
- Athens, Athens County, 1.
- Marietta, Washington County, 4.
- Zanesville, Muskingum County, 8.
- Guernsey County, 1.
- Middlebury, Summit County, 1.
- Salineville, Columbiana County, 4.

Indiana.—Notwithstanding the existence of extensive coal mines in Indiana with the usual plant beds accompanying them, it was not until 1876 that any account was published of the coal flora of the State. In the seventh annual report of the Geological Survey of Indiana for the year 1875 (Indianapolis, 1876, pp. 134–145, pl. i, ii) Prof. Lesquereux contributed a short paper on species of fossil marine plants from the Carboniferous measures. In this paper only fucoidal forms are treated and four new species of Palæophycus and Asterophycus are characterized and illustrated. The three species of Palæophycus were found imbedded in concretions of carbonate of iron on the banks of a branch of Salt Creek, one mile south of Bruilette Creek, Vigo County, and were collected by Professor Cox and Mr. J. F. Miller. The species of Asterophycus (*A. Coxii*) was discovered by Professor Cox in the "Cut-off" of the Wabash near New Harmony, Ind. Four additional plants from New Harmony are described in the Coal Flora of Pennsylvania, though in the summary (vol. 3, p. 879) the Vigo and the New Harmony plants are erroneously put under Illinois.

In the second annual report of the Department of Statistics and Geology (Indiana), 1880,[1] Dr. C. A. White gives four ferns and one Annularia, mainly from Shelburn, Sullivan County, and Spring Creek and Perrysville, Vermillion County, Indiana, quoting the descriptions of Professor Lesquereux for the species represented. These were mostly from the cabinets of Judge John T. Scott, Mr. William Gibson, and Professor John Collett. Dr. White gives in the same connection a fern from Grape Creek, Vermilion County, Illinois, furnished from the cabinet of Mr. Gibson. None of the species are new to science.

Including two duplications, fifty-four species of Indiana plants are described in the Coal Flora of Pennsylvania according to the summaries. Ten are from the subconglomerate Whetstone Beds of Orange County; thirty-three are from Spring Creek, Newport, Eugene, and other points in Vermillion County, and eleven from Sullivan County, in the bituminous coal region.

Professor Collett has collected two specimens of *Alethopteris Serlii* (Brongn.) Göpp. at Eugene, Ind., which, having found their way to the U. S. National Museum, were identified by Professor Lesquereux in the Proceedings of the National Museum in 1887 (vol. 10, p. 27).

Illinois.—With the exception of the description of a fossil tree in recent strata of northwestern Illinois on the Des Plaines River adjacent to its junction with the Kankakee, by Governor Lewis Cass and Mr. Henry R. Schoolcraft, in the year 1821,[2] no account of the fossil flora of that State was published until the year 1866, when Professor Lesquereux made his first contribution on that subject to the Reports of the Illinois Geological Survey.[3] This report is in the nature of a catalogue of the plants that had been submitted to him for determination and bears no evidence of his having had an opportunity to study them in the field; nevertheless he found in this material no less than thirty-four species new to science, and many of the specimens of species already known exhibited forms so instructive that it became essential to figure them.

[1] Second annual report of the Department of Statistics and Geology [Indiana]. (See pp. 520–522, pl. ix–xi.) The same matter appears as a reprint in Indiana Geological Report, 1879 (1880), Indianapolis, 1881, pp. 152–154, pl. ix–xi.

[2] Remarkable fossil tree, found about fifty miles southwest of Lake Michigan, by his excellency Governor Lewis Cass and Mr. Henry R. Schoolcraft, in August, 1821, on the River Des Plaines, in the northeast angle of the State of Illinois. Extracted from a paper presented by Mr. Schoolcraft to the American Geological Society. Am. Jour. Sci., vol. 4, 1822, pp. 285–291.

[3] Report on the Fossil Plants of Illinois. An enumeration of the fossil plants found in the coal measures of Illinois, with descriptions of the new species, by Leo Lesquereux: Geol. Survey Illinois, vol. 2 (Palæontology), Chicago, 1866, pp. 425–470, pl. xxxiii–l.

The localities at which these coal plants were obtained were Mazon Creek (most profuse deposit in the State), and Morris, Grundy County; Colchester, McDonough County; Murphysborough, Jackson County; Duquoin and Saint John, Perry County; Grayville and Carmi, White County; Pope County, especially at Carroll's place; Rock Island County; Crooked Creek; Springfield, Sangamon County; Big Vermilion River; Neelyville, Morgan County; Mercer County; Carlinville, Macoupin County.

The continuation of this report is contained in the fourth volume of the same publication (pp. 375–508, pl. v–xxxi). This is a much more important contribution, and embraces descriptions of seventy-seven additional new species. Appended to this report is a list,[1] in tabular form, enumerating all the species known at the time (March, 1870) from the coal measures of Illinois, and indicating the localities where the specimens representing them had been found. Besides those mentioned in the previous report the following occur: Marseilles, La Salle County; Rushville, Schuyler County; Alton, Little Vermilion River. The total number of species enumerated here is two hundred and fifty-six. The horizon of Mazon Creek has sometimes been regarded as Permian, but is probably Upper Carboniferous. The beautiful impressions from this place contained in nodules of argillaceous iron ore are among the most perfect examples of the preservation of plants in the earth's strata known to paleontology.

In the coal flora of Pennsylvania, including about one hundred and seventy-five duplications, some five hundred and ten species are enumerated by Professor Lesquereux from the Carboniferous of Illinois. Thirty-five of these are from the subconglomerate of the Chester group and Port Byron, Rock Island County, the remainder are from the productive bituminous coal measures, and are distributed as follows: Murphysborough, 31; Mazon Creek, 201; Morris, 107; Colchester, 41; Neelyville, 2; Marseilles, 3; Grape Creek, 20; Duquoin, 28; Saint John's, 8; Stark County, 11; Peoria County, 6; Grayville, 9; Carmi, 6; McDonough County, 1; Vandalia, 1.

Michigan.—Very few fossil plants have ever been discovered in Michigan strata. As early as 1851 Hall, in Foster and Whitney's report on the geology of the Lake Superior land district,[2] gave lists of fossil plants from the Potsdam, the Calciferous sandstone, the Trenton, Hudson River, and the Clinton and Niagara groups of the Lake Superior district, presumably from Michigan, but the only species definitely located is the new one, *Dictyonema fenestrata*, from the Lower Devonian of Mackinac.

[1] Geol. Survey Illinois, vol. iv, 1870, pp. 471–475.

[2] Report on the geology of the Lake Superior land district, by J. W. Foster and J. D. Whitney. Part 2, The iron region, together with the general geology. Washington, 1851, pp. 1-xvi, 1–406, pl. i–xxxv, 8°. (Fossils described by James Hall, pp. 203–231, pl. xxvi–xxxv.)

In 1864 Alexander Winchell[1] named and described *Palæophycus articulatus* from the Potsdam on the north flank of the Porcupine Mountains, Lake Superior, and *P. informis* from the same formation on the Montreal River, Lake Superior.

The same author has noted the presence of vegetable remains in the Marshall group,[2] in this State, supposed by him at the time to be of Upper Devonian age, but no definite localities are given.

Dr. C. Rominger,[3] in describing the Paleozoic rocks of Michigan, in part 3 of volume 1 of the geological report of that State, refers to the occurrence of plants in the Niagara, near the mouth of the Manistique River, and in the Trenton, near the mouth of the Menominee River, and on the Encampement d'Ours Island.

Wisconsin.—Among some fossils from the Potsdam at Devil Lake and Baraboo Bluffs, in Sauk County, Prof. Alexander Winchell was able, in 1864, to identify *Scolithus linearis* Hald. (see his paper cited above). The same species, along with *Oldhamia radiata* Forbes, was reported in 1876 by Mr. J. W. Porter,[4] in a letter to the editors of the American Journal of Science, as occurring in the same formation in the vicinity of Eau Claire.

Prof. T. C. Chamberlin, in the first and second volumes of the Geology of Wisconsin, Survey of 1873–1879, published in 1877 and 1883, mentions the existence of undoubted or supposed vegetable remains in the Potsdam (Cambrian), Trenton, Hudson and Cincinnati (Lower Silurian), Niagara and Lower Helderberg (Upper Silurian), Hamilton (Devonian), but the precise localities are not always given. The general areas, however, occupied by these several formations are clearly represented by maps. The following genera are reported: Palæochorda, Phytopsis, Cruziana, Palæophycus, Buthotrephis, Sphenothallus, and Fucoides, and fourteen species altogether are enumerated, of which six belong to Palæophycus and three to Buthotrephis. These two genera are chiefly represented in the Potsdam and Trenton. Scolithus also occurs, but is not classed with the plants. Among the localities for the Potsdam species are Mendota, Dane County; Bartholomew's Bluff in Kingston Township, Tuscola County; and Berlin, Green Lake County; for the Trenton, Janesville and Center, Rock County; Waterloo, Jefferson County; Ripon, Fond du Lac County, and Flintville, Brown County; for the Niagara, Sturgeon Bay, Door County.

[1] Notice of a small collection of fossils from the Potsdam Sandstone of Wisconsin and the Lake Superior sandstone of Michigan, by Alexander Winchell: Am. Jour. Sci., 2d series, vol. 37, 1864, pp. 226–232.

[2] On the geological age and equivalents of the Marshall group, by A. Winchell: Proc. Am. Philos. Soc., vol. 11, 1869–'70, pp. 57–82, 385–418.

[3] Geological Survey of Michigan. Upper peninsula, 1869–1873. Accompanied by an atlas of maps, vol. 1, New York, 1873. Pt. 3, Paleozoic rocks, by C. Rominger: pp. 1–105.

[4] Oldhamia in Wisconsin [from a letter to the editors], by J. W. Porter: Am. Jour. Sci., 3d series, vol. 12, 1876, p. 226.

Minnesota.—The evidence of vegetable remains in the Paleozoic rocks of Minnesota is somewhat doubtful. Dr. David Dale Owen[1] has figured several specimens supposed to be fucoids from the northwest shore of Lake Superior, probably in this State. They were found in a red sandstone which he was inclined to consider Triassic, but which, from the fact that he asserts its identity with that on Keweenaw Point, may perhaps be considered as Keweenawian, and at Marine Mill in the St. Croix River, in the Trilobite Grit, probably of Cambrian age.

The Dakota group, so prominent in Kansas and Nebraska, extends, as is well known, for some distance into Iowa and northward into Minnesota. Professor Lesquereux, in his Cretaceous Flora, described three species collected by Prof. James Hall near New Ulm, in the last named State (Cretaceous Flora, pp. 6, 7). They are as follows: *Ficus Halliana* Lx., *Laurophyllum reticulatum* Lx., and *Leguminosites Marcouanus* Heer.

Iowa.—The collections from the Dakota group of Iowa were somewhat more numerous than those of Minnesota, chiefly in the vicinity of Sioux City. It is also probable that some of the specimens labeled Big Sioux were found on its left bank and should therefore be credited to the former State.

Prof. Erasmus Haworth, of Penn College, Oskaloosa, informs me that he has in his possession a specimen of a dicotyledonous leaf from that place which he believes to belong to the Dakota group. He states that other specimens have been collected in the northwestern part of that (Mahaska) county, also that Carboniferous plants occur at Oskaloosa.

There are other Carboniferous beds in Iowa and two species (*Lepidodendron Veltheimianum* and *Sigillaria Saullii*) from Ottumwa, Wapello County, in the southeastern part of the State, are enumerated in the Coal Flora of Pennsylvania.

Fossil plants from a still lower (Subcarboniferous) formation were mentioned and figured by D. D. Owen in 1852, in his report referred to above. They were found in the Muscatine Bluffs near the mouth of Pine Creek, at Cedar Bluffs on the Des Moines River two miles above Soap Creek, near the mouth of Turkey Creek, and on the Mississippi about three and one-half miles below Hampton.

A fossil trunk from Keokuk was described in 1873 by Mr. Samuel J. Wallace.[2]

Specimens of fossil wood sent to Mr. W J McGee by Rev. E. M. Glasgow, of Estherville, Emmet County, Iowa, from that place have recently been microscopically studied by Prof. F. H. Knowlton, who

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[1] Report of a geological survey of Wisconsin, Iowa, and Minnesota, and incidentally a portion of Nebraska Territory. Made under instructions from the United States Treasury Department, by David Dale Owen: Philadelphia, 1852, folio, pp. i–xxxviii, 1–638, pl. i–xv. Owen, pp. 1–206, pl. i–viii[A]. (See pp. 187–189, pl. i, i[C], i[D], and ii.)

[2] Am. Jour. Sci., 3d series, vol. 15, 1878, p. 396.

finds it belongs to the genus Cupressinoxylon. Relative to the age of the deposit in which this wood occurs, Mr. McGee in a letter to Professor Knowlton, dated January 4, 1888, says: "There is every probability that the Emmet County (Iowa) wood is from the Cretaceous, though it is found in the drift, the Cretaceous strata from which it was originally derived having formerly extended over contiguous parts of Minnesota and been largely removed by glacial erosion during the Quaternary."

Missouri.—In Dr. B. F. Shumard's Description of a geological section on the Mississippi River from Saint Louis to Commerce, published in the first and second Annual Reports of the Geological Survey of Missouri (in one volume), by G. C. Swallow, State Geologist, Jefferson City, 1855, part 2 (pp. 139–208, pl. A–E), mention is made of the occurrence of impressions of Calamites and Lepidodendron on the North Missouri Railroad, between seven and eight miles from Saint Louis (p. 177), and in the descriptive part of this report (p. 208) one species (*Filicites gracilis* Shumard) is mentioned with an account of its mode of deposition, and figured on pl. A (fig. 11). It was found at Louisiana and Elk Spring, Pike County, and on North River in Marion County. This form has since been identified as the Ptilophyton of Dawson.

Two of the species of Cordaites which Professor Lesquereux includes in his monograph of that genus, published in the proceedings of the American Philosophical Society, March 1, 1878, were obtained by Dr. J. H. Britts, from Clinton, Henry County, Missouri. This locality has yielded eighty-five species of Carboniferous plants and is regarded by Lesquereux as belonging to the same horizon as the abundant plant-bearing beds of Cannelton, Pa. The only other locality in the State mentioned in the Coal Flora is in Vernon County, about half way between Nevada and Fort Scott, where two species of Conostichus were obtained by Prof. G. C. Broadhead and sent to the author. Three other species are mentioned as coming from the State, but definite localities are not given. The total fossil flora of the State, therefore, amounts to over ninety species.

Arkansas.—Dr. Nuttall, in the paper which has been referred to (supra, p. 873), published in 1821, recorded his observations upon the various petrifications which came under his eye while traveling through Arkansas. These are mentioned on pages 24 and 45 of that paper.

In 1850 Mr. Theodore F. Moss presented to the Philadelphia Academy of Natural Sciences a brief account, accompanied by a drawing, of *Trigonocarpus Woodruffii* Moss, n. sp., which was found in clay slate "ten miles north of Little Rock, Ark., and forty miles east of the coal formation, where it is probably in place."[1]

[1] Description of a new Carpolites from Arkansas, by Theodore F. Moss: Proc. Acad. Nat. Sci. Phila., vol. 5, 1850, p. 59.

The first considerable contribution to the fossil flora of Arkansas was made by Prof. Lesquereux and published in the Second Report of the Geological Reconnaissance of the Middle and Southern Counties of Arkansas, made during the years 1859 and 1860, by David Dale Owen, principal geologist, Philadelphia, 1860 (pp. 297–319, pl. i–vi). Twenty-two species were systematically treated and figured from the Paleozoic formation (Subconglomerate) in this report, fourteen of which were new; and in a list given on pages 314, 315, forty-eight species were enumerated and their localities stated. These localities are: Male's coal bank on the middle fork of White River, Lee Creek, Frog Bayou, Crawford County; Jenny Lind Prairie, Sebastian County; and James Fork of the Poteau River. This number had increased to one hundred and twenty species at the date of the publication of the Coal Flora of Pennsylvania, in 1884.

A specimen in the National Museum collection (No. 2226) collected by Dr. G. H. Horn at Liberty Springs, Van Buren County, Ark., proved to belong to *Lepidodendron clypeatum* Lx. (See Proc. U. S. Nat. Mus., vol. 10, 1887, p. 28.)

Texas.—In some Observations on the geology of the Trinity country, Texas, made by Dr. J. L. Riddell[1] in 1839, I find mentioned the occurrence of opalized wood, lignites, and "minor cauline plants" in the Tertiary formation (probably Eocene) on the Trinity River. The exact locality is not definitely stated, but the vicinity of New Cincinnati seems to be understood.

Dr. Ferdinand Roemer, who traveled through Texas in 1847, discovered fragments of silicified wood near La Grange and Gonzales not far from Peach Creek, and in many other places in middle Texas. They were submitted to Dr. Göppert, of Breslau, who regarded them as representing two undescribed genera from the family of the Leguminosæ and two coniferous genera,[2] one in the Cupressinæ, and the other a true Pinites. These latter were obtained from the vicinity of Fredericksburgh, Gillespie County, and from the Llano River. A portion of this material, as it appears, was also submitted to Professor Unger at Vienna, who detected three genera in it, two of which were new. Of these, his Sillimania (*S. Texana* Ung.), already published in the Genera et Species Plantarum Fossilium (p. 524), and the Roemeria (*R. Americana* Ung.), were dicotyledonous genera. The remaining species, *Thuyoxylon Americanum* Ung., was found at New Braunfels, the others at Gonzales.[3] Roemer regarded these deposits as of Creta-

[1] Observations on the Geology of the Trinity Country, Texas, made during an excursion there in April and May, 1839, by J. L. Riddell: Am. Jour. Sci., vol. 37, 1839, pp. 211–217.

[2] Texas. Mit besonderer Rücksicht auf deutsche Auswanderung und die physischen Verhältnisse des Landes, nach eigener Beobachtung geschildert, von Dr. Ferdinand Roemer: Bonn, 1849, 8°. (Fossiles Holz, pp. 369–370.)

[3] Die Kreidebildungen von Texas und ihre organischen Einschlüsse, von Dr. Ferdinand Roemer: Bonn, 1852, folio. (Fossil wood by Unger, pp. 94, 95.)

ceous age, but Unger thought the fossil wood belonged rather to the Tertiary. Fossil wood was also found by Dr. Arthur Schott and mentioned in his Substance of the Sketch of the Geology of the Lower Rio Bravo del Norte.[1] These petrifactions occurred in great abundance in the valley of the Rio Bravo [Grande], especially at the mouth of Elm Creek; also in Eagle Pass, as well as in the vicinity of Santa Rosa, Mexico. Dr. Schott states that most of this fossil wood apparently posse ses the structure of the palm wood, though the specimens from Santa Rosa had a different structure, and he thinks that some of it may be referred to the Coniferæ.

It was not until 1860 that any fossil leaves were reported from the strata of Texas. In that year Dr. B. F. Shumard found in Lamar County, near Red River, a large number of dicotyledonous leaves belonging to the genera Salix, Ilex, Laurus, etc.[2]

Dr. S. B. Buckley, State geologist of Texas, in his First Annual Report of the Geological and Agricultural Survey of Texas (Houston, 1874, page 25), mentions the occurrence of "impressions of leaves and palms, some two and three feet long; also many leaves of trees or shrubs of exogenous plants, nearly all of which are entire, only one specimen of a lobed leaf being found. This is a Platanus. Some of these entire leaves are very large and have prominent veins. They evidently belong to the Eocene of the Tertiary, and are in strata overlying the coal. In none of the Tertiary coals of the State have we seen vegetable remains in good preservation in the shales in contact with the coal, excepting in Fayette County, where are oblong ribbed fruits about an inch in length." He also found a Tertiary fruit in the shale above the coal in Fayette County, near the southern boundary of the Eocene.

One Carboniferous species (*Calamites dubius* Artis) has been collected in Texas strata by A. R. Roessler in Jackson County, of which two specimens are deposited in the U. S. National Museum (No. 2155).[3]

The records of the National Museum show that Dr. R. E. C. Stearns collected one specimen of fossil wood two miles east of Eagle Pass and another at Bryan, Brazos County; that Mrs. J. L. Sinks secured a specimen of Stigmaria at Giddings, Lee County, and that J. W. Pearson has communicated a supposed fossil seed pod from Colorado, Mitchell County. These specimens have not yet come up for examination.

Indian Territory.—At Eufaula two species of Carboniferous plants (*Bornia radiata* (Brongn.) Schimp. and *Cardiocarpus conglobatus* Lx.)

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[1] Report on the United States and Mexican Boundary Survey, made under the direction of the Secretary of the Interior, by William H. Emory: Washington, 1857, vol. 1, part 2, pp. 28–48, 4°. (Lignite Coal, pp. 35, 36. Fossil Wood, pp. 39, 40.)

[2] Trans. Acad. Sci. Saint Louis, vol. 2, No. 1, 1863, p. 140.

[3] Proc. U. S. Nat. Mus., vol. 10, 1887, p. 22.

have been obtained by Mr. H. F. Buckner and identified by Professor Lesquereux. They are in the National Museum collection, Nos. 2164 and 2388, respectively.

Mr. Lawrence Johnson, of the U. S. Geological Survey, has collected four species of fossil dicotyledonous plants (*Quercus furcinervis* (Rossm.)Ung., *Persea speciosa ?* Heer, *Laurus primigenia* Ung., and *Eucalyptus* sp. Lx.) at Selma, Cherokee County, the age of which is uncertain but seems to be Tertiary.[1]

Kansas.—The early papers relating to the discoveries of fossil plants from the Dakota group of Kansas and Nebraska do not discriminate carefully as to the precise localities at which they were found.[2] Dr. Newberry in his Later Extinct Floras (p. 23) gives his *Fagus cretacea* as from Smoky Hill, Kansas.

Professor Lesquereux in his early and important paper published in the American Journal of Science[3] for July, 1868, states that the plants therein described came from the vicinity of Fort Ellsworth, Nebraska, but the old Fort Ellsworth was located in central Kansas, so that there seems no doubt that the fifty-three new species of fossil plants described in it should be credited to that State. This error is perpetuated in his paper On fossil leaves from Fort Ellsworth, Nebraska,[4] in which nine additional species are treated. In his contribution to Hayden's (Fourth Annual) Report for 1870,[5] the Kansas localities given are Fort Ellsworth and Northwest Salinas, from which twelve of the forty-nine species in his list of Cretaceous plants on pages 379 and 380 were obtained.

Twenty-two species, eleven of which were new, were described in Hayden's Annual Report for 1872,[6] which Professor Lesquereux had himself collected in that year from a point nine miles above Salina, in the Salina Valley, and from another six miles south of Fort Harker.

The Fifth Bulletin of the U. S. Geological and Geographical Survey of the Territories (Washington, 1876), contains another paper by the same author on New Species of Fossil Plants from the Cre-

[1] Proc. U. S. Nat. Mus., vol. 11, 1888, p. 36.

[2] Remarks on the Lower Cretaceous beds of Kansas and Nebraska, by F. B. Meek and F. V. Hayden: Proc. Acad. Nat. Sci., Phila., vol. 10, 1858, pp. 265, 266. Am. Jour. Sci., vol. 27, 1859, pp. 219–227.

Les Phyllites crétacées du Nebraska, par J. Capellini et O. Heer: Nouv. Mém. Soc. Helv. Sci. Nat., vol. 22, No. I, Zürich, 1866, pp. 1–22, pl. i–iv.

[3] On some cretaceous fossil plants from Nebraska, by Leo Lesquereux: Am. Jour. Sci., 2d series, vol. 46, 1868, pp. 91–105.

[4] Trans. Am. Philos. Soc., vol. 18, 1869, pp. 430–433, pl. xxiii.

[5] On the Fossil Plants of the Cretaceous and Tertiary formations of Kansas and Nebraska, by Leo Lesquereux: Preliminary Report of the U. S. Geol. Survey of Wyoming, etc., 1870, Washington, 1872, pp. 370–385.

[6] Description of species of Fossil Plants from the Cretaceous of Kansas, by Leo Lesquereux: Sixth Ann. Rept. U. S. Geol. Survey of the Territories, etc., for 1872. Washington, 1873, pp. 421–427.

taceous formation of the Dakota Group.[1] These were collected principally by Messrs. H. C. Towner and Charles Sternberg, in Kansas, but the precise localities are not here stated. Thirty species, the greater part of which were new, are here described without figures.

These species are for the most part reproduced in Professor Lesquereux's much more extended paper in the Annual Report for 1874,[2] which is illustrated by eight plates. As this paper was prepared after the quarto report next to be considered was in type, and is mostly embodied in that report, it will not be necessary to discuss it separately. The author states, however, that all the new material for it was collected in Kansas by Messrs. Charles Sternberg, H. C. Towner, and B. F. Mudge.

The sixth volume of the final quarto reports of Dr. Hayden's Survey forms Professor Lesquereux's now well known Cretaceous Flora.[3] In this report are thoroughly characterized, discussed, and illustrated all the fossil plants from the Dakota group that had been made known to that date, amounting to one hundred and thirty species. They were chiefly from the strata within the States of Kansas and Nebraska.

The localities in Kansas are as follows: Fort Harker and vicinity, eight miles above Salina Station; Smoky Hills, Salina River, eight miles above its mouth; Smoky Hill River or Fork, Brooksville, Saline county, and Fort Larned; many of them, however, are labeled merely "Western Kansas in concretions," or still less definitely. The almost criminal carelessness which characterized most of the collecting done by Dr. Hayden's Survey merits the severest reprehension.

According to Professor Lesquereux's Report on the recent additions of Fossil Plants to the Museum collections,[4] "more than six hundred specimens of Cretaceous Fossil Plants have been obtained in the Dakota group of Kansas by Mr. Charles H. Sternberg" during that year; but this report fails to state the points at which Mr. Sternberg collected them.

A second important contribution to the Dakota group flora was made by Professor Lesquereux in 1883, and forms the first chapter of the third final quarto report of the Hayden Survey, namely, his Cretaceous and Tertiary floras (pp. 25–107). At the close of this chapter he gives a table of distribution which shows that the flora of the Dakota group had now reached four hundred and forty-two

[1] Bull. U. S. Geol. and Geogr. Survey of the Territories, vol. 1, 1874–'75, No. 5, 2d series, pp. 391–400.

[2] Report on the Cretaceous and Tertiary Floras of the Western Territories, by L. Lesquereux: Ann. Rept. U. S. Geol. and Geogr. Survey of the Territories, 1874, Washington, 1876, pp. 333–365, pl. i–viii.

[3] Contributions to the Fossil Flora of the Western Territories. Pt. 1, The Cretaceous Flora, by Leo Lesquereux. Report of the U. S. Geol. Survey of the Territories, by F. V. Hayden, U. S. Geologist in charge, vol. 6, 1874, 136 pp., 30 pl., 4°.

[4] Bull. Mus. Comp. Zoöl. Harvard Coll., vol. 7, No. 6, 1881, pp. 225–230.

species, or three times the number known in 1874. The new species are described and figured in this work, although many of those from Kansas were the result of more thorough exploration of the old localities. The following additional ones appear: Glasco, two and one half miles north of Glasco, Cloud County; seven miles northeast of Glasco; Clay Center, Clay County; Bluff Creek, Ellsworth County; four miles northeast of Minneapolis and eight miles northeast of Minneapolis, Ottawa County, principal locality not stated.

Mr. Sternberg has recently made further very extensive collections from the Dakota group plant beds of Kansas, and Prof. F. H. Snow has also obtained fine specimens of these leaf prints for the cabinet of the University of Kansas. All these collections have passed through the hands of Professor Lesquereux, who will consider them in a large work, now nearly completed, on the Flora of the Dakota Group.

Besides these extensive deposits of Cretaceous plant-bearing beds, Kansas possesses in its more easterly districts some Carboniferous deposits from which vegetable remains have been taken. Mr. R. D. Lacoe has obtained many specimens from various localities which he permitted Professor Lesquereux to examine and to embody in his report upon the Coal Flora of Pennsylvania. About twenty-five species are described from Kansas in that work, the localities being: Osage City, Osage County; Lawrence, Douglass County; Garnett, Anderson County; Thayer, Neosho County; Ottawa, Franklin County.

Nebraska.—The first paper describing fossil plants from Nebraska was published in the Proceedings of the Academy of Natural Sciences of Philadelphia for December, 1858. Messrs. Meek and Hayden had obtained a number of leaf impressions from the formation in that State which had previously been regarded as Triassic, which they had sent to Professor Heer, of Zurich. His report upon them was inserted in the communication made by them at that date.[1] Heer's report embraced eight species but no localities are given. The plants were typical Dakota group forms. Messrs. Meek and Hayden republished portions of their paper in the American Journal of Science for March, 1859, adding sketches of three of the most important species, *Liriodendron Meekii* Heer, *Populus litigiosa* Heer, and *Sassafras Cretaceum* Newberry.

In another paper which preceded this in the same journal,[2] these authors continue to argue against the Triassic age of this group, and adduce as evidence a report by Dr. J. S. Newberry (p. 33), in which

[1] Remarks on the Lower Cretaceous beds of Kansas and Nebraska, together with descriptions of some new species of Carboniferous fossils from the valley of the Kansas River, by F. B. Meek and F. V. Hayden: Proc. Acad. Nat. Sci. Phila., vol. 10, 1858, pp. 256–266. Descriptions of the Fossil Plants, by Professor Heer, pp. 265–266.

[2] On the so-called Triassic Rocks of Kansas and Nebraska, by F. B. Meek and F. V. Hayden: Am. Jour. Sci., 2d series, vol. 27, 1859, pp. 31–35.

he gives a list of thirteen genera, eleven of which are dicotyledonous, and insists that the formation can not be older than Lower Cretaceous.

We may pass over the mere discussions, interesting though they were, which took place at about this time relative to the age of this formation, and confine ourselves more especially to the geographical considerations. It was in 1867 that the first systematic paper on the flora of the Dakota group appeared.[1] This paper consists of an introduction by Capellini on the stratigraphical position of the beds, followed by Heer's description of the fossil plants that had been sent to him. From these seventeen species were identified, all of which were dicotyledons, and embraced some of the best known types of the peculiar vegetation of the Dakota group. The localities in Nebraska were Tekamah, Burt County, and Black Bird Hill, Holt County, from which places twelve of the species had been obtained.

Dr. J. S. Newberry, in his Later Extinct Floras, read April 22, 1867,[2] was able to enumerate thirty-seven species from the Cretaceous of Nebraska (pp. 8, 9), and sixteen of these are described in that paper, the localities being Blackbird Hill, Sage Creek, Big Sioux River, and Cedar Spring.

The greater part of the plants described by Professor Lesquereux in the American Journal of Science for July, 1868, although credited to Nebraska, came, as already remarked, from Fort Ellsworth, Kans.

The list of Cretaceous plants given by Lesquereux in Hayden's Fourth Annual Report, for 1870 (pp. 379, 380), were chiefly from Nebraska, namely, from Decatur, Burt County; from Beatrice, Gage County; from the Platte River, Cass County, and from Lancaster County.

No additional localities in Nebraska are enumerated in the Cretaceous Flora as having furnished fossil plants, neither do we find any others in the revision of the Dakota group flora in his Cretaceous and Tertiary Floras.

The alleged Permian at Nebraska City, has also furnished a very few plant remains, which were identified by Geinitz.[3] One of these is the *Guilielmites permianus* Gein., which is characteristic of the Rothliegende of Germany.

Dakota.—As early as 1815 the extinct vegetation of the Bad Lands of Dakota had been observed. In a letter of G. H. Crossman, of the U. S. Army, published in the Illinois Magazine in 1830, a considerable portion of which is quoted by Dr. Harlan in his paper published in 1834, already referred to,[4] a specimen "broken off

[1] Les Phyllites Crétacées du Nebraska, par MM. J. Capellini et O. Heer: Nouv. Mém. Soc. Helv. Sci. Nat., vol. 22, No. 1, Zürich, 1867, pp. 1–22, pl. i–iv.

[2] Annals Lyceum Nat. Hist. New York, vol. 9, 1868, pp. 1–76.

[3] Carbonformation und Dyas in Nebraska, von H. B. Geinitz: Nova Acta Acad. Leop.-Carol., vol. 33, Dresden, 1866, No. 4, xii, 91 pp., 5 pl. (See p. 73.)

[4] Trans. Geol. Soc. Pennsylvania, vol. 1, 1835, p. 106.

from one of the many large stumps and limbs of trees found near Yellowstone River, Missouri Territory, and brought away by some of the officers attached to the Yellowstone expedition, in 1815," is described. In this letter it is further stated that "for a distance of twenty or thirty miles over an open prairie upon the west bank of the Missouri River, and a few miles below its junction with the Yellowstone near latitude 48°, these remains are most abundant."

It was not, however, until Dr. Hayden's researches, commenced in 1864 or 1865, that the study of these remains was undertaken. Large collections were made by his parties in the upper Missouri region, particularly at Fort Clark; at Red Spring, thirteen miles above; at Fort Berthold; at Fort Union; at Crow Hills, one hundred miles below Fort Union; and at the mouth of the Yellowstone. These collections were placed in the hands of Dr. J. S. Newberry for determination, and described by him without illustration, in the Annals of the Lyceum of Natural History for April, 1868.[1] Twenty-seven of the species here treated came from the strata from within the Territory of Dakota; they are typical Fort Union group species, and, although this group was supposed at that time to be Miocene, it is now generally regarded as Laramie, or at least not later than Eocene. Dr. Newberry would place it in the last named system.[2] Among them are included the hazel leaves, *Corylus Americana* (Walt.) Newb. and *C. rostrata* (Ait.) Newb., which, in the absence of fruit, it is still impossible to distinguish from the living North American species. The illustrations which had been prepared to accompany this paper were published by Dr. Hayden's Survey in 1878,[3] with notes by Professor Lesquereux.

Plant beds have also been found in the Potsdam (Cambrian) formation of the Black Hills, and, from the specimens collected by Newton and Jenney in their exploration of the geology and resources of this region, and afterwards referred to R. P. Whitfield, the latter was able to describe, in 1877 and 1880, in both his preliminary and final paleontological reports of the expedition,[4] two species of

[1] Notes on the Later Extinct Floras of North America, with descriptions of some new species of fossil plants from the Cretaceous and Tertiary strata, by J. S. Newberry: Annals Lyceum Nat. Hist. New York, vol. 9, 1868, pp. 1–76.

[2] The Coals of Colorado, by J. S. Newberry: School of Mines Quarterly, vol. 9, No. 4, New York, 1888, pp. 327–341. (See p. 331.)

[3] Illustrations of Cretaceous and Tertiary Plants of the Western Territories of the United States [by J. S. Newberry]. Washington, 1878, 26 pl., 4°.

[4] R. P. Whitfield: Preliminary report on the paleontology of the Black Hills, containing descriptions of new species of fossils from the Potsdam, Jurassic, and Cretaceous formations of the Black Hills of Dakota. U. S. Geol. Survey, 1877, pp. 1–49, 8°.

Newton and Jenney: Report on the Geology and Resources of the Black Hills of Dakota, with atlas, by Henry Newton and Walter P. Jenney, Dept. Interior, U. S. Geol. Survey, 1880, pp. i–xiv, 1–566, 4°. Paleontology of the Black Hills of Dakota, by Whitfield, pp. 329–468, pl. i–xvi.

fucoids, *Palæochorda prima* and *Palæophycus occidentalis*, both from the head of the Red Water Valley, in the Black Hills.

A collection of fucoidal remains made by Mr. H. Newton in 1875, at the head of Red Water Valley and on Red Cañon Creek in the Potsdam formation of the Black Hills of Dakota, consisting of twenty-nine specimens, is deposited in the U. S. National Museum. Professor Lesquereux finds two species among these (*Palæophycus irregularis* Hall and *P. tubularis* Hall).[1]

Several additional new species from Fort Union and Fort Berthold were described in a much recent paper by the same author, published in the Proceedings of the U. S. National Museum.[2] These appear to have been partly the result of a re-elaboration of the original material and of the study of other material collected by J. M. Rothammer on the expedition of General Alfred Sully. It is very desirable that figures of these new species, as well as the others described in this paper, be published, since it is impossible to avoid the duplication of names where only descriptions are available for comparison.

The collections made by Professors Denton and McBride from the Bad Lands of Dakota were studied by Lesquereux, and his report upon them forms a chapter in his Cretaceous and Tertiary Flora (pp. 21–237). Though classed by him as Miocene, they appear to be Fort Union species, and have been included by me in the flora of the Laramie group.[3]

Drs. F. V. Hayden and A. C. Peale made collections in 1883 from the following localities in Dakota: One-half mile from the Little Missouri River, on the Northern Pacific Railroad; Sims, Morton County; Gladstone, in the clay of which brick is made, and two miles east of Gladstone on the north side of Heart River. These collections appear to be all from the Fort Union group.

While descending the Missouri River in the year 1883 I discovered a few localities along its banks below Fort Buford, and therefore within the Territory of Dakota, which, had there been time for thorough exploration, could not have failed to yield important results. Among these was one on the left bank of the Missouri about one hundred miles below Fort Buford, and another at Little Knife Creek; still a third near Fort Stevenson, all in the Fort Union group.[4]

Montana.—A considerable number of the species contained in Dr. Newberry's notes on Later Extinct Floras of North America, to which reference has just been made, were collected on the banks of the

[1] Proc. U. S. Nat. Mus., vol. 10, 1887, p. 21.

[2] Brief descriptions of Fossil Plants, chiefly Tertiary, from Western North America, by J. S. Newberry: Proc. U. S. Nat. Mus., vol. 5, 1882, pp. 502–514.

[3] Science, vol. 5, April 24, 1885, p. 348. Sixth Ann. Rept. U. S. Geol. Survey, 1884–'85 (1886), pp. 405–557, pl. xxxi–lxv. (See p. 406.)

[4] Sixth Ann. Rept. U. S. Geol. Survey, 1884–'85 (1886), p. 549.

Yellowstone River, but the exact position of these deposits is not in any case stated; it can only be surmised that they came from localities within the present Territory of Montana. Among these were the new species *Sabal Campbellii*, *Alnus serrata*, *Catalpa crassifolia*, *Populus cordata*, *nervosa*, *nebrascensis*, *cuneata*, and *genetrix*; *Platanus Raynoldsii* and *P. Haydenii*, *Aristolochia cordifolia*, and most of the conifers.

The localities usually designated Sage Creek, three miles above Spring Cañon, and six miles above Spring Cañon near Fort Ellis (Gallatin County), "are also in Montana, and from them quite a number of plants have been obtained."[1]

The plants collected by Prof. N. H. Winchell at Barr's Bluff and other points in the Yellowstone Valley, and published by Lesquereux in his Cretaceous and Tertiary Floras (pp. 221–237), are also to be credited to Montana.

In 1882 Dr. C. A. White made a valuable collection from the Lower Yellowstone Valley in the vicinity of Glendive, Dawson County. The specimens bore labels from the following localities: Iron Bluff, on the right bank of the river, 13 miles above Glendive; Cracker Box Creek, left bank of the Yellowstone, 18 miles above Glendive; Clear Creek, 14 miles above Glendive; Upper Seven Mile Creek, 4 miles above Glendive; Lower Seven Mile Creek, 10 miles below Glendive, on the left bank; near Gleason's Ranch, 28 miles below Glendive, also on the left bank. With the exception of the first and the last mentioned of these localities, which are close to the river's bank, they are situated from five to ten miles from the river along the terraces and smaller streams whose names they bear.

In 1883 I visited these localities, and made extensive collections from them, of which partial reports have already been published.[2]

I also visited during that same year a number of plant beds along the Upper Missouri River. At a point seven miles below Coal Banks, on the right bank, in dark carbonaceous ironstone of Upper Cretaceous age, a few dicotyledonous impressions were obtained.[3]

During the same year Drs. F. V. Hayden and A. C. Peale visited several points farther up the Yellowstone than those at which I made

[1] Prelim. Rept. U. S. Geol. Survey of Montana and portions of adjacent Territories, being Hayden's Fifth Ann. Rept. of Progress for 1871, pp. 290–299; Ibid., Sixth, 1872, pp. 404–408; Ibid., Seventh, 1873, p. 384. Lesquereux's Tertiary Flora, pp. 314–321 (1st group).

[2] Science, vol. 1, June 15, 1883, p. 559, 1st column. Fifth Ann. Rept. U. S. Geol. Survey, 1883–'84, Washington, 1885, pp. 55, 56. Sixth Ann. Rept. U. S. Geol. Survey, 1884–'85, Washington, 1886, pp. 542–557, pl. xxxi–lxv. Types of the Laramie Flora: Bull. No. 37, U. S. Geol. Survey. Remarks on an undescribed vegetable organism from the Fort Union group of Montana: Proc. Am. Assoc. Adv. Sci., 37th (Cleveland) meeting, 1888, pp. 189–201.

[3] Am. Jour. Sci., 3d. series, vol. 27, 1884, p. 300. Fifth Ann. Rept. U. S. Geol. Survey, Washington, 1885, p. 56.

my collections. They found fossil plants on the Bull Mountains, forty miles from Billings, in the Bozeman coal mines, in the bluffs back of Stillwater, and on the top of the bluff opposite Livingston. These plants, so far as they have been studied, appear to be Fort Union types.

Professor Lesquereux informed me in a letter dated August 9, 1887, that he had recently "received from Prof. N. H. Winchell, of Minneapolis, a number of specimens taken four miles above the mouth of Powder River, the leaves quite well preserved upon a hard whitish limestone shale and of Upper Senonian types." Professor Lesquereux has figured some of these leaves for a report to be published by the U. S. Geological Survey. I presume the bed from which these specimens came was of nearly the same age as that at Coal Banks.

Wyoming.—The earliest collections of fossil plants made in Wyoming seem to have been those brought back by Capt. J. C. Frémont, referred to Prof. James Hall for identification, and published in the report of Frémont's First and Second Expedition, in 1845.[1] These plants were collected, according to this report, in latitude 41½° N. and longitude 111° W. from Greenwich. This, according to present boundaries, would bring the locality within the Territory of Wyoming, but very near the Utah line, also quite close to the southeast corner of Idaho. The formation was supposed by Professor Hall to be of Jurassic age, and his comparisons are for the most part with the figures of Phillips, as published in the Geology of Yorkshire. Although the most of them are ferns, there are certainly dicotyledonous species among them.[2] A remnant of this collection has found its way to the U. S. National Museum and has recently been investigated by Professor Lesquereux, whose report upon it is included in the paper already several times referred to.[3]

Since the commencement of Dr. Hayden's Survey, the plant beds of Wyoming have been explored with great thoroughness, especially along the line of the Union Pacific Railroad.

To an article by Dr. F. V. Hayden in the American Journal of Science for March, 1868,[4] a postscript is added (pp. 205–208), in which

[1] Descriptions of organic remains collected by Captain J. C. Frémont in the Geographical Survey of Oregon and North California, by James Hall, paleontologist to the State of New York. In Frémont's First and Second Expedition, 1842–'44, Washington, 1845, pp. 304–310, pl. i–iv.

[2] Professor Heer was also of this opinion, as stated by Mr. Jules Marcou in his "American Geology. Letter on some Points of the Geology of Texas, New Mexico, Kansas, and Nebraska;" addressed to Messrs. F. B. Meek and F. V. Hayden. Zürich, 1858, 16 pp., 8°. (See p. 13.)

[3] Proc. U. S. Nat. Mus., vol. 11, 1888. (See pp. 37, 38.)

[4] Notes on the Lignite Deposits of the West, by F. V. Hayden, U. S. Geologist. Published by permission of the Commissioner of the U. S. General Land Office: Am. Jour. Sci., 2d series, vol. 45, 1868, pp. 198–208.

Professor Lesquereux reports upon the fossil plants which had been referred to him for identification. The most of these were from points in Colorado, but six species are enumerated from Rock Creek on the Laramie plains. These species represent the genera Populus, Quercus, and Platanus, and three of them were new to science. The exact locality is not known. I proved from actual observation that no Laramie strata exist in the immediate vicinity of Rock Creek station, and it must therefore be assumed that the plant bed lies on that stream some distance from the railroad. This report was published in the Third Annual Report of the U. S. Geological Survey of the Territories.[1] The subsequent reports contain Professor Lesquereux's lists of the plants that were collected by that survey and discussions as to their probable age as well as the descriptions of the new species. In the Fourth Annual Report for 1870 (p. 383) one species (*Populus æqualis* Lx.) is added from the locality last mentioned, and on the following page four species are described from Henry's Fork, one of the latter being *Lygodium neuropteroides* Lx., since that time found so abundantly in the Miocenes of Oregon and at other localities. Notwithstanding the attempts of Ettingshausen to identify this with Heer's *L. Kaulfussi,* from the Lignites of Skopau,[2] it certainly is not that species.

The Fifth Annual Report for 1871 (pp. 283–318) contains a third paper, a large part of which is devoted to Wyoming plants, namely, from Henry's Fork; Muddy Creek; Blake's Fork; Barrel Springs; Washakie; Creston; Medicine Bow; Green River; Point of Rocks; Carbon; Evanston; etc.; and the supplement to the same report constitutes an additional paper relative to other material from the same localities.

During the summer of 1872 Professor Lesquereux visited a number of these localities in person, and the Sixth Annual Report for that year (pp. 317–427) contains a full account of his investigations, and the systematic treatment of a large number of species collected by himself. At the conclusion of this paper he gives a table of distributions, with all the species that had been identified up to that time from each of the various localities.

In the Seventh Annual Report (1873, pp. 379–390) Professor Lesquereux, as I have already stated, attempted the geological classification of these, and all the other western plant beds, with lists of species belonging to each group. As this work was revised in his final report, it need not be further discussed in this place.

The Eighth Annual Report for 1874 (pp. 296–315) has a descriptive

[1] First, Second, and Third Annual Reports of the United States Geological Survey of the Territories for the years 1867, 1868, and 1869, under the Department of the Interior, Washington, 1873, pp. 195–197.

[2] Beiträge zur nähern Kenntniss der Sachsisch-thüringischen Braunkohlenflora, von Oswald Heer: Abhandl. Naturwiss. Ver. Prov. Sachsen, vol. 2, Berlin, 1861, pp. 407–438, pl. i–x. (See p. 409, pl. viii, fig. 21, pl. ix, fig. 1.)

paper, largely devoted to plants collected at Point of Rocks, by Mr. William Cleburne, but also dealing with specimens from other parts of the Territory. This paper reappeared as a bulletin of that survey (vol. 1, 1874–'75, pp. 363–389).

At Fort Fetterman, Lieut. A. W. Vogdes collected a specimen of a dicotyledonous leaf which was figured by Professor Lesquereux in his Tertiary Flora and named for its discoverer *Betula Vogdesii* Lx. (p. 137, pl. xvii, figs. 18, 19). The stratum is probably Laramie, but may be more ancient.

The substance of all these varied contributions, together with much other matter, is embodied in Professor Lesquereux's Tertiary Flora,[1] which was the second final report made by him on fossil botany of the west. Of the three hundred and twenty-nine species which this volume contains, one hundred and seventy-one had been taken from Wyoming strata. The localities, most of which have already been mentioned, are as follows: Henry's Fork; Black Buttes station; Point of Rocks; Alkali stage station; Carbon; Rock Creek; Washakie; Medicine Bow; Fort Fetterman; Barrell Springs; Green River station; Evanston; Troublesome Creek, and Bridger's Pass. The beds at Green River station and at Alkali stage station belong to the Green River group. Those at Black Buttes station, Point of Rocks, and probably those of Evanston and Carbon, belong to the Laramie group. The remainder are somewhat doubtful.

Professor Lesquereux's Cretaceous and Tertiary Floras brings the investigation of the fossil floras of the Western Territories down to the year 1883. In this work he endeavors to separate the Laramie group forms from those of the Green River group, and although adding nothing to the former from Wyoming, the chapter on the Green River group embodies some additional data for that Territory. It is probable that the locality called Randolph County is really in the Territory of Wyoming, it being sometimes credited to that Territory and sometimes to Colorado, although there is no such county in either. It is probably the same as Bell's Fish Cliff, which lies very near the Utah line opposite Randolph County, Utah, but within the Territory of Wyoming. About a dozen species are here introduced for the first time from that locality and half as many more from other points in Wyoming.

The localities visited by me in 1881 were Carbon station; Black Buttes station; Point of Rocks; Green River; Hodges Pass on the Oregon Branch of the Union Pacific Railroad; Bell's Fish Cliff, already mentioned, and two fossil forests to the north of Granger station. My operations at each of these localities were set forth in my administrative report for that year,[2] and the paleobotanical re-

[1] Contributions to the Fossil Flora of the Western Territories. Pt. 2, The Tertiary Flora, by Leo Lesquereux: Rept. U. S. Geol. Survey of the Territories, vol. 7, 1878, ix, 366 pp., 65 pl., 4°.

[2] Third Ann. Rept., U. S. Geol. Survey, 1881–'82, pp. 26–29.

sults were summed up in the Synopsis of the Flora of the Laramie Group in the Sixth Annual Report of the U. S. Geological Survey (pp. 538-541).

National Yellowstone Park.—Dr. Otto Kuntze, during his visit to the geyser region of the National Park in October, 1874, discovered a considerable amount of wood in and around the hot springs and geysers in process of petrifaction. He gives an account of these discoveries and a theory of the process of silicification in a paper Ueber Geysirs und nebenan entstehende verkieselte Bäume, published in "Das Ausland" in 1880 (pp. 361-364; 390-393; 669-672; 684-689) and reprinted as a Separat-Abdruck at Leipzig.

Besides the interesting and now well-known silicified trunks of Amethyst Mountain, in the Yellowstone Park, described by Mr. W. H. Holmes in 1878,[1] he also collected a few dicotyledonous leaves at the same points. Professor Lesquereux has determined some of the latter and finds among them *Juglans acuminata* Al. Br., and *Magnolia Inglefieldi* Heer.[2]

In Dr. Newberry's paper published in the Proceedings of the U. S. National Museum, 1883, already frequently referred to, twenty-four new species of fossil plants from Wyoming are described. They were nearly all collected by Dr. F. V. Hayden at two localities not hitherto mentioned in any of the reports, one of which is on the Yellowstone River, and therefore probably within the Yellowstone Park, and the other on Tongue River.

Since the geological work of the Park has been in the hands of Mr. Arnold Hague, geologist, U. S. Geological Survey, other collections of leaf impressions have been made, which, through the courtesy of Mr. Hague, I was permitted to examine in the spring of 1887.

Among the remarkable vegetable products from the Yellowstone Park obtained by Mr. Hague is an almost perfectly preserved pine cone transformed into chalcedony. The form of the cone and the character of the scales are so well shown that I doubt not it can be specifically determined.

Impressed by the importance of the occurrence of these remains in intimate association with the silicified trunks, I spent the month of August and most of September of that year in the National Park, and made a large collection of leaves from the shales interstratified with the eruptive deposits. The greater part of this material was obtained from the northern slope of Amethyst Mountain, along the East Fork of the Yellowstone (Lamar River of Mr. J. H. Renshawe's topographical map), and especially at numerous points and different

[1] Fossil Forests of the Volcanic Tertiary Formations of the Yellowstone National Park, by W. H. Holmes: Bull. U. S. Geol. and Geogr. Survey, F. V. Hayden, U. S. Geologist in charge, vol. 5, No. 1, 1879, Art. VII, pp. 125-132.

[2] Proc. U. S. Nat. Mus. vol. 10, 1887, pp. 40, 46.

horizons on the escarpments of the spurs known as Fossil Forest and Specimen Ridge, but plants were also found in the vicinity of Yancey's, in the hills to the west of Elk Creek. Prof. F. H. Knowlton, of the U. S. National Museum, accompanied me on this expedition for the purpose of making a collection of the fossil wood of the region, with a view to the study of internal structure. He obtained a large number of specimens from the extensive fossil forests that everywhere abound in this section of the Park. During a reconnaissance that was made from August 1 to 10 to the east and south of Amethyst Mountain the presence of these forests was demonstrated as far east as the Hoodoo district, outside of the Park and as far south as the mountains that overlook Beaver Creek and the Upper Yellowstone. Fragments of wood were found in the bed of the latter, five miles above its débouchure into the lake, and also along the southern shores of the South Arm, near the mouth of Grouse Creek. A few specimens were even found on the western shore of the lake, but these may have originally come from mountains to the eastward, forced across by ice action or by other agencies.

Professor Knowlton also spent the season of 1888 in the Park making extensive collections of leaf-impressions and silicified wood; a few from the localities visited in 1887, but mostly from deposits discovered by himself or by other members of Mr. Hague's party. A small but interesting collection of leaves was made near the summit of Mount Evarts, opposite the Mammoth Hot Springs. The most extensive deposit explored was on the left bank of the Yellowstone River, about one-half mile below the mouth of Elk Creek. The bluff at this point is about 300 feet in height, for a considerable portion of the distance being a perpendicular cliff of moderately fine ash. The leaf-impressions occur at the base and at the top of the bluff as well as at a few intermediate points. On the north and east sides of Crescent Hill deposits containing leaves were discovered, the former yielding an abundance of Platanus leaves, and the latter numerous conifers and an undetermined monocolytedon. On the eastern side of the hill above (north of) Lost Creek, at five horizons, plant-remains were collected, among them, many conifers and a fern. The Yancey fossil forest is on the southwestern side of this hill, and at about the same elevation. A few leaves and a large quantity of silicified wood were obtained on Mount Norris opposite Soda Butte, and a few pieces of wood also upon the southern end of the Thunderer. A considerable amount of valuable material was obtained from a bluff on the north bank of the East Fork, midway between Calfee Creek and Miller Creek, including leaves and silicified wood. A silicified forest as extensive as the original Fossil Forest was discovered on Cache Creek about 10 miles from its mouth, and a large series of specimens was obtained. A few fragmentary leaves were also obtained from the same locality. Small quantities of silicified wood were also secured from Bison Peak, head of Hell Roaring Creek, Pelican Creek, and Miller Creek.

Colorado.—Professor Lesquereux's report to Dr. Hayden, referred to when treating of Wyoming, which formed the postscript to the article of the latter in the American Journal of Science for March, 1868, and which was republished in his Third Annual Report, enumerates ten species from Marshall's mine, near Denver, and two from Golden. Seven of these were new species, and some of them have since been found abundantly in Laramie strata. The descriptions of these species were republished with some changes in the Fourth Annual Report, for 1870 (pp. 382, 383).

Twenty-one Laramie species from Fischer's Peak of the Raton Mountains, and also one new species (*Juglans thermalis*), from the hot springs of Middle Park, Colorado, were described by Professor Lesquereux in the supplement to the Fifth Annual Report, for 1871 (pp. 12–17).

The Sixth Annual Report, for 1872 (p. 371), contains the first notice of the plant bed in South Park, near Castello's Ranch, at Florissant. It had been discovered by Mr. S. A. Allen, who collected a few of the plants. Among these occurred the two abundant forms, *Salvinia* (then taken for an Ophioglossum) *Alleni*, and *Planera longifolia*, which Professor Lesquereux there describes for the first time. He also enumerates in this report plants from Gehrung's coal bed, near Colorado Springs, from Marshall's estate, and the Erie mines in Boulder Valley, and a large number from Golden. In the same report (pp. 372–375) are described seven additional new species from the Raton district in the vicinity of Trinidad.

In the descriptive part of Professor Lesquereux's contribution to the Seventh Annual Report (1873, pp. 391–419) we find many additional species from that State, both of his own collections of the year previous and of those of Dr. Hayden and his assistants. Among the localities not already mentioned we find that collections had been made by Rev. Arthur Lakes, at South Table Mountain; by Messrs. A. Gardner, W. H. Holmes, and A. R. Marvine, from the roof of coal mines on Sand Creek, at a point east of Colorado Springs; by Dr. A. C. Peale; by Mr. Holmes, on Troublesome Creek, at Mount Brosse, Willow Creek, and other points in Middle Park.

A portion of the same author's contribution to the Eighth Annual Report (1874, pp. 308–315) is little else than a continuation of the one last considered, and gives the following new localities for fossil plants in Colorado: Grand Eagle Junction, Pleasant Park, and Plum Creek.

Dr. A. C. Peale found plant beds in 1876 in the Grand River district at two different horizons, namely, on the Grand Hogback Range, just east of Cactus Valley, in Laramie strata, three species of Ficus, one of Diospyros, and fragments of Salix and Cinnamomum; and at

Cliff Spring and at his Camp Thirty-seven, in Green River strata, numerous typical Green River species.[1]

The compilation of the data obtained in this manner, as this was accomplished in Lesquereux's Tertiary Flora, shows that up to that date (1878) the fossil flora of that State was next only in magnitude to that of Wyoming, but in the Cretaceous and Tertiary floras large additions from Colorado were introduced. In that volume an attempt was made to separate the plants of the Laramie group from those of the Green River group. Only a few new species of Colorado plants, chiefly collected by Mr. Lakes at Golden, were added to the former, but quite extensive collections had been made in Green River strata, the principal of which was that of Prof. Samuel H. Scudder at Florissant, otherwise known as Castello's Ranch, in South Park. Professor Scudder had purchased for the Geological Survey, of Mrs. Charlotte Hill, to whom the land on which this plant bed belonged, the collection made by herself, which was very large in individual specimens, though containing a great number of duplicates of the leading species. Another collection from the same locality, made by Messrs. Scott, Osburn, Speir, Libbey, and McCosh, of the faculty of Princeton College, was also submitted for determination to Professor Lesquereux, who was permitted to publish the new species for this report. About ninety such were thus added, together with a large number of species already known but not hitherto met with in the United States.

At a point near Morrison, some distance south of Golden, Mr. Lakes has discovered a plant bed which Professor Lesquereux regards as Cretaceous, probably Dakota group. A small collection of plants from this locality was sent to the Museum of Comparative Zoology at Harvard College and reported upon by Professor Lesquereux in 1881.[2] Other collections from this same locality have been received and studied and will be published by the U. S. Geological Survey, in Professor Lesquereux's forthcoming monograph, devoted to a revision of the flora of the Dakota group.

Another and very unexpected discovery was made by Mr. Lakes in 1882 at a point near Fairplay, in South Park, of vegetable remains in strata apparently of Permian age. These specimens were contributed through Professor Lesquereux to the Museum of Comparative Zoology at Harvard College, and were reported upon in the Eighth Bulletin, October, 1882.[3] This is remarkable as being the

[1] Tenth Ann. Rept. U. S. Geol. and Geogr. Survey of the Territories, 1876, Washington, 1878, pp. 181, 184, 185.

[2] Report on the recent additions of fossil plants to the Museum collections, by Leo Lesquereux; Bull. Mus. Comp. Zoöl. Harvard Coll., vol. 7, No. 6, Oct., 1881, pp. 225–230.

[3] On some specimens of Permian Fossil Plants from Colorado, by Leo Lesquereux: Ibid., No. 8, 1882, pp. 243–247.

only locality in the United States at which the diagnostic Permian genera Walchia and Ullmannia have been found.

The plant-bearing beds visited by me in 1881 in Colorado were: Girardot's coal mine, 14 miles north of Fremont Orchard; mouth of the St. Vrain, near Platteville; and Golden and vicinity, including the southwestern slope of South Table Mountain.[1]

A small collection, made at Golden in 1881 by Mr. Whitman Cross, was placed in my hands for identification, and studied in connection with my own specimens from that locality. Some of the former have proved to be new, and are described in Bulletin No. 37 of the U. S. Geological Survey.

Colorado plants from the following localities occurred among the collections of the U. S. National Museum, which were recently elaborated by Professor Lesquereux and published in the tenth volume of the Proceedings of the U. S. National Museum: Crested Butte, Gunnison County, by Mr. George H. Eldridge, from strata which would appear to be Subcarboniferous; the Rhyolite beds of Silver Cliff, by Messrs. Whitman Cross and W. H. Holmes, Cretaceous or Tertiary; Las Animas, by Dr. C. A. White, probably Dakota group.

The fossil flora of Golden has recently been greatly increased by a collection made by Mr. A. Lakes, which, as in former cases, was sent to the Museum of Comparative Zoology at Cambridge, and by that Museum to Professor Lesquereux for determination. The latter's report on this collection forms a Bulletin of that Museum.[2]

This collection contained 873 specimens, representing 118 species, 28 of which were new to science and 32 others new to the flora of the Laramie group. Of these latter the greater part are Miocene species, in which the Golden flora does not greatly differ from the Laramie flora in general.

Messrs. S. F. Emmons, Whitman Cross, and J. H. Eldridge, of the U. S. Geological Survey, have recently made a careful study of the stratigraphical relations of the Golden deposits with the result, as they are convinced, that two distinct plant-bearing horizons are represented by them, one of which, called the Denver Formation, is considerably higher than the other, and entirely overlies the Laramie group. It can only be said here that, from present appearances, the plant-remains do not sustain this view, but it is too early to say that, upon closer study with better material, they may not indicate some difference of age corresponding to the two very different kinds of rock in which, as it has always been known, the plants occur.[3]

[1] Third Ann. Rept. U. S. Geol. Survey, 1881–'82, p. 27. Sixth Ann. Rept. U. S. Geol. Survey, 1884–'85, pp. 537, 538.

[2] Specimens of Fossil Plants collected at Golden, Colorado, 1883, for the Museum of Comparative Zoology at Cambridge, Mass., examined and determined by Leo Lesquereux: Bull. Mus. Comp. Zoöl. Harvard Coll., vol. 16, No. 3, 1888, pp. 43–59.

[3] The Denver Tertiary Formation, by Whitman Cross: Am. Jour. Sci., 3d series vol. 37, 1889, pp. 261–282.

New Mexico.—In the report of Lieut. J. W. Abert to Lieut. Col. W. H. Emory's report of his expedition of 1846–'47[1] he makes what was probably the first mention of the extensive leaf beds of the Raton Mountains, which are now known to form a southern extension of the Laramie plant-bearing strata of Wyoming and Colorado. He says: "We, however, obtained several specimens of the fossil leaves of dicotyledonous plants. These were of two sorts: one a lanceolate leaf resembling that of a willow; and the other a large cordate leaf like that of the catalpa, and both sorts of leaves are distinctly marked with branching veins. This formation extends throughout the Raton, according to the report of my hunters" (p. 523). A figure of each of the two sorts of leaves is given on a plate facing this page. He further states that the specimens had been submitted to the inspection of Professor Bailey, of West Point, and the report of the latter immediately follows that of Lieutenant Abert.[2] He adds nothing to the statement of Lieutenant Abert relative to the character of the leaves, but thinks they may indicate an age for the coal beds in which they occur corresponding to that of the Brora Coal. Another of the cordate leaves is figured on a plate facing page 547, and two specimens of silicified wood from Wett Mountain and Santa Ana are mentioned (p. 548). Mr. Jules Marcou, in the paper cited above (supra, p. 906, note), expresses the opinion that the lanceolate leaf belongs to *Laurus primigenia* Ung., and that the cordate one is a species of Ficus (p. 12). In the same year (1858) Mr. Marcou reported "numerous fragments of fossil silicified trees" from his Camp 28 at Alamo, in New Mexico, in "New Red Sandstone rocks" which he placed in the Upper Cretaceous epoch.[3]

The fossil plants discovered in 1859 by Dr. J. S. Newberry while accompanying the Macomb Expedition from Santa Fé to the junction of the Grand and Green Rivers, and described by him in the report of that officer,[4] came from the shale roof-stone of the copper

[1] Notes of a military reconnoissance from Fort Leavenworth, in Missouri, to San Diego, in California, including part of the Arkansas, Del Norte, and Gila Rivers, by Lieut. Col. W. H. Emory, made in 1846–'47, with the advanced guard of the "Army of the West." Washington, 1848, 30th Cong., first sess., Ex. Doc. No. 41, 8°; Report of Lieut. J. W. Abert of his examination of New Mexico in the years 1846–'47, pp. 417–546, 3 pl.

[2] Notes concerning the minerals and fossils collected by Lieutenant J. W. Abert, while engaged in the geographical examination of New Mexico, by J. W. Bailey, professor of chemistry, mineralogy, and geology at the U. S. Military Academy. Ibid., pp. 547, 548.

[3] Geology of North America; with two reports on the prairies of Arkansas and Texas, the Rocky Mountains of New Mexico, and the Sierra Nevada, etc., by Jules Marcou. Zurich, 1868, 144 pp., 9 pl., 4°. (See p. 58.)

[4] Report of the exploring expedition from Santa Fé, New Mexico, to the junction of the Grand and Green Rivers of the Great Colorado of the West in 1859, under the command of Capt. J. N. Macomb, with geological report by J. S. Newberry, geologist of the expedition. Washington, 1876, 4°. (See pp. 69, 141–148, pl. iv–viii.)

mines near Abiquiu, some fifty miles northwest of Santa Fé. Although it is stated that "thousands of impressions of plants" occurred there and that "abundant specimens were procured" (p. 69), nevertheless only two of the fourteen species described by Newberry in the report are credited to this locality, the rest being from Mexico, and already considered (supra, p. 825). These were *Otozamites Macombii* and *Zamites occidentalis*, here for the first time made known. The formation is given as Triassic.

Dr. John L. LeConte was the next to make collections of plants from New Mexican strata while on a survey to the Rio Grande.[1] These found their way into the hands of Professor Lesquereux and were reported upon in his early paper already referred to.[2] Three Laramie species from Raton Pass and one from the upper end of Purgatory Cañon, only one of which had been met with elsewhere, are recorded here.

In the supplement to the Fifth Annual Report, for 1871 (pp. 12–17), eight species from Placer Mountain, collected by Dr. Hayden and his assistants, are added to the Laramie Flora of that territory.

The total number of New Mexican species finally recognized in 1878, after careful study of all the material, and enumerated in the Tertiary Flora, was twenty-five.

This of course is exclusive of the species found by Dr. Newberry, and the latter author describes one more (*Pteris Russellii*) in the Proceedings of the U. S. National Museum, 1882 (vol. 5, Washington, 1883, p. 503), collected by Mr. I. C. Russell in Vermejo Cañon.

In the fall of 1887 the Director of the Geological Survey, Maj. J. W. Powell, visited this section and brought back both fossil wood and leaf impressions. The wood from the copper mines six miles northwest of Abiquiu is permeated by the green copper ore and is very heavy. The other vegetable impressions from near the mines are scarcely recognizable and have a Jurassic facies. They occur in a stratified deposit of volcanic ash. He also brought fairly well-preserved leaf impressions in a coarse brown sandstone resembling that of the Dakota group from the lower portion of the upper cliff on the west of the Nacimiento range, six miles northwest of station 1; and fossil wood from the highest cliff, six miles east of the Mexican settlements on the road from Jemez to Copper City (San Miguel), from creek drift eight miles from the same settlements, from the Gray Sandstone Cliff in San Pueblo Cañon (high on the mountain), and from the Middle Cretaceous seven miles southeast of San José Corral.

[1] Notes on the geology of the survey for the extension of the Union Pacific Railroad, E. D., from the Smoky Hill River, Kansas, to the Rio Grande, by John L. LeConte. Philadelphia, 1868, 76 pp., 8°.

[2] Am. Jour. Sci., 2d series, vol. 45, 1868, pp. 207, 208. 1st, 2d, and 3d Ann. Repts. U. S. Geol. Survey of the Territories, 1867–'69 (in one vol.), pp. 196–197.

One of the huge logs that now lies in front of the U. S. National Museum was obtained by Col. P. T. Swaine, U. S. Army, from a mesa two miles north of Fort Wingate, and an account of its collection and its transportation to Washington is given in vol. 5 of the Proceedings of the U. S. National Museum, p. 3.

The internal structure of both of these trunks has recently been studied by Prof. F. H. Knowlton from slides prepared by himself. He concludes that they are the same as Göppert's *Araucarites Möllhausianus*, collected by Möllhausen, as above stated, which is not Araucarites, as that genus is now understood, but Araucarioxylon, and he proposes for it the name *Araucarioxylon Arizonicum*, from the fact that the greater part of this fossil wood, as we shall presently see, is found in Arizona.[1]

Arizona.—On the 2d of December, 1853, Möllhausen[2] discovered a petrified forest in a ravine or gulch that went by the name of Rio Secco, near the Colorado Chiquito, in what is now Arizona. Besides giving a general account of the nature of the vegetable débris, he submitted specimens of it to Dr. H. R. Göppert, whose scientific report upon it he gives as a note (p. 492). He pronounces the wood coniferous, and as belonging to the Abietineæ, without indicating its generic affinities more closely.

It must have been in the same immediate vicinity as the last that Dr. Newberry observed the silicified wood described by him in his report upon the geology of the Ives Expedition,[3] since the Big Dry Fork of Dr. Newberry's map seems to be the Rio Secco of Möllhausen, and the vegetable débris lay between Camp 89 at the mouth of that stream and Camp 90, at the edge of the Blue Mesa to the northward. But the latter explorer, in continuing his journey northward among the Moki villages, discovered other beds containing impressions of leaves (see pp. 81–85 of the same report), particularly near the limestone spring at Camp 92 (see his map), and made some collections which were described in the paleontological part of the report (pp. 129–132) and figured on plate iii. He regarded the formation as Lower Cretaceous, although containing dicotyledonous plants. The plant named *Neuropteris angulata* (fig. 5) has been shown to be a Trapa,[4] and the other two dicotyledons might well have belonged to the Laramie group.

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[1] New species of Fossil Wood (Araucarioxylon Arizonicum) from Arizona and New Mexico, by F. H. Knowlton: Proc. U. S. Nat. Mus., vol. 11, 1888, pp. 1–4, pl. i.

[2] Tagebuch einer Reise vom Mississippi nach den Küsten der Südsee, von Balduin Möllhausen. Leipzig, 1858, 4°. (See pp. 299, 300.)

[3] Report upon the Colorado River of the West, explored in 1857 and 1858 by Lieutenant Joseph C. Ives, etc. Washington, 1861, 4°. Geological Report, by Dr. J. S. Newberry, geologist to the expedition, pt. 2, pp. 1–154, pl. i–iii, landscapes, text-figs., 2 geol. maps.

[4] Lesquereux, in Hayden's Ann. Rept. U. S. Geol. and Geogr. Survey of the Territories, 1874, p. 304; Tertiary Flora, p. 295.

Most of the vegetable remains thus far reported from Arizona have been those of trunks found scattered about upon the surface in various conditions of silicification, and all have been found within quite a recent date. One of the localities is known as "Lithodendron," a ravine heading at Bear Spring, twenty miles from the regular mail route to Prescott, at Navajo Springs. It was from this place that the second of the great petrified logs at the entrance to the U. S. National Museum was obtained, and the late Lieut. J. T. C. Hegewald's description of the journey from Fort Wingate and of the exhuming and transportation of the specimen to Washington forms the first paper of the fifth volume of the Proceedings of the U. S. National Museum, 1882.

Another noted locality is the one known as Chalcedony Park, eight miles south of Corriza, on the Atlantic and Pacific Railroad, in Apache County, twenty-four miles southeast of Holbrook. In an illustrated paper by Mr. George F. Kunz,[1] this weird region is graphically described and most of the scientific facts thus far made known are set forth. Mr. Kunz also read a paper on this subject before the American Association for the Advancement of Science at its New York meeting in August, 1887.

These remarkable petrifactions are believed to occur in the Shinarump group of Powell, and their mode of occurrence is described by him in his Geology of the Uintah Mountains, 1876, p. 69. These great trees of stone are believed by the Indians to be the shafts of their thunder god Shinauav, and from this Major Powell named the group, which he regards as of Cretaceous age.

Two species of Cambrian plants, *Cruziana Linnarssoni* and *C. rustica*, collected from the Tonto shale of the Grand Cañon of the Colorado River, Mohave County, by the Geographical and Geological Explorations and Surveys west of the One Hundredth Meridian, were described by Dr. C. A. White[2] preliminarily in 1873, and again in a final report dated 1875.

Mr. C. D. Walcott, who also collected much silicified wood in the Grand Cañon district, discovered a leaf-bed in the Deer Creek coal field in 1884. Among the collections made there by him, Professor Lesquereux has identified *Dryandroides lignitum* (Ung.) Ett., *Diospyros brachysepala* Al. Br., *Taxodium dubium* (Sternb.) Heer, and

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[1] The Agatized and Jasperized Wood of Arizona, by George F. Kunz: Pop. Sci. Monthly, vol. 28, 1886, pp. 362–367.

[2] C. A. White: Preliminary report upon Invertebrate Fossils collected by the expeditions of 1871, 1872, and 1873, with descriptions of new species. Washington, 1874, pp. 1–27, 8°.

Report upon the Invertebrate Fossils collected in portions of Nevada, Utah, Colorado, New Mexico, and Arizona by parties of the expeditions of 1871, 1872, 1873, and 1874. In Report upon Geographical and Geological Explorations and Surveys West of the One Hundredth Meridian, in charge of Lieut. George M. Wheeler, etc., pt. 1, vol. 4, Palæontology, 1875, pp. 1–219, pl. i–xxi. (See pp. 22, 32–34, pl. i.)

a fragment of a leaf of the genus Laurus.[1] Mr. Walcott considers the deposit to be of Laramie age.

Utah.—Two species (*Quercus antiqua* and *Q. sinuata*), collected on the banks of the Rio Dolores, in southern Utah, are described by Newberry in his Notes on Later Extinct Floras (pp, 26, 27) and referred by him to the Lower Cretaceous and by Lesquereux to the Dakota group. They are not figured in the Illustrations of Cretaceous and Tertiary Plants, which is a sort of atlas to that work.

A single specimen was collected by Dr. Hayden's party at Coalville, Utah, containing "small fragments of dicotyledonous leaves, none of which are large enough to be recognizable even for generic reference."[2] In the report from which this quotation is taken (pp. 291-295) Evanston is located in Utah, although in later reports it is correctly placed in Wyoming; as, however, it lies very near the line between these two Territories, the plants enumerated here may have been collected at a sufficient distance to the westward of the town to have really come from Utah soil; but this is not probable, as the correction seems to have been made in nearly all cases in the Tertiary Flora.

The locality at the junction of the White and Green Rivers, usually designated as "Mouth of White River," yielded to Prof. William Denton a number of species, which are described by Professor Lesquereux in the Eighth Annual Report of Dr. Hayden's survey for 1874 (pp. 308–315), in the Tertiary Flora, and in the Cretaceous and Tertiary Floras, under the Green River group, to which this locality is referred.

The only considerable collection that has been made from Utah was that of Mr. C. D. Walcott, from the Upper Kanab Valley. Twenty-one species from this locality have been identified by Professor Lesquereux; they embrace monocotyledons and dicotyledons, as well as such coniferous genera as Sequoia, Abietites, etc., indicating a Tertiary or Upper Cretaceous age. Dr. White found a specimen of *Stigmaria ficoides* in 1885, two miles west of Wales, Utah, and Mr. G. K. Gilbert obtained a specimen of *Cissus lævigata* Lx. near False Creek, southeastern Utah. All these are recorded in Professor Lesquereux's late paper in the Proceedings of the U. S. National Museum for 1887 (vol. 10, pp. 21–46) and the specimens are deposited in the collection of the Museum. The following additional localities in Utah are represented by specimens of fossil wood in the Museum: Rabbit Valley, collector, G. K. Gilbert; Pine Creek, southeastern Utah, collector, G. K. Gilbert; Vermilion Cliffs, collector, C. D. Walcott, 1882; east side of Sink Valley, collector, C. D. Walcott, 1879; Ashley, collectors, Pard and Dodd, 1883; Toquerville, collector, Lieu-

[1] Proc. U. S. Nat. Mus., vol. 10, 1887, pp. 34–41.

[2] Hayden's Fifth Ann. Rept. U. S. Geol. and Geogr. Survey of the Territories, for 1871, Washington, 1872, p. 290.

tenant Wheeler; Dry Cañon, Ashley's Fork, collector, J. W. Powell, 1874.

I saw in 1875 great numbers of petrified logs of a dark color, but showing concentric rings very distinctly, lying strewn about on the surface of the ground on the slope of Thousand Lake Mountain, and even as low as the bottom of Rabbit Valley, between this and Aquarius plateau.

Nevada.—The only important plant bed in Nevada that has thus far been discovered is at Elko, a station on the Central Pacific Railroad. The specimens occur in a white, fine-grained calcareous shale similar to that of Florissant, Bell's Fish Cliff, and other beds of the Green River group. Three species from this locality were identified among the early collections of Dr. Hayden in 1871, and published in his Fifth Annual Report, for that year (p. 286), and four more, three of which were new, collected by S. W. Garman, in the Sixth Annual Report (p. 372).

Prof. E. D. Cope's collection from the same place yielded some dozen new species, which were described in the Seventh Annual Report, for 1873 (pp. 409–418), and the flora of Elko, as given in the table of distribution in the Tertiary Flora in 1878, amounted to seventeen, which had not been increased at the date of publication of the Cretaceous and Tertiary Floras in 1883.

Fragments of silicified wood and other vegetable remains were collected by Mr. C. D. Walcott in 1880 southwest of Strahlenberg Mountain, and in 1882 at Eberhardt, White Pine County, and Mr. I. C. Russell obtained other specimens in 1883 at Pyramid Lake. These specimens are all in the collection of the U. S. National Museum and await investigation.

California.—During the exploration of Lieutenant R. S. Williamson for railroad routes in California in 1856[1] several localities were encountered at which silicified wood was observed in large quantities. One of these was on the Posuncula, or Kern River, on the western slope of the Sierras, and another near Pilot Knob not far from Fort Yuma in the southern part of the State. Still a third was near the summit of the Sierra Nevada at the pass called the Cañada de las Uvas. Specimens of these fossils were submitted to Prof. J. W. Bailey, of West Point, and also to Prof. George C. Schaeffer, and a magnified section made by the former is published in the report.

There is a specimen in the U. S. National Museum collection (No.

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[1] Explorations and Surveys for the Pacific Railroad, vol. 5, Washington, 1856, 4°; Report of Explorations in California for railroad routes to connect with the routes near the 35th and 32d parallels of north latitude, by Lieutenant R. S. Williamson, Corps of Topographical Engineers. Pt. 2, Geological Report, by William P. Blake, Geologist and Mineralogist of the Expedition, [dated] Washington, 1857, xvi, 370 pp., plates, maps, etc. (Cf. pp. 36, 37, 117, 118, Appendix Articles IV (Bailey) and V (Schaeffer), pp. 337–339, pl. xii.)

2334) labeled Placer County, Cal., William P. Blake, collector, 1853, showing a leaf which Professor Lesquereux on examination pronounced *Quercus chrysolepis* Liebm., *forma montana* (Proc. U. S. Nat. Mus., vol. 10, 1887, p. 38).

In October, 1870, Prof. O. C. Marsh visited remarkable fossil forests at a locality which he describes as "situated on a high rocky ridge in Napa County, Cal., about five miles southwest of Calistoga Hot Springs, and perhaps ten miles south of Mount Saint Helena," of which he gives an account in the American Journal of Science for April, 1871.[1] In the course of this article Professor Marsh states that Dr. M. C. White, who subjected some of the material to a microscopic examination, found it to agree substantially with the wood of the living Sequoias. As to their age he says that "as they rest unconformably on distorted and metamorphic Cretaceous strata, they are apparently as recent as Tertiary, and will probably prove to be Pliocene."

This locality, which was first discovered by Mr. Charles H. Denison,[2] was visited by John Holtz, of Danzig, in 1876, who obtained specimens, which he submitted to the eminent paleodendrologist, Dr. H. Conwentz, for microscopic investigation. That author published a report upon them in the Neues Jahrbuch für Mineralogie, etc., for 1878 (pp. 800-813, pl. xiii, xiv). He found all his material to belong to the genus Cupressinoxylon, which most closely resembles the genus Sequoia, and he correctly regards this as confirmatory of Professor Marsh's remark that they closely resembled the redwoods that still flourish in the same region. The only species described is *Cupressinoxylon taxodioides*, which was established for the reception of the specimens.

Three other specimens from the same locality which were subsequently sent him were thought to be specifically distinct from the last named, and one (probably two) of them bore evidence of having belonged to roots which, according to his rather objectionable terminology, would place it in the genus Rhizocupressinoxylon.[3]

The first plant determined from leaf impressions from California strata was collected by Prof. J. D. Whitney, State geologist of California, in clay beds of the Spanish Mountains, and identified by Professor Lesquereux in 1873[4] as *Quercus furcinervis* (Rossm.) Ung.

It is not to be supposed that these few localities are the only ones from which remains of fossil plants have been taken. Prof. J. D.

[1] Notice of a Fossil Forest in the Tertiary of California, by O. C. Marsh: Am. Jour. Sci., 3d series, vol. 1, 1871, pp. 266-268.

[2] San Francisco Bulletin between July and Oct., 1870.

[3] H. Conwentz: [Holzproben von Bäumen des versteinerten Waldes von Calistoga in Californien.] Verhandl. naturh. Ver. preuss. Rheinl. Westphal., 34th Jahrg., 1868, Sitzungsber. pp. 160-161.

[4] Hayden's Seventh Ann. Rept. U. S. Geol. and Geogr. Survey of the Territories for 1873, p. 398.

Whitney, formerly State geologist of California, has remarked "that the remains of vegetable life, in the form of trunks of trees, impressions of leaves, and the like, are of common occurrence in the strata worked by the hydraulic mining process. This is indeed the case; for from the most southern to the extreme northern localities mentioned in the detailed description of the gravel region, there seem to be but few districts where such remains have not been noticed."[1]

The fossil plants collected by Professor Whitney in his survey of the State were investigated by Professor Lesquereux, who prepared a most valuable report upon them.[2] The number of species made known in this report was fifty, all but one of which (*Sabalites Californicus* Lx.) were dicotyledonous plants, the largest genera represented being Quercus (eight species), and Ulmus, Ficus, and Aralia, with three species each. The localities at which they were collected were as follows: Chalk Bluffs, Nevada County, lat. 39° 12′ N.; Table Mountain, Tuolume County, lat. 38° N.; Bowen's Claim, fifteen miles southeast of Chalk Bluffs; and Roach Hill. In the appendix to this report three species of Quercus and two of Acer are described from a tunnel near the Bald Mountain Tunnel, on the North Fork of Oregon Creek, twenty miles north of Chalk Bluffs, at an altitude of 4,500 feet above sea level. The Auriferous Gravels are commonly regarded as of Pliocene age; but if the existence of glacial drift is to be accepted as the true line of demarkation between the Tertiary and the Quarternary (and no more definite one can be selected) these gravels will have to be referred to the latter formation.

In Lesquereux's Cretaceous and Tertiary Floras (pp. 239–255) a number of additional California plants are treated and credited to the Miocene formation. The localities are Corral Hollow, San Joaquin County; Contra Costa; Table Mountain, Plumas County; Old Field claim, Placerville, El Dorado County; and Rock Corral, Placer County. The five species enumerated on page 265 of the same work, from the Chalk Bluffs, had all been previously described in his Flora of the Auriferous Gravels.

Prof. J. S. Diller, while operating in the vicinity of Mount Shasta in 1883, made a small collection of fossil plants in the neighborhood of Pence's Ranch in strata overlying the Auriferous Gravels. The specimens which Professor Diller showed me were too meager and badly preserved to establish any opinion relative to the age of the deposits and it is hoped that additional material may yet be obtained.[3]

[1] The Auriferous Gravels of the Sierra Nevada of California, by J. D. Whitney: Mem. Mus. Comp. Zoöl. Harvard Coll., vol. 6, No. 1, 1880, xvi, 569 pp., 24 pl., 2 maps. (See p. 231.)

[2] Report on the Fossil Plants of the Auriferous Gravel Deposits of the Sierra Nevada, by Leo Lesquereux: Ibid., No. 2, 1878, 62 pp., 10 double pl.

[3] Notes on the Geology of Northern California, by J. S. Diller: Bull. U. S. Geol. Survey, No. 33, 1886. (See p. 16.)

Mr. George F. Becker sent to the U. S. Geological Survey a small collection made at Clear Lake, Cal., from a very recent deposit, which have been reported upon by Professor Lesquereux in his recent paper in the Proceedings of the U. S. National Museum.[1] Two of the plants from that locality are doubtfully referred to Miocene species of Europe (*Andromeda protogæa ?* Heer, *Poacites Mengeanus ?* Heer). The supposed Caulinites which Professor Lesquereux named in honor of the collector is believed by Mr. Becker to be nothing more than the tule of the western country, which is the true bulrush, *Scirpus validus*, which there attains a great size. This collection should be re-examined and carefully compared with the living flora of the immediate vicinity.

A catalogue of Californian fossils drawn up by Dr. J. G. Cooper, in which the list of plants was revised by Lesquereux, is contained in the Seventh Annual Report of the State mineralogist for the year ending October 1, 1887. Among the localities given out are found Forest City, Sierra County; Monte Christo Tunnel and Spanish Peak, Plumas County; and Lassen County.[2]

A collection made by Mr. H. W. Turner in Corral Hollow, and a second much larger one by Professor Diller from Monte Christo Tunnel, summit of Spanish Peak, and from Shasta and Lassen Counties, have recently been elaborated by Professor Lesquereux with important results.[3] The flora of the last-named beds, whose age is in doubt, points to late Tertiary rather than Eocene or Laramie, but at the same time it possesses other special affinities which will have weight in the settlement of this question.

Oregon.—In addition to the fossil plants described from Wyoming by Prof. James Hall in Frémont's report, 1845, already mentioned (supra, p. 906) there were two specimens of dicotyledonous leaves from the Cascades of the Columbia River. They are mentioned (p. 309) as "doubtless belonging to a very modern Tertiary deposit," and figured on plate iii (figs. 14 and 15).

One species (*Abies robusta* Dana) was collected by Prof. J. D. Dana at Astoria on the return of the Wilkes Exploring Expedition. It is recorded on page 729 of the report of that expedition. The figure (pl. xxi, fig. 9), given of it is not sufficiently distinct to enable one to judge of its true character. There is a specimen of lignite (Lot No. 175) in the U. S. National Museum collection, which was also collected by Professor Dana at Astoria at the same time.

Silicified wood and other vegetable remains were discovered in 1855 by Dr. J. S. Newberry in the Warm Spring district, between

[1] Proc. U. S. Nat. Mus., vol. 10, 1887, p. 35, pl. i, fig. 3, pl. ii, fig. 1-4.

[2] Catalogue of Californian Fossils, by J. G. Cooper; in 7th Ann. Rept. of the State Mineralogist for the year ending October 1, 1887, William Irelan, jr., State mineralogist. Sacramento, 1888, 8°. (Foss. plants, pp. 300-308.)

[3] Proc. U. S. Nat. Mus., vol. 11, 1888, pp. 25-31, pl. xi-xv.

Mount Jefferson and the Des Chutes River, one of the localities being on the Psuc-see-que Creek, a tributary of the Des Chutes flowing down from Mount Jefferson, and the other in the valley of the Wam Chuck River among the metamorphosed tufas produced by the hot springs. He also obtained a specimen of fossil wood from the hot springs at the head of Pit River from a gentleman who had visited that region.[1]

The U. S. National Museum collection contains five as yet undetermined leaf specimens collected by B. F. Dowell in 1873, at Jacksonville, Jackson County, Oregon (Lot No. 7). They were received through Mr. J. B. Marcou, December 16, 1884.

Prof. Joseph Le Conte collected specimens of *Quercus furcinervis* (Rossm.) Ung. under the lava beds of the Cascade Mountains, but the precise locality is not stated.[2]

Among the Miocene plants intrusted to Professor Lesquereux by Professor Whitney for description in the Cretaceous and Tertiary Floras were a number from the John Day Valley, Oregon, some of which are said to have been collected on Currant Creek and some on Bridge Creek, but most of the specimens were not thus definitely located. In this material Professor Lesquereux found twelve species, which he has duly recorded in that work (pp. 239–255).

The large and valuable collection made in 1881 by Capt. Charles Bendire from this same rich region, although not yet all published, may as well be mentioned here. It arrived at the National Museum in the fall of that year, and in the following spring I spent some time in its study, but was compelled by pressure of other work to relinquish the task, and to send the entire collection to Professor Lesquereux, who has already reported upon two important localities, viz: Van Horn's Ranch in the John Day Valley, and Cherry Creek, Wasco County (see Proc. U. S. Nat. Mus., vol. 11, pp. 13–24), describing and figuring a number of new species. The large collection from Bridge Creek is still in his hands and his work upon it is understood to be nearly completed. The specimens are for the most part beautifully preserved, but the number of distinct forms will be small in proportion to the profusion of impressions.

Dr. J. S. Newberry also received a collection from Bridge Creek and Currant Creek, made by Mr. Thomas Condon, from which he described fourteen new species in 1882.[3]

Washington Territory.—Dr. J. S. Newberry seems first to have called attention to the existence of vegetable remains in the coal beds

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[1] Reports of Explorations and Surveys, etc., vol. 6, 1854–'55, Washington, 1857, 4°; Pt. 2, Geological Report, by J. S. Newberry, M. D., geologist and botanist of the expedition, 85 pp., 5 pl. (See pp. 47–56.)

[2] Lesquereux, in Hayden's Seventh Ann. Rept. U. S. Geol. and Geogr. Survey of the Territories, for 1873, p. 398.

[3] Proc. U. S. Nat. Mus., vol. 5, 1882–'83, Washington, 1883, pp. 502–514.

of Bellingham Bay in his geological report of the survey of that region published in 1857, already referred to,[1] in which he notes the presence there of species of Platanus, Acer, Alnus, Taxus, Taxodium, and Juniperus.

A collection made by Dr. John Evans at this place was reported upon by Professor Lesquereux in the May number of the American Journal of Science (2d series, vol. 27, 1859, pp. 360–363). Eight of the fourteen species here described were from Bellingham Bay, the remainder being from Nanaimo, on Vancouver Island, and since shown to be of a different age (supra, p. 836).

A glowing letter from Professor Heer, of Zurich, relative to this flora, addressed to Professor Lesquereux, who had sent him drawings of some of the plants collected by Mr. Evans, was published in the July number of the same journal (second series, vol. 28, 1859, pp. 85–88).

On October 1, 1882, Dr. Newberry read a paper before the Boston Society of Natural History, giving descriptions of the fossil plants collected by Mr. George Gibbs, geologist to the United States Northwest Boundary Commission under Mr. Archibald Campbell, United States Commissioner.[2] Mr. Gibbs had not only revisited the original localities at Nanaimo and on Bellingham Bay, but he had discovered a new one at Point Doughty, on Orcas Island, which belongs to the United States and forms a part of San Juan County, Wash. This bed Dr. Newberry regards as Cretaceous and of the same age as that of Nanaimo. Mr. Gibbs made collections from still a fourth point, located on Birch Bay above Bellingham Bay. Omitting the Vancouver plants already treated (supra, p. 837), we find that these collections, as determined by Dr. Newberry, contained sixteen species, eight from Birch Bay and four from Orcas Island. One species (*Glyptostrobus Europæus*) was common to the two Miocene localities.

Alaska.—A small collection made by Lieutenant Doroschin on the peninsula of Alaska and on the neighboring Aleutian Islands, Kadjak, Uyak, Atka, and Hudsnoi, in latitude 59° N. was turned over by State Councillor Pander and General Hoffman, in August, 1859, to Dr. H. R. Göppert, of Breslau, for determination. His report upon the same was laid before the Silesian Society on the 12th of December, 1860, and was also communicated to the Imperial Academy of Sciences of St. Petersburg on the 8th of March, 1861.[3] The

[1] Reports of Explorations and Surveys, etc., vol. 6, 1857, Pt. 2, p. 64.

[2] Description of the Fossil Plants collected by Mr. Gibbs, Geologist to the United States Northwest Boundary Commission, under Mr. Archibald Campbell, United States Commissioner, by J. S. Newberry: Boston Jour. Nat. Hist., vol. 7, 1883, pp. 506-524.

[3] Ueber die Tertiärflora der Polargegenden, von H. R. Goeppert: 39. Jahres-Bericht und Abhandl. schles. Gesell., 1861, Breslau, 1862, pp. 195–207; Ibid., 44th, 1866, Breslau, 1867, p. 50; Bull. Acad. Sci. St. Petersburg, vol. 3, 1861, col. 448-461; Mélanges phys. et chem., vol. 4, 1861, pp. 704-712.

specimens from Ugolmi Bay, peninsula of Alaska; from near the village of Nenıltchık; from Taketschek or Osipnago; from the bay of Beketinzisnakıknu; from near Katmoschen and the coast of the bay of Nukhalilek; from Unga, on the west coast of Saharosch Bay; from the extreme southwestern end of the island of Ungi, and from the islands of Atka and Hudsnoi bore evidence of belonging to the Tertiary formation, while specimens collected on the northeastern shore of the peninsula, north of Jaklok, on the south bank of a small river, seemed to belong to the lower Carboniferous or Graywacke. Among the Tertiary remains Dr. Göppert identifies a number of species with those of Schossnitz and other European beds, but one species of Salix (*S. integra*) and one of Alnus (*A. pseudoglutinosa*) were established as new.

A more important contribution was Heer's Flora fossilis Alaskana, originally published in the eighth volume of the Memoirs of the Royal Swedish Academy of Sciences (No. 4), 1869, and now forming an integral part of the Flora fossilis Arctica (vol. 2, pt. 2). The specimens which are the subject of this memoir were collected by Mr. Furuhjelm of Helsingfors, who had spent nine years in Alaska Most of his collections were unfortunately lost on the ill-fated vessel that was bearing them away. The remainder reached Helsingfors in safety, and through the intervention of Professor Nordenskiold were submitted to Heer at Zurich. Only two localities are represented, the one on the small island of Kuju in the Indian Archipelago, near Sitka, the other on Cook's Inlet opposite the peninsula of Alaska. They show no difference in age, and belong to the formation that Heer always regarded as Miocene. Fifty-six species are carefully described and figured on ten plates. Nineteen were new species, most of the remainder having been previously found at other points in the district embraced in the Arctic Fossil Flora.

In 1870 Doroschin sent a collection of these Alaskan plants to Dr Eichwald, who correlated most of them with Goppert's and Heer's species, but found three that were new. His specimens were from supposed Miocene beds on the bay of Katschekmak, on the island of Kuju, opposite Sitka, on the island of Unga, on the shore of English Bay, and near the village of Nenıltschık, in Alaska, and in a bed probably of Subcarboniferous age on the northeastern coast of Alaska on the south bank of the Jaklok River. The plants are described in a work by Eichwald on the geology and paleontology of the peninsula of Mangischlak and the Aleutian Islands.[1]

The third contribution to the Fossil Flora of Alaska was made by Professor Lesquereux in 1883[2] upon material collected by Prof. W.

[1] Geognostisch-palaeontologische Bemerkungen uber die Halbinsel Mangischlak und die Aleutischen Inseln, von Dr. Eduard von Eichwald. St. Petersburg, 1871, 8°. (See pp. 107-116, pl iv [treated as pl vi])

[2] Contribution to the Miocene Flora of Alaska, by Professor Leo Lesquereux. Proc. U. S. Nat. Mus., vol. 5, 1882-'83, pp. 443-449, pl. i-v.

H. Dall at Coal Harbor, Unga Island, Shumagin group, south side of the peninsula of Alaska, Chugachik Bay, Cook's Inlet, and Chignik Bay. Seven new species are here described and a number of others treated. The material was in some cases abundant, but for the most part fragmentary. The figures are very poor. The species here treated are reproduced in Professor Lesquereux's Cretaceous and Tertiary Floras (pp. 257–263), but unfortunately without the figures, which, if they had been re-drawn and made to harmonize with the rest of that work, would have been a great addition.

Dr. Newberry in the paper so often referred to, published in the same volume as the one last mentioned (pp. 502–514), describes seven new species from Alaska, chiefly collected on Cook's Inlet and Admiralty Inlet, by Captain Howard, U. S. Navy. The locality for one of these plants (*Alnus Alaskana*), however, is given as "Kootzanoo Archipelago, latitude 57° 35′ N., longitude 134° 19′ W., Alaska Territory."

A few specimens collected at Sitka by E. W. Nelson, are noted by Professor Lesquereux in the Proceedings of the U. S. National Museum (vol. 10, pp. 35–38), and one lot of four specimens collected by Henry D. Woolfe at Cape Lisburne, besides furnishing a new locality, prove to belong to a new species (*Irites Alaskanus* Lx., Mus. No. 2320). A much larger collection, or perhaps the same collection from which the four specimens last mentioned had accidentally become separated, by Mr. Woolfe from the same place was reported on by Professor Lesquereux a year later (Proc. U. S. Nat. Mus., vol. 11, 1888, pp. 31–33). These forms include species of Ginkgo, Baiera, Podozamites, Zamites, and other genera that indicate a lower Cretaceous, or possibly an upper Jurassic age.

EXPLANATION OF THE MAP.

PLATE LXI.—Map showing the distribution of known fossil plant localities in the United States.

The plate exhibits the distribution of known fossil plant localities in the United States by means of the numbered dots and the geologic formations in which the fossils occur by means of colors. The numbered localities, with the formations, are enumerated in the following table:

[Those localities which are without numbers are too near other localities of the same geological age to admit of individual designation on the map.]

MAINE.

1.	Perry	Devonian.

VERMONT.

2.	Brandon	Eocene.
3.	Swanton	Silurian.

MASSACHUSETTS.

4.	Mount Holyoke	Trias.
5.	Montague	Do.
6.	Mount Tom	Do.
7.	Mansfield	Subcarboniferous.
8.	Adams	Trias.
9.	Wrentham	Subcarboniferous.
394.	Nantucket Harbor	Quaternary.
395.	Holmes' Hole	Do.
396.	Gay Head	Pliocene.
397.	Cape Cod, opposite Yarmouth	Quaternary.
398.	Provincetown	Do.
399.	Turner's Falls	Trias.
400.	Agawam River, in West Springfield	Do.
401.	Sunderland	Do.
402.	Northampton	Do.
....	Chicopee	Do.
	Springfield	Do.
....	Deerfield	Do.
	Greenfield	Do.
403.	Worcester	Carboniferous.
404.	Norton	Do.
...	Cape Ann	Quaternary.
....	Boston Harbor	Do.
....	Lynn Bay	Do.

RHODE ISLAND.

10.	Portsmouth	Carboniferous.
11.	Newport	Do.
	Newport Neck	Do.
12.	Mount Hope	Do.
	Warren	Do.
	Bristol Neck	Do.
13.	Warwick Neck	Do.

CONNECTICUT.

14.	Southbury	Trias.

NEW YORK.

15.	Chittenango	Silurian.
16.	Trenton Falls	Do.
17.	Ithaca	Devonian.
18.	Fort Plain	Silurian.
19.	Glens Falls	Do.
20.	Schoharie County	Devonian.
21.	Pulaski	Silurian.
22.	Rome	Do.
23.	Oswego River	Do.
24.	Rochester	Do.
25.	Canandaigua	Devonian.
26.	Cairo	Silurian.
27.	Amsterdam	Do.
28.	Canajoharie	Do.
29.	Chazy	Do.
30.	Keeseville	Do.
31.	Jacksonburgh	Do.
32.	Middleville	Do.
33.	Turin	Do.
34.	Martinsburgh	Do.
35.	Loraine	Do.
36.	Jackson	Do.
37.	Salem	Do.
38.	Union Village	Do.
39.	Lockport	Do.
40.	Milo	Devonian.
41.	Italy	Do.
42.	Marcellus	Do.
43.	Padelford's	Do.
44.	East Bloomfield	Do.
45.	Cattaraugus County	Do.
46.	Allegany County	Do.
47.	Steuben County	Do.
48.	Chemung County	Do.
49.	Washington County	Cambrian.
405.	Monroe	Devonian.
	Woodbury Falls	Do.

NEW JERSEY.

50.	Milford	Trias.
51.	South Amboy	Cenomanian.
52.	Woodbridge	Do.
53.	Raritan River	Do.
54.	Bridgeton	Quaternary.

PENNSYLVANIA.

No.	Locality	Formation
55.	Wilkes Barre	Carboniferous.
56.	Lewistown	Do.
57.	Carbondale	Do.
58.	Greensburgh	Do.
59.	Scranton	Do.
60.	Washington	Do.
61.	Towanda	Do.
62.	Pottsville	Devonian and Subcarboniferous.
63.	Pittston	Do.
	Caxton Narrows	Devonian.
64.	Wurtemburgh	Subcarboniferous.
65.	Lackawanna	Carboniferous.
66.	Nanticoke	Do.
67.	Jollytown	Do.
68.	Oil City	Subcarboniferous.
69.	Shamokin	Carboniferous.
70.	Lehigh Summit	Do.
71.	Trevorton	Do.
72.	Johnstown	Do.
73.	Gaines	Do.
74.	Broad Top	Do.
75.	Archbald	Do.
76.	Old Forge	Do.
77.	Hazleton	Do.
78.	Johnston, Allegheny County	Do.
79.	Cannelton	Do.
80.	Rauch's Gap	Do.
81.	Plymouth	Do.
82.	New Philadelphia	Do.
	Port Carbon	Do.
	Saint Clair	Do.
83.	Tremont	Do.
84.	Lorberry Junction	Do.
85.	Beaver County	Do.
86.	Huntingdon	Devonian.
87.	Meshoppen	Do.
88.	Montrose	Do.
89.	Mauch Chunk	Subcarboniferous. Devonian.
90.	Rausch's Gap	Subcarboniferous.
....	Ashland Gap	Carboniferous.

MARYLAND.

No.	Locality	Formation
91.	Frostburgh	Carboniferous.
92.	Baltimore	Potomac.
93.	Grove Point	Do.
94.	Deep Run	Do.
	Jessup's Cut	Do.
406.	Beltsville	Do.

DISTRICT OF COLUMBIA.

No.	Locality	Formation
95.	Washington	Potomac.

VIRGINIA.

No.	Locality	Formation
96.	Richmond	Rhetic.
	Carbon Hill	Do.
413.	Clover Hill	Do.
97.	Fredericksburgh	Potomac.
98.	Lewis' Tunnel	Subcarboniferous.
99.	Acquia Creek	Potomac.
100.	White House Landing	Do.
101.	Marlborough	Eocene.
102.	Dutch Gap	Potomac.
103.	Rawley Springs	Devonian.
104.	Wytheville	Tertiary.
105.	Augusta County	Subcarboniferous.
407.	Price's Mountain	Carboniferous.
	Brushy Mountain	Do.
408.	Cloyd's	Do.
409.	Midlothian	Rhetic.
410.	Manakin	Do.
411.	Hanover Junction	Do.
	Dover	Do.
412.	Norwood mines	Do.

WEST VIRGINIA.

No.	Locality	Formation
106.	Wheeling	Carboniferous.
107.	West Union	Do.
108.	Quinnimont	Subcarboniferous.
109.	Sewell Depot	Do.
110.	Arnettsville	Carboniferous.
	Brown's Bridge	Do.
111.	Cassville	Do.
112.	Belton	Do.
113.	Moundsville	Do.
114.	Freeport	Do.

NORTH CAROLINA.

No.	Locality	Formation
115.	New Berne	**Quaternary (?)** Rhetic (?).
116.	Craven County	Rhetic (?).
414.	Lockville	Do.
415.	Egypt	Permian (?).
	Haywood	Rhetic.
416.	Madison	Permian (?)
417.	Farmville	Do.

GEORGIA.

No.	Locality	Formation
117.	Dade County	Subcarboniferous.

FLORIDA.

No.	Locality	Formation
118.	Pease Creek	Tertiary (?.

ALABAMA.

No.	Locality	Formation
119.	Tuscaloosa	Potomac, Carboniferous.
120.	Montevallo	Subcarboniferous.
121.	Helena	Do.
122.	Warrior Station	Do.
123.	Jefferson County	Do.
124.	Blount Springs	Do.
125.	La Grange	Do.
126.	Saint Clair County	Do.
127.	Walker County	Do.
418.	Black Creek	Do.
419.	Gadsden	Do.

MISSISSIPPI.

No.	Locality	Formation
128.	Tippah	Eocene.
129.	Louisville	Do.
	Winston County	Do.
130.	New Prospect	Do.
131.	Marshall County	Do.
132.	La Fayette County	Do.
133.	Calhoun County	Do.
134.	Choctaw County	Do.
135.	Lauderdale	Do.
136.	Price's Mill	Do.

LOUISIANA.

No.	Locality	Formation
420.	Shreveport	Eocene.
421.	Cross Lake	Do.
422.	Mansfield	Do.

TEXAS.

137. { La Grange..................Eocene.
 { Fayette County.......... Do.
138. Giddings..................Cretaceous.
139. Gonzales.................. Do.
140. Fredericksburgh.......... Do.
141. Llano River.............. Do.
142. New Braunfels........... Do.
143. Colorado.................. Do.
144. Elm Creek................ Do.
145. Eagle Pass............... Do.
146. Lamar County........... Do.
147. Bryan..................... Do.

ARKANSAS.

148. Little Rock...............Subcarboniferous.
149. White River.............. Do.
150. Lee Creek................ Do.
151. Frog Bayou.............. Do.
152. Jenny Lind Prairie........ Do.
153. James Fork.............. Do.
154. Liberty Springs.......... Do.

TENNESSEE.

155. La Grange...............Eocene (?).
156. Somerville............... Do.
157. Centerville...............Carboniferous.
158. Tracy City............... Do.
159. Rockwood................ Do.
160. Sewanee.................. Do.

KENTUCKY.

161. Lebanon..................Devonian.
162. Hawesville................Carboniferous.
163. West Liberty............. Do.
164. Columbus.................Pliocene.
165. { Caseyville...............Carboniferous.
 { Bell's Mine............... Do.
166. Airdie..................... Do.
167. Hazel Green.............. Do.
168. Crittenden County........ Do.
169. Union County............. Do.
170. Carter County............ Do.
171. Hopkins County.......... Do.
172. Christian County......... Do.
173. Greenup County.......... Do.
174. Rock Castle.............. Do.
175. Covington.................Silurian.
176. Commercial Summit......Carboniferous.
423. Wickliffe..................Eocene.
424. Boaz.......................Quaternary (?).

OHIO.

177. Marietta..................Carboniferous.
178. Zanesville................ Do.
179. Gallipolis................. Do.
180. Springfield................Quaternary (?).
181. Youngstown..............Subcarboniferous.
182. Coshocton................Carboniferous.
183. Akron.....................Devonian (?).
184. { Athens....................Carboniferous.
 { Buchtel.................. Do.
185. Pomeroy.................. Do.
186. Newark...................Subcarboniferous.
187. Cuyahoga Falls.......... Do.
188. Palmyra..................Quaternary. (?)
189. Richfield..................Devonian.
190. Rushville.................Subcarboniferous.
191. Tallmadge............... Do.
192. Massillon.................Carboniferous.
193. Nelsonville............... Do.
194. Shawnee.................. Do.
195. Middlebury.............. Do.
196. Barnesville.............. Do.
197. Saint Clairsville.......... Do.
198. Salineville............... Do.
199. Addison.................. Do.
200. Barlow................... Do.
201. Harrisville................Devonian.
202. Eaton.....................Silurian.
203. Bantam.................. Do.
204. Lebanon.................. Do.
205. Highland County.........Carboniferous.
206. Holmes County.......... Do.
207. Cincinnati................Silurian.
208. Guernsey County.........Carboniferous.
.... Cleveland.................Quaternary.

INDIANA.

209. Newport..................Carboniferous.
210. New Harmony........... Do.
211. Shelburn................. Do.
212. Perrysville.............. Do.
213. Eugene.................. Do.
214. Spring Creek............ Do.
215. Salt Creek............... Do.
216. Orange County...........Subcarboniferous.

ILLINOIS.

217. Morris....................Carboniferous.
218. Murphysborough......... Do.
219. Vandalia................. Do.
220. Carmi.................... Do.
221. Grayville................ Do.
222. Marseilles............... Do.
223. Duquoin................. Do.
224. Saint John.............. Do.
225. La Salle................. Do.
226. Rock Island............. Do.
228. Springfield.............. Do.
229. Alton.................... Do.
230. Carlinville.............. Do.
231. Port Byron................Subcarboniferous.
232. Mazon Creek.............Carboniferous.
233. Colchester............... Do.
234. Neelyville............... Do.
235. Mercer County.......... Do.
236. Vermilion County........ Do.
237. Fulton County........... Do.
238. Grape Creek............. Do.
239. Drury's Landing......... Do.
240. Carroll's Place, Pope County.................. Do.
241. McDonough County...... Do.

WISCONSIN.

425. Mendota..................Cambrian.
426. Berlin.................... Do.
427. Kingston................. Do.
428. Janesville.................Silurian.
429. Waterloo................. Do.
430. Ripon.................... Do.
431. Center................... Do.
432. Flintville................ Do.
433. Sturgeon Bay............ Do.

MISSOURI.

242. Clinton....................Carboniferous.
243. Vernon County............ Do.
244. Elk Spring .... Do.

IOWA.

245. Ottumwa ... . .Carboniferous.
246. Sioux City . ...Dakota group.
434. Oskaloosa..... .... { Dakota group (?). Carboniferous. }
435. Mahaska County..... ....Dakota group (?).
436. Keokuk ....Subcarboniferous.
437. Estherville................Quaternary.

MINNESOTA.

247. New Ulm....................Dakota group.

DAKOTA.

248. Fort Clark.................Laramie.
249. Red Spring................ Do.
250. Fort Berthold............ Do.
251. Fort Union................ Do.
252. Crow Hills .... Do.
253. Little Knife Creek .... Do.
254. Fort Stevenson........... Do.
255. Black Hills..... ....Cambrian.
256. Red Cañon Creek .... Do.
438. Sims ....Laramie.
439. Gladstone.................. Do.
440. Heart River............... Do.

NEBRASKA.

257. Tekamah ....Dakota group.
258. Blackbird Hill............. Do.
259. Decatur................... Do.
260. Cass County .... Do.
261. Lancaster County......... Do.
262. Beatrice .... Do.
441. Nebraska City .... Do.

KANSAS.

263. Lawrence ....Carboniferous.
264. Garnett .... Do.
265. { Fort Ellsworth (old Fort E.)......................Dakota group.
Brookville .... Do. }
266. Osage City..... ....Carboniferous.
267. Thayer.................... Do.
268. Fort Harker ....Dakota group.
269. Smoky Hills .... Do.
270. Ottawa County ....Carboniferous.
271. Fort Larned..............Dakota group.
272. Glasco .... Do.
273. Clay Center............... Do.
274. Bluff Creek .... Do.
275. Minneapolis.............. Do.
276. Salina..................... Do.
277. Salina River. .... Do.

INDIAN TERRITORY.

278. Eufala ....Carboniferous.

MONTANA.

279. Fort Ellis ....Laramie.
280. { Glendive..... .... Do.
Upper Seven-Mile Creek... Do.
Clear Creek.............. Do. }
281. Iron Bluff................. Do.
282. Cracker Box Creek .... Do.
283. Lower Seven-Mile Creek ..Laramie.
284. Gleason's Ranch.......... Do.
285. Bozeman .... Do.
286. { Stillwater .... Do.
Livingston .... Do. }
287. Coal Banks................Senonian.

WYOMING.

288. Evanston ....Laramie.
289. Carbon.................... Do.
290. Medicine Bow............. Do.
291. Creston .... Do.
292. Point of Rocks............ Do.
293. Black Buttes Station...... Do.
294. Rock Creek .... Do.
295. Long. 111° N., lat. 41° 30′ W. Oolite (?).
296. Henry's Fork ....Green River group.
297. Washakie.................Laramie.
298. { Green River station ......Green River group.
Alkali Stage station ..... Do. }
299. Fort Fetterman...........Laramie.
300. Bridger's Pass.. .... Do.
302. Granger...................Tertiary.
304. Bell's Fish Cliff............Green River group.
305. Hodge's Pass ....Laramie.
442. Beaver Creek.............Tertiary.

YELLOWSTONE NATIONAL PARK.

303. Amethyst Mountain ......Tertiary.

COLORADO.

306. Marshall's mine (Denver) .Laramie.
307. Golden.................... Do.
308. Hot Springs............... Do.
309. Florissant................Green River group.
310. Gehrung's (Colorado Springs).................Laramie.
311. Erie mines................ Do.
312. South Lake Mountain.....Laramie.
313. Willow Creek .... Do. (?)
314. Plum Creek .... Do. (?)
315. Morrison ....Dakota group.
316. Fair Play.................Permian.
317. Girardot's coal mine......Laramie.
318. Saint Vrain River (Platte Station)................. Do.
319. Las Animas...............Dakota group.
320. Sand Creek ....Laramie.
321. Troub'esome Creek .... Do. (?)
322. Mount Brosse .... Do. (?)
323. Cliff Springs ....Green River group.
324. Crested Butte............Devonian.
325. Silver Cliff ....Dakota group (?).
329. Fischer's Peak (Raton Mts.)Laramie.
331. Purgatory Cañon .... Do.

NEW MEXICO.

326. Santa Anna..............Laramie (?).
327. Abiquiu..................Jurassic.
328. Raton Pass ....Laramie.
330. Rio Secco .... Do. (?)
332. Fort Wingate ....Jurassic.
333. Placer Mountain..........Laramie.
334. Vermejo Cañon........... Do.
.... Nacimiento Range ....Dakota group (?).
.... Copper City..............Jurassic.
.... San Pueblo Cañon ....Cretaceous.
.... San José Corral........... Do.

ARIZONA.

335. Lithodendron ....Jurassic (?).
336. Deer Creek................Laramie (?).
337. Chalcedony Park ....Jurassic (?).

UTAH.

338. Coalville ....Laramie.
339. Wales.....................Carboniferous (?).
340. Pine Creek.................Jurassic (?).
341. Toquerville .... Do.
342. Upper Kanab Valley......Laramie (?).
343. False Creek .... Do.
344. Vermilion Cliffs...........Jurassic (?).
345. Ashley .... Do.
346. Dry Cañon .... Do.
347. Ashley's Fork............. Do.
348. Rabbit Valley............. Do.
349. Thousand Lake Mountain. Do.
350. Rio Dolores .... Do.
351. White River ....Green River group.

WASHINGTON TERRITORY.

352. Bellingham Bay...........Miocene.
353. Orcas Island ....Senonian.
354. Birch Bay..................Miocene.

OREGON.

355. Cascades..................Pliocene (?).
356. Astoria .... Do.
357. Warm Springs .... Do.
358. {Mount Jefferson.......... Do.
{Psuc see-que Creek....... Do.
359. Jacksonville .... Do.
360. Bridge Creek .... Do.

NEVADA.

361. Elko ....Green River group.
362. Eberhardt .... Do. (?)
363. Pyramid Lake .... Do. (?)

CALIFORNIA.

364. Kern River................Quaternary.
365. Pilot Knob .... Do.
366. Cañada de las Uvas .... Do.
367. Georgetown............... Do.
368. Calistoga..................Pliocene (?).
369. Chalk Bluffs...............Quaternary.
370. Table Mountain, Tuolumne
County.................. Do.
371. Bowen's claim .... Do.
372. Bald Mountain tunnel .... Do.
373. Corral Hollow .... Do.
374. Table Mountain, Contra
Costa County .... Do.
375. Placerville .... Do.
376. {Mount Shasta............. Do.
{Pence's Ranch .... Do.
377. Clear Lake................ Do.

ALASKA.

378. Atka Island ....Tertiary.
379. Kadjak Island.............Miocene.
380. {Unga Island .... Do.
{(Coal Harbor) .... Do.
381. Cook's Inlet............... Do.
382. Kuju Island............... Do.
383. Shumagin group.......... Do.
384. Uyak Island .... Do.
385. Ugolini Bay............... Do.
(Alaska Peninsula)........ Do.
386. Kootzanoo Bay .... Do.
(Archipelago)............ Do.
387. Neniltchik Bay .... Do.
(Village) .... Do.
388. Sitka...................... Do.
389. Cape Lisburne ....Neocomian (?).
390. Chignik Bay ....Miocene.
391. North of Jaklök ....Subcarboniferous.
392. Admiralty Inlet...........Miocene.
393. Chugachik Bay .... Do.

INDEX

TO PAPER ON

The Geographical Distribution of Fossil Plants.

[NOTE.—Numerals in heavy type refer to pages on which pricipal headings occur.]

SUMMARY

OF THE

GEOLOGY OF THE QUICKSILVER DEPOSITS

OF THE

PACIFIC SLOPE.

BY

GEORGE F. BECKER.

CONTENTS.

ILLUSTRATIONS.

SUMMARY OF THE GEOLOGY OF THE QUICKSILVER DEPOSITS OF THE PACIFIC SLOPE.

By George F. Becker.

In accordance with the policy and practice of the Geological Survey, an abstract is here presented of a monograph prepared for it on the geology of the quicksilver deposits of the Pacific Slope. A very large part of the full memoir necessarily consists of detailed descriptions, written in order to enable readers to judge whether the facts warrant the opinions expressed, and of discussions of a somewhat technical character. There may be those, however, who will be interested to know in brief what conclusions have been reached, but who have no inclination to undertake the somewhat serious task of weighing the evidence adduced and of following the arguments in detail. For such readers this chapter is written; but it must be understood that for full and fully qualified statements reference must be made to the monograph.

STATISTICS AND HISTORY.

The commercial status of quicksilver is peculiar. It seems to be three or more times as abundant in nature as silver, and since 1850 the weight of silver extracted is about six-tenths that of quicksilver; but the total value of the latter is less than one-sixteenth that of the former metal. This is due to the limited demand for mercury, which is employed in large quantities only for amalgamating gold and silver ores and for the manufacture of vermilion. If it should prove practicable to extirpate phylloxera with mercury, this application will greatly benefit the quicksilver miners as well as the vine-growers.

Five regions in the world are yielding or have yielded great quantities of this metal. They are Almaden, in Spain; Idria, in Austria; Kwei-Chau, in China; Huancavelica, in Peru, and the Coast Ranges of California. Of the Chinese region little is known, except that it is extremely rich; in the opinion of a very competent judge, the richest of all. Almaden has produced more than any one of the other three. Idria, Huancavelica, and California have each yielded pretty nearly the same amount from the dates of discovery of the deposits to the present day, California taking the lowest rank. But considering only the period which has elapsed since the mines of the Pacific Slope were first opened the case is different. Peru produced nothing from 1850 to 1886; Idria, in round numbers, 300,000 flasks; Almaden, 1,140,000, and California, 1,400,000, or nearly half the entire product of the world. California, however, does not seem likely to maintain the same rank among quicksilver producers in the future.

Quicksilver was first recognized in California as occurring at the croppings of the New Almaden mine by Andreas Castillero in 1845. His means of testing the ore were quaint, but effectual, and he immediately began production on a small scale. A large number of other deposits were discovered at later dates, and some forty mines have produced metal, though from some of these the yield has been trifling. Half a dozen of them have yielded from 40,000 flasks upward, and New Almaden has turned out over 853,000 flasks. The sketch map of California (see Plate LXII) shows the distribution of some of the mines.

FOREIGN OCCURRENCES OF QUICKSILVER.

The account given of deposits known to occur in foreign countries will not bear condensation, being in itself a brief digest. The rocks inclosing quicksilver deposits are of very diverse ages, ranging all the way from Archean granites and schists to recent strata and lavas. The lithological variety of the inclosing rocks is equally great, including limestones, sandstones, and shales, many kinds of metamorphic strata, and massive rocks of acid, neutral, and basic types. Cinnabar does not even seem to exhibit any preference for one class of rocks rather than another. It is clear that the mere age of the surrounding material is without influence on the deposition of the ore and that the ore can not in general be derived from the walls of the deposits, for it is scarcely supposable that this metal forms an original constituent of all sorts of rocks.

A glance at the map (Plate LXIII) shows that the quicksilver deposits occur along the great axes of disturbance of the world. One of these is on the line of the principal mountain system of Eurasia, for which I suggest the name of Alpimalayan chain, because it includes the Alps and the Himalayas. The other coincides with the western ranges of the Cordillera system of America. In many parts of the world volcanic phenomena are intimately associated with these axes of disturbance and with the quicksilver deposits.

The minerals which occur in considerable quantities with quicksilver ores are few in number. Pyrite or marcasite is nearly or quite always present, arsenic and antimony are found at many localities, and copper ores sometimes accompany cinnabar. Other metalliferous minerals are comparatively rare. The principal gangue seems to be invariably either silica, sometimes hydrous, or carbonates, chiefly calcite. Cinnabar occurs in true, simple fissure veins, in im-

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Geo. F. Becker, Geologist in charge

pregnations, and stockworks. The forms which its deposits take do not apparently differ in any essential respect from those which deposits of other metals assume; but ore bodies precipitated by substitution do not appear from the descriptions to be common. In all cases a fissure system seems probably associated with the deposits.

The facts recorded point to the supposition that most of the quicksilver deposits, if not all of them, have been formed in a similar manner. They have all been deposited from solution, for the gangue minerals could have been formed in no other way. Cinnabar has certainly been deposited by thermal springs of very high temperature at Puzzuoli, in Italy, and at Lake Omapere, in New Zealand, and is most intimately associated with hot springs and other volcanic phenomena at a large number of other points. It has, perhaps, always been deposited by heated waters. It must be derived from some deep-seated substance of world-wide distribution, which has been exposed to the action of volcanic solvents by profound disturbance. The fundamental granitoid rocks answer this description, for they seem everywhere to underlie all other rocks; they are of great but unknown thickness, and they certainly in part overlie the centers of volcanic activity. Geological investigations have as yet revealed no other substance of similar distribution. There is no other rock from which it is equally probable that the quicksilver is derived.

LITHOLOGICAL GEOLOGY.

SEDIMENTARY ROCKS.

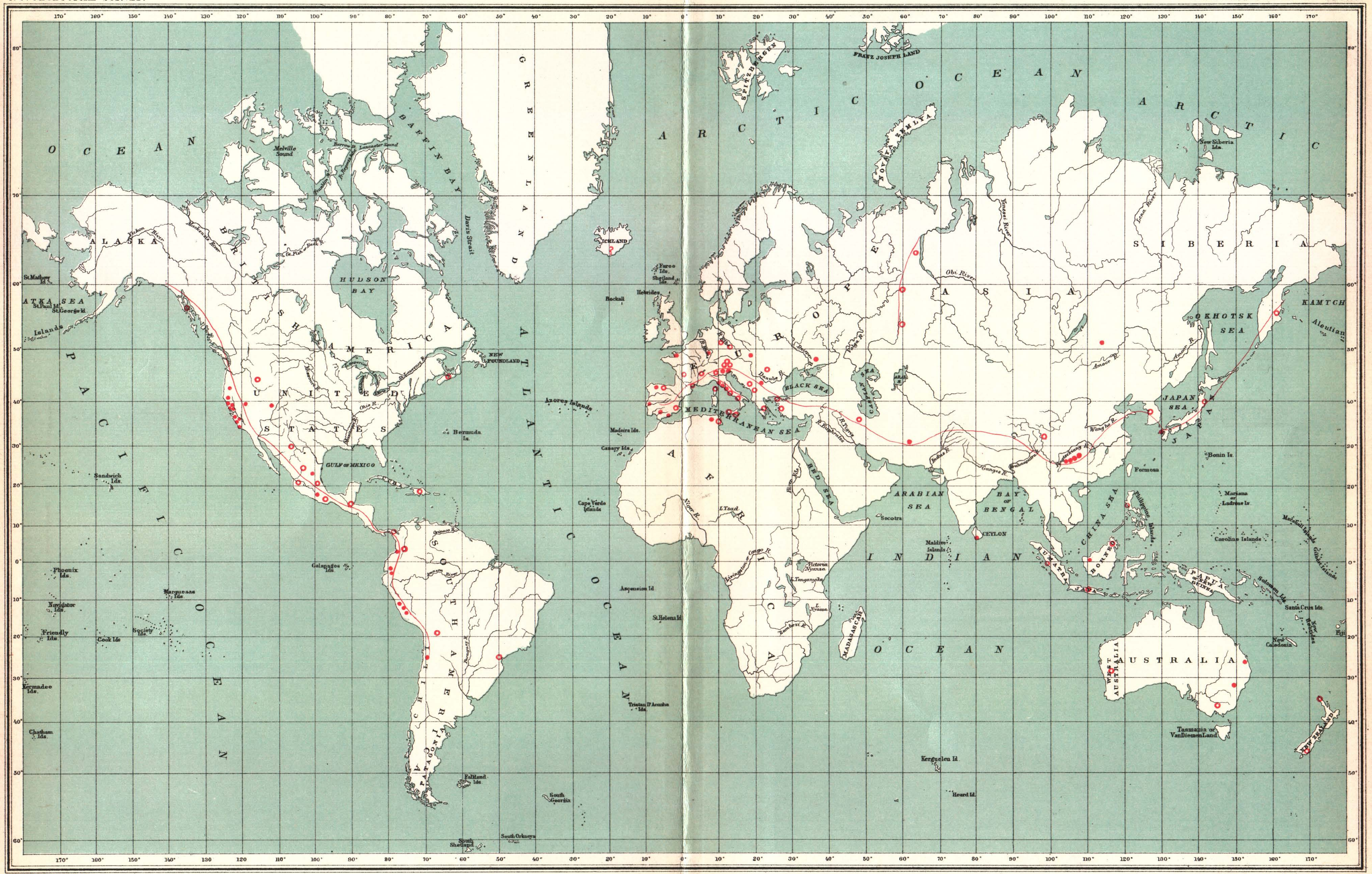
Excepting the light cream-colored schists of Miocene age, which occupy a narrow strip along the coast of California from the neighborhood of Santa Cruz southward, the rocks of the Coast Ranges where unaltered are mainly sandstones of Cretaceous and Tertiary age. Sandstones often occur here in practically uninterrupted series of beds many thousands of feet in thickness. The unaltered sandstones of the Coast Ranges are very much alike, whatever their age. The Téjon (Eocene) beds, however, are of a much lighter color than the Chico (late Cretaceous) or the Miocene rocks. The Chico again is usually more indurated than the Miocene. While the Knoxville (Neocomian) sandstones where unaltered closely resemble those of later periods, no case is known in which unaltered Knoxville beds are not intimately associated with greatly disturbed and metamorphosed rocks of the same age, so that there is no difficulty in discrimination when once it is established that the epoch of violent upheaval and metamorphism followed soon after the close of the Knoxville.

Field study shows that the Coast Ranges are probably everywhere underlain by granite. The microscopical examinations have given this inference unexpectedly strong confirmation, for, though on structural grounds it appears certain that a portion of the later sandstones were formed at the expense of earlier arenaceous beds, they all exhibit unmistakable evidence of granitic origin. They are thus so similar that they may be discussed together lithologically. The microscope shows that the main constituents are quartz fragments (containing abundant fluid inclusions and in other respects resembling the quartzes of the underlying granite), orthoclase, the same plagioclases found in the granite, and biotite. Most of the less important constituents of the granite are also found in the sandstones. The proportion of quartz in the sandstones is, as a matter of course, greater than in the granite. The grains are commonly rounded like ordinary beach sand, but are sometimes extremely sharp. The cement is largely calcite. The sandstones are subject to the ordinary decomposition known as weathering, by which the ferromagnesian silicates are in part converted to chlorite and in part to a ferruginous cement.

The unmetamorphosed late Cretaceous and Miocene sandstones show numerous concretions. These in rare instances contain fossils as nuclei. A representative concretion in which no organic remains existed was investigated. It was found that the cementing matrix contained a considerable amount of phosphoric acid, but was chiefly composed of a mixture of calcium carbonate and a hydrous subsilicate of iron. It is shown that this composition points to the action of organic acids, especially the humus acids, and that the class of concretions of which this is a type must have contained nuclei of organic matter which have decomposed and disappeared.

Rounded nodules resulting from the action of decomposition processes on angular masses are discussed, and it is shown that the rapidity of attack must be in an inverse ratio to the radius of curvature of the mass. This explains the fact that such nodules tend to a spherical form. The rounding of pebbles and of sand grains is shown to depend on the same mathematical law.

Sharply defined limits can not be drawn between the various early Cretaceous metamorphosed rocks of the Coast Ranges; they pass over into one another by degrees. For purposes of description, however, it is desirable to consider certain types as distinct. The divisions which appear to satisfy best both their field occurrence and their microscopical character are as follows: *Partially metamorphosed sandstones*, in which, although a process of recrystallization has begun, the clastic structure as seen under the microscope is not obliterated, but is often more or less obscured. This class will be referred to hereafter for the sake of brevity as altered sandstones. *Granular metamorphics*, in which metasomatic recrystallization of sandstones has transformed the mass into a holocrystalline aggregate, form another group. The third class embraces the *glaucophane schists*,



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Geo. F. Becker, Geologist in charge.

DISTRIBUTION OF QUICKSILVER DEPOSITS
THROUGHOUT THE WORLD.

Districts which are or have been productive ● Districts in which ore has been detected ○ Connecting lines ———

derived from certain shales, much as the granular metamorphics are produced from sandstone. The *phthanites* are a series of more or less calcareous, schistose rocks which have been subjected to a process of silification, resulting in chert-like masses, which retain schistoid structure and are intersected by innumerable quartz veins. They usually carry more or less zoisite. Finally the *serpentines;* which have resulted in part from the direct action of solutions on sandstones and in part from alteration of the granular metamorphics.

A considerable number of minerals have been generated in these rocks by metasomatic processes and weathering. These are biotite, muscovite, augite, hornblende, glaucophane, labradorite, andesine (probably), oligoclase, albite, orthoclase, quartz, zoisite, rutile, ilmenite, titanite, apatite, garnet, nacrite, chlorite, epidote, serpentine, and chromite. The most interesting and in some respects the most important mineral found is zoisite, which has been repeatedly analyzed and tested.

All the more important processes of metasomatic recrystallization can be traced in the altered sandstones, rocks whose clastic origin could not be doubted for a moment. In many cases one of the first stages in the process is the resolution of the clastic grains into crystalline aggregates from which new minerals are again built up. Augite, hornblende, and plagioclase have been observed which had formed in this manner. The feldspars also crystallize along tiny veins in the slides. A frequent occurrence is the resolution of quartz grains into plagioclase microlites. The reaction begins on the surface of the quartz grains and produces a fringe of twinned feldspar microlites in positions approximately normal to the surface of the residual kernel. The microlites do not merely abut against the kernel, but penetrate it for a sensible distance like closely set pins in a cushion. Zoisite is present in nearly all the altered sandstones. It forms in the aggregates which result from the clastic grains, and its microlites sometimes pierce quartz grains from the outside. It is abundant in the granular as well as in the prismatic form. This hydrous mineral forms simultaneously with the other products of metasomatic recrystallization, and does not here represent a decomposition process in rocks already recrystallized.

It is only necessary to suppose the processes indicated above carried further to obtain a product in which the clastic character of the rocks would cease to be evident. The altered sandstones thus form, under the microscope, as they do in the field, transitions from the clastic series to the holocrystalline rocks.

The granular metamorphic rocks of the Coast Ranges are separable under the microscope into several groups, but this is not practicable by unaided vision; indeed, there are many cases in which specimens which appear to the naked eye to be not greatly altered sandstones prove under the microscope to be holocrystalline rocks, with none of the microstructure of a sandstone. The most important class of the granular rocks is chiefly composed of plagioclase and augite. It sometimes resembles true diabase, and may conveniently be called *pseudodiabase*. The pyroxene sometimes assumes the form of diallage. Another class contains amphibole instead of pyroxene, and I call this rock *pseudodiorite*. No metamorphic rocks have been found in place which carry olivine. Glaucophane occurs in both the pseudodiabase and the pseudodiorite. The quantity of zoisite in these rocks is very variable, and in some cases is so great that with feldspar it forms almost the entire mass. The schistose metamorphics, not including phthanites, are all characterized by the presence of glaucophane. In every case but one, zoisite is associated with the glaucophane in this group and either muscovite or biotite is usually present.

The phthanites or silicified shales form a very distinct group, readily distinguishable from the granular metamorphics. They are usually green or brown and are intersected by innumerable quartz veins. They contain microscopic organic remains, and embedded in the quartz veins or projecting from their walls are often numerous zoisite crystals. All of these rocks are best represented by detailed descriptions of special examples, for which there is no space here.

Serpentine in a comparatively pure state occurs throughout the quicksilver belt in irregular areas. As nearly as can be estimated these areas amount to somewhat over one thousand square miles between Clear Lake and New Idria. Serpentine is also one of the mineral constituents of many of the altered sandstones and of the granular metamorphic rocks. It is a biaxial variety, often just perceptibly dichroitic, and rarely shows differences of tint as great as those characteristic of chlorite. It might be called antigorite if it seemed needful to separate the biaxial serpentines. The net structure so usual, though not invariable, in serpentine formed from olivine has nowhere been detected. Where any considerable quantity of serpentine is present it usually shows the now well known grate structure.

No considerable portion of the serpentine of the Coast Ranges has resulted from the decomposition of olivine. Only in one district have pebbles of olivine gabbro been found, and these contain a mere trace of serpentine, while the origin of the serpentine has been traced in a great number of cases to rocks containing no olivine.

Field observations show most conclusively that the great mass of the serpentine of this area is derived from the sandstones, either immediately or through an intermediate granular metamorphic rock.

Under the microscope it can be shown, as I think beyond question, that all of the principal components of the sandstones and granular metamorphic rocks are subject to serpentinization. Not only are the augite and hornblende subject to this kind of decomposition, but feldspar, quartz, apatite, and probably other minerals are also converted into serpentine.

In the present state of opinion it is not superfluous to insist upon the derivative character of the holocrystalline metamorphic rocks and the serpentine of the quicksilver belt. There are in fact two independent lines of evidence leading to this conclusion, for the known occurrences of zoisite and its composition indicate that rocks containing it otherwise than as a product of decomposition are metamorphic, while, even if zoisite were a common constituent of undecomposed lavas, the proof of the metamorphic character of these rocks would still be ample.

The depth at which the rocks now exposed were buried at the epoch of metamorphism, soon after the close of the Neocomian, was probably a moderate one; perhaps two thousand or three thousand feet. At a sufficient pressure rocks appear to be molded by dynamic action rather than crushed, and Dr. Lehmann has shown that under such conditions even crystals may be bent. In the Coast Ranges no such phenomenon has been observed. On the contrary, the amount of fracturing is really astonishing. The recrystallization of the sandstones and the serpentinization and silicification are regarded as due to the action of solutions rising from the underlying granite; and these solutions were heated, charged with mineral matter, and driven to the surface as a result of the same dynamical causes which produced the uplift.

In conclusion it may be noted that all the more important minerals of the Archean schists are found in the metamorphosed rocks of the Coast Ranges. The quantitative relations indeed are different, especially those of the feldspars; for, while orthoclase predominates in the Archean, plagioclase is much more common in the Coast Ranges; but it is evident that, under conditions not greatly dissimilar to those which prevailed in California at the close of the Neocomian, rocks not distinguishable from those of Archean areas might have been formed.

MASSIVE ROCKS.

The massive rocks met with in this investigation are granite, diabase, diorite, andesites, rhyolite, and basalt. The granites seem to underlie the entire Coast Ranges, and to form the lower and central portion of the Sierra Nevada. They are on the whole pretty uniform and present no known peculiarity. Diabase occurs in the Mesozoic conglomerates of Steamboat Springs, and seems to be identical with the diabase which forms the hanging wall of the Comstock lode. Diorite is represented chiefly by pebbles in the Neocomian conglomerates of the Coast Ranges.

The andesites are divisible into two groups, an older and a younger. The younger group is found at Steamboat Springs and elsewhere in and near the Sierra Nevada, at Mt. Shasta, and from Clear Lake to Mt. Diablo. It presents several varieties: one containing pyroxene, a mere trace of hornblende, and no mica; a second containing pyroxene and mica, but no hornblende; a third containing hornblende, with very small quantities of pyroxene, together with mica in quantities ranging from nil to a very large percentage. All of these pass over into one another, sometimes within a few feet, and in masses evidently not due to separate eruptions. Nearly or quite all of them are rough, soft rocks, such as were formerly supposed to be trachyte. They form a natural group, which should be recognized. I have proposed the name *asperite* to suggest their resemblance to trachyte. Asperites, then, are a group of andesites with external characteristics similar to those of trachyte.

Both the asperites and the basalts near Clear Lake pass by transitions into enormous masses of obsidian. The transitions have been traced in the field, in the chemical laboratory, and under the microscope. The glasses are more acid than the crystalline rocks into which they pass, but they contain much more alkali and much less lime and magnesia; their specific gravity is also much smaller. They have cooled as glasses, instead of as crystalline aggregates, because of their peculiar composition, and not because they have been subjected to different physical conditions from the associated, sensibly holocrystalline lavas.

The origin of the massive rocks of California is discussed in Chapter IV of the Monograph. It is shown to be probable that portions of the granitic rocks represent parts of the original crust of the earth, or that they are primeval rocks. That the primeval rocks must underlie all others is self-evident and the lowest rocks we know of are granitic. It has never been shown how the original crust could be wholly buried beneath its own ruins, and simple arguments are adduced to show this utterly improbable. It follows that a part of the granite must be Azoic and that the lavas which have broken through the granite can not be remelted sediments.

HISTORICAL GEOLOGY.

The following outline states in the briefest terms the main events in the geological history of the Coast Ranges, so far as they have been elucidated by former observers and by myself.

Prior to the opening of the Cretaceous the region of the Coast Ranges seems to have been chiefly occupied by granite. During the first period of the Cretaceous—the Neocomian—great quantities of sediments derived from the granite were deposited on the quicksilver belt. These were chiefly sands, though shales and calcium carbonate were also found. The sea must have been shallow and many islands must have existed in it. The most characteristic animals of the period were *Aucella concentrica* and *Aucella mosquensis*, of which a description, with illustrations, by Dr. C. A. White, is given in Chapter V. At the close of the Neocomian an upheaval took place with extraordinary violence, folding and crushing the rocks and producing the first ranges along the coast of California of which any record remains. It is probable enough that earlier ranges existed, but had been obliterated. The same upheaval affected the Sierra Nevada and added to its western side, along a part of the gold belt, an immense mass of Neocomian rocks, which were driven into a nearly vertical position. Accompanying this upheaval was a vast expenditure of energy. The heat into which this energy was converted brought about the solution of some components of the underlying granite, particularly of magnesia and soda. These solutions, acting on the Neocomian rocks, converted them into the metamorphic product mentioned in preceding paragraphs.

During the middle Cretaceous (the Turonian) the shore of California seems to have been nearly in the same position as it now is, and a series of beds discovered during this investigation, the Wallala group, was deposited. They are composed of granite detritus and fragments of metamorphosed Neocomian beds and certain fossils.

Late in the Cretaceous a great part of the Coast Ranges was again under water and the sea once more reached the flanks of the Sierra Nevada. The sediments laid down at that time, and now known as the Chico series, were of course deposited uncomformably upon the metamorphosed and eroded Neocomian rocks. There was no disturbance at the close of the Cretaceous, and sedimentation and the gradual development of the marine fauna went on undisturbed through the Eocene, which, in California, is represented by the Téjon series. The non-conformity between the Chico and the underlying rocks and the continuity of the Chico and Téjon were first established in this investigation.

Between the Eocene and Miocene there is a sharp faunal distinction, but there is no general corresponding non-conformity. At the close of the Miocene an important upheaval took place, though one which was much less violent than the earlier uplift. Professor Whitney first studied this post-Miocene disturbance. Only a small amount of Pliocene territory exists in this region, and part of it consists of lake deposits. It is of course unconformable with the Miocene.

After the close of the Jurassic no eruptions seem to have taken place in the Coast Ranges until the close of the Miocene, or possibly a little later. Andesites were then ejected and outbursts of these rocks recurred at intervals to the close of the Pliocene. The asperites of Clear Lake and of Mt. Shasta date from the end of the Pliocene. Only one dike of rhyolite is known to exist in the Coast Ranges. It is close to the New Almaden mine. It is probably later than the andesites, but its date is not certain. During the Quaternary and down to very recent times there were many basalt eruptions.

The formation of cinnabar deposits was confined to the period of volcanic eruptions with which they are most intimately connected. Almost all the massive and sedimentary rocks of the region inclose bodies of cinnabar, and the age and the chemical character of the rocks are without apparent influence on the ore.

DESCRIPTIVE GEOLOGY.

DEPOSITS OF THE PACIFIC SLOPE.

Clear Lake district.—The region of Clear Lake is a picturesque one, lying at the northwestern extremity of a belt of lavas which extend southward as far as the Bay of San Francisco. Extinct volcanic cones, borax lakes, hot mineral springs, and deposits of sulphur and cinnabar form its most noteworthy features.

Metamorphic rocks of the Neocomian series underlie the whole country so far as known, though the existence of granite pebbles in the stream which drains the lake suggests that this rock is exposed at no great distance. Upon a part of the metamorphic area about Lower Lake the Chico-Téjon occurs. The latter series is comparatively little disturbed and not metamorphosed.

The earliest eruptions in the district seem to have been that of Chalk Mountain, on the north fork of Cache Creek, and some of the rock near Thurston Lake. This lava was a dense pyroxene-andesite and the eruption seems to have occurred about the beginning of the Pliocene. Soon, and perhaps immediately afterwards, a large body of fresh water formed which I have called Cache Lake. It lay mostly to the east of Clear Lake and continued in existence up to the end of the Pliocene. At this period fresh eruptions of andesites took place. They are the asperites of Mt. Konocti (or Uncle Sam) and the neighborhood. A part of the lava flowed over a portion of the bed of Cache Lake, and the orography was so modified as to shift the position of the water to the new Clear Lake, which overlaps part of the more ancient bed. The change must have been somewhat gradual, for the same mollusks which lived in the earlier body of water also flourished in the new one and the forms are lacustrine.

The asperitic andesites of Mt. Konocti are interesting because they contain pyroxene and mica, but no hornblende, which is unusual, and because they pass over into acid glasses. The asperite is often almost wholly crystalline, though it has been subjected to substantially the same physical conditions as the glass, and the latter has remained vitreous because of its divergent chemical composition. The mountain nearly coincides in form with the theoretical shape of a volcanic cone and its highest point is 2,936 feet above the lake at high water. The lake is 1,310 feet above sea-level.

Much later than the andesite came basalt eruptions, which extended to modern times. A part of this rock also is glassy. All the springs which now issue at a high temperature are probably due to the basalt eruptions, and the borax, sulphur, and cinnabar are referable to the same source.

Sulphur Bank.—The general geology of the Sulphur Bank is indicated in the notes on Clear Lake. The bank itself is a small basalt area, through which hot solfataric springs reach the surface, owing their heat to the volcanic action of which the lava eruption was an earlier manifestation. The springs contain much sulphydric acid, which, oxidizing more or less fully at and near the surface, has yielded native sulphur and sulphuric acid. The latter has attacked the basalt in part, extracting the basis and leaving a mass of more or less pure silica, in which rounded nodules of undecomposed rock remain. The rounded form of these nuclei is certainly due to the more rapid corrosion of the edges and corners of the basalt blocks, not to any structural peculiarity of the rock. The lava is bleached to an average depth of about twenty feet.

In the lower portion of the decomposed layer of rock the sulphur is mixed with cinnabar. Near the bottom of this rock layer the sulphur disappears and the ore is richer, while the most extensive bodies are found at depths beyond the limits of the action of acid. The ores at one portion of the ground continued down for several hundred feet into the underlying recent lake beds and the metamorphic sandstones. Quartz, chalcedony, calcite, pyrite, and marcasite are the usual gangue minerals, but many other minerals are found in small quantities. The marcasite contains minute quantities of gold and copper. Bituminous matter is widely disseminated. The ore has been deposited exclusively in cavities, and not by substitution. The ore of the lower workings is exactly like that of most other quicksilver mines.

The gases escaping from the waters are carbon dioxide, hydrogen sulphide, sulphur dioxide, and marsh gas. The waters contain chiefly carbonates, borates, and chlorides of sodium, potassium, and ammonium; but alkaline sulphides are also present. At the ordinary pressure the water does not dissolve cinnabar, on account of the presence of ammonia, but I have proved that at somewhat higher pressures it would effect solution. It is beyond question that the cinnabar has been deposited from waters of almost exactly the same composition as those now issuing from the mine and that the formation of ore is still in progress. Deposition of the ore seems to have been effected chiefly by relief of temperature and pressure in the presence of ammonia, not by acidification of the solutions.

Very large quantities of quicksilver have been taken from this property, but it has not been worked with system and it has been in-sufficiently prospected below the basalt. There is no reason to suppose, however, that it is nearly exhausted.

Close to Borax Lake lies a very interesting area of glassy basalts, ranging all the way from a nearly normal olivinitic rock to a pure glass. As is the case with the andesites across the lake, the glass is very acid and contains little lime, but much alkali.

Borax Lake is a shallow pond, without an outlet, into which springs similar to those now flowing from Sulphur Bank once drained. These springs came from the obsidian area, and to them the borax contents of the lake are due. They issued at the point called Little Sulphur Bank, which is still hot and moist and shows native sulphur. It is stated on excellent authority that cinnabar in small quantities was found here. Maggots of *Ephydra californica* and of a species of *Stratiomys* live in the lake.

Knoxville district.—The region about Knoxville consists of metamorphosed and unaltered rocks of Neocomian age, through which a small basalt eruption has broken, and contains a number of quicksilver mines and prospects. I know of no other district so favorable as this for the determination of the age of the metamorphic rocks and for a study of their character, excepting Mt. Diablo. Rocks occur in all stages of metamorphism, and the transitions, together with the structural relations, show that even the serpentine is not of eruptive origin. The metamorphosed and unaltered rocks are also so related as to preclude the supposition that the former are crystalline sediments. One side of an eroded anticlinal is metamorphosed, while the other is unchanged and fossiliferous. Fossiliferous strata in a nearly vertical position pass over into metamorphic rocks in the direction of their strike, and patches of unchanged rocks remain in metamorphosed masses. The fossils of the unaltered strata are of Neocomian age and the principal species are *Aucella concentrica* and *A. mosquensis*. The series carrying these shells is called the Knoxville group from the name of this locality.

Excellent opportunities are here afforded for studying the passage of sandstone into pseudodiabase and pseudodiorite and the alteration of these rocks to serpentine. The direct change of slightly altered sandstones to serpentine may also be seen in a very striking manner. Serpentinization takes place from cracks in the sandstone just as it does in olivines, excepting for the difference of scale. The meshes of the net in sandstone croppings are often about a foot across, while those in olivine are microscopic.

The ore deposits occur at half a dozen points in the district, all of them near the basalt area, which is as nearly as possible in the center of the group of ore bodies. Ore is stated on good authority to have been found also in the Lake claim, at the contact of a basalt dike with the inclosing metamorphic rocks. Many mineral springs exist around the basalt area close to the mines and some of them carry borax. Solfataric gases still issue in small quantities at one point in the Redington mine and the upper portions of the ore deposits are of such a character as to indicate that they were deposited near an original surface. All of these facts indicate that the deposits are indirectly due to the basalt eruption and that the nature of the process was similar to that at Sulphur Bank.

The upper part of the famous Redington mine was an extremely rich bonanza of great size and irregular form. It carried much metacinnabarite. Leading up to this mass from below were three irregular fissures, and two of them were filled with ore, forming well-defined fissure veins. This is particularly interesting as a proof that true, simple fissure veins may be formed by hot solfataric springs, which has been doubted by some geologists.

The California or Reed mine, the Manhattan, the Lake, the Andalusia, and several prospects, as well as the Redington, lie in this district, but of late years only the last has been worked. Metacinnabarite was the principal ore of the California. Stibnite occurs on the Lake and Manhattan claims and is said to have been found in contact with cinnabar.

New Idria district.—The New Idria mining district lies among some of the highest peaks of the Coast Ranges, at the southern end of the Mt. Diablo Range. The views are very extensive and the scenery is picturesque, but it is in part very forbidding, the portion of the Coast Ranges lying to the northeast of the district being a mountainous desert.

The higher portion of the Mt. Diablo Range is here, as for the greater part of its length, composed of highly metamorphosed rocks of the Knoxville series. No fossils are known to occur in it here, but at the northern end of the range they are abundant, and they are found again at San Luis Obispo, to the south, in precisely similar rocks.

On the northeastern flank of the range lie the rocks of the Chico-Téjon series. These are tilted at angles averaging about 45°, but are only slightly flexed. The lower part of the series lies unconformably upon the metamorphic beds, as is proved by the structure and by the presence of metamorphic pebbles in Chico conglomerates.

The Chico and Téjon are absolutely conformable at New Idria and sedimentation went on continuously from one period to the other. Fossils are not numerous, but are present in sufficient number fully to identify the age of the rocks. Both portions of the series show many of the concretions mentioned above as due to induration by decomposing organic matter. The Téjon beds contain coal seams which were exploited on a small scale for many years.

No lava exists in the district, but there is a considerable area of basalt just north of Vallecitos Cañon, about 10 miles from the mine. There are cold sulphur springs, but no hot ones.

Next to the New Almaden, the New Idria has been much the most productive quicksilver mine in North America. The ore contains the usual mixture of cinnabar, pyrite, and quartz, accompanied by some bitumen; metacinnabarite also was found in the New Hope lode in very large quantities and in less abundance at another point in the mine. The structure is extremely complex, but typically developed stockworks, veins, and impregnations all occur. Faults and cross-courses make successful explorations very difficult and uncertain.

The ore is almost entirely deposited in Neocomian rocks, but to a small extent also in the Chico beds. The deposition has taken place since the post-Miocene upheaval and is seemingly referable to about the same period as the other deposits. The analogies point to the action of hot springs, but there is no direct proof that the solutions were of high temperature.

The San Carlos, Aurora, Picacho, and other mines which have yielded small quantities of ore lie at no great distance. In all of them the ore has been deposited in shattered rock masses of the metamorphic series. Nowhere in this region is there any evidence of the substitution of ore for rock.

New Almaden district.—The first discovered and the most productive of the quicksilver mines of North America is the New Almaden, and in the same district the Guadalupe, Enriquita, and other mines have yielded quicksilver. The district is well watered and wooded and is more attractive than any other of the quicksilver camps.

Upon highly metamorphosed rocks lie Miocene sandstones, which were sharply folded at the post-Miocene upheaval. They are not conformable with the lower series and contain pebbles from these older beds. In the older rocks near New Almaden Mr. Gabb found *Aucella*, proving the presence of the Knoxville series.

In this district is the only mass of rhyolite thus far found in the Coast Ranges. It forms a dike nearly parallel to the line connecting the New Almaden and the Guadalupe. It is almost continuous, and I have followed it for a distance of several miles. It is certainly post-Miocene and probably post-Pliocene.

The New Almaden is a very extensive mine, said to contain as much as 40 miles of galleries. Much of this length is open, and admirable opportunities are afforded for study of the ore and structure. The ore is cinnabar, with occasional traces of native quicksilver, accompanied by pyrite and marcasite, with rare crystals of chalcopyrite. The gangue is quartz, calcite, dolomite, and magnesite. These materials are deposited in shattered masses of pseudodiabase, pseudodiorite, serpentine, and sandstone. There is no deposition by substitution, and impregnations are very subordinate. Considered in detail, the ore bodies are stockworks; but they are arranged along definite fissures and the deposits as a whole have a vein-like character and answer to the "chambered veins" defined in a subsequent paragraph. The workings have developed two main fissures. One of these dips from the surface at a high angle and in a nearly straight line. The other strikes in nearly the same direction as the first, dips steeply from the surface, then flattens and approaches the first fissure rapidly, again becomes very steep, and in the lowest workings almost coincides with the first. In vertical cross-section the two fissures form a figure resembling a *V*. The great ore bodies are distributed along these two fissures, making irregularly into the walls. The wedge between the fissures also contains ore bodies. They are always accompanied by evidences of motion and by a mass of attrition products of various rocks—*clay* in a mining but not in a mineralogical sense. This clay is usually on the hanging wall and is called "alta."

The other mines of the district contained similar ores in similar rocks. The Guadalupe was the most productive, but was not at work and was full of water during my visit.

All the deposits of the district appear to occur along a rather simple fissure system. The main fissure is nearly parallel to the rhyolite dike at the Guadalupe. It follows the direction of the hills, the axis of which curves gradually away from the dike for a certain distance. Passing through or near the San Antonio and Enriquita, it seems to break across the ridge at the America and enters the Almaden on the strike of its two great fissures. It is near this fissure that new ore bodies are most likely to be found. The Washington seems to be on a branch of the main fissure.

This fissure was probably formed at the time of the rhyolite eruption, to which I also ascribe the genesis of the ore.

Steamboat Springs.—This curious thermal area lies just within the desert Great Basin, in full sight of the forests and snows of the Sierra Nevada. It is only six miles in a straight line from the Comstock lode.

Granite underlies the district and much of the area exposed is of this rock. Upon it lie metamorphosed rocks of the Jura-Trias series and lavas. Older andesites and younger asperites, described in a former paragraph, cover a large space, and there is a considerable area of basalt, which represents the last eruption.

The springs are numerous and some of them reach the boiling-point. They are unquestionably of volcanic origin and due to the basalt eruption. They reach the surface in the granite area. The flowing springs are confined at present to a small group of fissures, but steam in small quantities issues at many points in the region marked by evidences of solfataric action, and this region is substantially a continuous one. In some portions of it the sinters are chalcedony, in others they consist to a considerable extent of carbonates, and in one portion (at the mine) the deposits of sinter are insignificant in extent, the chief effect having been decomposition of granite and the precipitation of sulphur and cinnabar. In this part of the area also steam and gas still issue in small quantities.

The amount of cinnabar is considerable. The ore was mined and reduced a few years since, but mining would not pay at present prices.

Quicksilver in very small amounts is being deposited by the springs now active, together with gold and several other metals. They are dissolved as alkaline sulphosalts, as will be explained in a subsequent paragraph. The waters and gases are similar to those of Sulphur Bank, excepting that ammonia and organic compounds are absent.

The four metals most abundant in the present spring deposits, antimony, arsenic, lead, and copper, exist in the granite, but I was unable to detect quicksilver. This may be due to the small quantity of quicksilver in the average granite or, as I think more probable, to irregularity in the composition of that rock. The granite is the probable source of the mercury.

Oathill, Great Eastern, and Great Western districts.—The neighborhood of Oathill is a most interesting one and contains many quicksilver deposits within a small area. The underlying rock is of the Knoxville series, identified by the presence of *Aucella*. It is in part metamorphosed and serpentinized and in part unaltered. Andesite and basalt have broken through it.

The basalt eruption gave rise to hot springs, one of which still exists at Lidell, issuing from the workings of a now abandoned quicksilver mine. In two cases also cinnabar deposits occur at the contact between basalt dikes and the adjoining rock, forming veins. Irregular stockworks of the more usual type also occur.

The Oathill mine is the principal one of the mines belonging to the Napa Consolidated Company. It is in unaltered sandstone, the strata of which are nearly horizontal. The deposits are true veins, cutting the strata at an angle of 45°. From these veins ore bodies sometimes make out into the country, following the stratification. These are impregnations. The ore is the usual mixture of cinnabar, pyrite, silica, and calcite, and bitumen also occurs. Small quantities of barite are also found, and this is the only case in which this mineral is known to accompany cinnabar in California. It is also found at Almaden.

The Great Western lies near the extinct andesitic volcano called Mt. St. Helena. The country rock is of the metamorphic series, and both andesite and basalt have broken through it. A layer of opalized serpentine accompanies the ore-bearing ground. The ore is chiefly cinnabar, but at one point rock impregnated with native mercury was found. The cinnabar was deposited simultaneously with pyrite and quartz. The bitumen posepnyte was first described from this mine. The deposit consists of a tabular, reticulated mass connected with a fissure system and it lies at the contact between serpentine and nearly unaltered sandstone. If it does not come under the common definition of a vein, it is closely related to that class of ore bodies.

The Great Eastern lies in Sonoma County, far from other quicksilver deposits and six miles from lava. The rock is the ordinary metamorphosed material of the Coast Ranges. The ore occurs in black, opalized serpentine, which here forms a definite ledge. The ore seems, as usual, to be of somewhat later date than the formation of opal and is accompanied by pyrite, quartz, and bitumen. The ore seems to form a pipe, which is continuous from the surface to a depth of 450 feet. This pipe I believe to lie on a continuous fissure.

All of the above mines have produced important quantities of quicksilver.

Other quicksilver deposits.—So far as I know, the most northerly cinnabar deposits on the west coast south of British Columbia are in Douglas County, Oregon. In the northern part of Trinity County, Cal., there is also a mine. These widely separated deposits both lie on the northerly continuation of the middle Coast Ranges, where most of the deposits occur. From Clear Lake to Santa Barbara, as is shown on the map of California accompanying this report, the deposits are thickly scattered.

Of the very many deposits briefly described in Chapter XIII of the monograph, only a few can be mentioned here. The Manzanita mine, Colusa County, is very remarkable for the association with cinnabar of free gold, often in feathery crystals. Pyrite accompanies the ore and the gangue is chiefly quartz. There is free sulphur also, as well as other evidence that the ore was deposited by hot sulphur springs, such as still issue within a few hundred feet of the mine. There is no lava in the neighborhood. In the Stayton mines, San Benito County, large quantities of stibnite were associated with cinnabar. The Oceanic, in San Luis Obispo County, is in unaltered sandstone, supposed to be Miocene. Most of the other deposits occur in shattered rock masses of the Knoxville group, forming stockworks. In some cases they seem to be accompanied by true veins, and sufficient exploration would doubtless show a fissure system connected with each of them. The usual mineral association is the same so often described above.

On the gold belt of California cinnabar occurs in pebbles, in auriferous gravels, and in true gold quartz veins, so that there are mercuriferous gold veins as well as auriferous deposits of cinnabar. In the Barcelona silver mine, Belmont, Nev., cinnabar was found with silver ore in the vein. Cinnabar also occurs in a silver vein near Calistoga, Cal. In Idaho float cinnabar has several times been found, in some cases with a calcite matrix. A statement repeatedly made in the literature reads as if this ore had been found in place in Idaho, but this is not the case. In Utah, near Marysville, a deposit of the selenide of mercury, tiemannite, was being mined and reduced early in 1887. So far as I know this is the only case in which this mineral has been found in sufficient quantities to form the basis of commercial exploitation. None of the other deposits requires special mention in this abstract.

GENERALIZATIONS.

DISCUSSION OF THE ORE DEPOSITS.

The general results of the observations on the various mines are discussed in Chapter XIV of the monograph. Microscopical examination of the ores shows that cinnabar is usually deposited in immediate contact with quartz, and that, though opal and chalcedony are frequently found very near the particles of cinnabar, there is seldom, if ever, actual contact. More rarely the cinnabar is directly embedded in calcite. The evidence of the microscope also goes to prove that the ore is always deposited in fissures in dense rocks or in the interstitial spaces of porous sandstones. Macroscopically the same conclusion had been reached. The assertion often made that cinnabar has been deposited by substitution for wall rock at Almaden in Spain is certainly incorrect, and, in my opinion, no such case has been adequately proved to exist. The only substance, excepting metallic sulphides, which cinnabar is known to replace is organic matter, and this seems to be very exceptional.

The usual mineral association consists of cinnabar and traces of native mercury, with pyrite and marcasite, silica and carbonates; but sulphur occurs at three mines, chalcopyrite is not very uncommon, stibnite is found (though rarely), gold or auriferous pyrite occurs in a few cases, millerite in a number of instances, and barite in one. These substances and their decomposition-products are rare. Excepting in Steamboat Springs, at Calistoga, and in the Barcelona mine, I do not know of silver, lead, or zinc minerals accompanying cinnabar in the western United States. A new bitumen, two new chromium minerals, and a red antimony sulphide have been detected with cinnabar in this investigation.

The great similarity of the deposits points to a common history for them all. The evidence is strong in many cases that they have been deposited from hot sulphur springs and the remainder have probably been produced in the same way. The inclosing rocks have been without effect upon the deposits, for nearly all the rocks in the Coast Ranges inclose ore bodies. These facts point to a common, deep-seated origin.

It has often been asserted that quicksilver ores do not form deposits similar to those of the ores of other metals, but I can find no evidence of this. Stockworks, impregnations, and regular veins all occur, and no other or peculiar form of deposit is known to me. Many of the discussions as to whether or not deposits are veins depend on the various uses of this word. To miners it usually means deposits along, or directly connected with, a distinct fissure; to a geologist a vein means a deposit between well-defined, nearly parallel walls which have once been in contact. Irregular bodies of ore, even those connected with distinct fissures, are known to him as stocks, stockworks, or by some similar name. I propose to call the contents of distinct fissures with very irregular walls *chambered veins*, and the irregular openings or ore bodies connected with a main fissure *vein chambers*. A chambered vein may, then, be defined as a deposit consisting of an ore-bearing fissure and of ore bodies contiguous with the fissure, but extending into the country rock. The greater part of the cinnabar deposits would come under this definition, which would also apply to many deposits of other ores. If this term were adopted, simple fissure vein would still describe the form of deposits now known to mining geologists as veins.

SOLUTION AND PRECIPITATION OF CINNABAR AND OTHER ORES.

The waters of Steamboat Springs are now depositing gold, probably in the metallic state; sulphides of arsenic, antimony, and mercury; sulphides or sulphosalts of silver, lead, copper, and zinc; iron oxide and possibly also iron sulphides; and manganese, nickel, and cobalt compounds, with a variety of earthy minerals. The sulphides which are most abundant in the deposits are found in solution in the water itself, while the remaining metallic compounds occur in deposits from springs now active or which have been active within a few years. These springs are thus actually adding to the ore deposit of the locality, which has been worked for quicksilver in former years and would again be exploited were the price of this metal to return to the figure at which it stood a few years since. At Sulphur Bank ore deposition is still in progress. The waters of the two localities are closely analogous. Both contain sodium carbonate, sodium chloride, sulphur in one or more forms, and borax as principal constituents, and both are extremely hot, those at Steamboat Springs in some cases reaching the boiling-point. In attempting to determine in what forms the ores enumerated can be held in solution in such waters, it is manifestly expedient to begin by studying the simplest possible solutions of the sulphides, and particularly of cinnabar.

The statements in the previous literature of this subject are incomplete and in part discordant, so that the subject required reinvestigation, particularly as to the sodic solvents. It was found that, provided a small quantity of sodic hydrate be present, one molecule of mercuric sulphide unites with two molecules of sodic sulphide to form a freely soluble sulphosalt and that an excess of sodic hydrate is without effect upon the solubility. Even when sodic hydrate is entirely absent, mercuric sulphide is freely soluble in aqueous solutions of sodic sulphide, though the contrary has repeatedly been asserted; but either one molecule of mercuric sulphide then unites with three of sodic sulphide, instead of two, or a mixture of sulphosalts nearly corresponding to this compound is formed.

Sodic sulphydrate when cold is absolutely without effect upon mercuric sulphide, but when the mixture is heated on the water-bath the sulphydrate is decomposed and sodic sulphide is formed; it unites with the mercuric sulphide in the proportion of four molecules of the former to one of the latter. A perfectly limpid solution results. The same compound is produced when mixtures of sodic sulphide and sodic sulphydrate are brought in contact with mercuric sulphide. The presence of sodic carbonates diminishes the solubility of mercuric sulphide, but does not prevent solution. Ammonium carbonate completely prevents solution at temperatures below the boiling-point, but not at 145° C.

These facts suffice to lead to important conclusions with reference to spring waters, such as those mentioned above. When neutral sodic carbonate is treated with sulphydric acid at ordinary temperatures, sodic sulphydrate forms. At temperatures approaching the boiling-point, it is probable that a certain quantity of sodic sulphide is also produced. At these higher temperatures either of these sulphur compounds will dissolve cinnabar, and the presence of sodic carbonates will not prevent solution. These conclusions were amply verified by direct experiments.

Mercuric sulphide may be wholly or partly precipitated from solutions of the sulphosalts in many ways: by excess of sulphydric acid or of other acids, by borax and other mineral salts, by cooling (especially in the presence of ammonia), and by dilution. In the last case a certain quantity of metallic quicksilver, as well as mercuric sulphide, is formed, and this is very probably one of the methods by which native quicksilver has been produced in nature.

Metallic gold, iron pyrites, cupric sulphide, and zincblende were found to be soluble in solutions of sodic sulphide and in solutions of the carbonates to which sulphydric acid had been added. All of them appear to form sulphosalts with the alkaline compound. It has long been known that sulphides of arsenic and antimony are soluble in sodic sulphide. They also dissolve in mixtures of the carbonates and sulphides of sodium.

Natural solutions of sodic carbonates and sulphides, which are common components of hot spring waters, are thus capable of dissolving at least five of the principal metals, as well as sulphur, arsenic, and antimony. Combinations of these elements form a large part of the minerals found in mines. There is little or no doubt that the cinnabar of the California deposits has been dissolved and precipitated as indicated above, and that at least a part of the gold of that State has been produced in a similar manner, but I by no means assert that natural deposits of cinnabar and of gold have never been produced in any other way.

ORIGIN OF THE ORE.

There is the strongest evidence for the supposition that the cinnabar, pyrite, and gold of the quicksilver mines of the Pacific slope reached their present positions in hot solutions of double sulphides. Either the metals must have been leached from the granite or they were derived from an infragranitic source, for examination of the conditions of occurrence shows it utterly improbable that they were extracted from any volcanic rock at or near the surface, while the sedimentary strata of the region are composed of granitic detritus. No one fact or locality absolutely demonstrates whether the metals were originally components of the granite or came from beneath it, but the tendency of the evidence at all points is to the supposition that the grainte yielded the metals to solvents produced by volcanic agencies, and when all the evidence is considered together it is found that this hypothesis explains all the known circumstances very simply, while the supposition of an infragranitic origin leads to numerous difficulties. Though no one of these may be in itself inexplicable, when taken as a whole they appear to me to be so. Had solutions of quicksilver been formed in company with other products at the foci of volcanic activity, cinnabar would often be met with in craters. Though it is often found associated with volcanic effects, it perhaps never occurs in craters. Were the solutions formed below the granite, ore deposition would also almost certainly take place in part within the granite, and most ore deposits would continue down in that rock, probably growing richer with increasing depth. On the other hand, the distribution of the deposits relative to volcanic vents is such as would be anticipated if the ore were known to be leached from the granite by hot waters of volcanic origin. The varying richness of the different deposits also corresponds to the irregularity in the composition of the granite and in the extent of surface exposed along the underground passages through which the waters must have reached the surface. Finally, at Steamboat Springs, at least, the composition of the granite answers to that of the deposits of springs which are still depositing small quantities of quicksilver. It thus seems fairly certain that the quicksilver and gold are derived from the granite. I entertain little doubt that many of the gold veins of California have a similar origin, while others have probably been produced by the action of cold surface waters.

THE GEOLOGY

OF THE

ISLAND OF MOUNT DESERT, MAINE.

BY

NATHANIEL SOUTHGATE SHALER.

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GEOLOGY OF MOUNT DESERT.

By Nathaniel S. Shaler.

INTRODUCTION.

The following report on the island of Mount Desert presents in outline results of certain geological studies which were undertaken on that area for the purpose of determining what light they might throw on the recent changes of level of the Atlantic coast line. As the inquiry demanded a somewhat careful study of the general geology of the district, it seemed worth while to present in brief form the principal or at least the more evident points concerning its general structure.

A good deal of fragmentary work has been done upon the geology of Mount Desert, but as these various studies have little reference to the subject-matter of this report, it has not seemed desirable to accompany it with a bibliography.

This charming island is now much resorted to by persons who feel an interest in the structure of the earth and who have leisure which they may devote to such inquiries. It may be hoped that this sketch of its general geology may prove of service to beginners in the study of geologic phenomena. It will be at once apparent to a professional geologist that this report affords a very inadequate discussion of the greater part of the important problems which are presented by the structure of the region. Very many matters of importance presented by the geology of the district are not yet ready for discussion; they demand far more extensive inquiry than they have yet received. Thus, for instance, the microscopic structure of these rocks which present many points of greatest interest must remain unstudied until the inquiry can be undertaken for all the region in which the island lies.

Properly to gather the facts concerning the various elevated sea benches of this island would require not less than a year of careful field labor. The total time at my disposal for all the work done upon the island was less than three months.

It is to be hoped that individual students will undertake a careful study of this island and a comparison of its structure with that of the neighboring shores.

I am indebted to the gratuitous labor of Mr. Samuel Storrow, of Boston, Mass., for the photographs used as the basis of the illustrations of this report.

I. SURFACE AND GLACIAL GEOLOGY.

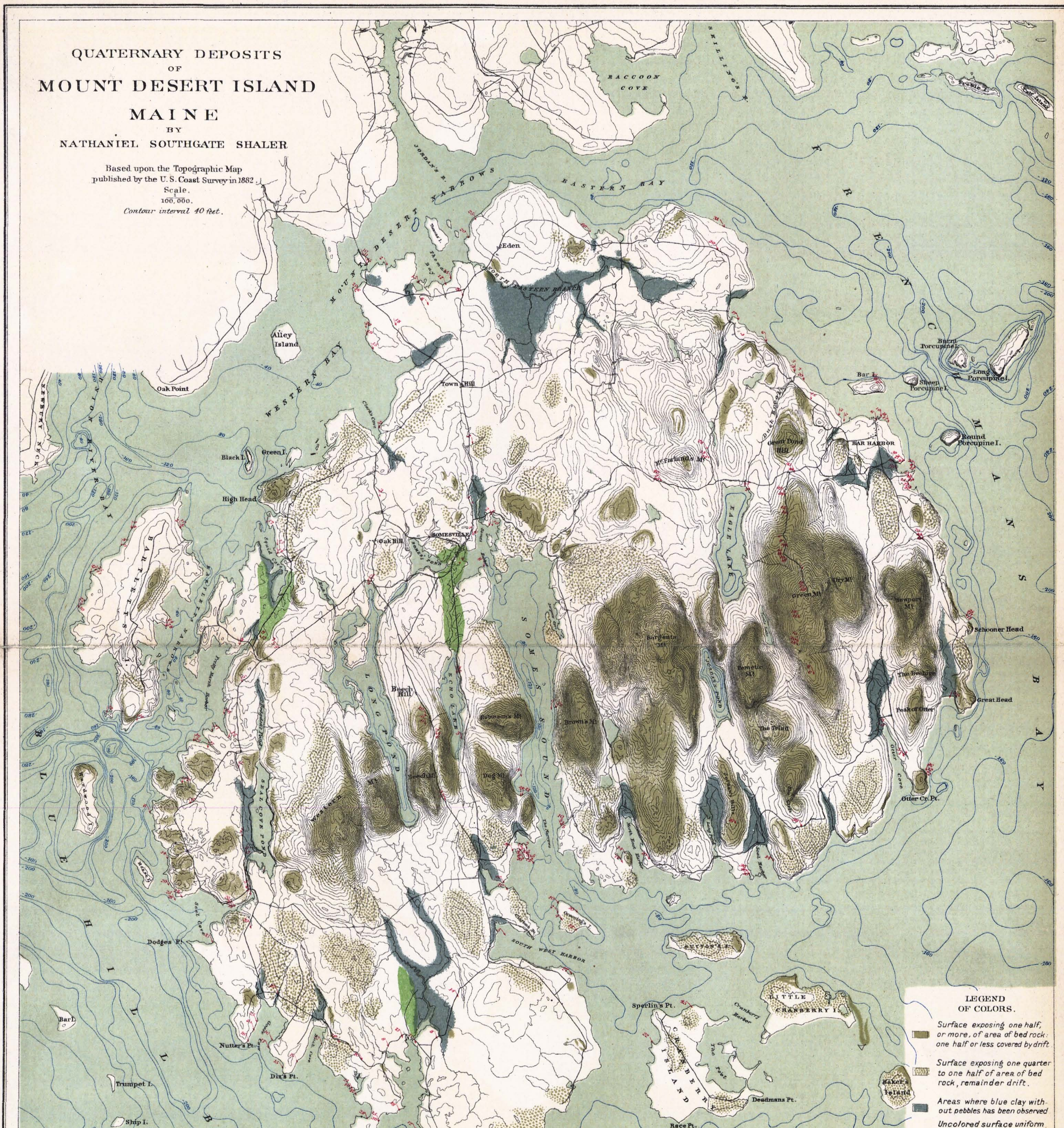
DESCRIPTION OF THE SURFACE.

The surface aspect of any district gives the observer a clew to some of the most important features of its physical history. The latest geological accidents which have affected it are in most cases clearly recorded on its superficial parts and the greater portion of the changes which it has undergone are in some way indicated by the existing surface. We will therefore begin an account of the geology of the island by a statement concerning its superficial aspect and structure.

As will be seen from the inspection of any good map of the shore of New England, Mount Desert is one of the largest of the several hundred islands that lie along that coast. A geological map will show that it is the largest that is composed of ancient or of highly metamorphosed rocks, the single larger isolated mass, Long Island, New York, being composed of incoherent glacial waste. It is evident that the geological conditions of this shore have not favored the production of large islands such as abound along the shores of the Old World. Although rocky isles occur plentifully along the coast of the United States from Massachusetts Bay to the eastern limit of Maine, they are rarely more than ten square miles in area; Mount Desert alone exceeds these dimensions, its area being about one hundred square miles.

This peculiarity of size which distinguishes Mount Desert so strikingly from the other isles of the fiord zone of the New England coast is connected with another feature of the mass which will be made evident by the accompanying illustrations. Mount Desert is much the loftiest part of the eastern coast line of the United States. While no other island of this shore has a maximum height of more than about five hundred feet or an average altitude of more than a hundred feet, Mount Desert rises at one point to the height of 1,527 feet and has an average elevation above the sea of almost five hundred feet. The only other large island on the coast whose maximum height nearly equals the average of Mount Desert is Isle au Haut, which lies a few miles to the west of Mount Desert.

It will be shown in the second part of this report that these peculiarities of the islands of the eastern coast are due to the geological structure of the region in which they lie. They are the remains of the old mountains which once occupied these shorelands and their size has been determined by the shape of the ridges which have been carved into islands by the action of the glaciers, the sea waves, and



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the atmospheric agents of erosion. Leaving this question for the present we turn to the details of form exhibited on the island itself.

Although differing from the neighboring islands in size and altitude, Mount Desert has a general outline which is in no way peculiar. Like all other large islands of the shore, its coast is much indented and is bordered by lesser islets.

As the contour lines of the map indicate, the coast belt of Mount Desert lies generally against a region of relatively low land. The sea cliffs of the coast at no point attain an altitude of much over one hundred feet, and within a half mile of the sea-shore there are few points which exceed three hundred feet in height. On the southern part of the island, south of a line drawn from Norwood's Cove[1] to Seal Cove, and on the northern face of the island, north of a line drawn from Bar Harbor to Pretty Marsh Harbor, the surface is generally of low elevation, the average height of the bed rocks not exceeding one hundred and fifty feet above the sea level. The central part of the island rises steeply from this plain to the mountain heights, which are its most characteristic feature.

The mountain ridge of Mount Desert is in many ways the most interesting elevation on the American coast. Its contour is eminently peculiar in that it consists essentially of a single axis of elevation, the summits of which differ a little in height and are placed in a very uniform and continuous alignment. The direction of this range is about N. 65° E. (true meridian). There are several other similar axes along the New England shore, but none of them have anything like this accurate linear arrangement of their elevations. This mountain mass of Mount Desert has a width proportionate to its height. In the meridian of Green Mountain, where the height rises to 1,527 feet, the width of the ridge may be taken as about four miles; while on the western section, that to the west of Somes Sound, where the peaks

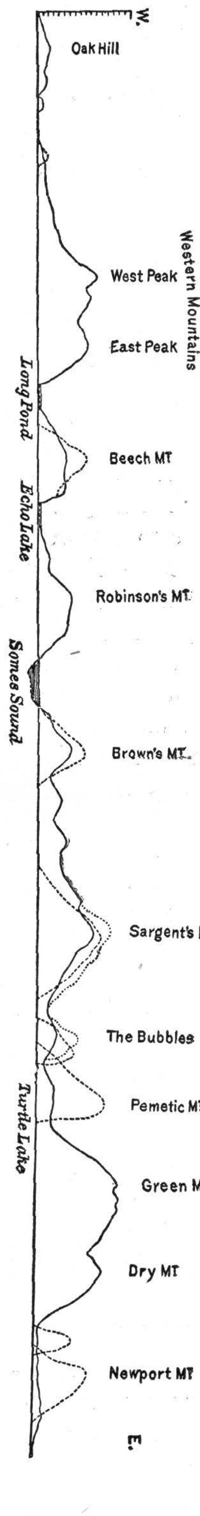


Fig. 23. Section through Mount Desert Island, from Seal Cove to mouth of Bear Brook, via Echo Lake.

[1] The deep inlet north of Clarke's Point.

rise to only 1,000 feet above the sea, the width of the mountain range is not much over two miles.

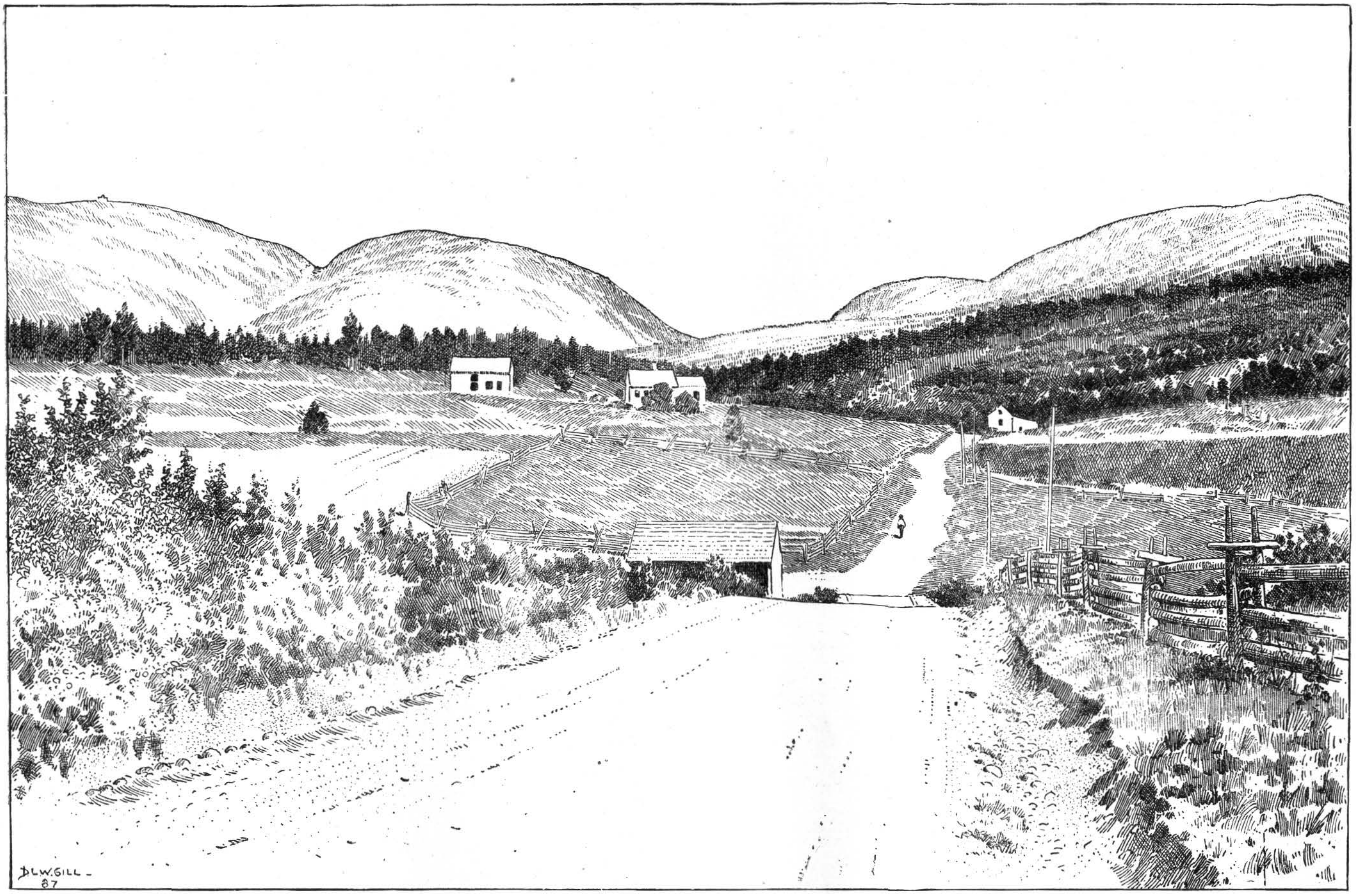
Although the exact alignment of this ridge and its singular uniformity of structure make it tolerably certain that the whole of it was originally united, it is at present made up of sharply detached mountains, separated from one another by ravines which at several points descend below the level of the sea. The general appearance given to the area by this depression may be judged from Fig. 23. Several of these basins are occupied by fresh-water lakes, viz, Turtle Lake, Jordan's Pond, Hadlock Ponds,[1] Echo Lake, Long Pond, and Seal Cove Pond. (See, also, Plates LXV–LXVIII.) One of them, which lies between Newport Mountain and Dry Mountain, contains a deep marsh which was recently covered by a considerable lake.

It is evident that inasmuch as some of these troughs are occupied by deep bodies of water, the actual relief of the mountains is much greater than appears on the map; were these lakes drained the apparent height of the mountains above their bases would be from one to two hundred feet greater than now. Looking more closely we perceive that each of these depressions has a continuation in the form of a valley on the north and on the south, which extends far beyond the border of the mountain elevation, terminating obscurely on the north in the lowlands, while on the south it is more or less clearly continued to the sea, appearing there as a curve or indentation of the shore.

The depression between Newport Mountain and Dry Mountain is continued in the Otter Creek Valley to the cove of that name (see Pl. LXV). The basin occupied by Jordan's Pond extends down to Seal Harbor (Pl. LXVI); that of the Hadlock Ponds to Northeast Harbor. Somes Sound, the greatest of these troughs, extends from the northern plain to the open sea south of the island. The valley of Echo Lake is continued to Norwood's Cove (Pl. LXX). The profound depression of Long Pond extends southward as a shallow trough to Bass Harbor, and that of Seal Cove Pond is obscurely continued, its valley being much masked by glacial drift to the coast indentation known as Seal Cove.

These depressions occupied by the lakes are in fact channels extending from the northern plain district of the island to the southern shore. They are deepest among the highest mountains, and slope upward for some distance either way from the middle portion of the central ridge. This is obvious from the soundings of Somes Sound, which is deepest between Brown's and Robinson Mountains, shoaling both to the north and to the south from that point. This eminently peculiar structure has light thrown upon it by the facts connected

[1] Hadlock Upper Pond, Hadlock Lower Pond, east and southeast of Brown's Mountain.



COVE CLAY, WITH FAINT ELEVATED SEA MARGINS, AT OTTER CREEK.

with the glacial history of the district, which will be considered in the next section of this report. (See Plate LXIX.)

A study of the detailed topography of Mt. Desert shows us that all the considerable irregularities of its rock surface have the same type of north and south trends, and that, to a certain extent, the form of the islets on its border is also related to the excavating work of the glacial period.

Thus, though the principal axis of the island has a general east and west course, the valleys are nearly at right angles to its trend. The principal axis of the mountain range extends from N. 65° E. to S. 65° W.; the valleys on the average trend from about N. 10° W. to S. 10° E. It is obvious that the creation of such deep valleys in what was once a strong barrier mountain ridge is a matter which demands explanation.

The sections given herewith will show the general form of the more important of these valleys. It will be perceived that while their north and south slopes are extremely gradual the east and west sections are remarkably steep.

In the hills the surface of the bed rocks is generally arched in broad, low curves, such as are naturally formed by the action of the glacial ice on substances of tolerably uniform hardness. The exceptions to this uniformity of outline are found at certain heights where there are steep cliffs extending in the form of narrow belts along the hill-sides; below each of these belts of cliff there are extensive accumulations of angular and subangular fragments derived from the cliffs. The origin of these benches will be considered below.

DESCRIPTION OF THE SUPERFICIAL DEPOSITS.

The covering of soil and drift material is distributed with singular irregularity. The mountains above the level of 400 feet, though often forest clad, have very little soil and this is accumulated in irregular patches between the more projecting points of the bed rock. This soil is in small part matter arising from the very slight decay of the rocks which has taken place since the glacial period, but it is mostly composed of the remains of the till or bowlder clay which was left on the surface at the time the glaciers retreated from this region. As we shall hereafter see, the greater part of this material was swept away from the uplands during the period of deep submergence beneath the ocean, which occurred immediately after the greatest extension of ice.

Below an altitude of 600 feet the amount of debris and consequently the continuity of soil increase rapidly. Below the level of 400 feet, the surface, except the slopes, which have an angle exceeding ten degrees of declivity, is generally deeply mantled in drift which, in all cases where observed, was found to be irregularly stratified.

These drift deposits at the higher levels, that is from 400 to about 600 feet, consist of pebbles and sand with but little clay; below that level the clay deposits become more common and at the level of 100 feet above the sea they occupy a large part of the principal valleys, superseding the coarser materials. These clays are peculiarly distributed; they are usually, if not always, confined to the valleys of the shore line. Thus, as is shown on the map indicating the surface geology, each cove of the shore has about its head as well as upon its bottom a more or less extensive sheet of clay, which on the surface is generally of a brownish color due to weathering, but at a depth of from a few inches to two or three feet is of the blue color common to all the deeper parts of the stratified glacial clays of New England. These clays on Mount Desert are always obscurely bedded and contain occasionally small pebbles evidently of glacial origin. They are sometimes found beneath a layer of till, as is shown in Fig. 27. Up to the height of about 100 feet above the tide they afford a few beds of marine fossils belonging to species common in clays of this age along the shore from Massachusetts Bay to Eastport and beyond. These beds of Leda clay, as the fossiliferous deposits of post glacial age have commonly been termed, are connected at their margin with the deposits which are now forming in the coves of the shore. Precisely similar clays are depositing in all these coves, and the accumulations are in every respect indistinguishable from those found in the lower levels of the Leda clay at Seal Harbor, between Northeast and Bar Harbors (Pl. LXVI). The fossiliferous clay discovered by my assistant, Mr. Henry Brooks, on the shores of Seal Harbor, about ten feet above the highest tide, so retains its marine character that even the odors given off by the decomposition of organic matter are still precisely the same as those produced from the mud on the flats now exposed at low tide at that locality.

At present these clay deposits are forming only in the inner parts of the coves of the coast, for the reason that there alone is the tidal movement so slight that the finer mud washed out of the glacial drift or formed by the grinding of stone on the beaches can be laid down. On the headlands these clays are not forming at the present day, nor did they form on such points in the past, because wherever the tide produces currents of moderate swiftness the mud is borne away from the shore and falls in the deeper water outside.

The surface of these clays usually forms a tolerably gentle slope leading down from the highest point where they occur to the present shore, though there are occasionally obscure indications of sea scarfs at various points on this generally continuous incline. There are reasons for believing that below these clays, and in most cases below the stratified sands also, there are sheets of the unstratified till which is normally the lowest of the glacial deposits in this dis-

SEAL HARBOR, SHOWING THE STRATIFIED DEPOSITS OF THE COVE.

trict; the whole series of beds having the relations to each other shown in the appended diagram. (Fig. 24.)

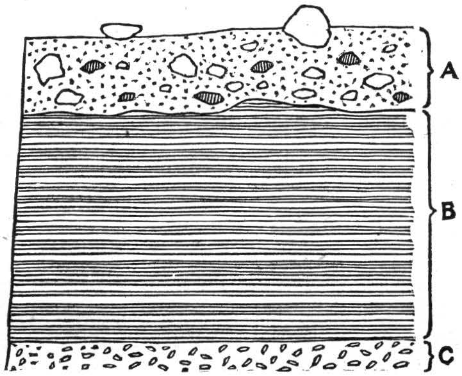


FIG. 24. Diagrammatic section showing relations of clay and till. A, recent drift; B, stratified clays; C, old till.

The blue clays on the northern shore of Mount Desert are much more extensively distributed than are the similar deposits on the southern coast; they there underlie nearly the whole surface which is below the level of 100 feet in altitude and, as would be expected, the deposits of clay now forming are also much more widely diffused than they are on the tide and wave-swept southern shore (Fig. 27). These clay deposits are even thicker and more continuous on the neighboring mainland than they are on the island of Mount Desert. The several promontories to the north, shown on the map accompanying this report, are so thickly covered by this sheet of stratified clay that they afford little indication of the underlying rocks, it often being impossible to find a single outcrop in a surface containing several square miles of area.

Thus the drift deposits of the island have great simplicity of structure. With trifling exceptions, shortly to be noted, they are composed of a thin sheet of bowlder clay containing relatively few large erratics, a set of stratified sands and gravels mostly lying between 200 and 400 feet of altitude, and a set of stratified clays, occasionally pebbly, extending from the height of 200 feet down to the sea level.

Where this clay does not exist the surface of the low lands is generally covered by a stratum of true till or bowlder clay lying immediately upon the bed rock. There are few sections which exhibit this till to advantage; from them it appears that the lower part of the deposit is almost always of a very clayey nature on the surface, though at some points it is altogether composed of bowlders and sand.

On first inspection it seemed to me that there were no deposits of kame drift on the island, but on carefully reviewing the ground it appears that there are a few patches of glacial drift of a nature which

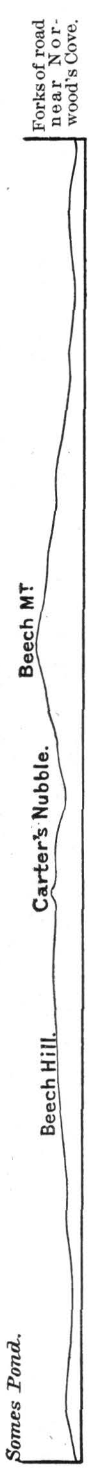


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Fig. 25. Profile of Beech Hill and Beech Mountain.

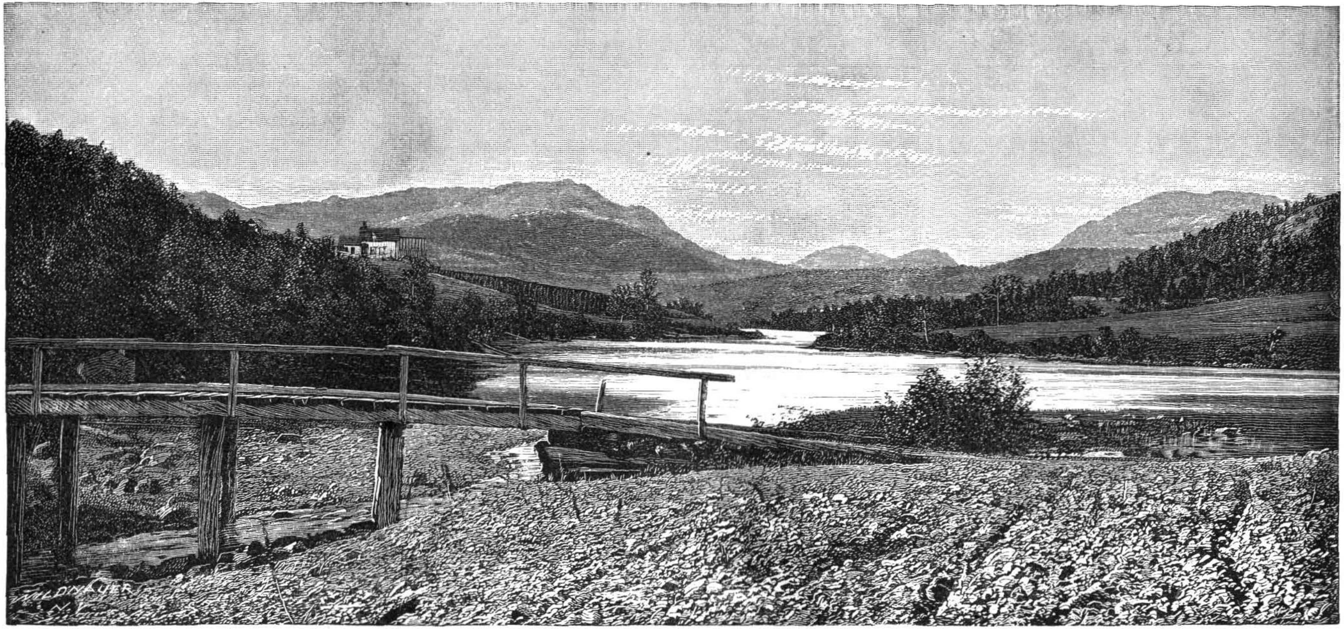
must be referred to that class of structures. As is shown on the map, there are certain points on the island where kames occur in a tolerably recognizable shape. One of these is on the western shore of the shallow fiord at the head of Bass Harbor—the southern part of the valley in which lies Long Pond; the other is on or near the isthmus which connects the peninsula known as Pretty Marsh with the main-land. At these two points there are considerable accumulations of pebbly sands more or less commingled with clay, having the form of ordinary kames of the hummocky type. As usual, these deposits have been utilized for burial places by the inhabitants of this district, for the reason that they are better fitted for such a purpose than the accumulations of till or clay.

Faint traces of similar gravel heaps may be observed on the shore near the narrow part of Somes Sound and at the southern border of Jordan's Pond, but at these last-named points the deposits are too obscure to be certainly classed as kames.

The scanty development of this class of deposits is the most striking feature in the surface structure of Mount Desert. The reason for this peculiarity will be considered when we endeavor to unravel the history of this island during the glacial period. We shall then see that these kames have probably been to a great extent buried beneath the gravels which have been washed from the region of the upper hills.

There are no distinct lenticular hills or drumlins, that other type of puzzling drift structures which abound in southern New England. Yet there are certain accumulations of drift which remind the observer of those hills and which deserve careful notice. These deposits are found only on the northern side of the mountain axis, where they appear as long tails of bowlder clay extending north and south, leading from the height of about 400 feet down to the height of about 200 feet above high tide. By far the most conspicuous of these is known as Beech Hill. It lies between the valleys of Echo Lake and Long Pond (Fig. 25). When seen from a distance east or west it looks to the observer like the northern half of an ordinary lenticular hill, its summit resting against the steep rocky mount on the south known as Carter's Nubble.[1] A good idea of

[1] Between Beech Hill and Beech Mountain.



LITTLE LONG POND, FROM SEA WALL OF BRACEY'S COVE.

its form may be gained from the regular contours which describe its surface on the map and the accompanying diagram taken from photographs, showing its aspect as viewed from the eastern side of Echo Lake, but it is not possible to give a sufficient idea of the extreme beauty of its regular semi-arch lying in the midst of a landscape of rugged and rocky hills. The form of this ridge is singularly regular; it is apparently composed altogether of till; no exposures of underlying rock project from any part of its evenly curved surface, except near its extreme southern end. (See Fig. 25.)

FIG. 26. Section showing position of the Leda clays.

It is possible, however, that Beech Hill may consist of a relatively thin coating of drift, twenty or more feet thick, lying upon a smoothly rounded mass of syenite. This view is made the more probable by the fact that the other similar tails extending from the mountain to the northward, though drift covered, have sufficient irregularities of outline to show the bed rock, and from such exposures of the smoothly rounded syenite it is certain that the coating of glacial waste which rounds their outlines is relatively thin. Therefore, I am driven to conclude that these semblances of lenticular hills are in fact only the familiar tails of drift known in all mountain countries over which the glacier has swept.

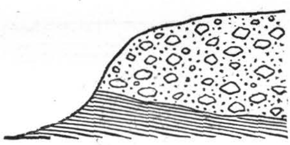


FIG. 27. Section showing stratified clay overlaid by till.

It is hardly too much to say that the whole northern slope of Mount Desert is an instance of tail structure, and that these ridges, such as Beech Hill, are only the accented portions of this accumulation. In passing it may be noted that these accumulations of glacial drift on the northern slopes of elevations which have a considerable east and west extension are noticeable in other parts of New England, especially in the region north of the White Mountains.

There is another class of glacial materials which is imperfectly represented on Mount Desert. This is the group of frontal moraines; of these there are but faint traces. Large bowlders are relatively rare, and at but few places are they accumulated in any great quantity in the heaped form characteristic of true frontal moraines. The most characteristic of these is found at a point just west of Sargent's Neck to the north of Brown's Mountain, on the east side of the road which runs from Northeast Harbor to Somesville. Here there is a heap of bowlders characterized by the roughly rounded outlines of the individual fragments so common in erratics composed of the crystalline rocks of this district.

These bowlders, no one of which exceeds ten feet in diameter, are massed in rude heaps. As a portion of the erratics is of materials from the north of the island, and as the whole accumulation has the general structure belonging to frontal moraines, it seems necessary to place it in this category. Its only eminent peculiarity is found in the fact that it is the sole deposit of the sort which I have found on the island, though other similar heaps in the forest-clad recesses of the valleys on the northern slope covered over with decayed vegetation may have escaped observation.

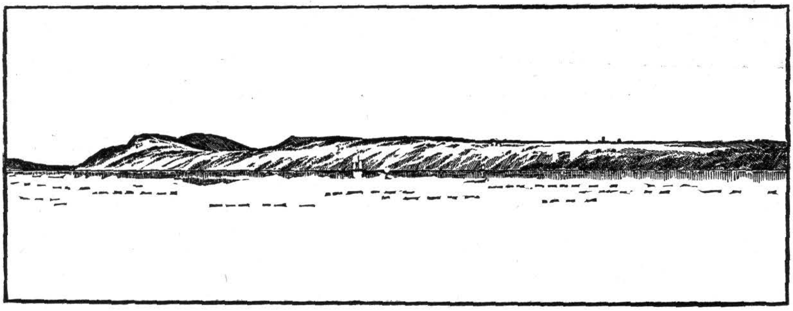


FIG. 28. Beech Hill from east side of Echo Lake.

It is noteworthy that the bowlders on this island are remarkably small, and their size diminishes as we go from the northern to the southern portion. South of the mountain range bowlders six feet in diameter are extremely rare, and none were observed with a diameter exceeding eight feet. North of the ridge they become noticeably larger, and on the extreme northern shore occasional specimens up to twelve feet in diameter may be found.

GLACIAL ACTION.

We have now completed the general account of the surface and superficial deposits of this district at least so far as to obtain a basis for further discussion. We will therefore turn to the glacial history of the district during the last ice time.

DIRECTION OF GLACIAL MOVEMENT.

First, let us consider the depth of the ice sheet and the direction of its movement during the several stages of glacial time. The only direct evidence as to the depth of the glaciers is derived from the fact that on or near the summit of the highest peak, as indicated on the map, glacial scratches show that the ice flowed, as is usual in this district, towards the south or southeast. There can be no question that the ice covered the hills to their summits; and that it

VIEW FROM McFARLAND'S MOUNTAIN, LOOKING SOUTHWARD.

was deep upon the tops of the highest peaks is shown by the large amount of erosion which is exhibited not only by the scratches but by the deeply channeled surface and the powerful effects of shock and lee action on projecting masses of rock. As to the direction of the ice movement, it is best exhibited on the lowlands, where the scratches are most numerous because they are better preserved. On the summits of the hills where the rock has been exposed to the weather it is extremely difficult to discern the glacial grooves. It is often necessary to scrape away the accumulations of earth in the shallow basins in order to obtain any trace of them. This is a tedious and difficult process and I was able to effect it at but few points, as will be seen from the map. The ice movement on the lowlands has been pretty well determined. The facts concerning this motion are very curious, and they show that the direction of movement was greatly influenced by the outlines of the surface. The map shows that there is a comparatively wide diversity in the direction of the scratches on points which are but a little distance apart. In a measure this diversity in direction is clearly due to the great ease with which the particles of ice at the base of the glacier in this district moved over and past one another. By the inspection of any slightly irregular surface we can see that the direction of the flow was changed by even trifling alterations of the surface contours of the bed rock over which the movement took place. It was often noticed in the course of the observations made for this report that a difference of ten degrees in the slope of the surface over which the ice moved, provided the slope was not at right angles to the path of its movement, would make a perceptible difference in the direction of the scratches. Therefore the effort was made to record only those grooves which occur on plane surfaces or on slopes inclined in the trend of the glacial motion, all others being regarded as untrustworthy and only useful as indications of the wide departure from the normal direction which peculiarities of surface might induce. Even with this care it is not likely that errors have been excluded from the determinations. On the same surface, crossing each other in fact, the scratches often exhibit, as before noted, a very wide range of direction. They often show a divergence of as much as 30° of azimuth. Such differences are not surprising if we remember that a mass of glacial ice when in motion is subjected to a constant succession of variations in the resistance to its motion, both from the formation of fissures in the ice itself and from the breaking away of points of the rock which may have perturbed its flow.

These facts make it plain that we must take great care to base any considerations derived from the direction of these scratches upon numerous observations selected with a view to avoid the above-mentioned sources of error. We may be assured moreover that a certain amount of error will enter into our calculations even if the observations are most carefully guarded. Judged by these conditions the following statement may be made concerning the glacial movement on the island of Mount Desert.

First we note that on the mainland north of the island numerous observations show that the glacial trend has the general direction common to this district of about 40° west. When we go southward across the channel which separates the island from the mainland we find at or near the site of Thompson's Island,[1] or in the middle of the north section of Mount Desert, considered with reference to the glacial flow, a partial division of the glacial current into two streams. The ice east of this line inclines eastward while that west of it turns still farther westward. We might therefore conclude that the mountain mass of the island began to influence the current even at this distance from its principal ridge. It is, however, possible and indeed probable that this disturbance near Thompson's Island came from the obstacle which the steep shore itself offered to the direct course of the ice stream, and that the ice at the bottom of the glacier was led eastward and westward by the deep channels in which lie the fiords which inclose the island.[2]

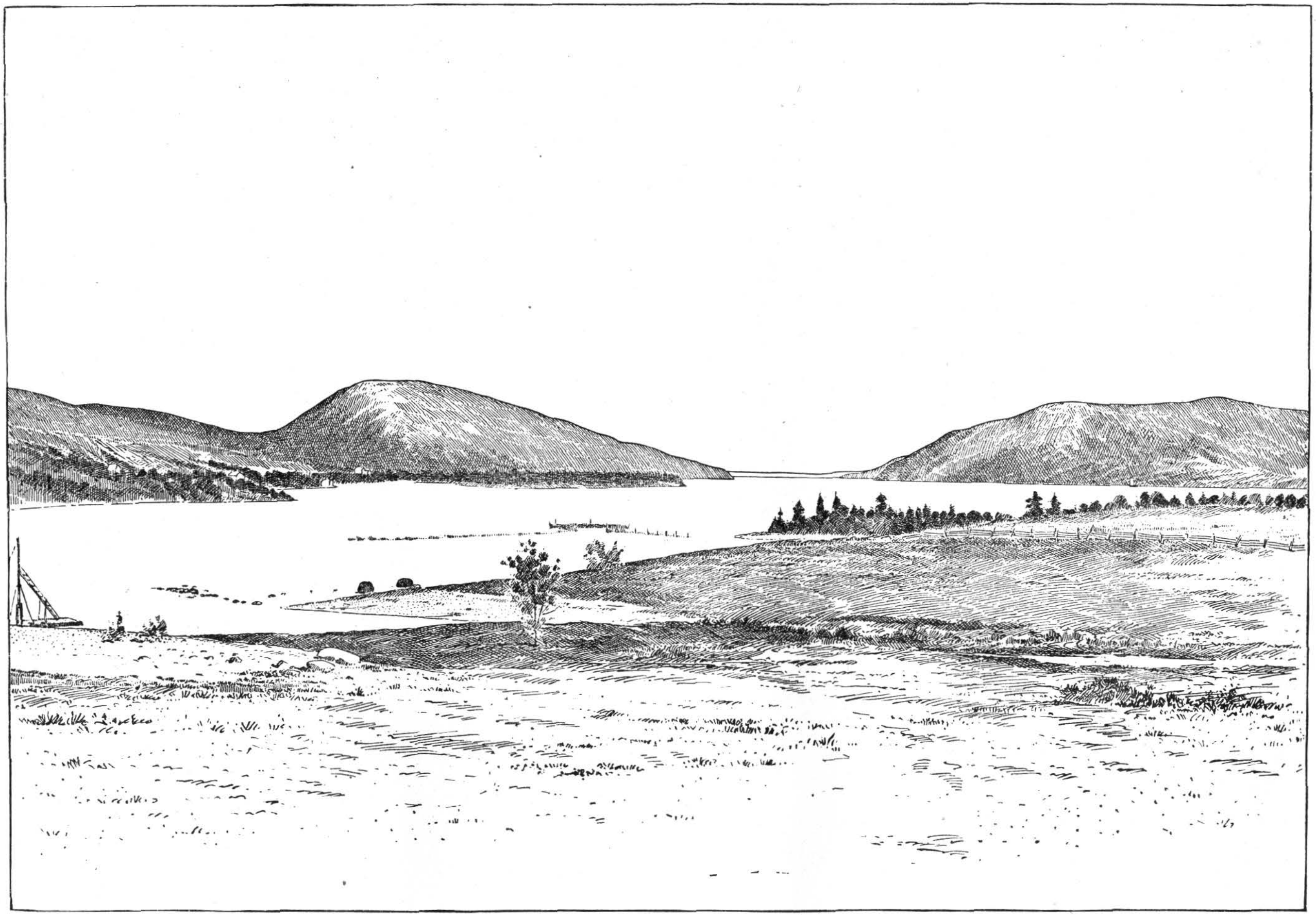
If from the parting line near Thompson's Island, we follow the scratches along the shore lines, we find that the above-described directions of flow continue southward on the east and west sides of Mount Desert until we pass by the line of the principal mountain axis. On the western side the direction is continued to about as far south as the middle of Seal Cove Pond, at which point are seen indications of a change in the direction of the flow.

A little farther south, as is shown on the map, there was an important eastward deflection of the stream. On the coast line this alteration in direction is slowly accomplished, the change of 40° in direction taking place in about a mile and a half. A mile inland to the eastward, on the shore of Seal Cove Pond and close to the western end of the mountain range, the westerly course persists to a point due south of the mountain axis. When we turn eastward a change in direction is made with singular suddenness, a variation of 30° being brought about in a distance of not over 500 feet in the direction of the glacial flow. South of the mountain axis on the west side of the island all the scratches have an eastward trend.

On the east shore of Mount Desert, starting again from Thompson's Island, we perceive a decidedly eastward trend of the scratches along the whole shore-line, except in some few cases which are probably due to local accidents of surface, until the eastern border of the mountain range is passed, when these grooves turn sharply westward, making a change of about 40° from their previous course. This di-

[1] In the western part of Mount Desert Narrows, crossed by the road to the mainland.

[2] This feature was first noticed by Louis Agassiz and is described in his "Glacial Phenomena in Maine." Atlantic Monthly, vol. 19, 1866, p. 283.



VIEW OF SOMES SOUND, LOOKING SOUTHWARD FROM NORTH END.

rection is maintained for two miles or more to Otter Cliff, where the course is about the same as on the western shore.

On the west side of Otter Creek Point there is a considerable change in the direction of the ice movement, the stream trending about 15° farther to the east than on the opposite slope of this narrow peninsula. Thus we see that there was a manifest tendency of the moving ice to divide on the north of the island and to join the divided streams on the south. The general eastward flow proper to this portion of the coast makes the westward turn on the east flank of the island less evident than the eastward turn where the ice rounded the westernmost border of the mountain range.

The same tendency to divide which was manifest in the ice on the north shore near Thompson's Island is seen, though less distinctly, on the northern section of the island as far south as the foot of the mountains. The axis of the great trough of Somes Sound is the dividing line of the current; through this deep valley which, as will be seen from the map, divides the island into very nearly equal halves, the ice flowed parallel to its boundary walls. On escaping from the south end of Somes Sound the ice stream turned sharply eastward, resuming the general course proper to this region.

As before remarked, the parting of the ice stream when it encounters a barrier is seen in a small as well as in a large way. Indications of it are perceptible on Bartlett's Island, the largest of the marginal islands of Mount Desert. There the scratches divide on the pointed northern end of the island, those on the western shore having a course of about 60° more to the west than those which are found on the eastern shore.

It should be understood that these statements concerning the flow of the ice relate only to its motion on the surface of the underlying rocks. There is no reason to believe that these diverse movements existed in the upper portion of the ice sheet, the surface of which probably pursued a uniform southerly course quite independent of the variations due to the irregular form of the ground over which its lower parts moved.

GLACIAL SCULPTURE.

We may now consider the effect of the action of the ice on the surface over which it moved and the association of these effects with the other forms of water action, viz, those which operate through the rain, frost, and sea waves. These several causes of geological change have their results so combined in this field that it is best to consider them all together.

In the general account of the superficial form of Mount Desert, attention was called to the most noticeable peculiarities of the island, viz, the steep east and west ridge of the central axis and the deep north and south channels which intersect it and which are more or less distinctly prolonged on the lowland area which borders the mountain range on its north and south versants. The valleys in which lie the lakes and fiords and swamps which penetrate the mountain range in a meridional direction are the most peculiar of these features. It will be seen that some of them differ from the ordinary inlets of this coast in the fact that they are deepest in the central part of the island where the bounding shores are highest and become shoaler towards the north and south; while the ordinary inlets deepen with a certain regularity from their heads towards the sea. It will be noticed that these troughs, with the possible exception of Somes Sound, are true rock basins and not walled in by mounds of glacial débris.

It is clear that these valleys can not be explained by the action of streams. In the first place it is quite unreasonable to suppose that nine deep valleys could, by river action, be cut transversely through a mountain range only twelve miles long. Secondly, some of these valleys as, for instance, those of Otter Creek and Hadlock Ponds are higher in the middle than at their ends. Thirdly, certain others, as Somes Sound, Long Pond, and Echo Lake, have their central parts much below the level of their outlets. Each of these several conditions is decidedly against the hypothesis that river action could have had anything to do with the formation of these meridional valleys across the great east and west axis of Mount Desert. It may be argued by the advocates of the theory that fiords were produced by rivers, that the valleys were formed before the northern part of the island was cut down to its present level by the action of glacial erosion and that, in fact, they are old river valleys which have been greatly modified by ice action. This may be a plausible hypothesis in the case of Somes Sound, but with the exception of this valley and perhaps that of Seal Cove Pond these basins lie so much above the level of the sea that it would be unreasonable to propose such an explanation.

The general geological map will show that the rock north of the mountain is, for some distance from the main ridge, of a solid and decay-resisting nature like that of the mountains themselves, so that its erosion can not be supposed to have been accomplished during the last ice time.

The history of these basins is fairly well shown by the study of the smaller depressions in the range, which are very much like the deeper troughs in every respect except their dimensions. Of these the most characteristic are the depressions between Beech Mountain and Echo Mountain directly south of Carter's Nubble, the notch between the east and west peaks of the Western Mountain and the cleft between Green Mountain and Dry Mountain.

It is true that these relatively shallow troughs have no lakes in them, but, considering them along with the more perfectly developed valleys, a complete series can be constructed giving a gradation from the conditions of the deepest valley to those of the smallest of the notches which divide these mountains in a north and south direction. It is perfectly clear that these smaller notches have not been formed by river action or even by mountain torrents. At the present time the streams which flow through them are trifling rivulets. If they ever were the seat of torrents all semblance of the original valleys has disappeared.

The history of these valleys has apparently been as follows: The granitic rock in which they lie varies very much in hardness, i. e., in the ease with which it breaks up under the influence of decay or of force applied by rending agents. The relative weakness of certain north and south bands of this rock is due in part to the intrusion of dikes having a general trend corresponding to that of the valleys, viz, from N. 20° W. to N. These dikes are decidedly more accessible to atmospheric decay and more easily worn by the ice or sea than the granites. The presence of these dikes seems in certain cases to soften the granitic rock, possibly through a process of kaolinization of the feldspar it contains. Furthermore, these dike injections appear to increase the jointing of the country rock on either side of the injection, and so, by these several actions, the granitic rock in the neighborhood of the dikes has its resistance to the several kinds of decay diminished. It is difficult to completely verify this hypothesis, for the reason that the bottoms of the greater valleys are not visible, but it seems clear that many of the lesser indentations are to be attributed to the presence of such dikes. The valley between Beech Mountain and Echo Mountain, through which runs the road from Carter's Nubble to Norwood's Cove, is cut down upon a dike about ten feet in width, which occupies the center of the trough, so that a depression of 200 feet deep apparently owes its existence to this dike and to the changes in the boundary rock, which are in some way connected with its injection. So, too, the shores of Somes Sound appear to show that it occupies a strip of country more than usually penetrated by dikes, whose axes in a general way correspond with the trend of its trough. As will be noted in the general geological description of the rocks of the island, the dikes, which have a course between N. 25° W. and N., are apparently softer and decay more readily than those lying in other directions.

The deepening of the valleys between the mountains so as to form the basins of the lakes is a matter which seems to admit of an explanation in the following manner: First, it is evident that there is a tendency in a glacial stream to draw into the mouth of a converging valley. This fact is as evident as the opposite tendency of the ice to divide on the end of a keel-shaped uplift of the land. This convergence of the ice is indicated by the scratches which are visible about the head of Somes Sound. Secondly, it is manifest that this convergence necessarily leads to a swifter motion of the ice in the valley towards which it converges than in the district on either side of that valley. (See Fig. 29.)

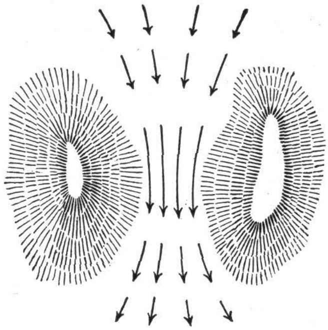


FIG. 29. Effect of convergence and divergence on ice flow.

This swifter movement would necessarily give rise to a more rapid down-cutting of the channel through which the accelerated stream made its way. Where the mountain valley opened out upon the southern plain, the divergence of the ice released from the confining walls would cause a diminution of the wear, and therefore the excavation produced by the ice would be shallower.

It is manifest that this hypothesis is one not easy to verify; only partial verification is found in the precise correspondence of the facts with the conditions demanded by the theory. None of these lakes contained in the mountain valleys have their southern ends projecting beyond the southern wall of the mountain. Their greatest depth is nearly opposite the highest points on their shores. All these features appear to be explained by these hypotheses, while by any other which has been suggested they are essentially unaccounted for.[1]

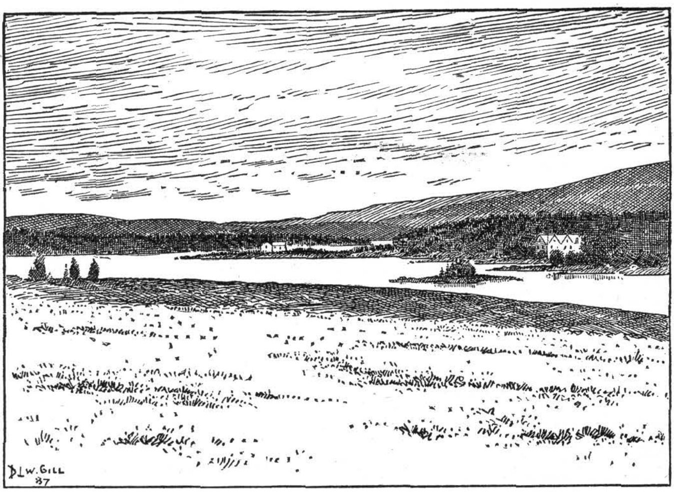


FIG. 30. Usual northern slope of Mount Desert hills.

The erosion on the mountains apart from that shown in the cutting

[1] It will be observed that these considerations open up the whole matter of the formation of fiord valleys. It would be interesting to pursue the inquiry beyond the suggestions which are given above, but a full consideration of the problem would demand more space than can be afforded in this report. I hope to deal with the subject in another place.

ROBINSON'S MOUNTAIN FROM CARTER'S NUBBLE.

of the above-mentioned valleys is exhibited in the smoothing and rounding of the rocks and the wearing down of their northern faces into long slopes. On their whole east and west extension these mountains slope much more gradually northward than southward, as is indicated in the distribution of the contours on the map. These differences in slope would make the mountains excellent specimens of crag and tail or shock and lee phenomena were it not for the fact that the sea has probably had a share in shaping the southern face of these elevations.

It seems to me probable, as will be shown in the later pages of this report, that the ancient sea slopes of these southern cliffs were not entirely obliterated by the action of the ice of the last glacial period or at least of that portion of the period which gave the island all the scoring and scratching that it exhibits. If this be the case this apparent crag and tail form of the surface is probably in part due to the action of the ocean surges and not altogether to the difference between the cutting power of the ice on the north and that on the south of the mountain axis. (See Pl. LXX).

It is a well-known fact that the surfaces of all northern lands which were covered by the glacial sheets were more or less depressed at the close of the ice time. Every part of the American shore north of New York and a large part of the interior of the continent within the limits of the old glacial field afford evidence of subsidence below the level of the sea, a subsidence which took place during the ice time and continued for a certain period after the glaciers passed away. The cause of this subsidence is still in debate; it constitutes one of the most difficult problems in the perplexing field of glacial geology. The importance of obtaining a clear understanding of the conditions prevailing during this subsidence is very great. Until it is possible we shall continue to be unable to deal with a large part of the questions that arise when we endeavor to understand the history of the glacial epoch.

EVIDENCES OF SUBSIDENCE DURING AND AFTER THE GLACIAL PERIOD.

The island of Mount Desert evidently affords peculiar advantages for the study of the problems connected with glacial subsidence. The considerable height of its surface and the great extent of its elevated area, as well as the position of this mountain ridge with reference to the open sea, give reason to hope that it may afford critical evidence as to the heights the ocean reached in the time of greatest subsidence and during the stages in which the land was re-elevated. It was with this view that I undertook the study of the island, and the facts which are given below show that the expectation was amply justified.

The best way to begin the inquiry was evidently by a careful study of the existing shore-line, in order that we might see in what way the sea marks its contact with the land on rocks such as form this portion of the shore. This inquiry might advantageously be made in a very special way, but in this memoir it will not be possible to do more than explain the more important indications by which we may recognize the action of the sea upon the land after the process of elevation has withdrawn the surface above the plane of the ocean.

The sea marks its contact with the land by several different classes of effects—by washing the superficial accumulations of earth and sand and gravel; by the erosion of the rocks in the form of a bench; by the construction of certain accumulations of materials in the form of benches; and, lastly, by forming terraces on the sea floor at some distance from the shore-line. Of these various effects the washing away of the superficial accumulations and the construction of sea benches out of the materials are by far the most characteristic results of marine action. The formation of sea benches in the re-entrant angles of the shore and the construction of terraces are facts which require peculiar conditions, and therefore these phenomena can not be expected along all parts of a coast line. To make such results possible the inclination of the shore at its contact with the

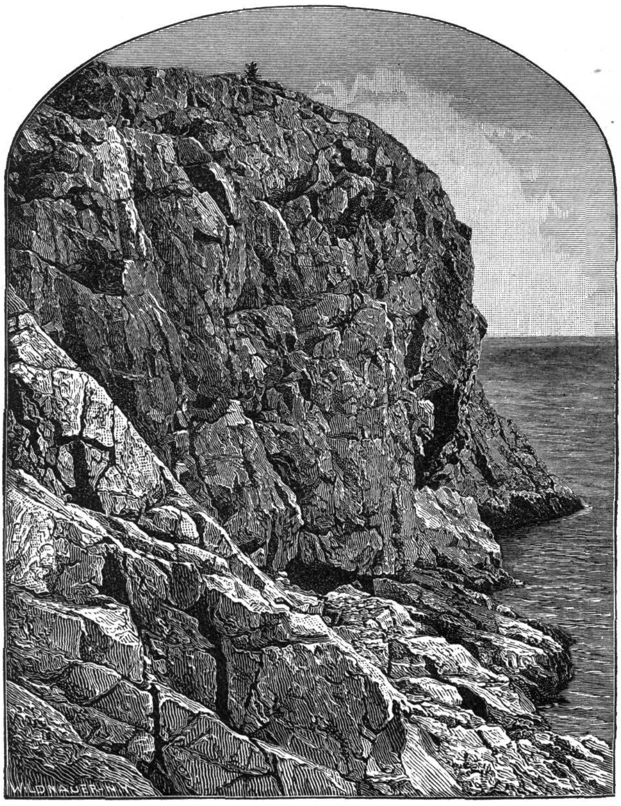


FIG. 31. Great Head.

sea must not exceed a certain angle, and the currents must not be so swift as to bear away the débris as fast as it is formed. If these conditions are lacking prolonged marine action will not produce benches and terraces.

It is evident on even a slight inspection that the sea shore of Maine has been for a considerable time at about its present level. There are reasons to believe that an elevation of from ten to forty feet has taken place within a few thousand years; still the sea has been acting on this strip of what may be called the actual shore for a sufficiently long time to give us a measure of what it can do under the present conditions.

In examining this coast the first thing that strikes us is the cutting which the sea has done on the rocks. Along the greater part of the shore-line where it rests against the bed rocks, as it does on at least three-fourths of the coast of this island, we find a scarf distinctly carved in the rocks; and, though not perfectly continuous, it is plainly exhibited along the greater portion of the shore. We next note that the extent of this bench is extremely variable. At one point we may find that the sea has carved its way back, so that a majestic precipice 100 feet high faces the ocean, while a few hundred feet away the waves beat against rocks which still bear the glacial scratches; yet the physical conditions existing at these two points, as far as regards the assaults of the sea, may appear to be essentially the same. It will not be possible in this place to undertake an inquiry into the causes of this very wide diversity in the conditions of the shore. It may be said, however, in passing that alterations in the number and direction of the joint planes, slight changes in chemical constitution of the material, or variations in the declivity of the slope by which the land meets the sea, may bring about the widest diversities in the cutting power of the waves. For our purpose we need to note only the fact that while rock-scarfs are produced by the cutting action of the sea and by no other cause they are by no means universal along this existing coast-line.

The next most characteristic mark of sea action is found in the removal of superficial detritus soil or glacial waste from the surface. Although this effect of wave action is less conspicuous than that arising from the rending of the rocks on the shore, it is far more generally distributed along the coast. We search in vain on the belt of shore where the waves have no considerable magnitude for any such covering of débris as the glacial ice left on the larger part of this land surface. It is clear that no part of the surface on which the ice lay was entirely without débris when the ice began to melt away. The streams of water produced during the period of melting occasionally scoured away this detrital material, but even where the surface is so cleared of the glacial waste we have a form and a distribution of the material which enable us easily to separate such areas from the surfaces which have been abraded by marine action. In a glaciated district where the ice has acted with great power, as is the case over all this part of the continent, if we find large areas of rocks lying at gentle inclinations which have had all the drift except occasional large bowlders removed from their surfaces, save perhaps where small patches of pebbles or clay lie in protected depressions, we may fairly conclude that the area has been swept by strong currents of water, such as the waves of the sea may produce.

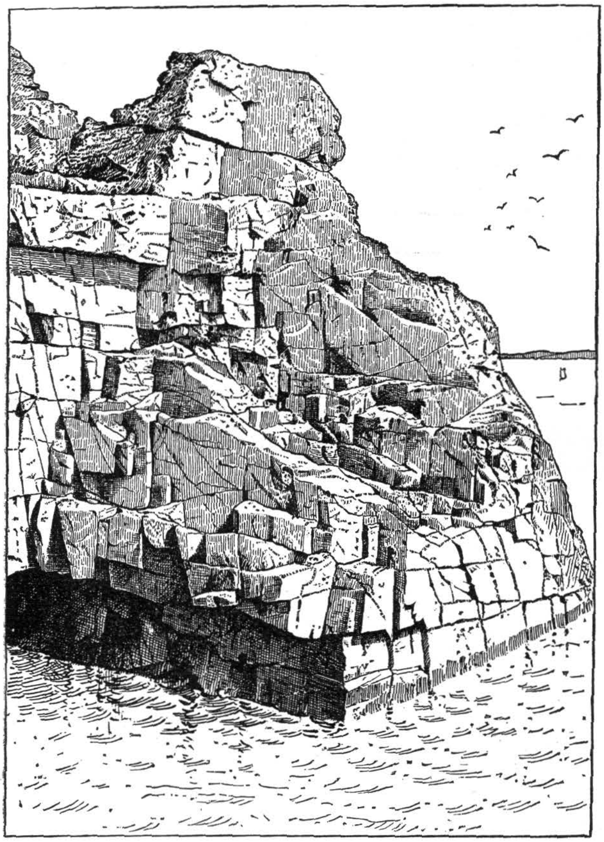
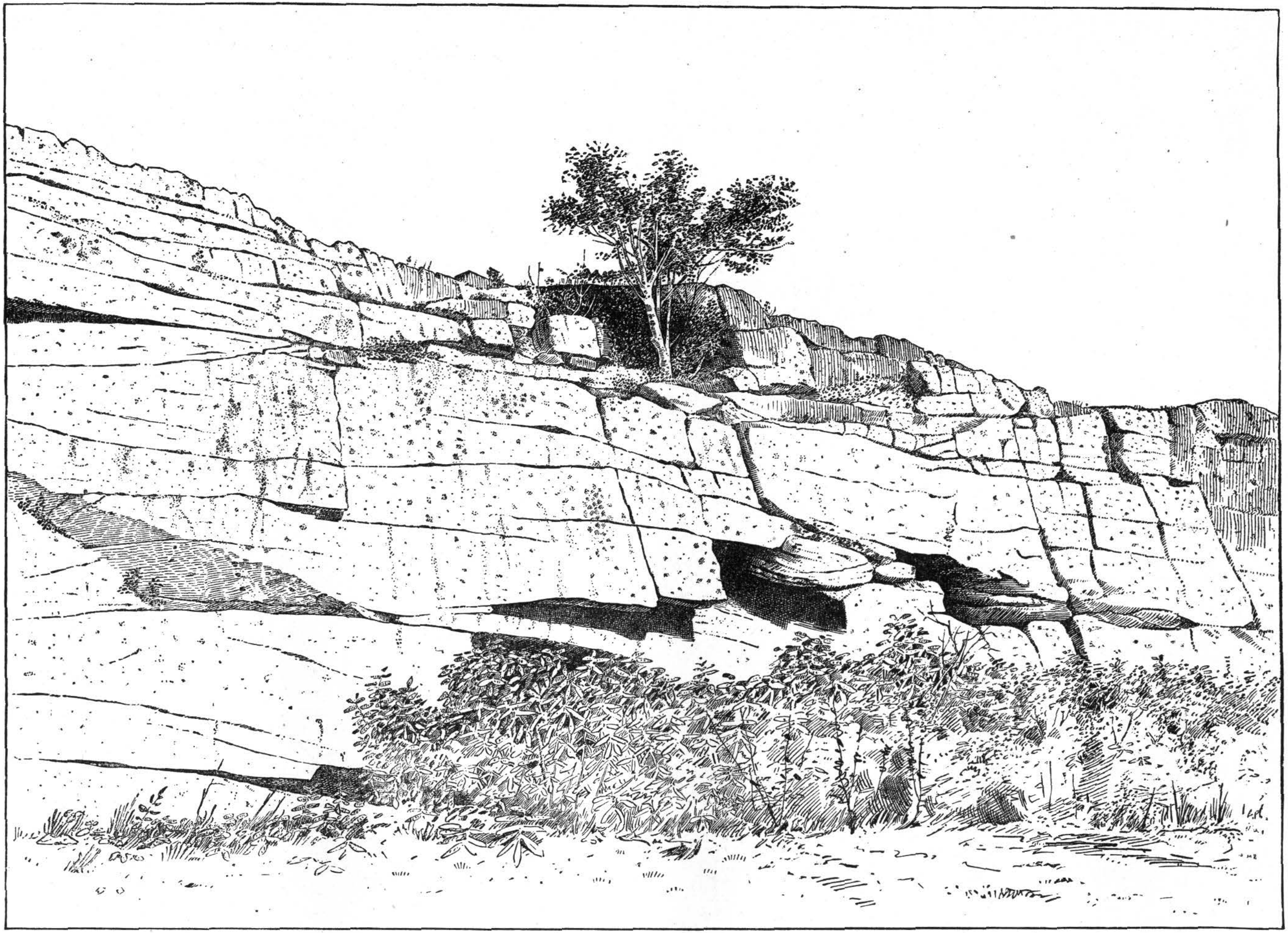


FIG. 32. Spouting Horn, Schooner Head.

To this conclusion we are inevitably brought by the very inspection of the surface within the limits of wave action as it is now going on along the coast. On this wave-swept surface we find here and there a large bowlder, which by its weight has escaped the disturbance that has overtaken all finer materials. Occasionally in the depressions and crevices of the rock we find patches of pebble, and more rarely of glacial clay, which, lying above the level of the strongest waves, have remained but little changed from their original



DODGE'S LEDGE, SEAL HARBOR.

state; still the wave belt of the shore shows scarcely a trace of drift upon the surface of its bare rocks.

The pebble beaches are found only in the re-entrant angles; they are rarely very conspicuous structures, and we can easily imagine that if the existing shore was elevated and covered for a long period with a thick mass of vegetation it would be nearly impossible to identify the beaches on such a surface as Mount Desert now presents, at least until the country had been cleared of its forest covering.

The submarine flats of clay and sand so common on the southern shores of New England appear, from the evidence afforded by soundings, never to have been formed on slopes of any considerable declivity such as Mount Desert would present if its surface were sunk beneath the sea. On such steep slopes the action of tidal currents, where the tides have a rise and fall existing on this part of the shore, is so strong that the detrital matter is quickly swept away into deeper water.

The slopes of a sea-girt rocky shore have a peculiar character that is given it by the action of waves alone. The general character of such shores is shown in the accompanying diagram (Fig. 33), which exhi-

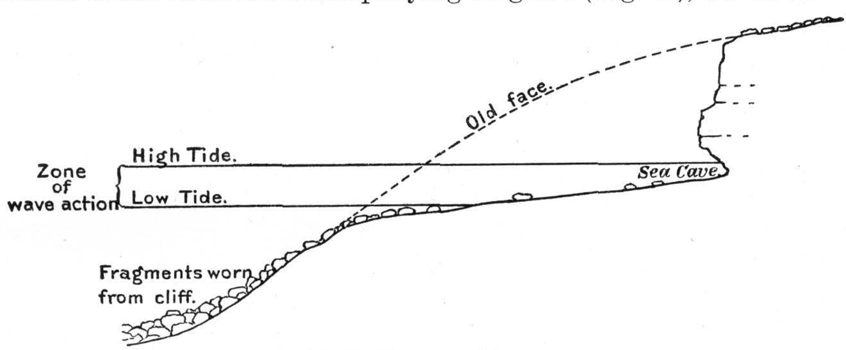


FIG. 33. Wave-carved shore,

bits the general type of the submarine bench now existing just below low-tide level along this coast, where it is formed on granitic rocks having the general nature of those which make up the greater part of Mount Desert. We see that this shelf is composed of the follow- parts, beginning at the top, viz: First, the cliff above the water line, where the removal of the rock material is dependent upon gravity assisted by decay and frost action; second, the belt assaulted by waves where the removal of matter is brought about by the horizontal blows of surges, aided, also in part by frost and in part by the chemical decay of rocks; third, a slope that I shall call the erosion shelf. This is the section below the level of the most vigorous wave action and represents by its width the extent to which the sea has cut back from the original front when the sea first came into its present relations with the land. Below this erosion shelf, beginning at about low-tide mark and extending to a depth that varies with many circumstances, is the section where the coarser fragments worn out from the cliff by the waves are dragged by the resurging waters or borne by the shore ice. This portion of the section I term the deposition shelf. With hard rocks this accumulation on different parts of the shore generally bears about the ratio shown in the scarf to the amount of cutting, but, as is readily perceived, the cubical contents of a section of this detritus is always less than that of a section of the scarf, because considerable of the material is entirely ground up and borne away by the ocean currents in the form either of mud and sand or of materials in complete solution. Examined at low tide we perceive that the fragmental material in the detrital

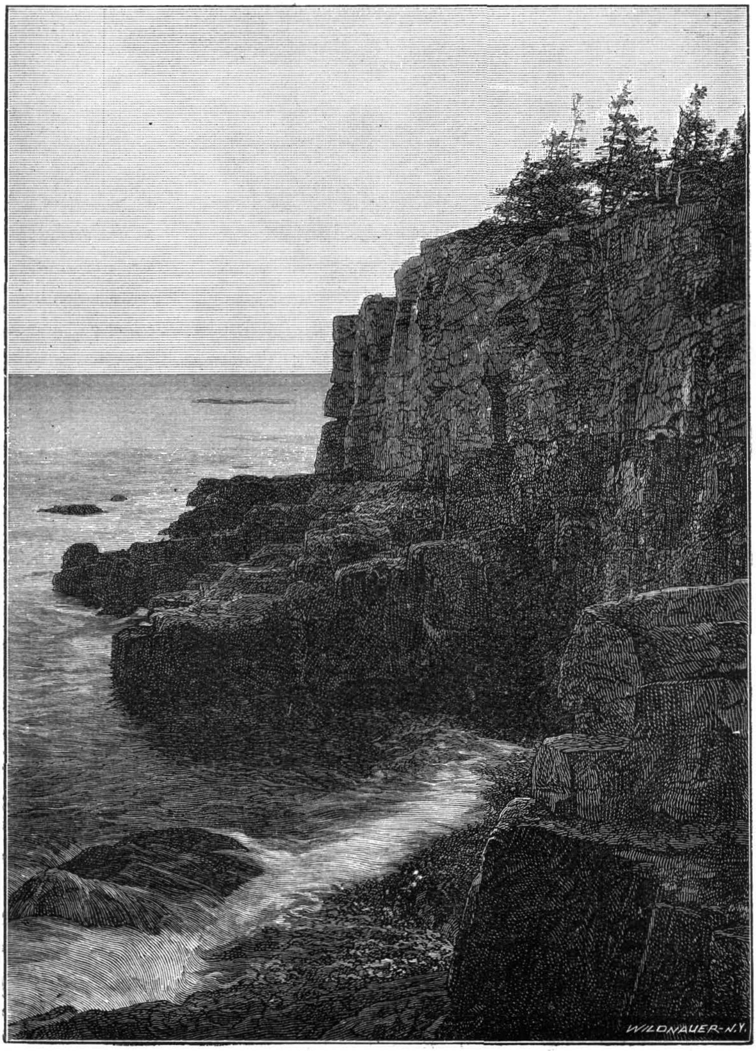


Fig. 34. Otter Cliffs.

apron, though often much battered, has a form different from that of ordinary glacial waste and the fragments are far more angular; indeed, it is frequently possible to trace the larger of them to their original place in the ragged face of the cliff.

There is one peculiarity of the rocky sea front which, though not very conspicuous on these shores, will serve us well in our quest. I refer to the sharp indentations of the shore made by the action of waves on soft portions of strata much intersected by joint planes. To these reëntrants we may give the common name of chasms. As soon as such a chasm begins to form it finds conditions favorable to its further development; the indentation becomes a lodging-place for fragments which may be torn from its sides or swept into it by waves. These fragments are used by waves to batter the walls of the crevice and thus to extend the excavation, while the steep slopes outside, though equally assaulted by the sea, are struck only by the unarmed waves, which have relatively little power upon the closely knit rock, however violent their blows may be.

Although the foregoing is an extremely imperfect statement of the action of the sea waves on the shore, it will serve as a basis from which to judge whether or not the sea has acted on this island at points above its present line.[1]

If we can find these several marks of marine erosion on the sides of the mountains of this island we may be certain that we have in them evidence of old sea levels which indicate the submergence of this part of the shore since the last ice sheet passed away.

At a height of about twenty feet above the sea level there are some very faint indications which lead me to infer that there was a brief period in which the sea paused during the process of elevation, while the waves cut a very faint scarf. Notwithstanding considerable study of this coast line, I do not feel it safe to indicate a bench of this level. At Hull's Cove,[2] on the north side of the island, there are two benches cut in the clay deposits; one, at the height of forty feet above the sea, is very indistinct. At Newport Cove, and near Southwest Harbor, there are faint traces of a similar bench at the same altitude. At Hull's Cove, at the height of sixty feet above the tide, there is an escarpment on the sloping clay deposits which is undoubtedly of marine origin. It is figured in Plate LXXV. Considering that these marks of marine action have not been traced for any considerable distance along the shore, and are not, at any

[1] I have in preparation a special report, to be published by the U. S. Geological Survey, intended to afford the student a basis on which to interpret problems concerning ancient sea margins. It will probably be a year or more before this paper is completed. An admirable memoir on the subject of lake margins from the pen of G. K. Gilbert appeared in the Sixth Annual Report of the U. S. Geological Survey.

[2] The extreme inlet northwest of Duck Brook.

point where I have observed them, in the form of scarfs in the solid rock, I have hesitated to assign them a place.

First bench.—Proceeding to our inspection of the land surface of Mount Desert, we find no very clear marks of wave action in the form of rock scarfs until we attain the height of about ninety feet above the sea. At that point there is a bench which is marked only on the more exposed portions of the southern shore line.

The best indication of this ninety-foot bench which I have found is on the east side of Seal Harbor. Here and elsewhere along the shore wherever the surface is bare of timber the erosion is clearly manifested. The actual benching of the rock is small in amount; still, as is shown in the diagram (Fig. 35), the scarf is plain, and in some instances the evidence of water action is well indicated by the dislocation of large blocks, by their motion down the slope, and by a certain lateral transverse movement which can not be explained save by wave action. In the diagram the general aspect of this terrace is shown at a point where it is unusually well exposed to view. The large angular fragment has been moved 115 feet down the slope of the old rock-apron from the point where it originally lay, descending a slope which is vertically twelve feet in height.

This great mass contains about 500 cubic feet and is one of the largest fragments removed by sea action which I have observed on the island. It does not seem reasonable to suppose that it could have been moved down the slope by the action of gravity alone or by gravity aided by the action of frost, or by the force developed by the growth of the roots of trees. The surface over which it traveled is by no means smooth, and the lower face of the rock is quite rough, so that unless a powerful lifting force had been applied to it the descent would have been impossible. A little farther up the hill, at the point indicated by *b* in the diagram, a fragment of several cubic feet in contents has been detached from the crest of a slight ridge of rock and moved a little way inland.

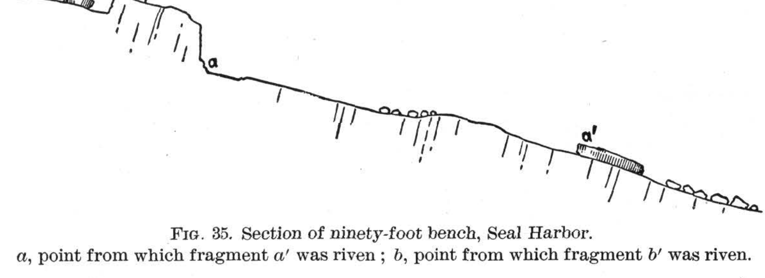
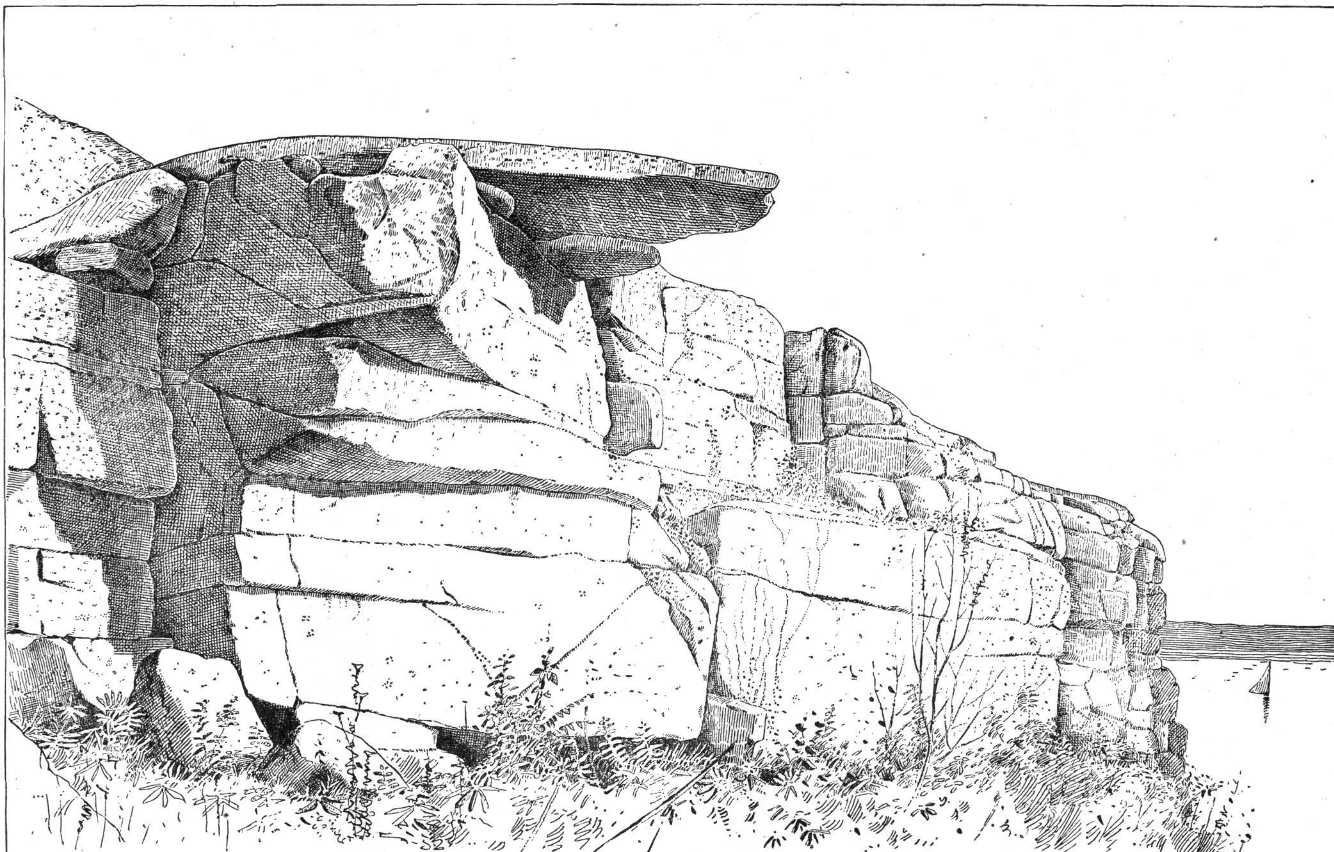


FIG. 35. Section of ninety-foot bench, Seal Harbor.
a, point from which fragment *a'* was riven ; *b*, point from which fragment *b'* was riven.

It will be observed that this bench, though its vertical relief is not great nor the excavation large in amount, presents all the



OVERHANGING CLIFF, DODGE'S LEDGE, SEAL HARBOR.

marks by which we found in our preliminary inquiry we might hope to identify an old sea cutting made in rock of this description. There is the vertical ragged cliff, which can not be the result of glacial action; for it faces the direction whence the ice movement came; but its existence is readily explained by the action of waves. Small bowlders of rock, which so well indicate the rolling and pounding action of sea waves, also abound upon this slope. The glacial waste is, of course, entirely swept away. The direction of movement of the large rock is almost at right angles to the path of the ice, and therefore this movement could not have been brought about by glacial action. The method of my inquiry, necessarily determined by the time at my disposal for its prosecution, has not made it possible for me to undertake the extremely laborious task of tracing this bench, or any of those hereafter to be described, around the whole shore of the island. I may say, however, that along the greater part of the southern coast, wherever I have had an opportunity to examine the surface, I have found more or less clear indications of its presence. On the north shore this bench appears to be wanting, as are most of the others at higher levels.

The duration of the sea level at this height can not well be estimated. It seems, however, evident that it could not have been as long continued as it has been at the present level of the shore, for the erosion is very much less, probably not amounting to one-fourth of that which has been effected since the sea came to its present position.

Further studies on the elevated benches of Mount Desert, made as this report was going to press, have shown me that the ninety-foot bench is at several points extended along the line of the cove clays in such a fashion as to afford strong corroboration of the hypothesis of marine action at this height. The most important of these benches is that found at Newport Cove, at the height of from eighty-five to one hundred feet above the present high-tide level. The slope of the old shore and its general structure are almost exactly like those of the present shore immediately contiguous. Although a great deal of matter has slid down over the original slope of the beach, it is still possible at several points to find pebbles exhibiting the characteristic shape of stones which have been rolled by waves.

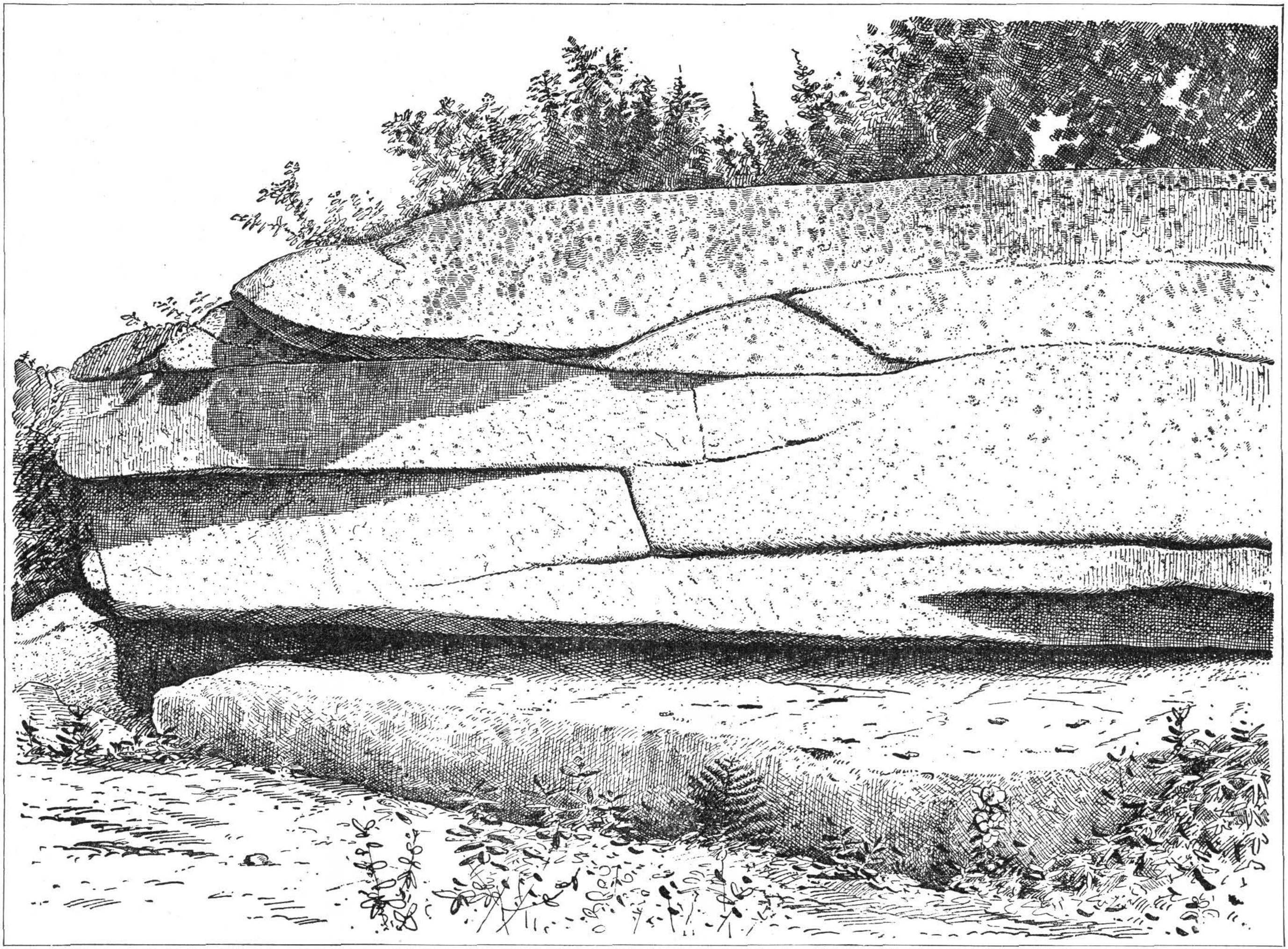
The fact that we do not find similar evidences of marine action on soft materials at greater heights above the sea level appears sufficiently accounted for when we consider that in the higher parts of the island we have very little detrital material on which such a record could be made. Where considerable accumulations of gravel exist they lie upon steep slopes, which would readily slip down after having been abandoned by the sea, and thus destroy the evidences of marine action.

Although at the point indicated in the above section the waves would have had a very great cutting power when the sea was at the level indicated, they did less work than they have done on the existing shores of Seal Harbor, and yet the force of the sea on that part of the shore is very much less at present than it was when it stood at the higher level. From this bench, which lies between ninety and one hundred feet in height, up to the level of about one hundred and sixty-five feet, I have observed no distinct benchings, though at many points there are faint marks of marine action.

Second bench.—Beginning at about one hundred and sixty-five feet above the sea level, and thence upward for perhaps thirty feet in altitude, occur some of the most remarkable benchings which exist on the island. So far as observed, the best examples of marine work at this level are on the southern, southwestern, and southeastern faces of the low granitic ridge shown on the map as Dodge's Ledge. This bench is most clearly shown on the southwest versant of this ridge, at the point where the accompanying views were taken. (Pls. LXXI, LXXII, LXXIII.) Here the marine character of the scarf or cliff is clear to any eye, though singularly enough its nature has not heretofore been remarked. No part of the existing shore-line exhibits the results of the wave action in a more characteristic manner. As will be seen from the sketches, which are based upon photographs, as well as upon drawings and measurements made upon the spot, the evidence as to the marine origin of this shelf is singularly complete. We find there the steep cliff with a crest which at one point overhangs the base ten feet or more. The cavern-like recesses at the base extend in from the face nearly twenty feet. There is a wide, smooth, sloping rock apron on which waves have evidently beaten for ages, and below its edge, as well as upon its surface, an accumulation of fragments, rounded by wave action, which are very unlike glacial débris in form.

They were evidently derived from the bench above and moved to their present position by the action of waves and ice rafts. It should be noted that these fragments have been moved westerly in part directly against the movement in the glacier and in part at right angles to the trend of its motion; also that the steep-faced cliff looks westward and that it could not have survived in its present form if it had been subjected to glacial erosion. This bench not only indicates marine action at this level but it unquestionably shows that this marine action took place after the disappearance of the last ice sheet. There can be no question that this sea face has been worn since the last retreat of the ice from this region. A slight amount of glacial action would remove this marine débris and destroy the overhanging part of the cliff. (Fig. 32.)

The excavation done on this level is evident around nearly the



NORTHERN END OF DODGE'S LEDGE, SEAL HARBOR.

whole periphery of the island, but it is particularly marked on the southern shores. It seems clear that the sea must have remained for a long time between one hundred and sixty and one hundred and eighty-five feet above its present level, for the total amount of excavation done at this height above the sea approaches if it does not equal that accomplished along the existing shore line. It should be noted, however, that the sea when at this level would have had a far wider sweep than it now has on the greater part of the shore of this island. It will also be observed that this one hundred and sixty to one hundred and eighty-five foot bench is not nearly so evident on the other parts of the island as it is at the point above described. For instance, on the unnamed hill midway between Seal Harbor and the cove of Stony Beach,[1] this bench, though observable, is relatively of small size. This wide difference in the amount of excavation which the sea did when it occupied this height is probably due in part to the variation in the original slope of the declivity on different parts of the shore, and in part to the difference in the extent to which the rock is penetrated by joint planes together with the position of these planes in reference to the blow of waves.

At other points on the shore this bench is apparently divided into two parts. This is notably the case on Cox's Hill,[2] one bench lying at the height of about one hundred and sixty feet, another at one hundred and eighty-five feet, with the surface between them indicating diminished erosion.

Third bench.—Above this one hundred and sixty to one hundred and eighty-five foot bench we have along all the southern shore a succession of slight steps which may indicate wave action; it is, however, not until we attain the height of about two hundred and twenty to two hundred and forty feet that another important bench is observed. At this level a very strong bench is visible at many points on the southern shore. It is perhaps best shown on Cox's Hill, in the deep ravine called the Cleft, and on Barr's Hill, but it seems to be present at all points where the headlands were exposed to the action of the sea in this period of depression. On the west face of the Cleft it appears as a scarf, having a maximum vertical height of about fifty feet with a distinct undercutting and a considerable mass of débris accumulated as an apron below. On the east side of the Cleft near the abandoned wagon road which is shown on the map, the scarf is very well shown and evidences of wave action are very clear, as is indicated in the accompanying diagram of Pulpit Rock, Plate LXXIV. No portion of the existing coast line of the island gives as good a picture of marine action as is afforded by this portion of the old 240-foot bench. For purposes of comparison, two

[1] Midway between Otter Cove and Seal Harbor.

[2] On the east side of Seal Harbor.

similar detached rocks occurring on the present sea shore are shown in Figs. 36 and 37.

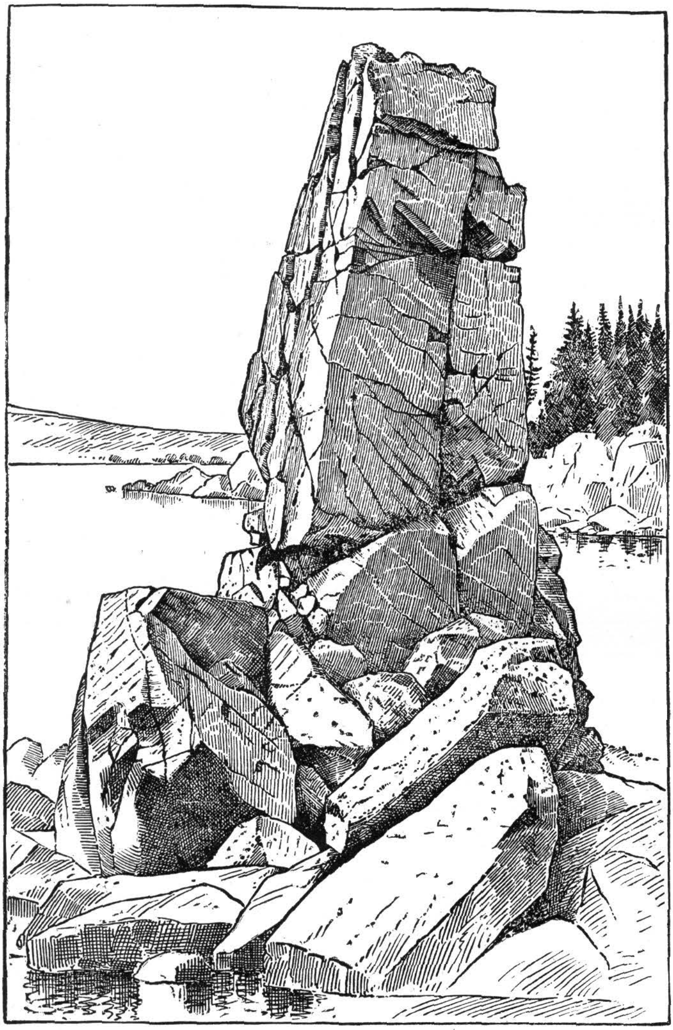
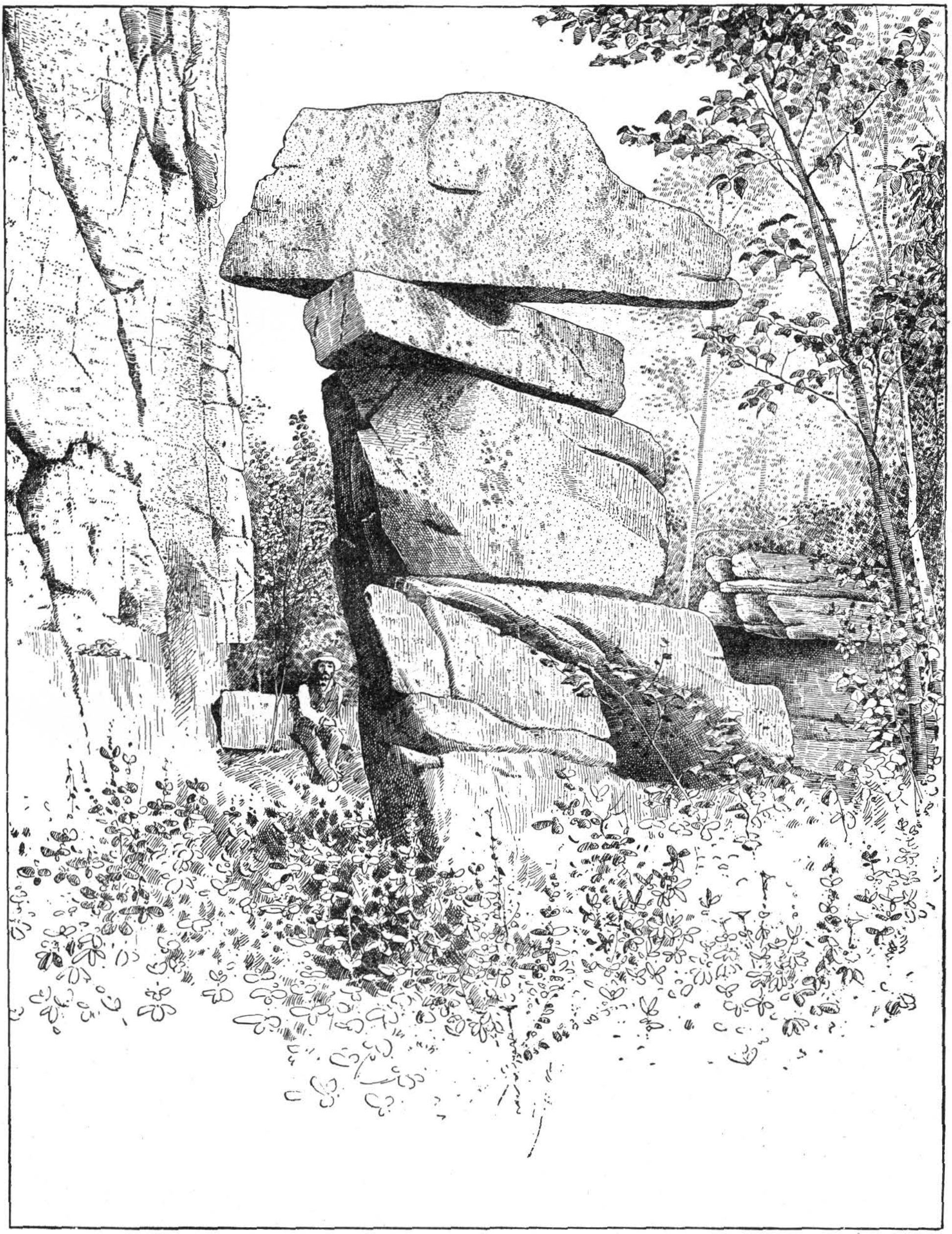


FIG. 36. Rock detached by wave action, Sutton's Island.

Fourth bench.—The next conspicuous bench in the ascending series lies at the level of from two hundred and seventy to two hundred and ninety feet above the level of the sea, or about fifty feet above the preceding. This is also a striking bench very nearly as conspicuous as that last described. It is very well shown on all the parts of the southern coast where it was sought for, having appeared along the greater part of the coastline. On Dodges' Ledge it forms a steep wall around the sides of the hill, except on the south, where,



ROCK DETACHED BY WAVE ACTION ON 220-FEET BEACH.

for a short distance, it is wanting, and at the northern end, where, for about forty degrees of arc, the shore was so protected from the

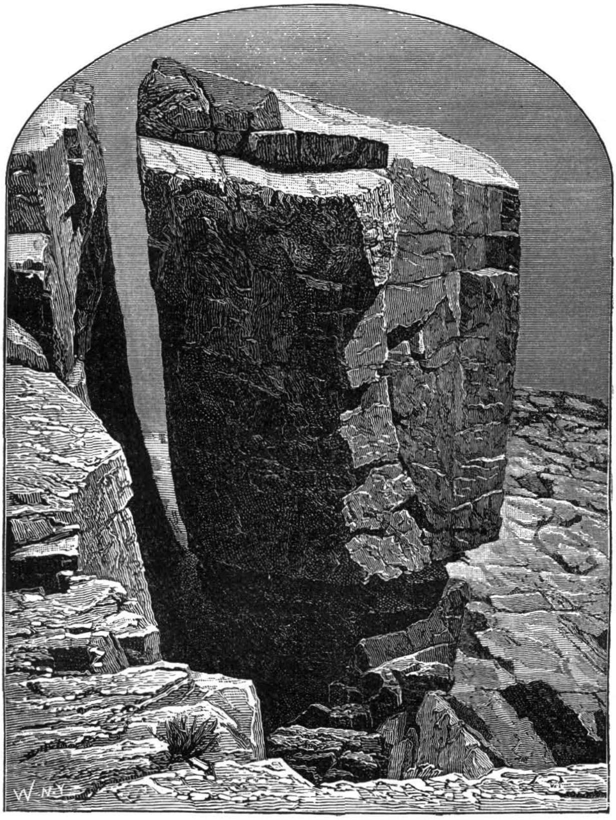


FIG. 37. Rock detached by recent wave action, Otter Cliff.

action of the wave by the higher lands of the island to the northward that we could not expect to find it. At no other point do we find this sea scarf exhibiting the continuity which it shows on this elevation, but elsewhere it is sufficiently continuous to make it plain that the sea remained at this level for a considerable geologic time.

Fifth bench.—A little above the top of this scarf and about ten feet below the summit of the hill, at the height of about three hundred feet above the high-tide level, there is a fragment of stone which affords a singularly complete bit of evidence serving to show that the sea has done its characteristic work at this height; if it had been constructed for the purpose it could not have been more admirably adapted to this end. The fragment in question is a block of granite about seven feet by four and on an average about fifteen inches thick which has been riven from its bed, turned completely over, and lodged at the height of a foot or so above its original bed place. Moreover, it has been moved six feet northwest of its original site. It is manifest that there are but two ways in which this movement could have been effected. It is conceivable that the displacement and reversal of the fragment might have been accomplished by the overturning of a tree whose roots had firmly inclosed its mass. To this hypothesis it must be objected that tall forest trees could hardly have developed on a surface as bare of soil as is all this elevation on which the dislocated fragment rests; moreover, that the fragment is far heavier than any but the largest tree could possibly have dislocated by its fall; and, indeed, it is scarcely credible that the complete overturning in this manner could have been accomplished under any circumstances. After several visits to this interesting specimen I have come to the conclusion that we must assume it to have been overturned by wave action. It is perfectly clear that the movement has taken place since the last glacial period, for as before noted the stone has been transported a little distance northwest or contrary to the direction of the glacial movement. Considered with the other marks of marine action noted at lower levels this dislocated fragment may entirely justify the conclusion that the sea has acted upon the surface up to this level at a time since the close of the glacial period.

Sixth bench.—Above the level of 300 feet, and thence up to about 380 feet, the surface shows at many points distinct evidences of marine action, but no proof of long-continued wearing by the sea is found at any of these points. At 380 feet, and thence upward to 430 feet, there are many very distinct scarfs, sometimes separated into distinct benches, but more commonly appearing as one steep cliff. This bench is well shown on the faces of the Cleft, and on the western Triad, and it is traceable all along the southern face of the island. It is, perhaps, less marked than the three most important lower benches, and indicates on the whole a less continuous action of the sea; still, it shows that the pause in the elevation, or, perhaps, several subordinate pauses, was continued long enough to permit an aggregate amount of excavation, probably exceeded only by the bench standing at 240 feet above the present level of the sea.

Seventh bench.—Continuing our way up the southern slope of the mountains, at the height of 50 feet above the last-mentioned bench, or about four hundred and eighty to five hundred feet above the sea, we find another level where marine action is at some points distinctly indicated. It is most conspicuous on the east flank of Jordan's Mountain near the south end of Jordan's Pond, where it is shown as a distinct scarf with a slight undercutting at its base. Again, on the same mountain, at the height of from four hundred to four hundred and twenty feet, there is another bench eight feet high, which shows distinct undercutting and a frontal apron of rock as in the lower terraces. The benches of these levels, from three hundred and eighty to four hundred and twenty feet, have not been carefully traced on other parts of the island, but they may apparently be relied upon as proving a certain amount of marine action at this level; that at 410 feet above the sea is seen also on the southern spur of Green Mountain, where it may be followed for a great part of the periphery of that spur.

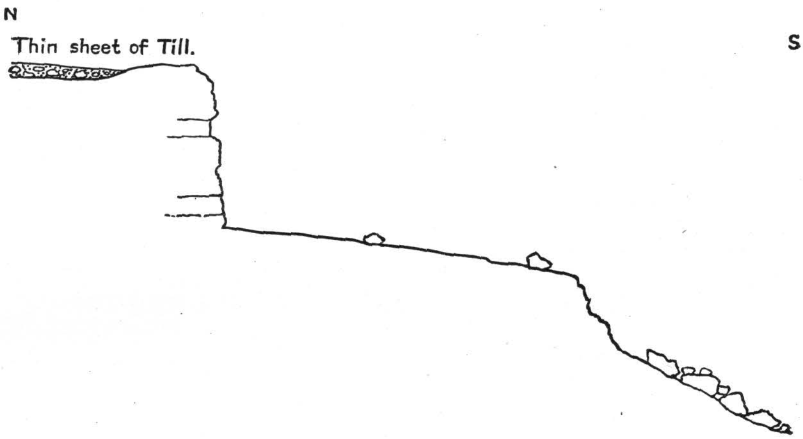


FIG. 38. Section of bench on east peak of Western Mountain, 520–600 feet above tide.

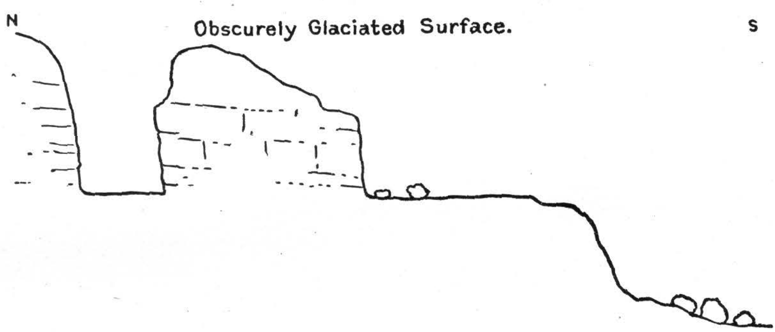


FIG. 39. Section of bench on east peak of Western Mountain, 520–600 feet above tide.

Sea-worn cliffs.—From about four hundred and fifty to five hundred and fifty feet no distinct benches were traced, though the surface has a sea-worn look. At about five hundred and fifty feet of altitude we enter upon the most curious set of steep cliffs, apparently worn by the sea, which the island exhibits. This band of cliffs extends upward to heights of from seven hundred and fifty to one thousand feet. These benches, with their steep and often nearly vertical slopes, give the crowding of the contour lines on the map, causing a deep shade of black on the middle part of the mountain slopes. They are particularly well seen on the steep precipices of Pemetic, Jordan's, Newport, and most of the other mountains. It is these steps which in great part give picturesqueness to the scenery of the island. On their precipitous slopes it was not found possible to separate the several benches into distinct levels, but it is tolerably evident that the general slope of these steps, which is shown in the sections across the mountains, is due in large measure to wave action. I am not yet certain that this wave action was wholly accomplished before the last glacial period, or at least in the time before the last recurrence of the glacial sheet on this district. I am inclined to believe that it was due in part to the action of the sea antecedent to the last work of the glaciers. Though there are distinct subordinate benches on the steps, they present at certain parts of their surfaces glacially rounded surfaces; moreover, we do not find on the slopes below these benches any such mass of material as it is necessary to believe was removed from their scarfs. I have been driven to the hypothesis that these somewhat glaciated benches, which have in a general way the shape of the marine scarfs found at lower levels, were formed before the last glacial period while the sea lay at this level, and that they were not very much changed in their form by the last ice movement. After the ice passed away and during the period of re-elevation the sea appears to have worked again on this bench, forming relatively small scarfs upon the steps cut by the ocean in the preglacial time.

From the height of six hundred feet to that of one thousand feet, for the reasons before given, no effort was made to ascertain the separate terraces or to determine their height above the sea. On this, the most extensively terraced portion of the island, great labor will be required to separate the crowded scarfs from each other so as to determine the successive levels at which the sea appears to have acted, and to divide the erosion done before the last ice time from that effected since the ice passed away. Above the level of 1,000 feet the task becomes again much easier.[1]

There are on this portion of the mountains a number of levels at which the evidence of marine action derived from benches is very good. It should be noted, however, that the surface above the height of about one thousand feet assumes the character of tolerably gentle slopes which extend up to the upper scarfs near the summits. Such a field as we may see by the unbroken surface of many syenitic islands of gentle slope which occur along the neighboring shores of Maine is a very unfavorable place for the sea to effect scarfing action upon. The waves slip over such gently inclined rock and do not have a chance to exert their erosive power upon it. To this, perhaps, may be due the indistinct benching of the upper portion of the mountain slopes. It may be, however, that this incompleteness of the marine action is owing to the shortness of the time during which the rocks were exposed to the action of the sea.

[1] Although the coast-surface map of Mount Desert which is reproduced in this report is, perhaps, as good a piece of topography as has ever been made upon the scale on which it is constructed, the generalization of the delineation is considerable. This makes it impossible to use this map in tracing the details of position of these old benches. If this task is ever effected it will be necessary to prepare, for the study of the problem, a map on the scale of about one twenty-five-hundredth of the natural dimensions.

Evidences of benches above the level of one thousand feet.—The first tolerably distinct indication of sea benching above the level of 1,000 feet is shown near the summit of Jordan's Mountain. Although this evidence is less clear than that afforded in the cases of lower levels the observer who has carefully followed up the problem from the sea level to this height will hardly doubt that he has here unquestionable evidence of marine action. This principal system of benchings indicated on Jordan's Mountain extends from about nine hundred and thirty feet up to about eleven hundred feet. There are two or three distinct scarfs; the intermediate spaces have the scoured and sea-worn look which belongs to the belt of rocks now swept by the waves. Although these benches, so far as observed, are most distinctly shown on the upper part of Jordan's Mountain they are observable on the flanks of Sargent's Mountain and Pemetic Mountain as well. Indeed, wherever at this level the surface of the rocks has a sufficiently steep slope towards the sea, the benching is more or less manifest.

The summit of Jordan's Mountain at the height of from 1,140 feet to 1,160 feet is strongly benched on all sides. The general aspect of the summit is precisely that of many rocky islets now existing along the storm-swept shore. It requires little imagination to picture this rugged summit when it was a little island in the small group of sea-worn isles which then rose above the ocean at this point.

The evidence of marine action derived from the displacement of bowlders on the benches between one thousand and eleven hundred feet of altitude is almost as plain as upon the lower levels. The cases of displaced fragments are very numerous. None of these, so far as observed, are overturned by the waves, though they often show by their removal to a considerable distance from their original positions that they have been subjected to a dislocating force since the close of the glacial period.

In considering this evidence afforded by the fragments care should be taken to exclude those cases in which the action of frost or of trees upturned by the roots might have produced the effects observed.[1]

[1]A comparison of the summits of these mountains with the summits of the White Mountains in New Hampshire affords us certain important suggestions. The work done by frost on the heights of Mount Desert is extremely small compared with that effected by the same agent on the upper levels of the White Mountain peaks. As is well known nearly the whole of the upper part of Mount Washington and the neighboring peaks of the group is covered by a mass of frost-riven fragments. This difference in the condition of the surface may be due in part to the diverse nature of the rocks of which the mountains are composed, the White Mountain group being made up in the main of schistose materials, while Mount Desert is composed of extremely massive granitic rocks. Nevertheless I am inclined to believe that we can not attribute all the difference in condition to these circumstances. Something is probably due to the greater energy and perhaps to the longer continuance of vigorous glacial action on the summits of the Mount Desert hills.

There are on Mount Desert only four peaks which rise higher than 1,100 feet, and above this level the action of the waves can be studied on relatively small areas only. We have already seen that no one of the benches made by the sea on this island, not even that at the present ocean level, is perfectly continuous; therefore it is readily perceived that as the region opened to study is narrowed our conclusions have less value. The four summits which rise above 1,100 feet are Pemetic, Sargent's, Green, and Dry Mountains. The upper 30 feet of Pemetic Mountain, at the height of 1,210 feet to 1,240 feet, show distinct benching, though the scarfs have little height. Apparently the period of water action was brief. In addition to the evidence afforded by indistinct benches we have on this summit a number of chasms formed by the cutting out of dikes apparently by the action of the sea. These channels are deep; their walls are nearly vertical. It does not appear possible that such sharp chasms could have been formed by glacial ice, and I am forced to believe that they are the product of wave action. The trend of these fissures is approximately north and south; their present depth does not exceed twenty feet, but they have been partly filled, perhaps to half their original depth, by matter fallen from the sides. They vary in width from twenty to forty feet.

The summit of Sargent's Mountain exhibits little trace of wave action in the upper 300 feet of its height. So far as observed, indeed, it shows less evidence of marine action than any other of the mountains of the Mount Desert group. The reason for this may perhaps be that it is on the whole in a more sheltered position as regards wave action than any other of the greater peaks of the island.

Between the summit of Sargent's Mountain and that of Jordan's Mountain there is a deep gorge the bottom of which is about ten hundred and fifty feet above the sea level. The form of this gorge is not well represented on the map, doubtless for the reason that it was covered with timber at the time when the map was made. The axis of this gorge lies in a northeast and southwest direction. The depth of the portion which appears to have been excavated by wave action is about one hundred feet. The rough character of its crumbling walls and its position with reference to the glacial movement make it seem extremely improbable that it could have been formed by the action of ice.

On the flanks of Green Mountain at about the same height as these benches and chasms of Pemetic Mountain there is a considerable scarf which is apparent on a portion of the hill only, appearing in a distinct manner where the original slope was steep enough to oppose a strong resistance to the action of the waves. I have little doubt that this bench marks a point where the sea acted for a considerable time. From this level up to about twelve hundred and eighty feet no distinct benches were observed. From 1,280 to 1,320 feet there are faint benches which are best shown on the eastern face of Green Mountain. They are so limited in extent that I do not regard them as affording conclusive evidence of marine action at this level though I can not otherwise account for their formation.

Above the last named level we have only the summit of Green Mountain on which to prosecute our studies and this surface is inclined in such gentle slopes that the waves could have had little opportunity to accomplish much erosion on the rocks. Still, at fourteen hundred and sixty to fourteen hundred and eighty feet above the sea there is a faint bench which on the south and east sides appears to give some indications of marine action. It is not distinctly to be traced around the contour of the hill but it is hardly to be expected that a brief period of ocean-wearing would produce a continuous scarf on a surface of such gentle inclination.

Finally, near the summit of the mountain at the height of about fifteen hundred and ten feet above the sea, or 17 feet below the highest point, there is a slight bench not over four feet high the front of which shows a number of detached blocks which may have been dislocated by waves though satisfactory evidence of such action was not obtained. I do not find it easy to explain the position of these blocks, or the general water-worn look of the surface on any hypothesis other than that of marine action.

Generalization of evidences from benches.—We have now considered in a general and imperfect manner the evidence derived from the various scarfs and benches found on its mountain sides. Although the evidence thus presented is but a small part of that which could be obtained by a detailed study of those mountains, it sufficiently indicates that these peaks have probably been submerged nearly if not quite to the highest crest since the close of the last glacial period and that in the re-elevation of the region, the land made many pauses in its upward movement; each pause enduring for a time sufficiently long for the sea to carve considerable benches in the rocks. The total number of these pauses was at least twelve. It may have been that the periods of re-elevation were even more numerous, for it is not at all likely that I have succeeded in identifying all the benches which a careful inquiry would show to exist.

Evidences from chasms.—We will now turn our attention to another class of evidence which has been only incidentally referred to in the preceding pages, viz, to the runnels or chasms formed where the sea has carved out the softer or more yielding parts of the rocks, such as those occupied by dikes. These chasms are much less conspicuous than the benches, but they afford equally good evidence of marine action. Their limited width and the extent to which they become filled in with the débris from their sides, together with the large amount of vegetable matter which accumulates in their moist recesses, makes the task of discerning them much more difficult than that of discovering benches. The most important points to note in connection with these chasms are that, like the benches, they are in the main limited to the southern face of the island, and that they are most plentiful in those levels which show the most abundant benchings, though they are not infrequently found in portions of these levels where the benchings are not traceable, or are very obscure. So far as I have observed, the most distinct of these chasms are found in the section between the present surface of the sea and the height of about three hundred feet. They can be seen along the greater part of the southern shore from Seal Harbor to Otter Creek. The best examples of these chasms which I have seen are found on the slopes of Cox's Hill, on the east side of Seal Harbor, where they may be traced from the present water level to the height of about two hundred and twenty feet, with but slight interruption in their continuity. These runnels are most distinct where they lie in the level of the benches, but they are frequently traceable for some little distance above and below that level. This upward and downward extension beyond the limits of the scarf may be understood if we consider that the chasms are cut upward and backward from the front of the cliff by a process of undermining which permits the superincumbent mass to fall into the chasm below. This process may be seen at any point along the shore where such chasms are now forming. In this way, operating from a few distinct levels, a trench may be cut the whole length of a long slope.

Above the level of 300 feet and up to 500 feet the chasms, though found at various points, are much less conspicuous than in the lower levels. From 500 feet to 1,000 feet the general steepness of the slopes makes it difficult for any long chasms to form. They appear in this belt as sharp reëntrant angles, none of them extending far in from the face of the cliff. They often have exactly the character of the small coves of the existing shore. Above the level of 1,000 feet it becomes necessary to divide these channels into two classes: the channels formed before the last glaciation, and those formed since that time. It is not always easy to separate these two classes of chasms; though in most instances they are sharply distinguished from each other, there are cases where we can not confidently class them in either group. The sharply notched defile between Green and Dry Mountains is probably a preglacial chasm further excavated by the sea, or it may have been originally a marine cleft afterwards widened and deepened by the ice and still later reëxcavated by marine action. The deep chasms near the summits of Jordan's and Pemetic Mountains are apparently postglacial in origin and bear what seem to be marks of marine action. Their steep-walled and unglaciated sides and the huddle of subangular sea-worn rocks in the crevices apparently leave no room for doubt as to the circumstances of their origin. (See Fig. 40).

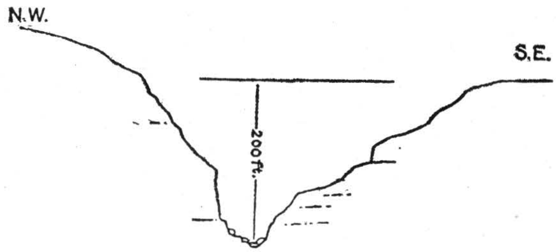


FIG. 40. Gorge between Jordan's and Sargent's Mountains.

It is to be noted that these chasms are wanting in the upper 200 feet of the mountain heights, where the evidences of marine action, though fairly clear, are far less marked than at the lower levels.

Thus, even with the imperfect study which I have been able to give to these scattered chasms, it is seen that they contribute important evidence to show marine action at various levels above the present shore-line, and that this evidence exactly accords with that which is afforded by the washing of the surface and the benching of that surface by the sea waves.

The absence of these chasms on the northern face of the mountain appears to me to be very strong corroborative evidence as to the sea-worn character of this southern face. Thus we see that the evidence as to the marine nature of the erosion does not rest upon the benchings, or the washed character of the surface, or upon the chasms, but upon the combination of these three features in the same belts at different heights on the mountain slopes. None except the washing of the surface can be noted on the northern slopes, except very faintly, above the line of 1,000 feet.

During the submergence of the island the area of the water to the north was undoubtedly much wider than at present. With a submergence of 500 feet the sea would penetrate fifteen or twenty miles northward of the present shore, and with a submergence of a thousand feet the water to the north would have a width of more than thirty miles, though its surface would be interrupted by considerable islands; still, even with the Mount Desert Mountains submerged to their tips, the open water to the north would not be wide enough to permit the formation of powerful waves. Moreover, the greater thickness of drift, as well as the gentler slopes which characterize the northern versant of the mountains, would hinder the scouring action of the sea.

Evidences of subsidence from distribution of glacial waste.—We now turn to give some special attention to the less important but still noteworthy division of the evidence as to submersion, viz: That derived from the distribution of the glacial waste which lies upon the slopes of the mountains. We have already considered this matter in a general way in connection with the other evidence, and have seen that this glacial waste, excepting the large bowlders, is generally swept away from all the exposed headlands and precipices, and that even in the more sheltered valleys it rarely attains to a greater height than 500 feet above the sea. Above this level the greater part of the surface of the rocks is bare, or is covered with a slight soil, composed in the main of vegetable waste commingled with a small amount of the decayed bed rocks.

Over most of the surface the only portion of the glacial waste which remains are the large bowlders, from between which the finer materials have been washed away. On the levels upon which benchings are carved even these bowlders, except in occasional cases, have been removed by the action of the waves. In the levels between the benches the extent to which the bowlders have been swept away is variable, depending in a measure on the steepness of slope and also on the degree to which it has been exposed to the sweep of the ocean.

The distribution of these remaining fragments of glacial waste can best be studied on the long slope leading from the summit of Green Mountain downwards to the height of 640 feet. On this slope there is little evidence of glacial action except occasional scratches, which have been preserved in places sheltered from the sea by projecting points, and in the bowlders which are scattered over its surface. These bowlders rarely exceed about one hundred to the acre, counting everything from six inches in diameter to the very rare fragments three or four feet in diameter. Not over one-twentieth of the surface is occupied by these fragments of glacial origin. They appear to be most plentiful in the belts between the levels of benchings, and least plentiful on the scarfed surfaces. In a word, the distribution of the glacial waste is substantially the same as that we have along the present shores.

Besides these bowlders there are in the region above 800 feet in altitude on the above-named mountain slope occasional small patches of bowlder clay and larger accumulations of sand and pebbles lodged in the sheltered places where these materials have had some protection from the sea. On the southern face of the mountains none of these patches appear to exceed a few square yards in area. On the northern slopes they are more plentiful and much larger. Above the level of 800 feet these patches of drift which remain on the south side of the mountain do not exceed in area a hundredth part of the surface, while on the north side within the same limits they cover at least one-third of the rock. This is an instructive fact, for the north side of the mountain during the period of depression must have been exposed to a narrow sea while the south side was open to the beat of the Atlantic surges. Below the level of 800 feet and thence to the sea the amount of glacial waste in the form of original till is much greater than in the upper part of the island. Except on the exposed headlands the drift covering between the several benches which are found on this part of the slopes is tolerably continuous and preserves its original character in a remarkable way. On the northern portion of the island, from the level of 800 feet down to the sea, the covering of drift has about the normal degree of continuity exhibited over the general surface of New England.

In considering the conclusions which we are led to form from the distribution of the drift on Mount Desert the first question that arises is whether there is any reason to suppose that the deposit was originally laid down in this scattered way on the uplands, and whether, in a word, its distribution can be due to the circumstance of its deposition rather than to the subsequent removal of the matter by the action of the waves. The answer to this question seems clear. The ordinary ground moraine drift was certainly carried in the ice. In no other way can we account for the occurrence of the scratches displayed upon these pebbles, or indeed for the carriage of the débris. The presumption is, that when the ice sheet melted it left something like as much waste on the high grounds as on the average of the lower levels. The diminished thickness of the ice in the uplands may have caused a diminution in its eroding power, but the sheet must have had sufficient rending action to produce a certain amount of débris. On this point we are not left altogether to conjecture; for, as has been noted, on these nearly driftless surfaces there are occasional patches of till, having all the characteristic features of that deposit, and sometimes of considerable thickness. The position of these usually shows that they owe their preservation to some local accident, which has given them just such shelter as would have protected them from sea waves. As it is manifest that we can not assume that they were originally the only portion of till formed upon this surface, we are again driven to the hypothesis of wave action on the upper parts of the island. Still it is evident that the duration of the wave action at the levels between the sea benches must have been brief, for even on the less exposed north face of Green Mountain a slight exposure to waves such as would have formed in the sea that lay to the north would have sufficed to strip away this covering of till.

CONCLUSIONS RESPECTING SUBSIDENCE.

We have considered in some detail the evidence which goes to show a submergence of this island after the close of the last glacial period. We have seen that the rock cutting of the scarfs, the formation of chasms or runnels, and the removal of the drift material agree in the evidence which they afford. We have also seen that the contrast between the amount of the eroding action on the north and south faces of the mountains confirms the view that the sea has operated at different heights all the way from the present level of the ocean to the summit of the mountains since the close of the last glacial period. We are now prepared to state the hypothesis of subsidence in a form which will reconcile the whole of this evidence in the following propositions, viz:

(1) That after the disappearance of the glacial ice from this district the area was depressed below the level of the sea probably to the very summits of the highest peaks (1,527 feet), and certainly to the height of 1,300 feet.

(2) That the uprise of the land did not take place by a uniform continuous elevation, but by a succession of uplifts and pauses.

(3) That these uplifts in certain cases must have taken place in a manner so sudden, that the glacial drift was not swept away from all the surface intervening between the levels at which the sea for a time remained steadfast.

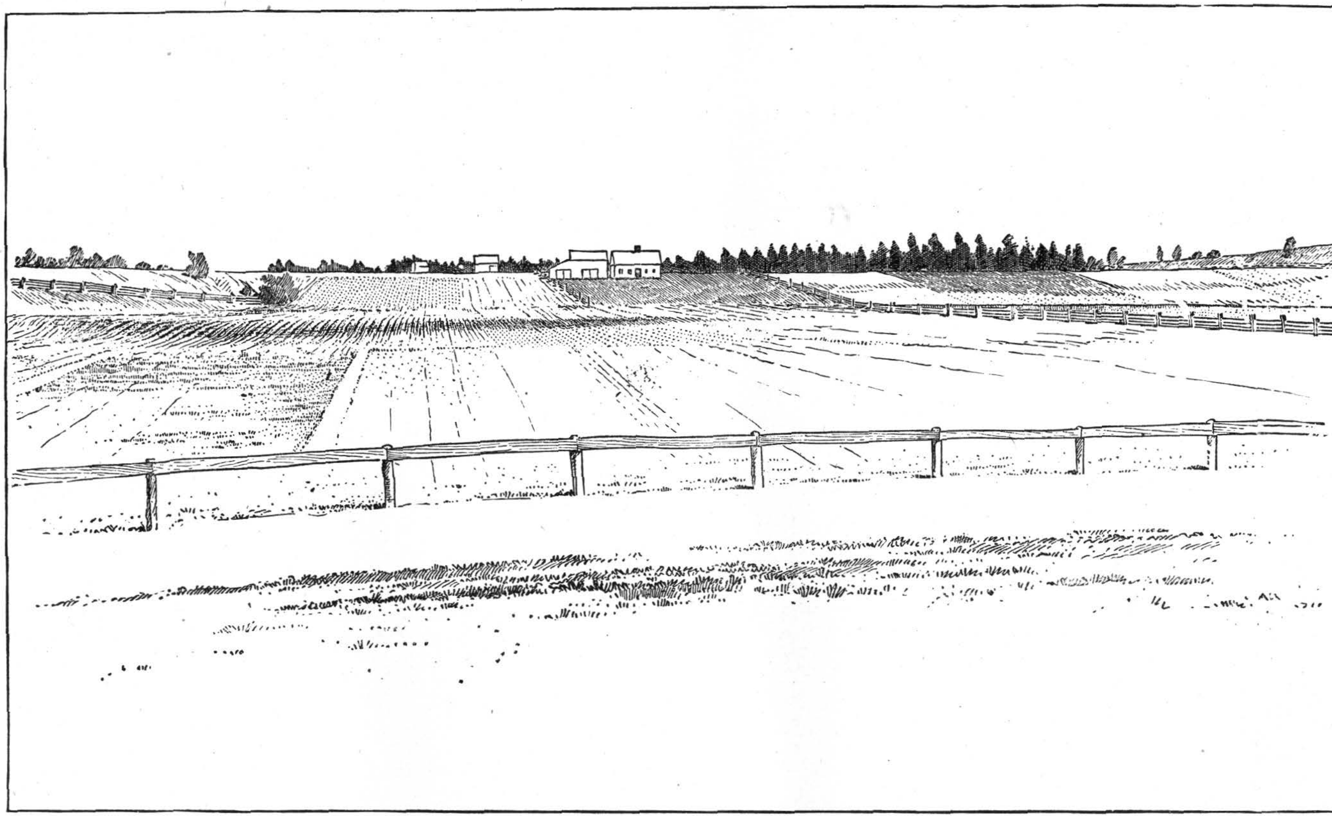
(4) That the sea in the course of the process of elevation remained at certain levels for considerable periods, during which benches were formed not much less conspicuous than those which now border the present shore.

(5) That these benches become more evident as we descend from the summit of the hills toward their base, whence we may conclude that the sea remained longer in its pauses at the lower than it did at the higher levels.

(6) That the stratified and fossil-bearing clays and the stratified sands enable us, without other evidence, to assert the former presence of the sea up to the level of about three hundred and forty feet above its present altitude.

(7) That while the difference between the uppermost scarfs and those of the lower three hundred feet is considerable, it is only a difference in the degree of cutting done on the rock. In its essential features the evidence is the same for all the levels up to near the summit of Green Mountain.

Unless I have entirely misapprehended the bearing of this evidence it opens a very wide field of inquiry as to the history during the post-glacial period of this portion of the American coast. All these mountains are peculiarly well placed for receiving the blow of the waves and they have a structure well fitted to receive and preserve the record of wave action. It is not likely that they are the only mountains of New England which were depressed during the glacial period, if the movement of sinking was general. We may therefore fairly expect that the other hills on this part of the shore which expose rocky faces to the ocean will afford similar marks of wave action.



ELEVATED BEACHES AT HULL'S COVE.

A question arises with reference to these benches which bears upon the application of the observations above related to other parts of the shore, viz: Are these sea levels horizontal with reference to each other and to the existing plane of the sea? In other words, Was the land of the district lifted in mass, all parts rising at the same rate, or were the several parts lifted to different heights? On this point I have no satisfactory evidence to offer. As before remarked, none of these benches are any more continuous than the bench now forming at the shore; nor is the cliff of the bench of the existing coast line, either at base or summit, of exactly the same height throughout its length. There is in these old sea faces, as in the present sea face, a range of ten or fifteen feet in the position of the base of the cliff, and an even greater difference in the height of its summit. These irregularities make it impossible within the narrow horizontal limits of the island to determine the question of relative movement during the re-elevation, at least without a very difficult and perplexing inquiry.

So, too, I am unable to determine whether the present sea shore marks the lowest level which the sea has occupied since the glacial period. In the more southern part of the coast, certainly as far north as Portland and also on the coast of New Brunswick, there is proof of a certain amount of subsidence since the close of the glacial period. I have been unable to find any evidence to show that such a downward movement has taken place on this shore. This negative evidence is of no importance, for the reason that the shore of this island is too precipitous to retain proofs in the way of submerged forests, which afford the only unmistakable evidence of submergence. As to the nature of these movements at present going on upon this coast, if any there be, I am likewise without positive information.

The only material evidence as to the constancy of the present sea level is that afforded by the existing forests. These at many points have their roots and stems down to the very edge of the high-tide level. Along the shores of sheltered inlets dead trees, at least two hundred years old, seem to show by their position that no recent upward movement of as much as one foot in a century can have taken place. All the facts seem to point to the conclusion that this shore is at present in a state of stability. Indeed the conclusion which may be fairly drawn from the evidence afforded by a comparison of the marine benches above the present level of the sea with intermediate belts in which no benching is traceable is that there has been in the past no process of gradual uplift along the shore of this island, but that the land has passed by sudden movements from one level to another. Judging by the evidence of the past, it may be considered probable that if the level of this part of the shore is to be again changed the change is more likely to be accomplished by a rather sudden than by a gradual movement.[1]

It is not my intention in this memoir to discuss the general questions which arise with reference to these changes which have been noted. It may be remarked, however, that just such sudden alterations are indicated with great clearness on the southern part of the New England coast. On the shores of the bays and on the islands which border it on the south there are extensive deposits of glacial kames which clearly were formed beneath the level of the sea. These kames have been lifted through the waves to their present position without losing any considerable part of the extremely delicate molding which characterized them. When we consider that these ridges and hollows are formed of the most incoherent materials of sand and gravel which would lose their shape if exposed for a few days to the cutting power of the waves we are driven to the conclusion that they were suddenly lifted through the plane of the sea surface. Such sudden elevations and depressions of the shore are not unexampled in the brief period during which the surface of the earth has been subjected to careful observation, but wherever such swift alterations of level have been observed, as in New Zealand or on the west coast of South America, or in western India, they have in all cases been connected with powerful earthquake shocks. It is clear, however, that on this portion of the shore there have been no earthquakes of any importance since the close of the last glacial period. The whole surface of the island abounds in poised bowlders which often can be dislodged from their positions by a touch of the hand and which certainly would not have escaped dislocation if the region had been convulsed by earthquakes. Such delicately poised fragments as that which occupies the summit of Pulpit Rock on the 220-foot bench of the island, could not have maintained their position against violent jarrings. I am therefore disposed to believe that this upward movement of the shore did not belong to the type of dislocations which are continued by earthquake shocks, but must be placed in another category.

[1] It should not, however, be assumed that the apparent stability of this portion of the shore necessarily leads us to the conclusion that the whole of the coast line of this part of the continent is in a similarly steadfast condition. There are reasons for believing that the movements of different parts of the shore exhibit a considerable diversity in their nature.

II. STRUCTURAL GEOLOGY.

PREFATORY.

In the foregoing account of the surface geology of Mount Desert I have been compelled frequently to make incidental reference to the rocks of which the island is composed. We shall now turn our attention to the dynamic features exhibited by these several parts in its mass.

As will be seen by a glance at the accompanying geological map the island consists of several structural elements, viz, the central granites, which are totally unmixed with any stratified rocks; the peripheral series or rather several series, which are composed of more or less metamorphosed stratified deposits, and an extensive and extremely varied system of dikes, some of which cut the granite as well as the overlying sedimentary rocks, while others are apparently limited to the sedimentary series alone.[1]

GRANITES OF MOUNT DESERT.

The granites may from the point of view of dynamic geology be divided into two groups, those which compose the central mountainous portion of the island and those which are found in the form of dikes, cutting through the stratified deposits on the periphery of the island.

The central mass of granite is of remarkably uniform composition, excepting where it is cut by the frequent dikes which intersect it, and where these dikes produce slight changes in the constituents of the granite at the points of contact. There is, however, a considerable difference in the direction and importance of its several joint planes. At some points it is very little jointed; this is the case with the central portions of the mass, i. e., those parts occupied by the higher mountains. The joints seem to be more frequent in the part of the granite which lies on the periphery of the central mass, and also in the portions of the mountains which contain the greater valleys inter-

[1] Throughout this memoir the crystalline rock which constitutes the central axis of Mount Desert will be termed granite. This rock is of a somewhat varied constitution, as noted by C. H. Hitchcock, in the Second Annual Report of the Natural History and Geology of the State of Maine, in 1863, page 271. In some portions of the rock the talcose material is substituted for mica. In other portions the mica is to a greater or less extent replaced by hornblende, producing a petrographic species which is now termed hornblendic granitite, but is more commonly known as syenite. There are yet other variations, interesting to the petrographer, but for the very general purposes of this memoir all this crystalline group may be classed under the term granite.

secting the main range. This increase in the number of joints in the valleys may be due to the greater number of dikes in those portions of the island. In that part of the field occupied by Somes Sound, which intersects the granites, the rocks appear to be softer than in the mountain region, the mass often being very considerably decayed. This decay apparently arises from a change in the feldspathic element leading to a kaolinization of that substance. The relative ease with which the rocks of these valleys have been eroded is doubtless in part due to the softening attendant on the penetration of the numerous dikes which are found there.

On the periphery of the central granite area that rock becomes somewhat finer grained and also of a whiter color. The change in the number and position of the joint planes seems also to alter the manner of weathering, so that the rock is modified in its superficial aspect though retaining the same mineral composition. The alteration in the character of the joint planes is well shown in the quarries on the west side of Somes Sound, a little south of Broad Cove.[1] In these quarries the joint plane which is nearest to horizontal, and which has a strike northwest and southeast, with a dip to the eastward at an angle of 20° is very much developed, while the other joints are to a great extent suppressed. This principal joint is so asserted that it is an easy matter for the quarryman to procure flat slabs of the stone 25 feet by 10 feet in surface and not over 7 inches thick. These joints are remarkably plane-surfaced. On an exposure of 100 by 60 feet or 6,000 square feet the departure from a perfect plane, as observed in this quarry in 1885, did not at any point amount to 6 inches in direction. It is probable that we owe the rapid superficial decay of these peripheral granites, under the influence of glacial and marine erosion, in part, at least, to the occurrence of these very perfect joint planes in a nearly horizontal position.

The effect of such joints in favoring the cutting action of the sea is well seen on the granite that composes the whole mass of Baker's Island, which lies three miles south of Mount Desert. This island belongs to a separate granite injection, but its character is essentially like all of the peripheral portions of the Mount Desert axis, closely resembling the beds of the above-mentioned quarries. On the present shore of Baker's Island the granite is rapidly and extensively disrupted by the sea. Waves trip the horizontally jointed rocks from their bed places and hurl them in large angular masses to the top of the slope of the shore. Such is the ease with which these masses are riven from their beds that a sea-wall many feet in height crowns the gradual slope of this shore, composed altogether of these angular fragments, containing each from ten to one hundred cubic feet of stone, which looks like masses artificially riven from a quarry bed. Wherever this

[1] West of Somes Sound, opposite Sargent's Cove.

rock has this nearly horizontal joint strongly developed it is worn down to a far greater degree than where the fracture does not exist.

The granite of the numerous dikes which penetrate the fringe of stratified rocks that surrounds the great central granitic area is generally rather finer grained and whiter than the material found in the mountainous part of the island.

STRATIFIED ROCKS OF MOUNT DESERT.

GENERAL STATEMENT.

The stratified rocks of Mount Desert may be grouped in the following series, viz:

(1) A thick layer of micaceous, chloritic, and sometimes gneissoid, schists, which lie upon the west side of the island, extending from Thomas Bay, on the north side of the island, to Nutter's Point, the extremity of the southwestern shore. To this I give the name of Bartlett's Island series.

(2) A similar series of micaceous schists and shales, possibly of the same age, but of a less distinctly schistose character, on the east face of the island, extending from near Schooner Head to Rodick's Cove.[1] I shall term this series the Schooner Head series,

(3) A series of highly metamorphosed slates and flags, with what appear to be bedded felsites between them, which form Sutton's Island and the greater part of the Cranberry Islands, and occur as a fringe along the south shore of Mount Desert.

(4) A somewhat similar series of granite and argillaceous flags and slates, with a set of beds of magnesian rocks, which occupy the north face of the island, from near Rodick's Cove to the Ovens.[2]

(5) A series of stratified volcanic breccias, porphyries, and ash-beds, closely resembling those which so plentifully occur in the district about Passamaquoddy Bay, Maine, and Saugus, Mass. These beds have been found only on the southern part of Mount Desert, south of Southwest Harbor, and on the neighboring Cranberry Islands and the adjacent islets. A careful search of the glacial drift specimens of the rock occurring in the concealed regions northward makes it appear very unlikely that these beds are present north of the places above indicated, as no trace of rock materials appears in the drift on Mount Desert north of Southwest Harbor.

The above-named five series include all the clearly stratified rocks in this district. It is evident, from the glacial drift of the island of Mount Desert that not far north of its limits there is a series of Devonian shales, limestones, and sandstones very rich in fossils and but little metamorphosed. The site of these beds is not yet ascertained.

[1] The inlet nearly opposite Round Porcupine Island.

[2] The Ovens can be identified on the map as the most northern point to which a road is shown.

The fossiliferous erratics are most abundant on the west shore of the island. Though carefully sought for, none have as yet been found by myself or my students east of the axis of Somes Sound.

As will be noted below, the divisions between these several series of rocks are not satisfactorily clear. As here presented they must be regarded as essentially provisional. As our knowledge of this district advances it is likely that the classification here given will have to be considerably modified.

BARTLETT'S ISLAND SERIES.

This series of schists, quartzites, and sandstones is the thickest and most characteristic of all those found on Mount Desert. It occupies nearly the whole west face of the island and of the islets near it. The sections show that the thickness of this series can not be less than 2,000 feet, and may much exceed it.

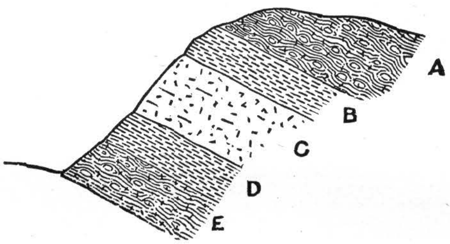


FIG. 41. Section showing relation between schists and quartzites. A, contorted schists; B, schists not contorted; C, quartzite; D, schists not contorted; E, contorted schists.

The schists have a very uniform character. They are generally thin bedded and much corrugated by the slight foldings to which they have been subjected. The layers consist of alternations of quartzose beds usually not exceeding half an inch thick, interlaid with talcose and micaceous layers, which retain in places a clayey look. In the lower portions of the section, especially on the north shore of Mount Desert, where the metamorphoses of the rocks seem to have been more complete than elsewhere, the banded character of the schists is not so evident. The quartz is gathered into short lens-shaped bodies, which rarely extend more than a few inches in any direction, though sometimes they are several feet in diameter. The micaceous and clayey portions of the schist have been pushed about in the segregation of the quartz until the original stratification has been in good part obliterated. The general dip of the strata in all parts of the field is shown by the occasional beds of quartz other than the lenses which occur in it. These distinct beds are from a few inches to five or six feet in thickness. In no cases have they any trace of the foliation or the flexing which seems to be so constant in the thinner-bedded materials with which they are associated. They have uniform dips in the various directions indicated by the following table, which is intended to show the prevailing attitudes of this series of rocks by the positions of these permanent quartz beds in a more compact form than those facts are exhibited by the map accompanying this report:

Strikes and dips of Bartlett's Island series.

Position.	Strike.	Dip.
South side of Pretty Marsh Harbor	N	E. 40°.
East side of Pretty Marsh Harbor	N	E. 30°.
Near Moose Island	N. 50° W	E. 85°.
Near Moose Island	N. 75° E	E. 50°.
North side of Seal Cove	N. 20° W	E. 30°.
South side of Seal Cove	N. 90° E	S. variable.
Thompson's Island	N. 90° E	N. 47°.
Just south of Thompson's Island	N. 45° E	S. 20°.
One mile south of Thompson's Island	N. 40° E	S. 15°.
One-quarter mile north of Negro Point[1]	S. 80° E	S. 20°.
One-quarter mile south of Negro Point	S. 85° E	S. 32°.
Indian Point[2]	N. 44° E	S. 27°.
Bartlett's Island, north end	N. 35° E	S. 38°.
Bartlett's Island, north end	N. 20° E	Vertical.
Bartlett's Island, west side	N. 45° E	10° to 20°.

[1] West of Clark's Cove.
[2] East of Western Bay.

These included quartzose beds have apparently not only maintained themselves against the peculiar shoving action which has given rise to the corrugations in the schists, but they have also in some manner protected the neighboring portions of thin-bedded rocks from the flexing which has been elsewhere manifested. This protecting action frequently extends a foot or more above and below the margins of the quartzose beds. (See diagram, Fig. 41). It thus appears that the corrugation of the schists is probably due to some actual thrust operating to compel the beds to fold in the plane of the foliation. This evidence also seems to make it clear that such a pressure could not have resulted from a thrust external to the whole rock section in which it is manifested, for it is difficult to conceive such a pressure acting to produce very small folds in thin-layered beds without at the same time producing foldings in the thicker-bedded quartz deposits. It seems most likely that this compulsion to folding must have originated from some internal change in the thin beds themselves, probably connected with the formation of the concretions which they contain.

In its original constitution this Bartlett's Island division of schists appears to have been a very uniform mass of shales, in which there existed a few sandy layers. Under the metamorphic influences to which these rocks have been subjected, the layers of shale have been changed to contorted schists, while the more siliceous beds have taken on the form of vein-like quartz. That the masses are not in fact veins is clearly shown by their internal bedding, which is often distinct, and by the fact that at some points they are associated with dark-colored quartzose rocks, which preserve distinct evidence of their stratified origin.

No evidence as to the geological position of this extensive section has been obtained. There can hardly be any doubt that it lies low in the series of Paleozoic rocks. I know no unmetamorphosed sections on the Atlantic coast with which it can be compared. There seem to be no limestone beds in this section, which fact makes all efforts to identify its place extremely unpromising, though it serves to indicate that the series does not belong probably in any portion of the Atlantic coast section above the level of the Cambrian series. In the region about Eastport, Me., at a distance of not more than about 100 miles eastward of this locality, there is an extensive series of Silurian rocks previously described by me.[1] These rocks if much metamorphosed might assume a form having a general resemblance to these schistose rocks of Mount Desert, but there can be no question that such a section would retain in the form of crystalline limestone the limy beds originally present in it.

The fact that the west front of Bartlett's Island is to a great degree covered with a glacial waste of this series makes it plain that this succession of rocks extends for a considerable distance farther northwest than we find them now exposed in this district. It is not improbable that it occupies a greater part of the basin of Blue Hill Bay, just as the similar if not identical schists on the eastern face of Mount Desert probably form the floor of Frenchman's Bay. The total thickness of this Bartlett's Island series has not been well determined, for it is not certain but that the section is in part duplicated by folding; still it is likely that the total thickness of this series, making no allowance for the part of it which is concealed beneath Blue Hill Bay, amounts to more than two thousand feet and if we make some allowance for the extension beneath Blue Hill Bay it may be that it has twice the above-mentioned thickness. There can be no question that this series of rocks was laid down before the injection of the central granites. At various points, as is indicated on the map, dikes extend from this central granite through the Bartlett's Island series. Ample evidence of the pre-existence of this series is afforded by the other details of relation of these rocks to the central mass of the island.

It is evident that these soft rocks readily gave way before the wearing action of the waves and ice sheets which have operated upon them. Their preservation in low-lying elevations on the west side of the island is probably due in the main to the greater hardening they received from their propinquity to the ejections which form the

[1] Am. Jour. Sci., 3d series, vol. 32, 1886, pp. 1–82.

central parts of Mount Desert. This hardening increases as we go from the points most remote from the central nucleus toward the point of contact. In part the preservation of these schists is also due to the existence of a very extensive system of dikes which penetrate them near the contact with the central granitic mass. But for these circumstances the beds would doubtless have been worn away to points below the present level of the sea, as indeed the parts of the section most remote from the preserving agents have been. The relation of erosion (due to sea and to glacial ice) to the resisting material is beautifully shown in the topography found on the western flank of Mount Desert.

SCHOONER-HEAD SERIES.

The shore from Rodick's Cove southward to Schooner Head is occupied by a belt of schists and slates which closely resemble these just described on the west side of the island. The general character of these eastern schists is the same as those of the Bartlett's Island series, though they are apparently less metamorphosed. They are, moreover, thicker bedded and appear to have been originally more like flags than shales. As they are on the side of the island which has received the greatest impact of waves the area which they occupy above the water surface is less extensive than that occupied by the beds on the opposite shore. As these two series of schists occupy different sides of the island and are not connected, it seems best to consider them separately, though but for this feature of discontinuity there would be little hesitancy in referring them to the same age. Further study of these rocks on the mainland will be necessary in order to solve the question whether they are parts of the same system. A large part of the area beneath Frenchman's Bay is probably occupied by this series, and it is likely that the similar deposits found on the mainland north of Mount Desert, at least in part, belong to it.

SUTTON'S ISLAND SERIES.

This series is found only on the southern border of Mount Desert, in Sutton's Island and in the two Cranberry Islands. We should first notice that this so-called series can not be proved to be a continuous section. It consists of two divided portions, that which is found on Sutton's Island and that which appears on the Cranberry Islands; between these two there is a strait about three-quarters of a mile wide. It is not certain that any considerable part of these beds is repeated on the coast of the mainland south of Southwest Harbor, as there is very likely a considerable fault occupying the section between Cranberry Island and the south shore of Mount Desert. There is therefore nothing but convenience to determine the association of the rocks on Sutton's Island with those on the Cranberry Islands.

The greater part of Sutton's Island is occupied by massive dikes of granite, which are probably connected with the principal granites of Mount Desert. Along with these are many massive extrusions of felsites and porphyries. Only about one-fifth of the island, and perhaps less, is taken up by the stratified rocks. These consist of dark greenish and grayish thick, flaggy, rather siliceous clay stones decidedly indurated but presenting the characteristic aspect of similar deposits on Campobello and Deer Islands, in Passamaquoddy Bay, deposits which at the lowest points lie clearly below the zone of the Silurian proper.[1]

Although much cut up by dikes the flags of Sutton's Island preserve a tolerably uniform strike of S. 10° E., dip about 14° E. At some points there is a faint schistose structure in the beds of which the strike is N. 45° E., with vertical dip. It is barely possible that this last named may be the true dip and that which appears to be the dip may be a secondary structure, but I think this is not the case. The principal exposures of these flags are at the east and west ends of the island, the intermediate section being in the main occupied by the intrusive rocks, which however contain some patches of slate. We observe that between the numerous dikes here as elsewhere in this district the intrusions of rock have left the strikes of sedimentary deposits but little changed and their dips not greatly altered.

The beds which are found on Sutton's Island probably extend beneath the water to the shore of Mount Desert, for beds of this nature are found lying as patches on the shore from Bracey's Cove to Great Head, as is indicated on the map. Along this shore the contact of the Sutton's Island series with the principal granitic mass of the island is quite distinct though irregular, owing to the number of dikes of granite which pass from the central mass into the stratified rocks. (See Fig. 42.)

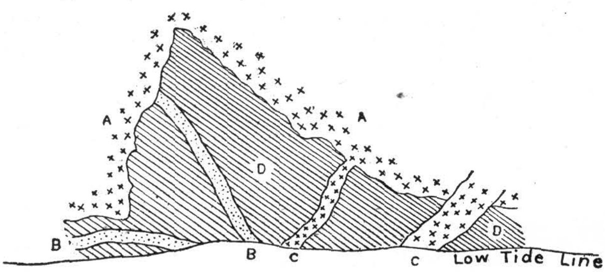


FIG. 42. Section showing relation between schists and quartzites, near eastern horn of Seal Harbor. A A, granitic mass; B B, dikes formed before granitic injection; C C, small granitic dikes; D, Sutton Island schists.

On the northern border of Little Cranberry Island we have a series of siliceous flaggy layers, which are probably closely related to

[1]See Preliminary Report on the Geology of Cobscook Bay, Am. Jour. Sci., 3d series, vol. 32, 1886, pp. 35–60.

the stratified beds of Sutton's Island. The section is not over 100 feet thick, but it probably occupies a considerable area beneath the surface of the strait which separates the two islands. This is shown by the glacial drift, which at this point is in the main composed of fragments derived from similar beds. The beds of this part of the section are nearly vertical, striking about N. 45° E., dip SE. 80°. Above this we find a very extensive series of volcanic rocks, which have a thickness of at least 2,000 feet; to which I give the name of Cranberry Island series.

CRANBERRY ISLAND SERIES.

At their contact with the Sutton's Island series the volcanic beds of the Cranberry Islands consist of porphyries, breccias, and amygdaloids, all apparently bedded, probably by a succession of lava flows and volcanic ash showers. After the beds were lifted to a high angle there appear to have been some injections of volcanic rock which followed the bedding plane of the strata, so that some of the deposits which appear to be beds may turn out to be dikes.

The deposits of felsite porphyry occur in the two common banded and spotted varieties; in their prevailing aspect they closely resemble the deposits of this nature found along the shores of Massachusetts Bay and in a general way resemble the extrusions of porphyry near Eastport. Besides the masses of apparently bedded porphyry the material occurs in the shape of dikes traversing the other rocks on the north shore of Little Cranberry Island.

These porphyries pass by what appear to be gradual changes into the amygdaloids. The amygdaloidal beds are remarkable for the large size of the amygdules, many of these having a diameter of three inches or more.

The deposits of breccias or volcanic ash, the two materials being so commingled that distinctions cannot readily be made, are very extensive and form an important part of the series. Their appearance is, in a general way, like the similar deposits occurring on the waters of Passamaquoddy Bay, especially those on the western extremity of Moose Island, where stands the town of Eastport, Me. They exhibit no evidence of flow structure. It seems probable that they were formed of fragments which fell through the atmosphere, and that they were derived from volcanic ejections which took place in the open air, though it is possible that they may have fallen through water to their present bed places. In the Passamaquoddy district a large part of the volcanic material of this nature has a reddish hue. No beds of this color were found on the Cranberry Islands, but it is noteworthy that a single bowlder about three feet in diameter lies on the north shore of Little Cranberry Island, which is precisely like those remarkable reddish volcanic breccias found along the shore of Cobscook Bay. It is therefore likely that such beds lie buried beneath the sea under the water which separates this from Sutton's Island. The whole width of Little Cranberry Island, from its north shore to the south end of the tide-swept isthmus which connects it with Baker's Island, is composed of an alternating succession of porphyries and ash-beds.

Some of these fragmental beds nearest Baker's Island have a very remarkable aspect. The fragments contained in the mass are drawn out into ribbon-like bands, as if the rock in which they lie had been melted and much extended after they had taken their place. I have seen a similar effect in the recent volcanic ashbeds which lie near the western base of the steep on which stands the well-known Camaldoli monastery, near Naples, where the conditions favor the assumption that the extension of the fragments has been produced by the softening of the breccias by heat and the stretching of the mass by pressure.

The whole of Baker's Island consists of granite essentially like that found in the marginal portions of the Mount Desert district. Its character will be further considered in that section of the report which concerns the dikes of this district.

Thus the whole of Little Cranberry Island except a narrow strip on the north shore appears to be made up of volcanic rocks bedded, but with their beds at angles exceeding 45° of declivity and generally nearly vertical The fact that they are essentially beds is indicated not only by their general aspect but by the circumstances that their strike lines are substantially the same as those of unquestionably stratified deposits of this district. The following strikes were observed on the Cranberry Islands, the dips being nearly vertical:

Strikes and dips on Cranberry Islands.

	Strike.	Dip.
Little Cranberry Island:		
Slates	N. 45° E.	
Volcanic ashbeds	N. 45° E.	
Bedded amygdaloids	N. 45° E.	
Blue fragmental felsites	N. 68° E.	
Cranberry Island:		
Green schistose shales	E. 70° E.	
Green schists and shales	N. 70° E.	S. 80°.
Dark schists	N. 70° E.	
Volcanic breccia	N. 70° E.	S. 75°.
Greenish slates	N. 85° E.	S. 48°.
Greenish slates	N. 71° E.	S. 55°.
Purple flags	N. 80° E.	S. 72°.

These several strikes are pretty evenly scattered along the shores of the two islands. They seem to show that the attitudes of distinctly sedimentary deposits are essentially the same as those of volcanic materials. I therefore assume that what seems to the eye to be bedding is such in fact. It may also be noted that the dips of the volcanic deposits are apparently somewhat steeper than those of the slates on which they lie. This appears to indicate that the original inclination of these volcanic deposits was rather steeper than that of the ordinary sedimentary materials on which they were superimposed. It seems also to show that the slates and flags were once less inclined than they now are. We may conclude, therefore, that inasmuch as the inclination of these beds was probably brought about by the injection of the granitic mass of Mount Desert, they were formed before that injection took place.

On Cranberry Island we find essentially a repetition of the section shown on Little Cranberry Island, with the exception that the proportion of clay slates and bedded quartzites is much larger than the volcanic materials. We also observe that the schists and slates are more distinctly mingled with the igneous materials than on the smaller island. Moreover, as there are extensive deposits of metamorphic shales at a higher level than the volcanic rocks, we are able to prove, save for the possibility of unseen faults, that the latter series were inclosed within normal sedimentary deposits. (Figs. 43 and 44.)

On the shores of Mount Desert, south of Southwest Harbor, we have the series of Cranberry Islands and Sutton's Island rather obscurely represented. The rocks on this shore from Fernald's Point southwardly to the Nubble[1] are so much cut up with dikes that it is almost impossible to ascertain their original relations. On this shore, as on all the points where we approach the central granites, the amount of dike injection greatly increases, and the confusing effect on the stratified deposits is far greater than in the outlying districts. Omitting the dikes this section gives us, beginning at Fernald's Point, the following succession, viz:

(1) On Fernald's Point, or the point just south of Fernald's Cove,[2] we find a mass of trap commingled with highly metamorphosed greenish shales and sandstones; associated with these is a section of white quartzites distinctly bedded, striking about N. 50° W., dip NE. 25°. These quartzites have a thickness of a hundred feet or more. South of these beds, on the shore north of Norwood's Cove, we have an extensive though much ruptured section of reddish and greenish slates with a strike of S. 85° E., dip southwardly 23°. Only a small portion of the shore from Fernald's Point to Norwood's Cove is composed of slates; by far the greater part is made up of trappean rocks, which inclose masses of slate amounting altogether to only 300 feet in thickness in a section of coast line of 2,000 feet or more.

(2) On the south side of Norwood's Cove there is a small section

[1] The rounded point a little east of Locust Reach.

[2] The first cove on the right passing out of The Narrows from Somes Sound.

of flaggy slates which closely resemble in general aspect the Cambrian slates of Braintree, Mass.; these beds are nearly horizontal. From the last-named point to the west side of Southwest Harbor all the exposures consist of eruptive rocks, but it is likely that the many parts of this shore which are concealed by drift contain portions of the sedimentary series. At the head of Southwest Harbor there is a considerable exposure of clay slates, which also resemble, like the last named, the Braintree sections. The fragments of stratified material which are embedded in the igneous sections have the strike of N. 80° E. and a dip of S. 78°. Beds about one hundred feet thick are exposed, but the total thickness, including that which is concealed by drift deposits, is at least as much more. It will be observed that there are faint indications of an anticlinal axis in this section. Near Clarke's Point we had strata dipping northward, then beds nearly horizontal, and lastly, at this point, beds dipping southward. A brief search for fossils in these beds failed to reveal any traces of organic remains, but it is desirable that this portion of the section, which contains greater thickness of relatively unmetamorphosed material than any other part of the island, should be carefully examined with a view to ascertaining if it be fossiliferous.

(3) From Southwest Harbor southward, the exposures for a mile or more are infrequent. The rocks which have survived the erosion so far as to remain above the level of the sea are altogether of igneous origin. They consist mainly of felsites of a whitish color, but there are probably other deposits contained in this section which are hidden by the sea or by deposits of drift. It is particularly to be regretted that the exposures are so scanty along this portion of the coast, because it affords us our only chance to determine the character of the rocks which are hidden by the strait between Sutton Island and the Cranberry Islands.

Where the line of strike of the ashbeds on Cranberry Island comes upon this shore we find traces of that series, but the exposures of these volcanic deposits are very imperfect, owing to the large amount of dike injection and the exterior marine erosion which has occurred in this portion of the shore. These ashbeds, however, are visible from point to point all the way from the place where they first appear to about a mile south, having nearly the same width as they show on the Cranberry Islands though they are much less clearly disclosed.

As before remarked this section of volcanic ashbeds is essentially like that exhibited on the shores of Cobscook Bay and near Boston, Mass. In all of these sections are very extensive felsite porphyries which sometimes appear as indistinct dikes, and again have the aspect of broad sheets like flows of lava which had been very fluid at the time of its ejection.

So far these volcanic rocks have been found in place at but three points on the whole coast line between Eastport and New York, but their plentiful occurrence in the drift on Nantucket and Cape Cod, in positions that make it certain that they could not have been derived from any localities remote from the positions in which we find them, shows that they occur in place at points south of the latitude of Boston. As the above parts of the coast are the only ones which have been submitted to a careful search for these beds it is very likely that they may occur elsewhere along the eastern shore line of the United States.

So far these volcanic breccias and ashes have not been found far away from the coast of New England, excepting, perhaps, in the Connecticut Valley, where deposits are found different in aspect but perhaps identical in the essential circumstances of their origin. The evidence indicates that there is along this shore, in good part beneath the sea, a region characterized by the occurrence of extensive fields of volcanic matter produced by outbreaks which took place in an early stage of the Paleozoic period. That these deposits do not occur in the interior district of New England is proved by the fact that a careful search of the drift materials along the whole of this coast line has failed to show any trace of them. The evidence obtained at Cobscook Bay pretty clearly establishes the time of the ejection of the volcanic matter as the period below the middle Silurian age. In the field near Boston there is reason to believe that the eruptions occurred during or before the Cambrian period. In the Mount Desert section it does not at present seem possible to place these volcanic deposits in the geological section.

BAR HARBOR SERIES.

In this group we shall for convenience place the bedded rocks which are found on the north and east shores of Mount Desert from Rodick's Cove to the Ovens. This section includes the most extensive series of distinctly stratified rocks that occur about the shores of the island. The several divisions of the series differ much in their general character, and on that account may need to be divided into distinct groups of strata.

These deposits are in the main composed of quartzose and argillaceous slates, shales, and flags. Near Rodick's Cove and in some other places they consist in the main of bluish green and purple shales; at some points the beds are crowded with siliceous concretions, which are best seen on the point just south of Rodick's Cove. The physical condition of these beds is not so far changed that any fossils originally preserved in them would necessarily be lost, yet they appear to be entirely without trace of organic remains. The beds generally lie at a low angle, the strike being from N. to N. 20° E., the dip southerly with an angle of from 5° to 20°. Over two hundred feet of this section of shales can be traced on this shore and the beds do not reappear at any other point on the island. These beds seem to have been formed in deep water. This is indicated by their very thin and even bedding as well as by the peculiar colors which belong to rocks formed in the deeper portions of the Paleozoic seas. I am disposed to think that this small series represents the beds deposited at a later period than any other of those represented on the island. The relatively small amount of metamorphism to which they have been subjected seems to indicate that they may have been formed after the greater igneous injections had taken place.

North of Rodick's Cove and from that point to the bar which extends from Mount Desert to Bar Island the shore is fringed with a section of siliceous flags often a good deal metamorphosed, occasionally appearing as mica schists, but always preserving their distinctly bedded character, and, except near their contact with the numerous dikes which intersect them, exhibiting very little dislocation. The strike of these beds, as will be seen from the accompanying map on which they are indicated, is pretty generally from NNE. to E., with a dip varying from northerly to southerly. The sudden changes in direction of the dip seem to have been brought about by the injection of considerable dikes near which the beds are often sharply crumpled. The same series of beds appear on the southeast side of Bar Island with the same general strike and a northerly dip. Making a rough allowance for the changing dips and strikes, for the accurate computation of which there are not sufficient data, I am disposed to estimate the total thickness of these argillaceous and quartzose flags at from seven hundred to one thousand feet. As far as seen these deposits are of an even character, excepting for the before-mentioned local metamorphisms near the contacts with the intruded dike materials. The beds appear to indicate a great continuity in the sedimentary process during the period of their formation. A very careful study of the extensive exposures afforded along this shore line has failed as yet to reveal any traces of fossils, though the general condition of the beds is such that there is no reason to believe that any fossils they may have originally contained would have been effaced by metamorphic action.

The small amount of interstitial change which these flaggy beds have undergone and the slight amount of folding to which they have been subjected may possibly be due to the effective resistance which the thick, even section offered to such changes. It may be, however, that, like the beds at Rodick's Cove, they were laid down after the most considerable part of the metamorphic actions which have affected this district had taken place.

On the north shore, beyond Bar Harbor, we obscurely discern the series which has just been described. At the little cove immediately west of Bar Harbor we have indications of a considerable fault, in the path of which there have been extensive extrusions of igneous matter. The greater part of this dike matter is granitic in its nature. Involved in this plexus of ejected materials there is much stratified rock which may well belong to the Bar Harbor series. These disorganized masses of sedimentary strata seem originally to have been sandstones and flags. They are very much more metamorphosed than are the other portions of the deposits before described. At certain points where these disturbances have been greatest the sedimentary beds are hardly at first sight to be distinguished from the traps which have penetrated them.

Midway between the small cove last mentioned and Duck Brook we have an extensive exposure, a hundred feet or more in thickness, of flaggy slates which are more metamorphosed than those at Bar Harbor, but which probably belong to the same series. Still further west these beds rapidly change their character; they become finer grained and their metamorphism has led to the formation in them of very large siliceous concretions having a lenticular form. These lenses are remarkable for their size, some of them being as much as fifteen feet in diameter and over a foot in thickness. The layers of the slates are pushed about by these concretions, as are the beds of the mica schists on the western side of the island by the smaller concretions which occur there ; but as these large concretions are of exceptional occurrence the general deposition of the section in which they lie is not to any great extent affected by their growth. Along this part of the shore the prevailing strike is from N. and S. to N. 40° E. and the prevailing dip westerly from 15° to 25°; a few small faults and numerous dikes perturb the directions of strike and dip for short distances, but as a whole the attitudes of the strata are tolerably uniform.

West of Duck Brook the flaggy beds become rather more disturbed by pressure. At a point one-third of a mile west of that stream the layers are crumpled into small sharp folds which have their axis in the line of the strike or between N. and N. 40° E. Approaching Hull's Cove from the eastward we find the mass of the trappean intrusions steadily increasing. There is probably a considerable amount of faulting through this part of the coast, accompanied, as are all the faults which have been observed on the island, by the extrusion of large amounts of igneous matter. The dike material on this part of the shore includes not only the ordinary contents of these fissures but a considerable amount of porphyritic felsites which appear to show flow lines. The slates and traps are remarkably entangled with these ejections; in places the stratified and volcanic materials are fairly churned together.

On the west side of Hull's Cove the shore is for a considerable distance hidden by drift. At about half way to the point which forms the western face of the cove the bed rocks reappear and continue visible for the distance of a mile or more. At that point the section shows a series of rocks which differs from those previously described on this part of the shore. These beds are more argillaceous and much less metamorphosed. In general character they closely resemble the Cambrian section, which contains fossil trilobites, at Braintree, Mass. They are probably, in part, equivalent to the clay flags which are seen on the east side of Bar Island. These beds are very generally undisturbed; the strike varies from N. 14° to N. 16° E.; they dip westward with an angle of from 6° to 10°. The total length of this unbroken section, measured along the coast line, is about two thousand feet, and the total thickness exposed to view is about three hundred feet. This section is remarkable for the small amount of trap injection which appears upon it. No dikes were perceived in its whole length, and if any exist they must be very small. No other equal length of the coast line on this island is so destitute of these intrusions.

At the end of this section we have again a broad field six hundred feet or more in length where the rocks have been extensively ruptured by dikes. These intruded rocks offer much less resistance to decay than the slates. They have therefore been so much worn down that for several hundred feet of shore-line the coast is hidden by drift. Beyond this interruption the flaggy slates again appear, but much cast about by the numerous intrusions of trap. The strike is here from N. 20° W. to N. 35° E.; the dip westerly from 9° to 35°.

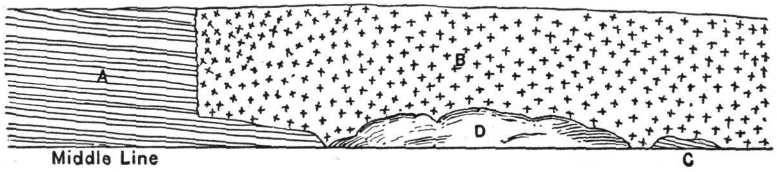


FIG. 43. Section of cliff at the Ovens.
A and C, stratified rock; B, igneous rock; D, arches of "Ovens."

On the east side of the beautiful cliffs known as the Ovens we have the last exposure of this series of argillaceous and quartzose flags. At that point they are interrupted by the extremely massive extrusion of felsitic trap, which continues for a long distance along the shore westward. The conditions of this junction are shown in Fig. 43. As exhibited in the diagram the junction of the felsitic traps with the slates appears to be partly as a ruptured contact and partly as an overflow. No exposures of this contact were seen except along the cliff which faces the bay. This contact demands a more careful examination than I have been able to give it. The impression which is made upon the observer is that the felsitic is not in its nature a dike, but rather a great surface flow which has scoured away the rocks by its motion, or else that it is the remains of a massive injection of a laccolitic nature.

From the Ovens to Salisbury Cove (the deepest indentation of Eastern Bay), a distance of nearly a mile, these felsitic lavas continue with little interruption. The whole of this considerable portion of the shore is composed of intrusive rocks. The only interruption to the continuity of the felsites which was observed consists of some later traps which have penetrated its mass. At Salisbury Cove there are some beds which may turn out to be very highly metamorphosed flags. The exposure is small and the relations of the deposit are not well known.

For a few hundred feet west of Salisbury Cove the shore line is occupied by volcanic deposits like those in which the Ovens are excavated. At some points the deposit appears to be faintly bedded as by successive flows. At the western horn of Salisbury Cove we come upon a peculiar series of quartzites, which differ from any rocks seen elsewhere on the island. These quartzites, if such indeed be their nature, are thick-bedded, generally of a greenish-white hue, the greenish matter often gathered into large blotched concretions. This peculiar series has a prevailing strike of about N. 45° to N. 65° E., dip southerly with an angle of from 10° to 20°. The peculiar hue of these beds, as well as the sudden and considerable change in the strike and dip, seems to indicate that they belong to a different series of rocks from anything else upon this shore. I have not seen elsewhere in this district or in New England any beds which present any distinct likeness to them.

At Emery's Cove we have what seems to be another part of the same series. The beds are thinner and faintly resemble those previously described as occurring at Rodick's Cove. The general color of the strata is much the same, as is also the character of the bedding. In both cases the rock is affected by changes which have developed the concretions of the mass. These greenish sedimentary rocks continue to a point a little westward of the base of Emery's Cove, beyond which they are not to be traced. Farther on we have a belt in which dikes abound for some hundreds of feet, and in which no stratified deposits are discovered. We then come upon some gneissoid rocks, which appear to have a distinct bedding, striking N. 40° W., dipping eastward at an angle of 15°. These gneissic rocks are intermingled with argillaceous and quartzose deposits, which have the same strike and dip as the gneissic beds. (See Pl. LXXVI.)

From the points where the gneissic beds and the associated schists come in, which is at the first salient on the coast, about half a mile west of Emery's Cove, to the west side of Thomas Bay or the water lying south of Thomas Island, the bed rocks are generally hidden by glacial drift. A few points of rock exposed are, as far as observed, the harder parts of various trappean injections, which abound along this part of the coast. As far as may be judged by the glacial drift these portions of the section are filled by beds of a gneissic and schistose character, essentially like those of the section just described. Immediately west of Thomas Bay we come upon the north part of the section of foliated schists, which have been described under the name of Bartlett's Island series and which form the west side of Mount Desert. All the beds from Emery's Cove westward may belong to the Bartlett's Island series.

General reflections concerning these several series of stratified beds which lie on the margin of Mount Desert will be postponed until we have considered the facts as to the dynamic features of the trappean and other injections which have occurred in this district. These masses have so far perturbed the original conditions of the strata that it is best to give some account of them before we proceed to review the stratigraphic history of the island. This consideration of the igneous rocks of Mount Desert is intended to be only of the most general nature. All questions concerning the petrographic nature of the various dike stones are necessarily left out of account. The aim of the presentation will be to consider only the relations of these injections in so far as they bear on the physical history of the district.

DIKES OF MOUNT DESERT.

The great central mass of granite which constitutes the mountain range of the island is essentially a dike. It is true it may be said that it differs from ordinary dikes by its great extent and by its relative shortness, but in its structure and its relations we find every important feature which characterizes massive injections which we unhesitatingly class as dikes. It cuts through the sedimentary rocks of the district, and though it has elevated them so that at many points they slope away from its mass, the same dislocation of the bordering strata is found alongside of many lesser dikes. The only difference between this great dike and the lesser injections is that it was a concomitant in the construction of an anticlinal ridge, while the lesser dikes have no such distinct relations to anticlines.

The dike-like nature of this great central injection of granite on Mount Desert will be the better perceived if we study some of the smaller but still very extensive intrusions of the same material which are exhibited in or near the island.

GRANITIC DIKES.

Baker's Island dike.—Of the normal granitic dikes of the Mount Desert district one of the largest is that which forms the whole of Baker's Island and intersects the southern shore of Mount Desert between Sea Wall Point[1] and the Nubble. At Baker's Island this dike is at least three thousand feet wide, its southern boundary not being seen at that point. It is, however, probable that it lies near the

[1] The nearest point of Mount Desert Island to Cranberry Island.

southern shore of the last named island. On the main island it has about the same width, which, at right angles to its trend, is not far from one-ninth that of the central granitic belt.

At the contact of the Baker's Island dike with its wall rocks on Cranberry Island, the dike, as is the case with most such massive injections of trap, exhibits many minor protrusions of its matter into the inclosing strata. The circumstances of its contact with the country rock are shown in the appended diagram, which indicates the junction at Bunker's Head,[1] on Cranberry Island. (See Fig. 44.)

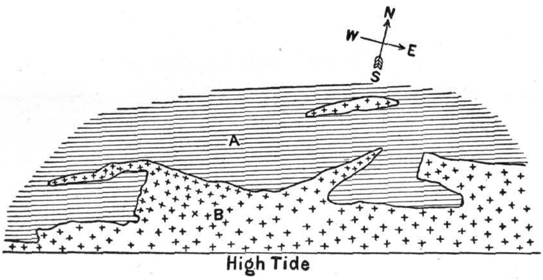


FIG. 44. Junction of granite and slates at Bunker's Head, Cranberry Island. A, stratified rock; B, granite. The section has a length of about one hundred feet.

This Baker's Island dike extends in a direction parallel with that of the great central granitic mass of Mount Desert, and has the same mineralogical composition. Macroscopically considered the two rocks have precisely the same appearance, hand specimens being indistinguishable from each other. The only observable difference is that the granite of Baker's Island is somewhat more jointed than that of the Mount Desert hills, though not more so than the granite quartz on the northern shore of Somes Sound.

Dix's Point dike.—A similar dike intersects the southern shore of Mount Desert at Dix's Point. It has about the same width as that of Baker's Island, but its compass course is very different. It apparently extends in a general north and south direction or nearly at right angles to that of Baker's Island. The circumstances of its contact with the country rock and the mineralogical nature of its contents are the same as those of the other great dikes of this nature. It is evident from the extent to which they are cut by the dark-colored injections hereafter to be described that the great granitic intrusions are among the earliest of the many groups of volcanic materials which appear on this island. These granites seem indeed to be the oldest volcanic ejections which intersect the deposits of volcanic ash, except, perhaps, the felsitic dikes.

Lesser dikes.—Besides the two dikes of granite before mentioned, there are very many similar branches from the great central mass

[1] Between Race Point and Deadman's Point.

intersecting sedimentary deposits, through which it breaks. At the contact of the central granite with the bounding walls the number of these divergent dikes is extremely great. They are so many, indeed, that it would be desirable to represent this contact section on the map by means of a distinct color, but for the fact that the forest-covered nature of the country makes the determination of the limits of the dike area extremely difficult.

The dikes extending from the central granitic mass are most plentiful near that mass and become less in size and of rarer occurrence as we go away from what we may call the contact wall, until, at a distance of about half a mile from that line, they are inconspicuous. Near the line of contact between the sedimentary forms and the central granites the dikes proceeding from the great intrusive mass exhibit a slight degree of secondary mineralization, as do also the sedimentary strata which they traverse. So far as noticed the most important feature in this mineralization is found in considerable segregations of iron pyrites which are scattered through the masses of the dikes and of the rocks which they traverse. These pyrite crystals are best shown on the western shore of Seal Harbor. The crystals are often large, even exceeding an inch on the face, and at certain points they are extremely abundant, tending by their decay to the disintegration of the rocks in which they are contained. Wherever this pyrite is present the decay which it induces has led to the rapid removal of the material by the various agents of erosion. The result is that such rocks are generally hidden and indeed are only disclosed in clear fashion along the present shore line. The erosion of these deposits makes it impossible save by careful observation to form an estimate of the importance of this pyritic material in the contact district of the island.

Wherever the exposures made such observations possible care was taken to note the contact lines of the larger intruded masses with their wall rocks, with the expectation that contact deposits of a vein-like nature might be found, but the search was without result. Over fifty such contacts were observed, but in no case were mineral-bearing deposits present. This is a significant point inasmuch as on the mainland we have some fields containing quite extensive vein deposits.

FELSITE PORPHYRY MASSES.

Next in importance to the granitic dikes come those which we may group as felsite porphyries. These like the granitic dikes are in some instances of very great size. So far as my observation goes they are limited to the peripheral portions of the island; though there may be cases in which they traverse the central granites, they have not been observed in that position. In the peripheral section of Mount Desert they are large and more extensively developed on the north and south shores. It is possible that they may exist on the east and west flanks of the island, but they have not been observed there. Wherever these felsitic dikes are abundant there are more or less extensive deposits of what appear to be flows of the same material exhibiting at certain points somewhat distinct bedding. As before remarked, the porphyritic injections probably occurred, partially or entirely, before the granites were deposited, for at no point have they been observed to traverse the granite intrusions. It seems to me likely that these felsitic ejections occurred in the period when the volcanic ash and breccia before noted were laid down, for the reason that on the Cranberry Islands these felsites appear to be distinctly interbedded with the volcanic ashes, as is the case about Passamaquoddy Bay and near Boston. We thus arrive at the conclusion that this volcanic series existed before the formation of the great central granites of Mount Desert.

OTHER DIKES.

A third series of dikes is composed of a dense dark-colored group of dike stones. These occupy the whole field of the island and appear to be generally of later date than any other deposits or intrusions found within its limits. In some cases they are possibly cut by the granites, but no clear instances of such intersection were observed.[1]

These dikes are generally much narrower than those of the beforementioned series. They appear to be also rather more continuous than the felsitic injections. They are far more uniformly distributed over the area of the island than either of the preceding groups. In general, it may be said that they occupy every part of the surface of Mount Desert and the adjacent islands. It is rarely possible to draw a line a thousand feet in length in an east and west direction without crossing one or more of them.

The last and least important group of dikes is that which contains certain injections consisting of a greenish trap. Only a few of these have been observed, and of these the most conspicuous is the one which is exposed in the road from Beech Hill to Southwest Harbor. This dike, like others of the same limited group, is decidedly softer than the rocks which bound it on either side, and its decay has led to the formation of the deep crevice in the granite constituting the narrow gorge through which the road makes its way. The contact

[1] An observer is apt to be misled in his conclusions as to the intersecting or non-intersecting of one dike by another through the faulting which is apt to occur along the contact of a dike with its country rocks. He may, for instance, trace a given dike to the walls of another dike and find that it fails to traverse the field occupied by the given intrusions. He may therefore conclude that the dike which he was originally tracing did not intersect the dike against which he has traced its fissure, when in fact it may be that a faulting movement with a horizontal throw has carried the original continuation of the dike beyond the field of observation.

of this dike with its bounding walls shows a very extensive rounding in its formation; in this regard it is unlike the most of the dikes of its class. (See Fig. 45.)

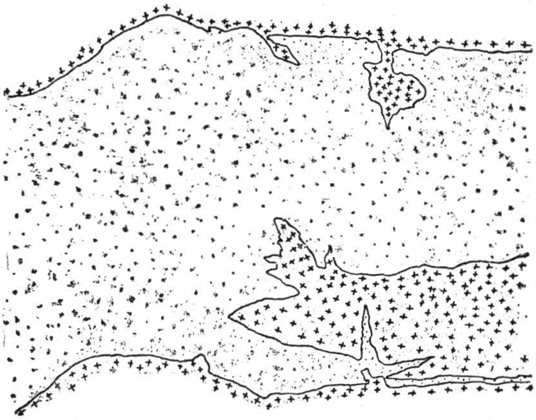


FIG. 45. Dike on Beech Mountain road.

TREND OF THE DIKES.

The compass courses of these several groups of dikes is a matter of interest. Although there is considerable diversity in their direction, the variations generally fall within certain limits. The greater dikes of granite appear to follow the trend of the central granitic mass of the island, having a nearly east and west course. A prominent exception to this exists in the great dike which extends from the central part of the island at Dix's Point, for this seems to have the more north and south trend. It is not impossible, however, that this dike, which, owing to the swampy nature of the country, can not be traced for any great distance north of Dix's Point, may be only a local spur proceeding from the great Baker's Island dike.

Of the other groups of dikes the feldspathic or felsitic injections are apparently the most various in their compass course. Some of them seem to have a general north and south direction; others appear to follow the strike of the strata into which they have been injected and thus depart widely from the trend common to the series. These dikes are so combined with the interbedded sheets of lava that it is difficult to form any clear idea of their compass course. Moreover, having been the first injection in this neighborhood and the rocks into which they were forced having subsequently been very much dislocated, they no longer retain the directions which they originally had.

By far the larger part of these dikes, at least nine-tenths, belong to the group of ordinary dark-colored trappean materials, such as is common throughout all the highly metamorphosed districts of New England. On Mount Desert these dikes have two principal directions, the larger and more numerous fissures traversing the rocks in a general northeast and southwest direction. A few of the fissures are nearly at right angles to this course, having strikes varying from N. 55° W. to N. 45° W. These last-named dikes appear to be in the main limited to the district about Somes Sound and may be connected in some way with the formation of that remarkable inlet. These dark-colored dikes are found traversing all the several series of rocks which appear on Mt. Desert and the adjacent lower islands in something like equal abundance for equal areas· their distribution indeed exhibits a remarkable uniformity.

DIKES OF WHITE QUARTZ.

Before closing this imperfect account of the injected rocks of this district it is necessary to note the small but very peculiar group of what appear to be dikes of white quartz. They occur on the eastern side of the promontory which lies south of Norwood's Cove. We have at that point a considerable section of quartzites of a whitish color. In the immediate vicinity of this peculiar quartz there are several fissures filled with quartz rock. These vein-like masses present none of the normal features of veins deposited by water action. They are entirely massive, or, in other words, have no trace of the banded or comby aspect so generally exhibited in true veins. It seems possible that they are in fact true dikes, and that their materials have been melted and driven in a molten state into the fissures which they occupy, and not brought into them by the action of the heated waters. These quartz dikes appear to be very short; none of them were traced for a distance of more than a hundred feet or so, but one of them is several feet in diameter.

ORIGIN AND PHYSICAL HISTORY OF THE MOUNT DESERT ROCKS.

I propose now briefly to consider the origin and the physical history of the rocks described in the previous pages in so far at least as they can profitably be treated from the conditions of this limited field.

It is evident from what has already been said that the several divisions of stratified rocks which appear on Mount Desert are very irregularly distributed. There are at least half a dozen series which must be regarded as representing different parts of the geological section and no two of them are found superimposed upon each other. The schists on the east and west sides of the island may be, and indeed most likely are, of the same age, but they alone by their aspect suggest the idea of equivalency. The Cranberry Islands series of volcanic ashes, the Bar Harbor slates, the coarse greenish quartzites of the northern shore, the white quartzites near Norwood's Cove, the bedded slates of Rodick's Cove, are isolated deposits which can not be grouped in any order of succession.

The first question to be determined is the cause of this fragmentary condition of these sedimentary deposits. It is at the outset clear that this lack of continuity of the several sections may possibly be due to causes which operated before the time when these rocks were divided by the great central granites; their fragmentary character may have been due to some action occurring at the time of that injection or it may perhaps be due to causes which have come into operation subsequent to that event. Simple inspection seems to indicate that the two last suppositions are inadmissible. There is no case in which these several sedimentary series are shown one above another. Each of them may be traced in contact with the granitic injections. Unless this granitic matter in some manner, at the time of its intrusion, eroded the beds missing in the different parts of the island, we can not well explain how the injection could have destroyed the original sequence of the deposits; nor can we suppose that the erosions and dislocations which have taken place since the injection of the granites brought about the present fragmentary aspect of the sedimentary deposits. While it can not be denied that such accidents may produce great confusion in strata, we can not see how they could cause such extreme discontinuities as we find here.

The only explanation which seems to me to give a satisfactory account of this peculiar distribution of the stratified forms is the following: Before the injection of the granites this district must have been the seat of deposition at many successive periods. Between these periods of sedimentation there must have been times of erosion in which the greater part of the beds deposited in the earlier periods was worn away, so that it came about that this surface was occupied by a number of discontinuous fragments of deposits.

We can find in other parts of New England conditions analogous to those which I have hypothecated to explain the aspect of the Mount Desert series. The area of Massachusetts, for instance, gives us patches of Archean or Cambrian schists and slates of Silurian rocks and of beds belonging to the Mesozoic period, all within a small field, but exhibiting no sequence in their sections.

In order to account for their disordered nature we have only to suppose that the eastern and western schists of Mount Desert are fragments of a once continuous field of slates and sandstones; that these beds were subjected to erosive action and were worn away on the north and south sides of the island before succeeding deposits were formed; that these in turn were worn to fragments before the next overlying beds were laid down, and so on to the end of the chapter.

Although this hypothesis does not aid us in the task of effecting any formal arrangement of the Mount Desert series it explains a puzzling phenomenon and incidentally gives us some light as to the ancient conditions of this surface. Certain other important conclusions are attained by examining the constitution of these several series, conclusions which may aid us in determining the geological age of the Mount Desert deposits.

We note in the first place that there is a total absence of limestones in all the sections exposed to view. A careful study of the drift materials on the south part of Mount Desert and on the Cranberry Islands where we could hope to find traces of hidden limestones, shows that there are no limy beds in the sedimentary deposits of this island. The aggregate thickness of the various Mount Desert sections can not be less than about six thousand feet and may amount to one-half more than this estimate. It seems as if this fact must exclude the hypothesis that these strata were formed anywhere in the periods above the level of the Cambrian, for nowhere above that level do we have any such sections barren of limy matter.

It may be next noted respecting the schistose series of Mount Desert that those of its east and west margins are of singularly uniform composition. They were doubtless originally shales and thin sandstones of great uniformity of structure. Their texture is not such as at all points to exclude the preservation of fossils; indeed the greater portion of the deposits are well fitted to exhibit organic remains, yet they have afforded no trace of them. Nowhere above the level of the Cambrian series do we find any section of this description. On these grounds, it seems reasonable to place the greater part of the Mount Desert rocks in the lower portion of the Cambrian section, if not yet lower in the geologic column.

It is possible that we may have to make an exception in the case of the volcanic rocks of the Cranberry Islands. These rocks closely resemble the deposit of a similar nature found near Eastport, Me., which seems to be of Silurian age. For the present, at least, I am disposed to place the Cranberry Island series above the other sedimentary deposits of Mount Desert, except perhaps those at Rodick's Cove, and to consider that they belong in the Silurian section. They may, however, be of the same age as the volcanic breccias of Massachusetts Bay district, which probably appertain to a time at least as remote as the Middle Cambrian period.

It is evident that at the time when the granitic ejections took place that form the central granitic district of Mount Desert, the surface of this region was covered with extensive sedimentary deposits which have since been worn away. This granite was evidently in a fluid condition, as is shown by the degree to which it penetrated into narrow crevices and the extent to which it has metamorphosed the rocks with which it came in contact, yet at no point is there any trace showing that it flowed superficially in the manner of lava. In fact, we nowhere know of any granitic rocks which have flowed over the surface of the earth. Thus theory, as well as fact, compels us to suppose that these granites were completely incased in deposits which once mantled high above the existing surface of the highest hills of the island. The thickness of this envelope, and consequently the amount of the erosion required for its complete removal, can be only a matter of conjecture.

EXPLANATION OF GEOLOGICAL MAPS.

MAP OF SURFACE GEOLOGY.

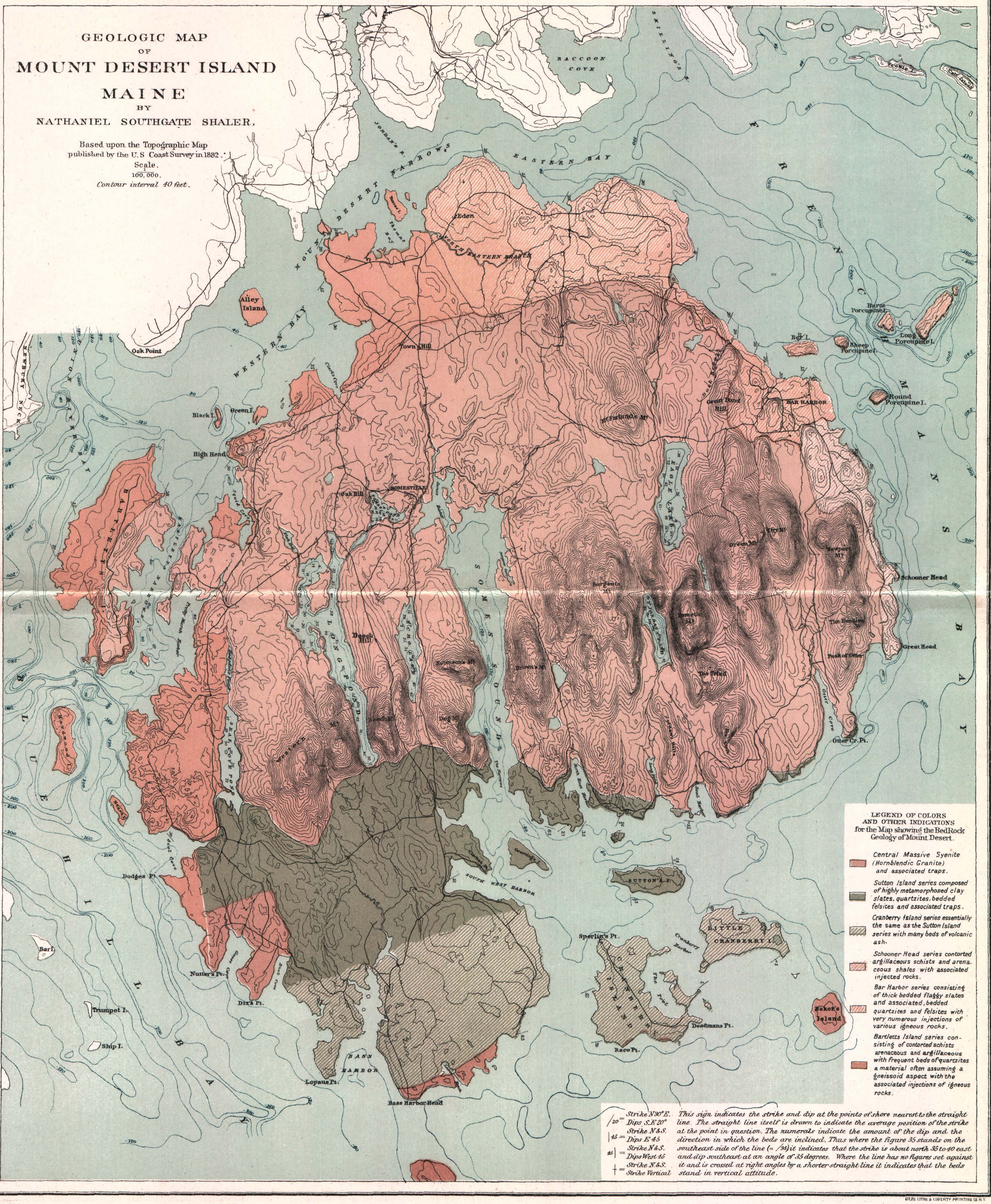
The object of this map is to set forth the superficial deposits of Mount Desert and the neighboring shores, and also to indicate the direction of movement of the ice sheet at its contact with the earth's surface on the various parts of the island. The distribution of the color indicates the relative thickness and continuity of the glacial deposits. Where the surface is left uncolored the reader is to understand that more than half of the area is entirely without a connected sheet of glacial waste, presenting only occasional bowlders, usually of large size. Where the surface is dotted over with color it is to indicate that more than one-fourth of the surface is without a covering of drift. Where the color is continuous it is to indicate that not more than one-eighth, in most cases a much smaller proportion, of the surface is destitute of drift.

The arrows show the direction of glacial scratches. In most cases pains was taken to exclude from the map scratches which are in such positions as to make it probable that the movement of the ice was locally diverted from the general trend of the glacier at the particular point. It will be observed that at the base of each of these arrows there are one or more numbers. Where the numbers are to the east of the shaft they indicate that the run of ice was from the east, and the difference in numbers shows the range of variation in degrees of arc. If the number is west of the arrow it indicates that the general trend was from the westward, the figures, as before, indicating the variation in the course of the scratches.

The distribution of the blue clay which is found extensively developed in the sheltered valleys of the island is approximately indicated by the color assigned to it. It should, however, be understood that this deposit probably extends over very much wider areas than is indicated by the map. The opportunities for observation are imperfect and care was taken not to extend the indications beyond the limits of the observations. It is likely that further inquiry will at least double the area which should be colored as underlaid by this formation.

MAP SHOWING BED ROCK GEOLOGY.

The purpose of this map is to indicate in a general way the distribution of the more important groups of rocks which are exposed on Mount Desert. It is impossible to complete the classification of these deposits in a satisfactory way until the geology of the neighboring shores has been carefully studied. The reader will therefore understand that the several divisions instituted in these rocks and represented by the coloring are of a provisional nature and are liable to be overthrown when an adequate research into the neighboring region has been instituted. Owing to the fact that by far the greater portion of the island is covered with drift or masked by primeval forests, the boundaries of these series of rocks are most incompletely indicated. Furthermore, the extent of metamorphism which in all cases has occurred near the contact between the sedimentary deposits and the central granite makes it in many cases impossible to discriminate between the several series in their metamorphozed conditions. It will be observed that the more or less stratified series which lie around the periphery of the central mass of crystalline rock is divided into five groups. It may in the end happen that some of these groups are to disappear or be merged in a more general classification. It is particularly doubtful whether the beds known as the Schooner Head series are of a different age from the Bar Harbor series. It may also be found that a portion or the whole of the Bartlett's Island series is to be placed with that found about Bar Harbor. There are, however, certain differences in these groups which appear to me to make it worth



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while for the present to designate them by particular colors. The Sutton's Island series and that of Cranberry Island are much more distinct from the three before mentioned than any one of those from the other. At first I was disposed to put the Sutton's Island series and that of the Cranberry Island in one group. So far as my observations have gone, however, it seems clear that the Sutton's Island group of rocks, though containing an abundance of volcanic material, shows no trace of the volcanic breccias which abound in the Cranberry series. I therefore have kept these two groups apart.

In the southwestern portion of Mount Desert, between Bass Harbor and the western portion of the island, the injected rocks are so abundant that it is impossible to find any considerable portion of stratified material in the field. I am inclined to think, however, from the glacial waste which covers the surface, that the whole of this doubtful ground should be classed with the Sutton's Island series.

It will be observed that the volcanic breccias or ashbeds which characterize the Cranberry Island series do not extend to the west of Duck Cove. Their western limits have not been well ascertained, owing to the dense coating of drift and the mantle of vegetation which covers this part of the island.

In a word, it should be understood that this geological map is in its nature a preliminary sketch of the field.

On the scale of this map, it has been found impossible to show the various intrusions of granitic and other trappean rocks which penetrate the several marginal series. At many points much more than half the total mass of material indicated as belonging to the sedimentary series consists of these volcanic intrusions. Adequately to indicate this wonderful entanglement of dikes would require a map on a much larger scale than can be afforded in a memoir of this nature. In the final geological map of this region, which is to be published on the scale of an inch to a mile, an effort will be made to represent some of the most important of these intrusions.

In the preparation of this map I have made some slight use of an uncompleted sketch of the geology of the island prepared by several students of Harvard College, under the direction of my colleague, Prof. William M. Davis.

INDEX TO PART II.*

*A separate index is appended to Prof. Ward's paper on the geographical distribution of fossil plants.