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SKETCH OF PALEOBOTANY

BY

LESTER F. WARD

[EXTRACT FROM THE FIFTH ANNUAL REPORT OF THE DIRECTOR, 1883-'84.]

WASHINGTON
GOVERNMENT PRINTING OFFICE
1885

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SKETCH OF PALEOBOTANY.[1]

By Lester F. Ward.

I.—ON THE TERM "PALEOBOTANY."

The term *paleobotany* has the advantage of brevity over the more common expressions *vegetable paleontology* and *phytopaleontology*, while at the same time its etymologic derivation from two purely Greek words renders it equally legitimate. Still, neither of the other terms should be entirely discarded. While it is always necessary to use the specific term for the science of fossil plants, the practice of employing the generic term *paleontology* when treating of animal remains only seems objectionable. The corresponding term *paleozoölogy* should be recognized, and used whenever the more restricted expressions *vertebrate paleontology* and *invertebrate paleontology* are inapplicable. It is thus only that the terminology of the science becomes consistent and itself scientific.

II.—INTERRELATIONS OF GEOLOGY AND BIOLOGY.

The science of paleontology has two objects, the one geologic, the other biologic. The history of the earth is to a large extent the history of its life, and the record which organic life leaves constitutes the principal index to the age of its successive strata. In paleozoölogy this record is implicitly relied upon and forms the solid foundation of geological science. In paleobotany so much cannot be said, yet it too has already rendered valuable service to geology, and is often the only guide furnished by nature to the solution of important problems.

The contribution that paleontology thus makes to the history of the earth—to geology—is not more interesting than that which it makes to the history of the earth's life—to biology. No questions are more engrossing, nor in fact more practically important for man as one of the living forms developed on the earth, than those that pertain to the origin and development of the various forms of life, and a knowledge of the past life of the globe is that by which we are enabled to understand its

[1] Being a preliminary draft of a portion of the introduction to a "Compendium of Paleobotany," in preparation.

present life as a product of development. Paleozoölogy has already thrown a flood of light upon the true nature of animal life as it now exists, and now paleobotany is rapidly coming to the aid of those who have hitherto so long groped in darkness relative to the origin, development, and distribution of the plant life of the globe.

III.—SCOPE OF THE PRESENT PAPER.

With the second of these objects the present work is only incidentally concerned, its chief aim being to secure, so far as its influence extends, the better realization of the first. Still, it cannot be denied that a considerable degree of mutual dependence subsists between the biologic and the geologic standpoints. To understand the true force of the facts of paleobotany as arguments for geology it is essential that their full biologic significance be grasped. It has therefore been deemed proper, in this introduction to the several tabular and systematic statements which will make up the bulk of the volume and bear chiefly upon the geological aspect of the subject, to consider certain of the more important biologic questions, in addition to the specially geologic ones, and to discuss, from an historical and developmental standpoint, some of the leading problems of modern phytology.

IV.—NEED OF A CONDENSED EXHIBIT.

First of all it must be insisted upon that, notwithstanding the large amount of work that has been done in paleobotany and the somewhat formidable literature which it possesses, the present state of the science is far from satisfactory when regarded as a guide to the attainment of either of the ends above mentioned. Its value, as compared with that of paleozoölogy, in the determination of the age of formations in which vegetable remains are discovered is very small, yet it may well be asked whether the habit of discounting the testimony of fossil plants, acquired at a time when much less was known than now, may not have been continued to an extent which is no longer warranted by the present state of our knowledge. Whether this be so or not, it is at least certain that the real present insufficiency of this department of paleontology as an exact and reliable index to geologic succession is largely due to the exceedingly fragmentary and desultory character of the science, considered as a body of truth, and that a proper and careful collation and systemization of the facts already in the possession of science will add in a high degree to their value in this respect. It was this consideration, so obvious to me from the beginning of my investigations in paleobotany, that moved me to undertake the compilation of this work, and it has been the growing importance of this same consideration, becoming more apparent at every step, that has impelled and encouraged me throughout its laborious preparation.

It is especially in America that this want of methodical arrangement in paleobotany has been most keenly felt. The most important works on fossil plants have been published since the last attempt of this kind was made in Europe, and very little of our knowledge of the science has ever been embodied in any of the works of this class. The literature of this country is scattered throughout the scientific serials and official publications of the various geological surveys, and the few more comprehensive works that have appeared not only leave this branch of the subject in great doubt and confusion, but contain, besides, many fundamental misconceptions and positive errors.

Whatever degree of inadequacy paleobotany may reveal for the solution of geologic questions, no one can deny that its value can never be fairly judged until its materials are first so classified and arranged that all the light that can be shed by them on any given problem can be directed full upon it and the problem deliberately studied by it. When this can be accomplished, even should it do no more than emphasize the insufficiency of the data, it would, even then, have the effect of pointing out the proper direction of future research with a view to increasing the material and perfecting the data. This work has been conceived and is being conducted primarily to this end of thus focalizing, as it were, the knowledge already extant in this department of research, and of bringing it to bear with its full force, however feeble this may be, upon the questions to whose solution it is capable of being legitimately applied.

V.—FUTURE PROSPECTS OF PALEOBOTANY.

While it is particularly as a contribution to American science, and with special reference to its application to American geology that the work has been undertaken, still, for many and obvious reasons it was found impossible to confine it to purely American facts. The usefulness, for the purpose intended, of any such compilation increases in an accelerated ratio as its scope is expanded, and its value only begins to be really great when it approaches complete universality and compasses the whole field of facts so far as known within its particular department. While this would be true of any science, it is conspicuously so of paleobotany, where, more than anywhere else, the record is so notably incomplete. A more special reason in this case lies in the fact, only recently so strongly felt by paleobotanists, that the floras of the successive epochs in the history of the earth have been differentiating and becoming more and more varied according to their degree of territorial separation, so that in studying them in reverse order we find greater and greater uniformity over the whole globe as we go back in time. The fact that even the Tertiary floras of the most remote regions of the world possess a striking resemblance among one another, wholly unknown among existing floras, has only just now fairly revealed itself to science, and found its striking confirmation in the very recent work[2] of Baron von Ettingshausen on the Tertiary Flora of Australia. This uniform character of the fossil floras of different epochs, combined with their variation from one epoch to another, lends hope to paleobotany and leads to the belief that when we shall have learned with precision the true characteristics of each flora—learned to distinguish the accidental from the essential, and geographic from chronologic characteristics—we shall be in a condition to apply the data at hand to the explanation and elucidation of the geologic and biologic history of the earth.

While it is upon the defectiveness of the geologic record, so far as plants help to make it, that the chief stress is usually laid, still, could this record be so edited that it could be made to convey its full meaning it would probably be found that it is really more complete than the biologic record; in other words, the knowledge we have of fossil plants would go further in explaining geologic succession and determining questions of age than it can be made to do in explaining the mode of development, distribution, and differentiation of plant forms on the earth's suface. On the subject of geographical distribution, with which are inevitably bound up many questions of origin, variation, and descent, much has already been written. De Candolle. Hooker, Gray, Grisebach, Ettingshausen, Heer, and Engler have at different times and in numerous ways succeeded in building up a body of valuable literature relating to phytogeography. Since, however, this concerns itself principally with explaining the origin of existing floras, chiefly dicotyledonous, it cannot reach back to the primary and doubtless ever insoluble problems of the differentiation of the great types of vegetation that have successively dominated the plant life of the globe through past geologic ages. Yet, however hopeless the task when the idea of complete solution is considered, it is nevertheless these very questions which are constantly pressing upon the thoughtful student, and he cannot suppress them if he will, or cease to recognize that they are legitimate, and that every, even the least, approach towards their solution is so much clear gain to science.

VI.—INTERDEPENDENCE OF BOTANY AND PALEOBOTANY.

It is only quite recently that botanists have begun to turn their attention to questions of this kind. The overthrow of the doctrine of fixity of species opened the door to such considerations, rendering them legiti-

[2] Beiträge zur Kenntniss der Tertiärflora Australiens. Von C. von Ettingshausen. Denkschr. d. k. k. Akad. d. Wissensch., Bd. XLVII, Wien, 1883.

mate, and the doctrine of the descent of all plant forms from remote ancestors more or less unlike them may now be said to prevail, although few and feeble have been the attempts to indicate the character of the genetic relationships existing among living types. This general subject will be treated later, but it is mentioned here merely to show how it has naturally come about that botanists are now turning their attention towards paleontology as the only source that holds out any promise to them of even partial success in explaining the development of existing floras. The effect of this can but be salutary, and paleobotany is likely to gain as much as botany proper. Even should no success be attained in the direction sought both sciences will gain, since it will bring them into more intimate relations and tend to blend them, as is natural, into one science. Hitherto, it must be confessed, they have been studied too independently. In fact, not only have botanists as a rule ignored the existence of paleontology, but paleobotanists have generally gone on with their botanical classifications and discussions in total disregard of the elaborate systems of the former. Without comparing the results thus independently arrived at, it is safe to pronounce this entire method unwise and improper. To harmonize these results after so long a course of divergence will be a difficult task, and in the effort which is here made in this direction complete success is neither claimed nor hoped for. But if the existing vegetation of the globe has descended from its past vegetation, as almost every botanist as well as paleontologist now assumes, what reason can exist for having two sets of classification? The botanist is thus dependent upon paleontology for all his knowledge of vegetal development and should listen closely to the voice of the past and learn from it the true order in time in which the ancestors of each living type appeared on the earth. Every one must see that this will be of the highest importance as a guide to classification, and will supplement in the most effective manner the data furnished by the developed organs of living plants. We shall ultimately see that, when rightly interpreted, these two sources of proof, instead of conflicting, agree in a most instructive manner, rendering that system of classification which is in harmony with both classes of facts in a high degree probable and satisfactory.

On the other hand, every candid paleobotanist must admit that he can understand fossil plants only as they resemble living ones, and that the botanist, studying the perfect specimen with all its organs of reproduction as well as of nutrition, can alone declare with absolute certainty upon its identity or affinity. This mutual dependence of the two branches of botanical science upon each other is so apparent that it is certainly a matter of surprise that it has received so little recognition by scientific men.

VII.—HISTORICAL REVIEW OF PALEOBOTANICAL DISCOVERY.

A.—BIOGRAPHICAL SKETCHES.

Paleobotany is a science of the nineteenth century. Nevertheless its dawn at the beginning of this century was preceded by a long fading twilight extending entirely through the eighteenth. But even when we consider the nineteenth century alone, its progress shows us that it has as yet scarcely entered into the full light of day. If we judge it by its literature, not always a safe guide, but certainly the best one we possess, we find that the first half of this century produced less than one-fourth as much as the third quarter, and this less than the still unfinished fourth quarter. If we measure the literature, as we may roughly do, by the number of titles of books, memoirs, and papers that have been contributed to it, we will arrive at a rude conception of the accelerated rate at which the science is advancing.

Ignoring for the present certain vague allusions that were made to the subject by the ancients and by writers down to the close of the seventeenth century, some hundred and fifty works might be named belonging to the eighteenth century that bear in a more or less direct way upon vegetable fossils, but this would exhaust the enumeration. A nearly equal number could be named which appeared during the first quarter of the nineteenth century, while fully two hundred titles, including many large works, issued from the press during the second quarter of the century. And yet, as already shown, this was but the beginning, and the true season of interest and activity did not set in until the sixth decade, since which time this activity has steadily, if not uniformly, increased until the present, when the number of works and minor memoirs relating to fossil plants that see the light each year often reaches a hundred.

Although the number of persons who have interested themselves in paleobotany and have published more or less upon it is very great, while those who have become eminent in this field may be counted by scores, still, if we confine ourselves to such only as may be called pre-eminent, who have devoted their lives chiefly and successfully to it, and have either constituted its true founders or enriched in an especial manner its literature and perfected its methods, we may restrict them to eight or ten. If called upon to specify, we might reduce this enumeration to the following great names which stand forth as the true leaders and heroes of this science: Adolphe Théodore Brongniart, Heinrich Robert Göppert, Franz Unger, Leo Lesquereux, Oswald Heer, Abramo Massalongo, Baron Constantin von Ettingshausen, and the Marquis Gaston de Saporta. Whether we consider the number of works actually produced, the volume of this literature, the quality or importance of their work, or the amount of painstaking labor devoted to the science, we find that much more than half of all we possess of permanent value in paleobotany has emanated from the brains, the hands, and the pens of these eight lifelong and laborious devotees of their chosen science.

It thus appears that the history of paleobotany must consist largely in an account of the labors of a few persons, and had we nothing more to offer than such an account, a fairly just conception of its origin, progress, nature, and scope might be thus afforded. But it might be justly objected that so limited an enumeration not only leaves out of the account some of the most important works and most fertile workers, but also fails to give the true relative importance to those earliest pioneers, who, though they cannot be classed as the true founders of the science, nevertheless first pointed out, and then actually broke, the way to future research and discovery. Let us then extend our list to cover these two important classes, and we still find that though much longer than before it is not so long as to be burdensome. By nearly trebling our former number the selections may be so made that, while not denying great eminence and merit to many others, the history of discovery in vegetable paleontology may be fairly represented by the labors of about twenty-two men. A bare enumeration of these names in the order in which they commenced to write would at least embrace the following:

1. Johann Jacob Scheuchzer 1709
2. Ernst Friederich, Baron von Schlotheim 1801
3. Kaspar Maria, Graf von Sternberg 1804
4. Adolphe Théodore Brongniart 1822
5. Henry T. M. Witham 1829
6. Heinrich Robert Göppert 1834
7. August Joseph Corda 1838
8. Hans Bruno Geinitz 1839
9. Edward William Binney 1839
10. Franz Unger 1840
11. Wilhelm Philip Schimper 1840
12. William Crawford Williamson 1842
13. Leo Lesquereux 1845
14. Sir John William Dawson 1845
15. Oswald Heer 1846
16. Sir Charles James Fox Bunbury 1846
17. Abramo Massalongo 1850
18. Constantin, Freiherr von Ettingshausen 1850
19. John Strong Newberry 1853
20. August Schenk 1858
21. Marquis Gaston de Saporta 1860
22. William Carruthers 1865

From this list are omitted the names of a considerable number of the younger active workers in this field whose thorough and successful work has already placed them in the front rank, but whose career is so far from completed that its proper characterization will belong to the future historian of the science.

A brief biographical sketch including the mention of some of the more important contributions of each of the above-named paleobotanists may now be made.

1. *Scheuchzer*.—Switzerland, which furnished one of the last and greatest of all the cultivators of this science who have now passed away, furnished also the first name that can with any true propriety be placed in the list of paleobotanists. Although he wrote on many other subjects, and worked in some very different fields, the paleontological works of Scheuchzer are the only ones that possess any enduring value, and although he did not confine his studies to vegetable fossils, he still gave these a much larger share of his attention than they now receive from paleontologists in general, compared to that which is bestowed by them upon the other forms of extinct life. He was born at Zürich in 1672, and died in the same city in 1733. He traveled quite extensively and made large collections of all kinds of curiosities, which he described and figured in numerous works. He regarded all fossils as relics of the Noachian deluge, and gained a permanent place in the history of science by describing the bones of a gigantic salamander as "Homo diluvii testis." His most important work was his "Herbarium diluvianum," first published at Zürich in 1709, but thoroughly revised and republished at Leyden in 1723. In this work many fossil plants are figured with sufficient accuracy for identification. Several of Scheuchzer's other works contain mention of fossil plants, particularly his "Museum diluvianum" (1716), and his "Oryctographia helvetica" (in Part III of the "Helvetiæ historia naturalis," 1716–'18), but their value to the science, as indeed that of all his writings, is now chiefly historical. When, however, we consider that Scheuchzer antedated by almost a full century the earliest properly scientific treatises on paleobotany, we are prepared to overlook his deficiencies, and to regard him as the true precursor of the science.

2. *Schlotheim*.—Ernst Friedrich, Baron von Schlotheim, of Gotha, whose career began with the first years of the present century, is the second name that stands out prominently in the history of paleobotany. Not that there had not been many in the course of the long century which separates him from Scheuchzer who had interested themselves in the study of fossil plants, and who collectively had accumulated the data which rendered the work of Schlotheim possible, but to him is due the credit of first marshaling the evidence from vegetable remains in support of a true science of geology. A sketch of the early struggles and final triumph of strictly scientific principles as drawn from paleontology will presently be presented from the phytological side, and we may therefore content ourselves here with mentioning the grounds upon which Schlotheim's claims rest to a place in the present enumeration.

Born at Almenhausen (Schwarzburg-Sondershausen) in 1764, and educated at Göttingen and Freiburg, he took up the study of mineralogy and metallurgy, which naturally led him into paleontology, for which he had a strong attachment. In 1801 he published in Hoff's "Magazin" (I, pp. 76–95), at Leipzig, his "Abhandlung über die Kräuter-Abdrücke im Schieferthon und Sandstein der Steinkohlen-Formation," and in 1804 his "Beschreibung merkwürdiger Kraüter-Abdrücke und Pflanzen-Versteinerungen, ein Beitrag zur Flora der Vorwelt" (I. Abtheilung), with fourteen plates, illustrating by accurately drawn figures a large number of Carboniferous plants. In 1805 he was made councilor director and in 1820 president of the College Cameral of Saxe-Gotha, and in 1822 director of the Museum at Gotha. In 1820 he published at Gotha "Die Petrefactenkunde auf ihren jetztigen Standpunkt," the first Heft of which really constitutes the second part (Abtheilung) of the work last mentioned, and the number of plates here reaches twenty-nine, all but the last two of which are devoted to fossil plants. The remainder of this work relates to animal remains, as does also all but Part III of the "Nachtrag" to the work, which appeared two years later.

These works, though few in number, were systematic and conscientious, and constituted by far the most important contribution yet made to the knowledge of the primordial vegetation of the globe. They form the earliest strictly scientific record we have in paleobotany.

3. *Sternberg.*—Kaspar Maria, Graf von Sternberg, though contemporary with Schlotheim, is mentioned after him in this enumeration, first, because his first contribution to paleobotany[3] was made three years later than Schlotheim's first, and, secondly, because his great work on this subject was not completed until after Schlotheim's works were all published and in his hands for use and criticism, and, in fact, not until after Schlotheim's death.

Sternberg was born at Regensburg in 1761 and died at Prague in 1838. He was an assiduous collector, not only of specimens but of books, and when in 1822 he was made president of the Bohemian National Museum he turned over to it all his collections, including 4,000 volumes of rare works. His specialty was botany, on which he wrote many memoirs, but scattered through the different periodicals of the time are to be found some dozen papers relating to fossil plants. The most important of all his works was his "Versuch einer geognostich-botanischen Darstellung der Flora der Vorwelt," which appeared in numbers from 1820 to 1838, and was translated into French by the Comte de Bray.[4] To the eighth number, 1838, was appended Corda's "Skizzen zur vergleichenden Phytotomie vor- und jetztweltlicher Pflanzen." In this work that of all his predecessors, including Schlotheim, is reviewed, and considerable progress made toward the correct interpretation of the record, so far as then known, of vegetable paleontology.

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[3] Notice sur les analogues des plantes fossiles. Annales du Muséum d'histoire naturelle, 1804, Vol. V, pp. 462–470, pl. 31, 32.

[4] Essai d'un exposé géognostico-botanique de la flore du monde primitif. Ratisbonne, 1820–1826, fol., 64 pl.

4. *Brongniart.*—Schlotheim and Sternberg may be regarded as pioneers of the science of paleobotany. Brongniart is universally admitted to have been its true founder. The science may properly be said to have been born in 1828, the year in which both the "Prodrome" and the "Histoire des végétaux fossiles" appeared. It was these two works that gave it that powerful impetus which forced its immediate recognition and called into its service a large corps of colaborers with Brongniart, rapidly multiplying its literature and increasing the amount of material for its further study.

Adolphe Théodore Brongniart was born at Paris in 1801 and died in the same city in 1876. His father, Alexandre, was eminent in science, and the author of at least one memoir relating to fossil plants.[5] Adolphe turned his attention early to botany and continued through life to devote himself to living plants; but his great specialty was the study of the extinct forms, and his labors in this field extend through nearly half a century. His very first memoir, "Sur la classification et la distribution des végétaux fossiles en général, et sur ceux des terrains de sédiment supérieur en particulier," which appeared in the "Mémoires du Muséum d'histoire naturelle de Paris" (pp. 203–240, 297–348) in 1822, was one of great merit and importance, as shadowing forth the comprehensive system which he was to elaborate. It was a decided improvement upon the classifications previously proposed by Steinhauer, Sternberg, Martius, etc., and was later employed, with extensive modifications, in the "Prodrome." The great "Histoire," though pushed well into the second volume and enriched by nearly two hundred plates, was unfortunately never finished, and has come down to us in this truncated condition. The causes which led to this result are understood to have been of a pecuniary character, and the author continued his investigations and published his researches for many years chiefly in the "Annales des sciences naturelles de Paris." His next most important work, however, viz., his "Tableau des genres de végétaux fossiles," was published in the "Dictionnaire universel d'histoire naturelle" in 1849. The mere mention of these titles gives a very inadequate idea of the importance of Brongniart's work. The systematic manner in which the science was organized and built up by him made him the highest authority on the subject of fossil plants, and the numerous, more or less elaborate memoirs that continued to appear showed that none of the minor details were neglected. Of his reforms in botanical classification we shall have occasion later to speak more particularly.

5. *Witham.*—Henry T. M. Witham, of Edinburgh, was the first of a line of British investigators who looked beyond the external form of fossil plants and undertook the systematic study of their internal structure. It is for this reason rather than on account of the bulk of his works that his name is inserted in this enumeration. He is well known for his de-

[5] Notice sur des végétaux fossiles traversant les couches du terrain houiller. Annales des Mines, Tome VI, 1821, pp. 359–370.

scription of the great Carboniferous tree found in the quarries of Craigleith, and for other similar investigations. One of his principal works is entitled "The Internal Structure of Fossil Vegetables found in the Carboniferous and Oolitic Deposits of Great Britain, described and illustrated," Edinburgh, 1833. The illustrations are numerous and well executed, and form a secure basis for all subsequent researches of the kind.

6. *Göppert.*—Heinrich Robert Göppert, of Breslau, who was born in the year 1800 and who has died since this sketch was first drafted, was the most voluminous writer upon fossil plants that has been produced thus far. In his "Literarische Arbeiten," prepared by himself in 1881, one hundred distinct works, memoirs, and papers are enumerated relating to this subject, and several have appeared since. Nearly an equal number relate to living plants, and a few to medicine, which was his profession. But his work in vegetable paleontology exceeds by far all his other works in its value to science, embracing as it does many large treatises on the Paleozoic flora ("Flora der Uebergangsgebirge"), on the amber flora, on the fossil Coniferæ, on the fossil ferns, etc. Especially important has been his microscopic work upon the structure of various kinds of fossil woods, particularly those of the Coniferæ and the Dicotyledons. Endowed with the true German devotion to his specialty, with keen observing and analytic powers, with a restless activity, exceptional opportunities, and long life, he was able to create for the science a vast wealth of new facts and give it a solid body of laboriously wrought truth. If Brongniart laid the foundations of paleobotany, Göppert may properly be said to have built its superstructure. Though born one year earlier than Brongniart, he did not turn his attention to fossil plants until the latter had been twelve years in that field. His first paper appeared in 1834, or just a half century ago.[6] It was historical in its character. Like many other men who have been destined for a great career, he began it by taking a bird's-eye view of his subject. He did not despise the literature of his predecessors, even though they groped in the darkness of medieval ignorance. With patriotic pride he first told the story of his own countrymen's attempts to elucidate the flora of the ancient world, although even in this paper, he by no means confined himself to the limits of Silesia, and two years later he published a great expansion of this historical research as an introduction to his first great work.[7]

No attempt within our present limits of space to convey an idea of the true merits of Göppert's services to paleobotany could hope to do them justice, and we can only point to the monument he has himself

[6] Ueber die Bestrebungen der Schlesier die Flora der Vorwelt zu erläutern. Schlesische Provincialblätter, August und September 1834. Also in Karsten und Dechen's Archiv, Band VIII, 1835, pp. 232–249.

[7] Systema filicum fossilium: Die fossilen Farnkräuter. Nov. Act. Acad. Cæs. Leop. Car., Tom. XVII, suppl., pp. 1–76.

reared, and enroll his name alongside those of Brongniart, Unger, and Heer.

7. *Corda.*—The propriety of placing Corda's name in this roll of honor may be questioned by some, but his contributions to paleobotany were important, and there can be no doubt that had his life not been prematurely cut off they would have been far more so. Born in 1810 at Reichenberg, Bohemia, he early turned his attention to botany, and especially to close histological investigations in fungology. Humboldt, attracted by his productions, called him to Berlin in 1829, and Sternberg recalled him to Prague in 1834. His "Skizzen zur vergleichenden Phytotomie," appended to Heft 8 of Sternberg's "Flora der Vorwelt," was a valuable addition to that work, and led the way to his two other principal works, "Beiträge zur Flora der Vorwelt," Prague, 1845, and "Die fossilen Pflanzen der böhmischen Kreideformation" (in Reuss's "Versteinerungen der böhmischen Kreideformation"), Stuttgart, 1846. In these works and other of his memoirs a large number of species of fossil plants are named, described, and carefully figured, forming a permanent tribute to the growing science. In 1847 Prince Colloredo sent Corda to Texas to collect scientific material. He remained there two years, making large accumulations, and started back with them in the Bremen steamer Victoria, which was lost in the middle of the Atlantic, and Corda, with all his scientific treasures, went down with her.

8. *Geinitz.*—Only a comparatively small number of Geinitz's papers relate to paleobotany, and a still smaller number are devoted exclusively to that subject; and yet not less than thirty-five titles belong to this department of paleontology. Born at Altenburg in 1814, he has stood for a full half century in the front rank of continental geologists, and still continues his indefatigable labors. His protracted studies into the age and character of the Quadersandstein formation of Germany, in which so many fossil plants have been found, have shed much light upon this difficult horizon, while his investigations in the Permian (Dyas, Zechstein), the Carboniferous, and the Graywacke have always led him to study and describe the floras of these periods. We thus possess in his works a geological authenticity for very many fossil plants, which all paleobotanists know how to appreciate. His "Characteristik der Schichten und Petrefakten des sächs.-böhmischen Kreidegebirges," Dresden, 1839–42, appears to have been his first work relating to our subject, and his paleobotanical labors therefore date from 1839.

9. *Binney.*—If Witham deserved enumeration in our present list for founding the British school of what may be called phytopaleontological histologists, Binney must be admitted in recognition of the extent and importance of his researches in this department. He seems to have commenced publishing the results of his investigations in 1839,[8] and

[8] The first of his papers whose title appears in the "Royal Society Catalogue" is "On a Microscopic Vegetable Skeleton found in Peat near Gainsborough." British Association Report, 1839 (Part II), pp. 71, 72.

continued them without interruption to the end of his life. His most important work, on the "Structure of Fossil Plants from the Carboniferous Strata," published by the Palæontographical Society of London, was commenced in 1868. His death took place in the year 1882.

10. *Unger.*—Franz Unger of Steiermark, who was born in 1800 and died in 1870, was one of the most illustrious of European botanists and paleontologists. His memoirs and books on paleobotany are only less numerous than those of Göppert, and among them is an unusually large number of monographs of great value. His investigations were chiefly confined to the more recent formations, and his "Chloris protogæa," "Flora von Sotzka," "Iconographia plantarum fossilium," and "Sylloge plantarum fossilium" are worthy of special mention. His "Synopsis plantarum fossilium" and "Genera et species" are systematic attempts to compile the known data of the science in condensed and convenient form. His first paper[9] on the subject was published in 1840.

11. *Schimper.*—Although Schimper contributed a paper[10] on fossil plants as early as 1840, and was associated with Mougeot in preparing their important "Monographie des plantes fossiles du grès bigarré de la chaine des Vosges" in 1844, as also with Köchlin-Schlumberger in his "Terrain de transition des Vosges" in 1862, still, but for his great "Traité de paléontologie végétale," the third volume of which appeared in 1874, it is evident that this eminent bryologist would not have been entitled to be also ranked among the great paleobotanists. The "Traité" is unquestionably the most important contribution yet made to the science. Although necessarily to a large degree a compilation of the work of others, still it is by no means wanting in originality, and contains a great amount of new matter. Its chief merit, however, is in its conception and plan as a complete manual of systematic paleobotany. The classification is highly scientific and rational, and the discussion of abstruse points in defense of it is acute and cogent. Every species of fossil plant known to the author is described in Latin, and much independence is manifested in the rejection of synonyms. Very important is the geological classification at the end of Volume III, showing that the author had clear ideas of the uses of the science. The selections for the atlas are always the very best, and not a few of the figures are original. Although not in possession of all the extant data, particularly from America,[11] Schimper succeeded in supplying in this work the greatest need of paleobotany. His great talent as an organ-

[9] Ueber ein Lager vorweltlicher Pflanzen auf der Stangalpe. Steyermärkische Zeitschrift, Grätz, 1840. I have only been able to consult this memoir in Leonhard & Bronn's Neue Jahrbücher (1842, pp. 607, 608), which may not contain it *in extenso.*

[10] Baumfarne, Schachtelhalme, Cycadeen, Aethophyllum, Albertia * * * im bunten Sandstein der Vogesen; Hysterium auf einem Pappel-Blatte der Wetterauer Braunkohle. Leonhard und Bronn's Neue Jahrbücher, 1840, pp. 336–338. Communication dated 14. März 1840.

[11] See "The American Journal of Science," 3d series, Vol. XXVII (April. 1884), p. 296.

izer and text-book writer was again seen in his able contribution to Zittel's "Handbuch der Paläontologie."

Wilhelm Philip Schimper was born at Dosenheim (Alsace) in 1808, and died at Strasbourg, where most of his work had been done, in 1880. He became director of the Museum of National History of Strasbourg in 1839.

12. *Williamson.*—In Mr. W. C. Williamson we have a third of the line of eminent British paleobotanists, whose chief attention has been directed to the study of the internal structure of Carboniferous plants, and the one who at the present time unquestionably stands at the head of this school of investigators. If we include his paper "On the Origin of Coal," published in the report of the British Association for 1842 (Part II, pp. 48, 49), his place would be where we have assigned him, but his special work upon the plants themselves seems not to have commenced until 1851, and then to have been more or less interrupted until 1868, since which time it has been incessant, culminating in his great work "On the Organization of the Fossil Plants of the Coal Measures," which runs through so many volumes of the "Philosophical Transactions." Of the merits of this work, as of all of this author's investigations, it is certainly unnecessary to speak here.

13. *Lesquereux.*—Mr. Leo Lesquereux of Columbus, Ohio, is one of those acquisitions which America has so often made at Europe's expense when political turmoils arise there and make liberty dearer even than country. He was of that little band, which also included Agassiz and Guyot, who were compelled to abandon Switzerland in 1847 and 1848, on the occasion of the breaking up of the Academy of Neuchâtel and the coming into power of the so-called Liberal party. His ancient family name was Lescure, afterwards Lescurieux, and finally Lesquereux, and his immediate ancestors were French Huguenots. He was born November 18, 1806, at Fleurier, canton of Neuchâtel. His father was a manufacturer of watch springs and endeavored to teach him that business, though, since his health was somewhat delicate, his mother preferred to prepare him for the ministry; but Science had marked him for her own, and no power could withdraw him from nature. With a taste for plants in general, he was led by circumstances first to the study of mosses, then naturally to that of peat, and lastly to that of fossil plants. The government of Neuchâtel was then greatly interested in the protection of peat bogs on account of the difficulty of procuring fuel for the poor, and offered a prize (a gold medal of 20 ducats) for the best memoir on the formation and preservation of peat. Lesquereux competed and won the prize. His prize memoir[12] gained a wide reputation, was extensively copied, and is still quoted as one of the best on the subject.

[12] Quelques recherches sur les marais tourbeux en général. Mémoires de la Société des sciences naturelles de Neuchâtel, Tome III, 1845. (See summary in the Archives des sciences phys. et nat. de Genève, Tome VI, p. 154.)

The connecting link between this study and that of fossil plants was supplied two years later, when he wrote a short paper "Sur les plantes qui forment la houille."[13]

On his arrival in America he studied the coal formations of Ohio, Pennsylvania, Illinois, Kentucky, Arkansas, and other States, and his reports appear in those of the geological surveys of all of these States. Especially important are those upon the coal flora of Pennsylvania. The first of these appeared in the second volume of the report of H. D. Rogers, in 1858, consisting of some quite elaborate "General Remarks," and a "Catalogue of the Fossil Plants which have been Named or Described from the Coal Measures of North America." This is accompanied by twenty-three excellent plates. But this was a mere beginning, for when the second geological survey of Pennsylvania was undertaken Mr. Lesquereux was employed to work up the coal flora, which appeared in 1880 in a volume of text and an atlas, the most important work on carboniferous plants that has been produced in America. A third volume, supplementary to these, has just been issued.

In 1868 Mr. Lesquereux began the study of the floras of later formations in the West, and contributed an important paper on the Cretaceous leaves of Nebraska to the "American Journal of Science."[14] Dr. F. V. Hayden employed him to work up the collections of his surveys of the Territories, and important papers on the subject appeared in the annual reports of the survey for 1870, 1871, 1872, 1873, and 1874. In the last of these years appeared his "Cretaceous Flora," forming Volume VI of the quarto reports. In 1878 the seventh volume of these quarto reports was published, a still larger work, devoted to what he called the "Tertiary Flora," though a very large proportion of the species were from the Laramie Group. The eighth of these volumes will also be by Mr. Lesquereux, and will consist of a thorough revision of the entire Cretaceous and Tertiary floras of North America. Mr. Lesquereux is still living, and though infirm with age is actively engaged in bryological and paleontological studies.

14. *Dawson.*—To Sir J. W. Dawson is due the greater part of the knowledge we possess concerning the vegetable paleontology of Canada and the British North American provinces in general. His numerous papers, running back as far as 1845,[15] are almost exclusively confined to the description and illustration of material from this part of the world, and all except a few recent ones relate to the older formations of the East.

[13] Archives des sciences physiques et naturelles (Bibliothèque universelle), Tome VI, 1847, pp. 158-162. Genève.

[14] On Some Cretaceous Fossil Plants from Nebraska. Am. Journ. Sci., 2d series, Vol. XLVI (July, 1868), pp. 91-105.

[15] His paper "On the Newer Coal Formation of the Eastern Part of Nova Scotia" (Quart. Journ. Geol. Soc. Lond., Vol. I, 1845, pp. 322-330) merely names a few genera occurring there, but his "Notices of Some Fossils Found in the Coal Formation of Nova Scotia" (l. c., Vol. II, 1846, pp. 132-136), giving his views on Sternbergia, attracted immediate attention.

His reports upon "The Fossil Plants of the Devonian and Upper Silurian Formations of Canada," upon "The Fossil Plants of the Lower Carboniferous and Millstone Grit Formations of Canada," and upon "The Fossil Plants of the Erian (Devonian) and Upper Silurian Formations of Canada" are monographs of especial value. A geologist rather than a botanist, he has done excellent service, not only in elucidating the important problems of Acadian geology, but also in demonstrating the value and legitimacy of the evidence furnished by vegetable remains.

Dawson was born at Pictou, Nova Scotia, in the year 1820, and though educated at Edinburgh, he returned to his native country and has devoted his whole life to the study of its geology and paleontology. He is a fellow of the Royal Society of London and of the Geological Society, and has long honored the well-known post of Principal of McGill University, Montreal. We learn with great satisfaction, though almost too late to be fittingly mentioned here, that the order of knighthood has just been conferred upon him on the occasion of the meeting of the British Association in his adopted city.

15. *Heer.*—The numerous obituary notices that have so recently appeared in all the scientific journals render it unnecessary to give in this place any extended biographical sketch of this eminent savant. He was born at Glarus, Switzerland, in 1809, and died at Lausanne in 1883, after having long filled the chair of botany in the University of Zürich. Vegetable paleontologists note with some surprise that he is mentioned by his biographers chiefly as an entomologist,[16] and naturally wonder how great must have been his eminence in that department to overshadow his vast and invaluable labors in the domain of fossil plants.

He commenced writing upon this latter subject in 1846.[17] The first volume of his great work, "Flora tertiaria Helvetiæ," appeared in 1855, the second in 1856, and the third in 1859. The exceedingly great care, accuracy, and thoroughness with which this *chef d'œuvre* of science was executed, especially in the matter of illustration, is a marvel to contemplate. Nothing comparable to it had appeared before, and nothing equal to it has appeared since. He became interested in the fossil floras of remote parts of the globe, and among the first of his memoirs on such subjects was one that may be found in the Proceedings of the Academy of Natural Sciences of Philadelphia for 1858 (pp. 265–266), on the "Fossil plants of the Lower Cretaceous beds of Kansas and Nebraska." He also figured the "Phyllites Crétacées du Nébraska," collected by Marcou and Capellini.[18] In 1866 his memoirs upon the fossil floras of the Arctic regions commenced to appear, and to this fertile subject he devoted the greater part of the rest of his life. The first volume of his "Flora

[16] "Science," Vol. II, p. 583, 1883; "Nature," Vol. XXVIII, Oct. 25, 1883.

[17] The first paper of which there is a record is the one "Ueber die von ihm an der hohen Rhone entdekten fossilen Pflanzen," which appeared in the Verhandlungen der Schweizerischen Gesellschaft for 1846, pp. 35–38.

[18] Neue Denkschriften der Schweizerischen Gesellschaft der Naturforscher, Zürich, 1866. Mém. I.

fossilis arctica" appeared in 1869, the second in 1871, and the remaining five at intervals of about two years, the seventh and last coming out in the year of the author's death. With the exception of the first volume, this colossal work consists entirely of a compilation of more or less independent memoirs, which were published as fast as prepared in various scientific periodicals in several languages, and which are merely put together into volumes of convenient thickness. Each memoir has its own independent pagination, generally that of the volume of Transactions in which it originally appeared, all of which renders it very inconvenient for consultation, but cannot detract from its great value as a reservoir of facts.

Bunbury.—It may be doubtful whether the paleobotanical works of Sir Charles Bunbury are of sufficient importance to entitle him to enumeration among the principal cultivators of that science, but they have certainly been quite numerous and covered a wide range of subjects, both geographically and botanically. He began by elaborating certain material from the United States[19] and the British provinces,[20] collected by Sir Charles Lyell and Dr. Dawson, and was the first to recognize the merits of the views of the latter respecting the fossils known as *Sternbergia* from the coal fields of Sydney. But he also worked up material from France, Portugal, Madeira, and India, as well as from Yorkshire and other parts of England. His investigations have been chiefly confined to carboniferous fossils, but in a quite recent work[21] he has published some interesting views on the subject of nervation which may prove of value.

17. *Massalongo.*—Abramo Massalongo, the first of the Italian school of paleobotanists whose work claims our attention here, commenced publishing in 1850,[22] and continued with great activity until 1861. He confined his investigations almost exclusively to material from his own country, and contributed more to the elucidation of the fossil floras of Italy than any other author. The number of his papers is very large, considering the comparatively short period during which he was permitted to work, and an unusually large percentage of them are monographs of considerable size. His greatest work, for which Scarabelli contributed the stratigraphical part, was his "Studii sulla flora fossile e geologia stratigraphica del Senigalliese," Imola, 1859, but of which

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[19] On some remarkable Fossil Ferns from Frostburg, Md., collected by Mr. Lyell. Quart. Journ. Geol. Soc., 1846, Vol. II, pp. 82–91. Observations on the Fossil Plants of the Coal Field of Tuscaloosa, Ala., etc. Silliman's Journal, 1846, pp. 228–233. Description of Fossil Plants from the Coal Field near Richmond, Va., Quart. Journ. Geol. Soc., 1847, Vol. III, pp. 281–288.

[20] Notes on some Fossil Plants, communicated by Mr. Dawson, from Nova Scotia. Quart. Journ. Geol. Soc., 1846, Vol. II, pp. 136–139. On Fossil Plants from the Coal Formation of Cape Breton, Nova Scotia. *Ibid.*, 1847, Vol. III., pp. 433–428, and numerous similar memoirs.

[21] Botanical Fragments. London, 1883.

[22] See his Schizzo geognostico sulla Valle di Progno (Preludium Floræ fossilis Bolcensis), Verona, 1850. Collett. dell' Adige, 14 sett., 1850.

his "Synopsis floræ fossilis Senogalliensis," Verona, 1858, forms an integral part, having been prepared from the plates of the former, to which reference is constantly made. This work is thoroughly illustrated by forty-five large quarto plates of well executed but not very well printed figures, and is one of the most important contributions to the Tertiary flora of Europe. It virtually and fittingly closed the too short but perhaps too active career of one of Italy's most talented scientists

18. *Ettingshausen.*—Since the death of Oswald Heer the great merits of Baron von Ettingshausen's paleobotanical researches, always highly appreciated, have seemed to command especial attention. Beginning this career simultaneously with Massalongo in the year 1850,[23] he has had the advantage over the Italian savant of being permitted to continue it uninterruptedly under the most favorable auspices down to the present time. He immediately began his studies in the Tertiary flora of the Austrian Monarchy, and published the Tertiary Flora of Vienna in 1851. His "Beiträge zur Flora der Vorwelt," "Proteaceen der Vorwelt," and numerous lesser papers appeared in the same year. From the number of important papers that appeared during 1852 and 1853 it is clear that he must have been very active, entering as he did into the study of Paleozoic and Mesozoic floras, as well as continuing his work on the Tertiary plants. It was, however, in 1854 that he laid the foundation for that deserved renown which he now enjoys in taking up under such extraordinarily favorable conditions the investigation of the true principles of nervation in dicotyledonous leaves. The process of nature-printing, or physiotypy (*Naturselbstdruck*), had been invented in the Austrian imperial court and state printing-office by Auer and Worring, and Ettingshausen at once perceived its special applicability to the science of botany. Recognizing the vast importance of this discovery to paleobotany he obtained permission to employ the new method and proceeded to prepare his first monograph "Ueber die Nervation der Blätter und blattartigen Organe bei den Euphorbiaceen mit besonderer Rücksicht auf die vorweltlichen Formen,"[24] which he followed up with a similar memoir, "Ueber die Nervation der Blätter der Papilionaceen.[25] To the first of these memoirs was prefixed a brief synopsis of the classes of nervation found in euphorbiaceous leaves. Availing himself of the efforts in this direction which had been previously made by Leopold von Buch,[26] Bianconi,[27] and others (he seems

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[23] No less than four of his papers appeared in that year, one in the Sitzungsberichte of the Vienna Academy, one in the first volume of the Austrian Geological Jahrbuch, and two in the sixth volume of Haidinger's Collections of Memoirs.

[24] Sitzungsberichte d. Akad. d. Wiss. Wien. Bd. XII, 1854, pp. 138–154, Pl. I–XVII.

[25] *Loc. cit.*, pp. 600–663, Pl. I–XXII.

[26] Ueber die Blattnerven und ihre Vertheilung. Monatsbericht der Berliner Akademie der Wissenschaft, 1852, pp. 42–49, with plate.

[27] Giuseppe G. Bianconi. Sul sistema vascolare delle foglie, considerato come carattere distintivo per la determinazione delle filliti. N. Ann. d. Sc. Nat. Bologna, 1838, Ann. I, Tom. I, pp. 343–390, Pl. VII–XIII.

not to have been acquainted with De Candolle's "Organogénie"), he proposed a classification and terminology, which, so far as they went, Heer was willing to adopt,[28] and which are in common use by paleobotanists at the present time. In 1855 Ettingshausen and Pokorny received instructions to prepare a work for the Paris Exposition to be held in 1867 that should thoroughly illustrate the application of the nature-printing process to the science of botany. The result was that immense and astonishing production entitled "Physiotypia plantarum Austriacarum," with its six enormous volumes of most exquisite plates, not only illustrating the leaves of the trees and shrubs, the flowers with their petals, sepals, stamens, and pistils, but the entire plants wherever within the ample limits of size, and these stand forth from the plates in actual relief like a veritable *hortus siccus*. This grand success was followed up by various monographs upon the nervation of certain important orders, as the Celastrineæ, Bombaceæ, Gramineæ, etc. Aided further by this magic process he commenced in 1858[29] a series of works illustrating the skeletons only of leaves, the most important of which is his "Blattskelette der Dykotyledonen," which appeared in 1861. The way thus cleared for the successful study of the Tertiary floras of the world, Ettingshausen, from this time on, has continued his important investigations in this field, and each year our knowledge of fossil plants is increased and extended by his enlightened contributions. It would carry us quite beyond our limits to attempt an enumeration here even of the most important of these memoirs, but we cannot complete our brief sketch of Ettingshausen's invaluable labors without a passing reference to such productions as his Flora of the Tertiary basin of Bilin, his Cretaceous Flora of Niederschöna, his Floras of Wetterau, Steiermark, Radoboj, Sagor, etc. Coupled with his great powers of accurate observation and strictly scientific method of investigation, Ettingshausen displays an unusually broad grasp of the deeper problems which paleobotany presents and has undoubtedly been for many years far in advance of all his contemporaries in this field in correctly apprehending and announcing the true laws of phytochorology and plant development.

Baron von Ettingshausen was born in 1826 at Vienna, and is a member of many learned societies and scientific bodies.

19. *Newberry*.—Dr. John Strong Newberry, of the School of Mines, Columbia College, New York, one of the most eminent American geologists, was born at New Windsor, Conn., December 22, 1822, and graduated at Western Reserve College in 1846. Two years later he took the degree of M. D. from Cleveland Medical College, Ohio. Before commencing the practice of his profession at Cleveland, in 1851, he spent two years in Europe. On his return opportunities soon presented them-

[28]Flora Tertiaria Helvetiæ, Band II, pp. 2–6.

[29]The first was his "Blattskelette der Apetalen," Wiener Denkschriften, Band XV, 1858, pp. 181–272, with fifty-one plates.

selves for joining parties of exploration in the far West, and he finally became a member of the celebrated Ives Exploring Expedition. With a special fondness for geology and mining he combined a deep interest in paleontology, in all of which specialties he has distinguished himself. The Carboniferous formation of Ohio had early interested him much, and especially the vegetable remains found embedded in it, and as far back as 1853 we find him reading papers before the American Association, "On the structure and affinities of certain fossil plants of the Carboniferous era," and "On the Carboniferous Flora of Ohio, with descriptions of fifty new species of fossil plants."[30] In 1859 he reported upon the fossils, including plants, of the Macomb Exploring Expedition,[31] in 1861 those of Lieutenant Ives's Expedition,[32] and in 1863, those of the Northwest Boundary Commission.[33] Probably the most important of his paleobotanical memoirs thus far published was his "Notes on the Later Extinct Floras of North America," which appeared in the Annals of the New York Lyceum of Natural History for April, 1868. No plates accompanied this memoir, but a large number of the plants described had been figured by Dr. Newberry, which he had expected to be published by the Geological Survey of the Territories, but none appeared until 1878.[34] He has, however, been more or less constantly engaged since that time in figuring the large collections which have been reaching him each year at the School of Mines, and over one hundred plates have, up to the present writing, been prepared, most of which are printed and awaiting the text of a large work which will be published by the United States Geological Survey.

20. *Schenk.*—Hofrath Dr. August Schenk, professor of botany at the University of Leipsic, was born at Hallein, Upper Austria, in 1815, and held the chair of botany at Münich and Würzbach before being called to that of Leipsic. His paleobotanical researches have been chiefly directed towards a little known horizon lying between the Buntersandstein and the Lias, and upon this dark region they have shed a flood of light. His earlier papers[35] related to fossil plants from the Keuper, chiefly collected in the vicinity of Bamberg and Bayreuth, and, in addition to material collected by himself and Dr. Kirchner, he elaborated that brought together by the Count of Münster, but later he turned his attention to some rich plant beds overlying these strata and situated intermediate between them and the Lias. It is upon this narrow horizon

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[30] Proceedings, pp. 157–166.

[31] Report of the Expedition, pp. 142–148, Pl. IV–VIII.

[32] Report upon the Colorado River of the West, by Lieut. Joseph C. Ives, Washington, 1861, pp. 129–132., Pl. III.

[33] Boston Journal of Natural History, Vol. VII, 1863, pp. 506–524.

[34] Illustrations of Cretaceous and Tertiary plants. Washington, Government Printing Office, 1878.

[35] The earliest seems to have been "Ueber einem in der Keuperformation bei Würzburg aufgefundenen fossilen Farnstamm (Chelepteris strongylopeltis). Verhandlungen der Würzburger physicalisch—medicinschen Gesellschaft, Band VIII, 1858, pp. 212–216.

that he has bestowed the closest attention, and his final monograph upon the subject, which, dropping the term *Rhetic*, he has entitled "Die fossile Flora der Grenzschichten des Keupers und Lias Frankens," is a very valuable contribution to paleobotany. Still later (1868), he took up the Muschelkalk beds of Recoaro, first noticed by Catullo,[36] but treated by a number of authors, and produced a finely illustrated little work "Ueber die Pflanzenreste des Muschelkalkes von Recoaro." Besides his "Beiträge zur Flora der Vorwelt" in the *Palæontographica*, and numerous minor contributions, Dr. Schenk has elaborated the fossil plants for Baron Richthofen's "China,"[37] and, since Schimper's death, has gone on with the vegetable department of Zittel's "Handbuch der Paläontologie."[38]

21. *Saporta.*—The death of Professor Heer broke up the illustrious trio of continental paleobotanists who had so long taken the lead in the study of the fossil plants of the Tertiary formation—Heer, Ettingshausen, and Saporta. The two that remain are of more nearly the same age, and in many respects admit of a more ready comparison; still their fields of labor are so well separated that no conflict can occur in their operations, and both seem likely to continue uninterrupted for many years their already extensive investigations.

The Marquis (until a year ago Count) Gaston de Saporta, was born in the year 1823 at Saint Zacharie, department of Var, in Provence, France, and it was in the near vicinity of his native place that he first began[39] his paleobotanical studies, and to the thorough illustration of the fossil botany of Provence he has always devoted his best energies. His "Etudes sur la végétation du sud-est de la France à l'époque tertiaire,"[40] begun in 1863, has thus far remained his *chef d'œuvre*, and most of the localities treated in this work are situated in Provence. In 1873 he published "La revision de la flore fossile des gypses d'Aix," which was practically a revision of the "Etudes."[41] Among his other more important works on Cenozoic floras may be mentioned his "Prodrome d'une flore fossile des travertins de Sézanne,"[42] in which the flora of the Eocene, or Paleocene, as he terms it, is better set forth than in any other work, and his "Essai sur l'état de la végétation à l'époque des marnes

[36] Nuovi annali di scienzi natur. di Bologna, serie II, Tom. V. 1846, pp. 81–107 (see p. 106).

[37] Band IV, pp. 209–269, 284–288, Pl. XXX–LIV.

[38] II. Band, III. Lieferung.

[39] Note sur les plantes fossiles de la Provence, Lausanne. Bulletin de la Société vaudoise des sciences naturelles, Tome VI, 1860, pp. 505–514. Examen analytique des flores tertiaires de Provence, Zürich, 1861.

[40] Annales des sciences naturelles—Botanique—4e série, tomes XVI XVII, XIX; 5e série, Tomes III, IV, VIII, IX, 1861–'68.

[41] *Loc. cit.*, 5e série, Tome XVIII.

[42] Mémoires de la Société géologique de France, Tome VIII, 1865, pp. 289–438, Pl. XXII–XXXVI.

heersiennes de Gelinden,"[43] in which, as in his "Recherches sur les végétaux fossiles de Meximieux,"[44] he was assisted by Prof. A. F. Marion. But Saporta's contributions do not all relate to the Tertiary. Of nearly equal importance have been his studies in the Jurassic flora of France.

The three volumes of his "Plantes jurassiques,"[45] which have already appeared, with accompanying atlas, constitute, without any doubt, the most exhaustive treatise upon the vegetable paleontology of that horizon that has thus far been produced. Its value is by no means confined to the light it throws upon the Mesozoic flora of France. The manner in which the determinations are supported by comparison with other fossil and with living floras, renders the work a thoroughly general one. Indeed no better treatise exists on the histology of coniferous stems and on the classifications of the Coniferæ in general than is to be found in the introduction to the third volume of this work. Besides numerous other minor descriptive papers and memoirs of greater or less length and importance on fossil plants, Marquis Saporta has written two interesting popular books on the subject. That entitled "Le Monde des Plantes avant l'apparition de l'homme," which appeared in 1879, is unquestionably the best popular treatise in this branch of science. The first volume of the work on "L'evolution du règne végétal," confined entirely to a study of the Cryptogams from the point of view of evolution, appeared in 1881 as one of the International Scientific Series, though it seems never to have been translated into English. In this work Professor Marion was associated. Other volumes showing the evidence of phenogamous plants for the doctrine of evolution are anxiously looked for. Saporta has long been a strong supporter of this class of views, and his writings display a broad and enlightened spirit.

22. *Carruthers.*—The subject of this sketch was born at Moffat, Scotland, and educated in Edinburgh. In 1859 he entered the British Museum as assistant in botany, and became keeper of the department of botany in 1871. He began his paleobotanical work by re-editing Lindley and Hutton's "Fossil Flora of Great Britain," and is understood to be now preparing a supplement to it. During this time he has been constantly contributing articles upon various points connected with his investigations. The number of such papers is very large and their merit so great that his title to a place in the present enumeration will not probably be disputed. Although pursuing somewhat the same line of investigation as the other British paleobotanists, he still has given himself a much wider field. He has not limited his researches to the Paleozoic, but has made incursions into the Mesozoic and even into the Tertiary. Fossil fruits have formed a favorite study for him, and his investigations have widely

[43] Mémoires couronnés de l'Académie des sciences de Belgique, Bruxelles, 4e édition, Tome XXXVII, No. 6, 1873.

[44] Archives du Muséum d'histoire naturelle de Lyon, 4e livraison, 1876, p. 131.

[45] Paléontologie française. Série 2. Végétaux, 1873, 1875, and 1876–1883.

expanded this field of knowledge. Mr. Carruthers was elected a fellow of the Royal Society in 1871.

In terminating this enumeration here it is evident that the limit of space and not of matter has been the motive. The aim has been rather to consider the great names in the past history of the science than to venture an estimate of the worth of present workers in it, and if a number of living representatives have been named it is because their services have already been so great as to have given a special color to that history and to afford a safe basis for judging of their future work. With most of the many present devotees of paleobotany this last condition at least does not exist, and the fear of coming far short of doing them justice, at least in the estimation of their future biographers, has deterred me from introducing their names into this brief *résumé*.

But aside from this class no little difficulty has been encountered in choosing from among the older workers, and although in many cases no two would agree where the line should be drawn, it is by no means improbable that some obvious mistakes have been made, and that names which have been omitted should have been substituted for some that have been mentioned. Defects of this class, and also those of various other kinds, may, however, be partially remedied in the treatment of the next division of the subject, in which the field will be less restricted in this respect, and we shall look more especially to the work done than to the men who have done it.

B.—SKETCH OF THE EARLY HISTORY AND SUBSEQUENT PROGRESS OF PALEOBOTANY.

1. THE PRE-SCIENTIFIC PERIOD.

Science often has its origin in wonder at unexplained phenomena, and there is no science of which this is more true than of paleontology. Nearly all the early writers openly avow that they have been chiefly spurred on to undertake and carry on their investigations by an "eager curiosity"[46] respecting the objects they were treating, and the first collections of such objects were looked upon simply as curiosities, while what have since become the greatest scientific institutions in the world sometimes betray their origin by perpetuating the original names expressive of their sense of wonder.[47]

No greater objects of wonder have presented themselves to man's consideration than the fossils which from the earliest times have been observed in different parts of the earth's crust. The efforts of the rational mind to interpret these phenomena, although they may seem amusing to the unthinking, are really of deep philosophic and even scientific interest. It may surprise some to learn that the conclusions

[46] Parkinson's Organic Remains of a Former World, 1804, p. v.

[47] For example the great Academia Cæsarea Leopoldino-Carolina Naturæ Curiosorum, founded in 1670 at Frankfort-on-the-Main.

reached by the ancients were far more correct than those drawn twelve to sixteen centuries later, from much more ample data. Strabo, Xenophanes, Xanthus, Eratosthenes, and even Herodotus believed that the fossil shells they had seen once contained living animals, and that in process of time they had been turned into stone. They further concluded that the mountains in which they were found imbedded were once under the sea. These doctrines were known to the Romans, and of their popular acceptance by the cultivated classes we have evidence in the familiar lines of Ovid's "Metamorphosis." [48] This view was also shared by Pliny and other post-Augustan writers, and even Tertullian[49] did not perceive its inconsistency with Christian philosophy, which caused its complete rejection during the next thirteen centuries. Of the fact of this long stagnation not only in this but in nearly all other departments of science there is no question,[50] but as to its cause there are differences of opinion which this is not the place to discuss. The doubtless charitable attempt, however, to throw the responsibility back upon Aristotle and his famous doctrine of *generatio æquivoca*,[51] merely because that doctrine was found more in harmony with the cosmogony which became ingrafted upon those sombre ages, should, in the single interest of historic truth, be condemned, while it is too late in the scientific epoch to make it either necessary or prudent to hesitate in confessing that the reasoning powers of man were virtually destroyed during that period by the almost universal and thoroughly honest acceptance of a false cosmogony.[52]

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[48] "Vidi ego, quod fuerat quondam solidissima tellus
Esse fretum, vidi factas ex æquore terras,
Et procul a pelago conchæ jacuere marinæ,
Et vetus inventa est in montibus ancora summis."
(Lib. XV, 262.)

[49] "Mutavit et totus orbis aliquando, aquis omnibus obsitus; adhuc maris conchæ et buccinæ perigrinantur in montibus, cupientes Platoni probare etiam ardua fluitasse." (De Pallio, II.)

[50] "During the next thirteen or fourteen centuries fossil remains of animals and plants seem to have attracted so little attention that few references are made to them by writers of this period. During these ages of darkness all departments of knowledge suffered alike, and feeble repetitions of ideas derived from the ancients seem to have been about the only contributions of that period to natural science." (Address of Prof. O. C. Marsh as president of the American Association for the Advancement of Science, 1879. "Proceedings," Vol. XXVIII, p. 4.)

[51] "In den darauf folgenden Zeiten verdrängte die aristotelische und nachherige scholastiche Philosophie die Naturkunde, wobei man natürlich auch die Petrefakten fast gänzlich vernachlässigte und sie fast nur erwähnte, um die ungegründete Lehre des Aristoteles von der *generatio æquivoca* alsbald auch auf sie anzuwenden." (Göppert, Systema Filicum Fossilium, p. 4.)

[52] "Cette science eut beaucoup plus de peine à se développer que les autres sciences naturelles, telles que la physique et la chimie, car elle rencontra tout d'abord une opposition religieuse qui en entrava longtemps les progrès. L'orthodoxie biblique craignant que la science ne s'écartât trop des traditions de la Genèse, interdisait aux savants l'étude indépendante des fossiles, dans lesqueles elle ne voyait que les débris des êtres anciens détruits par le déluge de Noë." (Schimper, Traité de paléontologie végétale, Tome I, p. 6.)

It is only in so far as they relate to fossil plants that these general considerations can be entered into here, although so closely are all branches of paleontology blended in those early and, as it were, undifferentiated stages of their historical development that too strict a construction of this rule might exclude matter which has an important bearing upon paleobotany. The special science, however, must be regarded as very much younger than the general one. Indeed, while there is no doubt that the ancients were familiar with several kinds of animal fossils, particularly shells and corals, it is generally believed that they were wholly unacquainted with any form of vegetable petrifaction.[53] This complete ignorance seems to have continued throughout the middle ages down to the thirteenth century.

It is certainly surprising that so common an object as a piece of petrified wood should never have been observed by intelligent people inhabiting limestone regions like those of Greece and Italy, and it is hard to believe that this was really the case. It is more reasonable to suppose that such things were sometimes seen and wondered at by rustics, but that for some reason they escaped being recorded; or they may have been recorded in some work that has failed to come down to us, like the two lost books of Theophrastus.

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[53] "D'empreintes végétales ou de débris végétaux pétrifiés, nulle mention chez les anciens." (Schimper, *loc. cit.*, p. 1. See also Brongniart, Histoire des végétaux fossiles, Tome I, p. 1; Sprengel, Commentatio de Psarolithis, p. 7; Göppert, Syst. Fil. Foss., p. 8.)

The following are among the passages most commonly quoted in support of the opposite view:

"Palmati [lapides] circa Mundam in Hispania, ubi Cæsar dictator Pompeium vicit, quoties fregeris." (To the word "palmati" is attached the following foot-note: "Qui palmæ intus fracti referant.") (Plinius, Nat. Hist., XXXVI, 29. Delphin Classics, 111, Pliny, 9, p. 4749.)

"In Ciconum flumine, et in Piceno lacu Velino lignum deiectum, lapideo cortice obducitur, et in Surio Colchidis flumine, adeo ut lapidem plerumque durans adhuc integat cortex. Similiter in Silaro, ultra Surrentum, non virgulta modo immersa, verum et folia lapidescunt, alias salubri potu ejus aquæ. In exitu paludis Reatinæ saxum crescit." (*Loc. cit.*, II, 106.)

"Syringitis-stipulæ, internodio similis, perpetua fistula cavatur." (*Loc. cit.*, XXXVII, 67.)

"Qui navigavere in Indos Alexandri milites frondem marinarum arborum tradidere in aqua viridem fuisse, exemptam sole protinus in salem arescentem. Juncos [truncos] quoque lapideos perquam similes veris per littora," etc. (Theophrastus, *loc. cit.*, XIII, 51.)

"Quarti generis elatiten vocari quamdiu crudus sit: coctum vero militen, utilem ambustis, ad omnia utiliorem rubrica." (*Loc. cit.*, XXXVI, 38.)

"Dryites e truncis arborum: hæc et ligni modo ardet." (*Loc. cit.*, XXXVII, 73.)

Consult also, Theophrastus, *Περι Λιθων*, Sect. XXIX; Strabo, Geographica, Lib. XVI; and Pausanias, Græciæ Descriptio, Lib. I, cap. 43.

All these passages have, however, been carefully studied, and the conclusion reached that they refer only to stones resembling trunks, fruits, etc., to madrepores, to incrustations, or other mineral substances, and not in any case to real petrifactions.

Brongniart has offered an apology for the ancients,[54] on the ground that no coal mines occur in Greece or Rome, and that Spain, Northern Africa, and Western Asia, with which alone they were acquainted, are all equally wanting in that formation; and he very truly remarks that the knowledge of fossil plants really began simultaneously with the use of coal, as the destruction of the forests of Western and Northern Europe forced the growing population to discover some substitute for wood as fuel. This is quite true so far as coal plants are concerned, and somewhat so for all those fossils which are only exposed by mining, yet when we consider the extensive public works that were carried on by the Romans, in connection with the large number of rich beds of fossil plants now known in Italy, Dalmatia, Eubœa, and with the petrified forests of northern Egypt and other countries of the Roman Empire, some other explanation is certainly needed to account for the silence of ancient literature upon the subject. This is to be found in the highly artificial character of their civilization, and the little interest taken in or attention paid to the phenomena of nature around them. This state of society can be easily imagined by eliminating from our own society the very minute fraction of the citizens of any modern country who ever observe or reflect upon natural objects or phenomena. In any large city these can almost be counted upon the fingers, and this could then be done for the whole Roman Empire, while during the succeeding ages even these few were wanting, and the flicker that Pliny kindled upon the dying embers of Grecian learning was allowed to go entirely out.

It was long supposed that Agricola[55] was the first to make unequivocal mention of petrified wood, but a passage has been found in Albertus Magnus,[56] which leaves no doubt that his attention had been definitely drawn to this subject, and which carries it back to the thirteenth century. This passage, however, seems to have attracted no attention, and it was only after Agricola had twice[57] expressed his views on the subject that other writers took it up. Matthiolus in his letter to Bauhin (1564), and Gesner[58] (1565), described specimens which came into their possession. A long discussion followed as to the true nature of these petrifactions and all kinds of theories were put forward. Already for

[54] Histoire des végétaux fossiles, Tome I, p. 1.

[55] Georgius Bauer Agricola. De natura fossilium, 1558, Lib. VII, pp. 324, 328.

[56] "Similiter autem ligna jacentia in quibusdam aquis et maribus convertunt in lapides et retinent figuram lignorum. Et aliquando natæ plantæ in aquis et maribus illis ita sunt vicinæ lapidum naturis quod ad modicum exiccatæ in aëre, lapidum formam assumunt," etc. (Beati Alberti Magni De mineralibus. Tractatus I. Caput VII. Opera, Tom. II, p. 216, Lugduni, 1651.)

[57] "De ortu et causis subterraneorum. Lib. III. In De re metallica, Basileæ, 1657, p. 507. Arbores * * * lapidescunt * * * tum sic in saxa commutatæ, ut suus cujuscunque; truncus et rami mox sub aspectum veniant: cortex a ligno non difficiliter internoscantur."

[58] Conrad Gesner: De rerum fossilium, lapidum, et gemmarum maxime figuris et similitudinibus. Tiguri, 1565. (See cap. ix, fol. 125, f. 1.)

centuries had the discussion of petrifactions in general been raging and the discovery of petrified wood only added new complications to an old controversy. Enlarging upon Aristotle's doctrine of spontaneous generation, the scholastic writers had affirmed that it was as possible for stones of any required form to produce themselves as for living animals and plants. Avicenna in the tenth century had proposed his *vis lapidifica*, and Albertus Magnus in the thirteenth his *virtus formativa*. Bauhin[59] predicated a spirit of the Universe, or Archæus, while Libavius[60] held that fossils sprang, like living things, from a true germ or seed. Balthasar Klein obtained a specimen, one side of which was stone, the other coal, and this excited intense curiosity. He sent the specimen to Matthiolus, who studied it and came to the conclusion[61] that coal was the third or final step in the process of transmutation, and that just as wood turned into stone so stone in turn was transformed into coal. Klein's own views were much more rational. The discovery in the mines of Joachimsthal of a petrified trunk with the bark on added to the interest already aroused on this subject and kept alive the discussion.

Thus far only petrified wood had been observed or considered, and although Johannes Kentmann,[62] in 1565, had given an account of some leaf impressions formed by incrustations of tufa, no mention of the remains of the foliar organs of plants in any true rock formation seems to have been made until 1664, when Johann Daniel Major published at Jena his "Lithologia curiosa, sive de animalibus et plantis in lapides versis." This work was so little known that whatever its merits it attracted no notice, and the subject of fossil plants in the sense now commonly understood remained practically untouched until the close of the seventeenth century.

In 1699 appeared at London Lhwyd's "Lithophylacii britannici Ichnographia,"[63] in which were not only described but figured with sufficient fidelity for identification a number of ferns from the coal measures of England. A period of great activity in this department of human observation, we can scarcely say science, followed the appearance of this work, but before attempting to follow the development from this point we may pause a moment to consider the history and progress of ideas which in all ages so largely formed the spur to observation and investigation.

With the discovery of fossilized leaves and fronds by Major and Lhwyd all the departments of paleontology had been opened to discussion, and in those early days discussion was the primary consid-

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59 De fontibus et balneis Bollensis.

60 Hist. et invest. font. medic. ad Tubarin sub Rotembergo. P. III, Franc. ad Mœnum.

61 Epistolæ ad Bauhin, III, pp. 141, 142, 1564.

62 Nomenclatura rerum fossilium, etc. Tit. vi, Lapides. Tiguri, 1565, fol. 38.

63 Eduardi Luidii Lithophylacii britannici ichnographia, sive lapidum aliorumque fossilium britannicorum singulari figura insignium * * * distributio classica. Londini et Lipsiæ, 1699. 8°. (See Tab. 4 & 5, Figs. 184a, 186, 188, 189, 190, 191, 197; see, also, two Annularias, Figs. 201 & 202, Tab. 5.)

eration. The end was then, as now with modern science, the ascertainment of truth, but the lesson had not yet been learned that to this end the accumulation and investigation of facts is the first and principal requisite.

The mystic views of Avicenna, Albertus, Bauhin, Matthiolus, and Libavius, already referred to, prevailed in varying forms throughout the seventeenth century. Sperling[64] (1657) advocated a stone-making spirit, or *aura seminalis*. Kircher[65] (1665) propounded his theory of *seminaria* of *corpuscula salina* as the true principle of petrifaction, and as really constituting the *vis lapidifica* or *spiritus architectonicus* which controls the action of the *succus petrificus*, or petrifying juice, in which he was followed more or less closely by Lachmund[66] (1669), Plot[67] (1677), Rhin[68] (1682), and Lhwyd[69] (1699), while others considered fossils as mere freaks of nature. Indeed, Camerarius[70] (1712) declared that in the beginning God had supplied these varied forms to the earth's interior the same as grass and herbage to its surface. This class of ideas, however, could with difficulty withstand the light of the accumulating facts after the commencement of the eighteenth century, and Lange's[71] attempt (1708) to demonstrate the germ theory proved one of the latest efforts of the kind. A modified Democritism, however, cropped out later, as seen in Dr. Arnold's (1733) investigation of the origin and formation of fossils, in which he postulated the existence of infinitesimal particles which were brought together in the creation of the world to form the outline of all the creatures and objects upon and within the earth, a work which found some favor on the continent and was translated into German in 1733.[72]

The theory which was destined to supplant these vague, unreal speculations and to prevail throughout the eighteenth century was what may be called the *flood theory*, viz., the idea that all or nearly all fossils consist of the débris of the life of the globe prior to the occurrence of the Noachian deluge, having been tossed and washed about in that great disturbance and then left stranded on or near the surface in the places where they now occur after the waters had retreated. This view may seem to us a poor substitute even for the worthless dreams which

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[64] John Sperling. Lithologia, quam sub præside viri, etc., examini submittit G. E. Wiegandus. Viteb., 1657.

[65] Athanasius Kircherus. Mundus subterraneus, Tom. II, Lib. VIII, Sect. I, Cap. III; Sect. II, Cap. I. Amsterdam, 1665.

[66] Friederich Lachmund. Oryctographia Hildesheimensis. Hildesheim, 1669.

[67] Robert Plot. Natural History of Oxfordshire, pp. 32, 33, 122, 124. Oxford, 1677.

[68] Lucas Rhin. Dissertatio de ebore fossili. Altdorf, 1682.

[69] Edward Lhwyd. *Loc. cit*

[70] Elias Camerarius. Dissertationes taurinenses physico-medicæ, Francf., 1712.

[71] Carolus Nicolaus Langius. Historia lapidium figuratorum Helvetiæ, p. 165. Venetiis, 1708. 4°.

[72] Theodore Arnold. Eine Untersuchung des Ursprungs und der Formirung derer Fossilien. Leipzig, 1733. 8°. I know this paper only from a mention of it by Schultze in his "Kräuterabdrücke im Steinreiche," S. 10.

had to make way for it, but when philosophically viewed it will be seen that it was really a decided advance upon those. This is clear when we remember that it involves the admission that the petrified forms represent true living forms that once inhabited the earth, which in so far is a scientific truth not embodied in any of the hypotheses thus far considered. He who reads the discussion of those times cannot fail to observe that it bears the stamp of all progressive controversy, in which a more realistic conception is confronting and overthrowing older idealistic ones.

The first intimation that remains of the Flood might be looked for seems to have come from Martin Luther, who in his commentary on the book of Genesis said he had no doubt that surviving indications of the Deluge might be found in the form of wood hardened into stone around the mines and smelting mills.[73] Alexander ab Alexandro in his "Geniales dies" (1522), also held this view, and was followed by Agricola (1546), Matthiolus (1564), Gesner (1565), and Imperatus[74] (1599). But this explanation made little or no headway against the fanciful theories of the time, and it was not until nearly a century later that the flood-theory, revived perhaps by a new edition of the work of Alexander ab Alexandro,[75] began to be reasserted and to take firm root. Dr. John Woodward, of London, who was a great collector of fossils, published a work in 1695[76] in which he held that all the solid parts of the earth's crust were loosened by the Flood and mingled promiscuously in its waters, and that at its close everything sank back to the surface according to its specific gravity, the remains of animals and plants assuming the positions in the respective strata in which they are now found petrified. Lhwyd, also, in the work already cited (1699) and other writings, gave countenance to this theory, which had thus acquired considerable respectability prior to the opening of the eighteenth century. But the greatest champion and expounder of the diluvian hypothesis was still to come in the person of Johann Jacob Scheuchzer, a brief sketch of whose life and work has already been given. His great work[77] appeared in 1709, in which he severely attacks all other theories and brings forward a mass of evidence in favor of his own which has proved of the greatest value to the progress of substantial knowledge and especially to that of paleobotany. It is not by this really useful and for its time important and remarkable work that, we fear, the name of

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[73] "Und ich zweifele nicht, dass noch von der Sündfluth her ist, dass man an Oertern, da Bergwerck ist, oft Holtz findet, das schier zu Steinen gehärtet ist." Martin Luther's Gründliche und Erbauliche Auslegung des Ersten Buchs Mosis, Halle, 1739, Band I, col. 176.

[74] Ferrante Imperato. Dell' historia naturale. Napoli, 1590.

[75] Alexander ab Alexandro. Genialium Dierum, libri vi. Parisiis, 1539, Lib. v, Caput ix, fol. 120.

[76] John Woodward. An essay towards a natural history of the earth and terrestrial bodies. London, 1695. (See pp. 74 et seq.)

[77] Johann Jacob Scheuchzer. Herbarium diluvianum. Tiguri, 1709.

(1665), Merret[95] (1667), Steno[96] (1669), Wedel[97] (1672), Boccone[98] (1674), Lister[99] (1678), Leibnitz[100] (1693), Tenzel[101] (1694), in the seventeenth; Carl[102] (1704), Rosinus[103] (1719), Kundmann[104] (1737), Schultze[105] (1755), Parsons[106] (1757), Blumenbach[107] (1780), in the eighteenth century, and numerous others, recognized in one form or another the real character of the fossils they were dealing with, some comparing them with living animals and plants, and some, especially in the later years, boldly combating the vagaries and supernatural explanations of the dominant schools. Most of these writers investigated the specimens themselves and drew their conclusions fresh from them, and in not a few cases the amount of such material in their hands for investigation was considerable.

During the seventeenth century these more rational utterances were of course without avail, but during the eighteenth they commenced to make themselves felt with increasing force. The diluvian hypothesis, as already remarked, was an advance toward the true conception, and the question now turned upon the manner in which these petrified remains of once living things could have been placed where they were found. Kundmann and Schulze were among the boldest, and Morand[108]

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95 Christopher Merret. Pinax rerum naturalium Britannicarum, continens vegetabilia, ammalia et fossilia in hac insula reperta inchoatus. London, 1666 & 1667.

96 Nicolaus Steno. De solido intra solidum naturaliter contento dissertationis prodromus. Florentiæ, 1669.

97 G. W. Wedel. De conchis saxatilibus. Ephemerid. Naturæ Curiosorum, 1672. III, pp. 101–103, Pl. LXX. Lipsiæ et Francf., 1681.

98 Paul Boccone. Recherches et observations naturelles touchant le corail, etc., Amsterdam, 1674.

99 Martin Lister. Historiæ animalium tres Angliæ tractatus quibus adjectus est quartus de lapidibus ad cochlearum quandam imaginem figuratis. London, 1678. See the "Præfatio" to this fourth treatise, in which, while favoring a *terrigenous* origin, he admits that if real animals they have now ceased to be generated. P. 199.

Idem. Synopsis methodica conchyliorum. 1685.

Idem. A description of stones figured like plants, and by some observing men esteemed to be plants petrified. Phil. Trans. London, 1673, Vol. VIII, No. 100, pp 6181–6191. Pl. I.

100 G. W. Leibnitz. Acta erudita. Lipsiæ, 1693. P. 40.

101 W. E. Tenzel. Epistola ad Magliabechum de sceleto elephantino Tonnæ nuper effossæ. Jena, 1694.

102 Samuel Carl. Lapis Lydius philosophicus pyrotechnicus ad ossium fossilium docimasiam analytice demonstrandum adhibitus, etc. Franc. ad Mœnam, 1704.

103 Michael Reinhold Rosinus. Tentaminis de lithozois ac lithophytis, olim marinis, jam vero subterraneis, prodromus, etc. Hamburg, 1719.

104 J. C. Kundmann. Rariora naturæ et artis, oder Seltenheiten der Natur und Kunst des Kundmannscher Naturalienkabinets. Breslau u. Leipzig, 1737. I. Abschnitt, 14. Artickel.

105 Ch. Fr. Schultze. Kurtze Betrachtung derer Kräuterabdrücke im Steinreiche. Dresden und Leipzig, 1755, S. 10.

106 James Parsons. An account of some fossils, fruits, and other bodies found in the island of Shepey. Phil. Trans., 1757, Vol. 50, pt. 2, p. 396.

107 Johann Friedrich Blumenbach. Handbuch der Naturgeschichte. Göttingen 1779–1780. 6. Aufl. 1799. Theil II, § 222, 225. (See especially pp. 688–708, ed. 1799.)

108 J. F. C. Morand. Die Kunst auf Steinkohlen zu bauen. Leipzig u. Königsberg, 1771, 4°. (Translated from the French.)

(1771), Bauder [109] (1772), and Suckow [110] (1782), wrote treatises in the true scientific spirit. But to Blumenbach is generally ascribed the credit of having fairly broken the spell and prepared the way for a science of paleontology. Not only in his "Handbuch" already mentioned, but also throughout his later "Beiträge" [111] which began in 1790, and his other works, he taught with authority that the beings to whose former existence these fossil forms were due were not only antediluvian but preadamitic, and that moreover there had been a series of faunas and floras inhabiting the earth before the age of man.

The revolution, however, was not instantaneous nor abrupt. It had been preparing for many years and could not have been much longer postponed. To understand the nature of this preparation it will be necessary to consider a few of the questions that came up for discussion and solution during the eighteenth century, and in attempting to do this we must now confine ourselves exclusively to those presented by the different forms of fossil vegetation. Without denying the superior importance of the evidence from animal remains, it may still be possible to vindicate the truth of the rather paradoxical statement of Brongniart that the vegetable kingdom should perhaps claim the honor of having caused the ridiculous ideas which attributed these remains of the ancient world to freaks of nature and plastic forces to be abandoned. [112]

Among these questions the two that seemed to dwarf all others were, first, Are these the remains of the same kind of plants that are now found growing upon the earth? and, second, When did the originals live that have been preserved in this remarkable manner by turning into stone?

When we consider what is now known about the geological strata of the earth's crust we can scarcely realize that but two generations ago comparatively nothing was known on this subject. Geology was not yet born. The investigators of the last century were really not discussing the geologic age of fossil remains. The assumption was universal that these were plants that grew somewhere in the world only a few thousand years ago at most, plants such as either grew then in the countries where their remains were found or in other countries from which they had been brought by one agency or another, generally that of the Flood, or else, as some finally conceived, had been destroyed by these agencies, so as to have no exact living representatives. The writers of that period were therefore more or less divided among these three theories which we may respectively call (1) the indigenous theory,

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[109] F. Fr. Bauder. Nachrict von den seit einigen Jahren zu Altdorf von ihm entdeckten versteinerten Körpern. Jena, 1772.

[110] Georg Adolph Suckow. Beschreibung einiger merkwürdigen Abdrückevon der Art der sogenanten Calamiten. Hist. et comment. Acad. elector. Theodoro-Palatinæ, Tom. V, Physicum Monheimii, 1784, p. 355.

[111] Beiträge zur Naturgeschichte. 1790–1811.

[112] Histoire des végétaux fossiles, Tome I, p. 2.

(2) the exotic theory, and (3) the extermination theory. The most of them, however, admitted two or more of these explanations to account for different facts which could not be brought under a single one.

Scheuchzer, the great apostle of the Flood theory, considered the fossils as ordinary plants still to be found, and he gave them names taken from the standard botanical works, with all of which he was familiar, as well as with the flora of Switzerland, the Alps, and Europe in general. In the "editio novissima" of his "Herbarium diluvianum," 1723, he attempted in an appendix to arrange them all according to the system of Tournefort. Among the genera which he confidently puts down are found Gallium (= Galium), Fragaria, Fumaria, Osmunda, Saxifraga, Sorbus, Trifolium, Vitis, etc., and he occasionally ventures to give the species, as *Populus nigra.* Volkmann, in his "Silesia subterranea" (1720), is not less certain that he sees in one impression the myrrh of the Scriptures, and in another the common Hippuris, or mare's-tail. Lange[113] (1742) and Moering[114] (1748) were satisfied with the faintest resemblances to living plants, while Lehmann[115] (1756) labored hard to prove that the impressions of *Annularia sphenophylloides*, which occur at different depths in the coal mines near Ihlefeld, Hohenstein, were flowers of *Aster montanus* (*A. Amellus* or *A. Sibiricus*) caught in full bloom and petrified *in situ.* Many others[116] preceded Walch, who was himself unable to free himself from the popular conceptions. He compared his Lithophytes with indigenous plants, from which he also derived certain supposed fossil flowers.

The exotic theory, though equally untrue with the indigenous theory, marked a decided advance, since it was the outcome of careful study, and a supposed escape from some of the objections to the other mode of explanation. Very early in the century certain authors had been led by curiosity or some other motive to compare the finest of these impressions with specimens of living plants, then already well represented in European herbariums, from many distant countries. The earliest case of this kind on record is that of Leibnitz, who in 1706 furnished a note[117] on the occurrence of impressions of supposed Indian plants in Germany, a conclusion which he arrived at from a comparison of fossils with living species from India, and believed them to agree. Twelve years

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[113] Nicolaus Langius. De schisto ejus indole atque genesi meditationes cum descriptione duorum vegetabilium rariorum, etc. Acta Acad. nat. cur., Tom. VI. App., p. 133, tab. II.

[114] Paul Gerard Moering. Phytolithus zeæ Linnæi in schisto nigro. Acta Acad. nat. cur., Tom. VIII, p. 448.

[115] J. G. Lehmann. Dissertation sur les fleurs de l'Aster montanus, ou pyrénaique précoce à fleurs bleues et à feuilles de saule, empreintes sur l'ardoise. Hist. de l'acad. des sci. et de belles lettres de Berlin, 1756, pp. 127–144.

[116] C. F. Schultze. Die bei Zwickau gefundenen Kräuterabdrücke. Neue gesellschaftl. Erzählungen, 1758. Theil I, pp. 42–48.

P. F. Davila. Catalogue systématique et raisonné des curiosités de la nature et de l'art. Paris, 1767. See Tome III, pp. 237–254, Pl. VI, VII, VIII.

[117] Histoire des sciences, Paris, 1706, pp. 9–11.

later Antoine de Jussieu[118] published his celebrated memoir upon the coal plants of Saint Chaumont, in which he discussed the differences between them and European ferns and their resemblance to those of the tropics.

The idea of the tropical facies of fossil plants was thenceforward frequently put forth, as by Lesser[119] (1735), Capeller[120] (1740), Sauvages[121] (1743), etc. Parsons[122] (1757) declared that some of the petrified fruits found on the Island of Sheppey were "absolutely exotics," and Dulac[123] (1765) discovered in the coal mines of Saint Etienne, now so carefully explored by Grand' Eury, impressions which he likened to American ferns. Walch leaned toward the exotic theory, and declared that so imperfect were the remains that their true identity could not be made out, and that the tendency had been too much to imagine indigenous species to exist where they were in reality foreign ones. He pointed out the fact that the fossil plants of England, France, and Germany were substantially the same, which is not the case to any such extent with the living floras, and even where no similarity with living plants could be traced he had no better explanation than that they must belong to unknown exotic species.

As intermediate between the exotic theory, or that of transportation by the Flood, and the extermination theory, or that of destruction by the Flood, and as, to some extent, an initial stage of the latter, there was called in a *degeneration* theory, which Volkmann[124] sets forth as clearly as it was probably ever conceived by any of the contemporary writers, which certainly is not saying a great deal. According to this theory the antediluvian vegetation was of a far higher order than that of postdiluvian origin, and contained none of the thorns, thistles, and other scourges with which we are familiar. It also contained many useful and wholesome fruit-bearing trees, of which our modern forests are the degenerate representatives. Ideas like these were frequently expressed, and even Buffon entertained some notion of a state of faunal and floral degeneration.

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[118] Examen des causes des impressions des plantes marquées sur certaines pierres des environs de Saint Chaumont. Mém. de l'acad. royale des sciences. Paris, 1718, p. 287. It is remarkable that both Brongniart (Hist. des vég. foss., Tome I, p. 3) and Schimper (Traité de pal. vég., Tome I, p. 4) should have committed the error of crediting this paper to Bernard instead of Antoine de Jussieu. The former would have been only nineteen years of age; but Brongniart makes the further mistake of assigning the date as 1708 (loc. cit., foot-note 1), which would have made him only nine years old. See also a second memoir, loc. cit., 1721.

[119] Friedrich Christ. Lesser. Lithotheologie, oder noturhistorische und geistliche Betrachtung der Steine. Hamburg, 1735, p. 642.

[120] Maurus Antonius Capeller. Sciagraphia lithològica. Gedani, 1740, p. 6.

[121] L'Abbé de Sauvages. Sur différentes pétrifications, etc. Mém. de l'acad. roy. des sciences. 1743, p. 415.

[122] James Parsons. Philosophical Transactions. 1757, Vol. L, p. 397.

[123] Alleon Dulac. Mémoire pour servir à l'histoire naturelle des provinces de Lyonnois, Forez, et Beaujolois. Lyon, 1765. Tome II.

[124] Silesia subterranea, p. 92.

The conception of a gradual degeneration would be logically followed with that of complete extinction, but, so far as we know, the latter view found expression earlier than the former. Leibnitz, in the memoir already cited (1706), speaks of the proofs of great physical changes taking place on the surface of the earth. Both Scheuchzer and Mylius admitted that many kinds of living creatures may have been utterly exterminated by the Flood. Jussieu proposed extinction as an alternative explanation. Rosinus[125] (1719) stated that among fossil Encriuites and Belemnites there were some whose originals were unknown. Volkmann and the other theological expounders believed in diluvian extermination, and thus explained the facts known to them that fossil trunks are often found on barren islands where no trees ever grew.[126] Walch admitted very little in this fertile direction, although he regarded the Calamitæ as the remains of great reeds which had no known living representatives. Suckow, however, in the memoir already referred to, where he was the first to recognize the affinity of the Calamitæ with Equisetum, decided, after careful comparison with *E. giganteum* and other large living species, that they probably belonged to extinct species.

The idea that the fossil remains might represent extinct species of forms once indigenous to Europe now began to take shape and to work a profound revolution in prevailing theories. The question then, referred to a few pages back, as to the time when the originals must have been living, became oue of paramount importance and led to the investigation of the stratified rocks. This was the origin of true paleontological research. But it could scarcely have been begun earlier. Stratigraphical geology was also at the same moment in the act of being born. Werner had founded his Neptunian theory, and Hutton his Plutonian, while William Smith was teaching how to determine the age of rocks by the fossils they contain.

The puerile speculations about the nature of fossils which we have been considering can be better excused when we remember that nothing whatever was known of the earth. So long as it was supposed to be only a few thousand years old, and as the only disturbance of which men had ever heard was that of the Mosaic deluge, we may well doubt whether the most astute of our present geologists would have conceived any better explanations. In this respect the Ancients had the advantage. Even Pythagoras is said to have taught that the land was once under the sea. Xenophanes and Herodotus both expressed this same idea, and Aristotle himself is known to have entertained something like an adequate conception of time limits.[127] Tertullian (*supra*, p. 386, note 49) uttered the last faint echo of this thought, which thenceforward seems to have slumbered until the middle of

[125] *Supra*, p. 394, note 103.

[126] Volkmann. Silesia subterranea, p. 93.

[127] Meteorologicorum, Lib. I, Cap. XIV, 31; Lib. II.

the fifteenth century, when Leonardo da Vinci revived it, attacked the current scholastic doctrines, and maintained that the fossils which had been the subject of so much interest in Italy had been living creatures and had once lived in the sea. A century later Sarayna, as we have seen, asserted the organic origin of the Veronese petrifactions, and Fracastorius explained the fossils of the Kircherian, Moscardan, and Calceolarian Museums by assuming that the mountains containing them had stood in the water during the time the animals lived, and that these had left their remains on the retreat of the waters. These and all similar voices were, however, drowned amid the angry and senseless discussions of the time. Nicholas Steno, towards the end of the seventeenth century, in a work to which attention has already been called (*supra*, p. 394, note 96), recognized the different ages of stratified rocks, and asserted that the oldest rocks contained no fossils. In the posthumous "Protogæa"[128] of Leibnitz, which must have been written very early in the eighteenth century, a cosmogony is elaborated which recognizes something like the true process of sedimentation, but is vitiated entirely by an attempt to harmonize it with the literal six days cosmogony of Moses. Lehmann (1756), whose errors, so far as his conclusions were concerned, we have already mentioned, nevertheless performed a truly pioneer work both for geology and for paleobotany in correctly indicating the relative depth, position, and relations of the different strata with their characteristic vegetable remains in the coal region at Ihlefeld. These and a few other like treatises prepared the way for Blumenbach and the sound views which began to prevail at the close of the eighteenth century. The inadequacy of the Flood theory to explain the facts and the conviction that there must have been a series of antecedent revolutions in the floras and faunas of the globe began to inspire research, and promised the fruitful results which, in fact, so soon and so richly followed.

2. THE SCIENTIFIC PERIOD.

Having thus rapidly passed in review the long crepuscular period of speculation, conjecture, and groping research which was necessary to precede and prepare for the true advent of science—a period throughout most of which no real science of paleontology could be said to exist, or, if having a quasi-existence, its zoologic and phytologic branches were as yet for the most part undifferentiated—the scientific period, which, so far at least as plants are concerned, literally began with the beginning of the present century, next claims attention. In the biological sketches which preceded this historical one the chronologic arrangement was adopted, and in this, therefore, was necessarily embraced much of the true history of the science, but, as there stated, this form of treatment

[128] G. W. Leibnitz. Protogæa, sive de prima facie telluris et antiquissimæ historiæ vestigiis in ipsis naturæ monumentis dissertatio; ex schedis manuscriptis viri illustris in lucem edita a C. Scheidio. Gottingæ, 1749. § XLV treats of fossil trees and wood; § XLVI of peat, and § XLVII of the Luneburg fossil trees.

necessarily leaves out many of the important facts in the history of the subject. It also fails to connect the principal points into an unbroken series and to correlate events and discoveries into a systematic whole. The chiefly chronologic treatment which will now be presented, while still lacking in philosophic method and otherwise defective, will aim to supply most of the omissions referred to, and will perhaps be more useful than any other form of treatment which could well be made within the limited space which can be devoted to it.

The new epoch was auspiciously ushered in on the first year of the century by the memoir, already once referred to (*supra* p. 371), of the Baron von Schlotheim in Hoff's Magazine, in which he applied the same reasoning to plants that Blumenbach had done to animals.

Leopold von Buch[129] (1802) inaugurated the remarkable discussion as to whether the coal plants actually grew on the spot where they are found in the carbonized or silicified state, which was continued by Steffens,[130] Leonhard,[131] Noeggerath,[132] Sternberg, Brongniart, and Lindley and Hutton,[133] but is by no means settled, and still goes on in France, England, and the United States. Two papers, by M. Faujas de Saint Fond,[134] breathing the true scientific spirit of research appeared at about the same time and attracted much interest.

In 1804 appeared Von Schlotheim's epoch-making work, "Flora der Vorwelt," as it is now universally quoted, although the author himself merely entitled it a description of remarkable plant impressions and petrifactions, a contribution to the flora of the former (or primeval) world. To us this seems modest enough, but in view of the history of paleontology which we have been considering, we may readily see that this second part of the title was a bold declaration, and accordingly we find him defending it in his introduction by these words: "The petrifactions which so early engaged the attention of investigators, and which, without doubt, afforded one of the first incentives to the founding of mineral collections and to the earnest study of mineralogy and geology, have, as is well known, since Walch began to arrange them systematically, been for a long time, as well in as outside of Germany, almost wholly

[129] Leopold von Buch. Geognostische Beobachtungen auf Reisen durch Deutschland und Italien. Band I, Berlin, 1802. S. 92.

[130] Heinrich Steffens. Geognostisch-geologische Aufsätze. Hamburg, 1810. S. 267.

[131] K. C. Von Leonhard. Bedentung und Stand der Mineralogie. Frankfort, 1816. S. 70, 71.

[132] Jacob Noeggerath. Ueber aufrect im Gebirgsgestein eingeschlossene fossile Baumstämme und andere Vegetabilien. Historisches und Beobachtung. Bonn, 1819-'21.

[133] Fossil Flora of Great Britain, Vol. II, pp. xvii, xx, xxii.

[134] Barthélemy Faujas de Saint Fond. Description des mines de Turffa des environs de Bruhl et de Liblar, connues sous la dénomination impropre de mines de terre d'ombre, ou terre brune de Cologne. Annales du Muséum d'histoire naturelle, Tome I, pp. 445-460, avec 2 planches. Paris, 1802. (See Pl. XXIX.)

Idem. Notice sur des 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. (*Loc. cit.* Tome II, 1803, pp. 339-344, Pl. LVI et LVII.)

neglected. They were content to regard them as incontestable proofs of the Deluge, and closed all further investigation until they were at last compelled to explain their occurrence through other great natural operations which had probably been going on earlier and more universally than the flood described in the Bible, and influencing the formation of the upper strata of the earth's crust; and more recent observations and investigations have even led us to the very probable supposition that *they may be the remains of an earlier so-called pre-adamitic creation, the originals of which are now no longer to be found.* * * * In the continued investigation of this subject this opinion, with certain restrictions, has in fact gained a high degree of probability with the author of the present work, so that he ventures to announce his treatise as a contribution to the flora of the ancient world (*Vorwelt*)."

Since its introduction by Schlotheim this expression, "Flora der Vorwelt," has been applied to nearly all the German works on fossil plants, and "Beiträge zur Flora der Vorwelt" still continue to appear. Only one volume of this work appeared at this time, with fourteen plates; the completion, owing to political disturbances which so often interrupt the quiet march of science, was deferred until the year 1820, when the remaining plates were published with the first and with those relating to animal remains as an atlas to his "Petrefaktenkunde."[135]

Schlotheim worked conscientiously, drew his figures clearly and well, and sought diligently in all the European herbaria for forms with which his fossil plants could be compared. He seriously doubted the identity of the plant that had always been regarded as the common *Hippuris vulgaris*, and concludes that if any of the species he has figured are still living they must belong to tropical countries.

An important English work,[136] one volume of which is devoted to vegetable remains, and bears date 1804, or the same as Schlotheim's "Flora der Vorwelt," has for its title "Organic remains of a former world," the last two words of which are a fair translation of the German *Vorwelt*. Dr. Parkinson was a very learned man, and shows that he was familiar with the continental literature of his subject, but he nowhere refers to Schlotheim's work, and may safely be assumed to have been unacquainted with it.[137] The work is written in an erudite manner, and is full of historical interest, but as a contribution to science it is far inferior to that of Schlotheim. The figures, though better than most of those of the time, are less clear than the German author's, even where true leaf-prints and fronds are figured. But they mostly depict specimens of petrified wood and problematical fruits. Parkinson did

[135] See the "Petrefaktenkunde," p. 424.

[136] James Parkinson. Organic remains of a Former World. An examination of the mineralized remains of the vegetables and animals of the antediluvian world; generally termed extraneous fossils, Vol. I, containing the Vegetable Kingdom. London, 1804.

[137] A remark made by M. Schimper (Traité de pal. vég., Tome I, p. 8) might lead to the supposition that this work had been written many years later.

not regard it possible to identify the plants. For this work he called to his aid Dr. James Edward Smith, president of the Linnæan Society, an accomplished botanist, and together they faithfully compared all the specimens they had. The result was that while a greater or less similarity was detected between different ferns and the living genera Pteris, Dicksonia, Osmunda, Polypodium, and Adiantum, Dr. Smith was unwilling to say that they actually represented these genera, and he "conjectured that they were all foreign, and productions of a warm climate."

In the conclusions which he draws from the facts stated in the first volume of his work, Dr. Parkinson clearly shows that he is still heavily shackled by the current fallacies relating to the subject he has treated. The Deluge is still a potent influence and the "Former World" is not the modern geologist's *Paleozoic*, nor even the "Vorwelt" of Schlotheim.

Great activity in this branch of science followed the appearance of these works. As already shown (*supra*, p. 371), it was in 1804 that Count Sternberg began to write, though partly instigated by the papers of Faujas de Saint Fond,[138] who still continued his investigations.[139] Voigt[140] (1807) discussed the so-called Psarolithes of the Museum Lenzianum at Jena, and pronounced them fossil polyps, but retracted this decision the next year,[141] and admitted their vegetable character. Weppen[142] (1808) also mentions a number of specimens of petrified wood from the East Indies, Siberia, and various parts of Europe. This question was further treated by Steffens,[143] Oken in his "Lehrbuch der Naturgeschichte,"[144] Hoff,[145] and Schlotheim. Martin's "Petrificata Derbiensia"[146] is regarded as a forerunner of future work in Great Britain on the structure of trunks and on the study of the vegetable remains of the coal-measures. Schlotheim's "Beiträge zur Naturgeschichte der Versteinerungen in geognostischer Hinsicht"[147] (1813) was an appeal for greater thoroughness in paleontological research. In 1814 Kieser[148] first pointed out the characteristic structure of coniferous wood which

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[138] Bemerkungen über die von Faujas de St. Fond beschriebenen fossilen Pflanzen. Botanische Zeitung. No. 4. 29. February, 1804, pp. 48–52.

[139] Faujas de Saint Fond. Memoirs in the "Annales du muséum d'histoire naturelle", Tome VIII, 1806, p. 220; Tome XI, 1808, p. 144; and in the "Mémoires," Tome II, 1815, p.444; Tome V, 1819, p. 162.

[140] Johann Karl Wilhelm Voigt. Kurze minerogische Bemerkungen. Leonhard's Taschenbuch für Mineralogie. Erster Jahrgang, pp. 120–124.

[141] *Idem. Loc cit.* Zweiter Jahrgang, pp. 385–386.

[142] J. A. Weppen. Nachricht von einigen besonders merkwürdigen Versteinerungen und Fossilien seines Kabinets. Leonhard's Taschenbuch, Band II, p. 178.

[143] Heinrich Steffens. Handbuch der Oryktognosie, Halle. 1811, Band I, p. 172–186.

[144] Th. I, p. 300, 1812.

[145] K. E. A. von Hoff. Beschreibung des Trummergebirgs und des ältern Flötzgebirgs, welche den Thüringen Wald umgeben. Leonh. Taschenb., Band VIII, 1814, p. 350.

[146] William Martin. Petrificata Derbiensia; or, Figures and descriptions of Petrifactions collected in Derbyshire. 4to, Wigan, 1809.

[147] Leonhard's Taschenbuch, Band VII, 1813, p. 1.

[148] Dietrich Georg Kieser. Elemente der Phytonomie, oder Grundzüge der Anatomie der Pflanzen. Jena, 1815. Appendix.

has had such an important bearing on the study of petrified woods. In 1796 Hagen[149] had published a memoir on the origin of amber, which was supplemented by Dr. John, of Cologne, in his large work[150] on that substance, discussing it from almost every conceivable point of view. Relative to the kind of tree that is supposed to have produced the amber he says (p. 168) it is very probable that a species of the genus *Pinus* formerly grew in Prussia which, as is the case with many other plants, is now wholly extinct.

Passing over some less important memoirs we come to that of the Rev. Henry Steinhauer "On Fossil Reliquia of Unknown Vegetables in the Coal Strata."[151] Few papers of this period are more often or approvingly quoted than this. Although presented to an American society by one of its members, then a resident of Bethlehem, Pa., it treats the subject in a thoroughly general way. The author had evidently spent the greater part of his life in Great Britain, and was well acquainted with British localities and British fossils. In fact, no mention whatever is made of any American locality, and the paper would have been perfectly at home in any of the scientific journals of England. The remark, therefore, of M. Schimper[152] to the effect that Steinhauer had laid the foundations of vegetable paleontology in America by a study of the vegetable impressions of the coal-measures of this country, seems not to be historically accurate. Probably the most important feature of this able paper is the attempt made in it to classify the vegetable remains of the Carboniferous. No special mention has thus far been made of similar previous attempts by Scheuchzer, Walch, Sclotheim, etc., because the more complete treatment of this important subject is reserved for a future place as an independent and connected study, and we will not anticipate this branch of our subject here.

Omitting a number of works in which vegetable fossils are either expressly treated, or least casually referred to, as by Ballenstedt and Krüger,[153] Raumer,[154] Schweigger,[155] d'Aubuisson de Voisins,[156] and Nilsson,[157]

[149] K. G. Hagen. De succini ortu. Ueber den Ursprung des Bernsteins. Riga, 1796; see, also, Gilbert's Annalen, Band XIX, 1805, p. 181.

[150] J. F. John. Naturgeschichte des Succins, oder des sogenannten Bernsteins. Köln, 1816.

[151] Transactions of the American Philosophical Society. Philadelphia, Vol. I, 1818, p. 265.

[152] Traité de Pal. Veg. Tome I, p. 16.

[153] J. G. F. Ballenstedt. Die Urwelt. 3. Aufl. Quedlinburg, 1819.

Johan Gottlob Krüger. Geschichte der Urwelt. Leipzig, 1820, Bd. II, pp. 95–254.

Ballenstedt & Krüger. Archiv für die Entdeckung in der Urwelt. 6 Bde. Quedlingburg, 1819–1824.

[154] Carl von Raumer. Das Gebirge Niederschlesiens . . . geognostisch dargestellt. Berlin, 1819, p. 166 (Anmerkungen).

[155] A. F. Schweigger. Beobachtungen auf naturhistorischen Reisen. Berlin, 1819.

[156] D'Aubuisson de Voisins. Traité de Géognosie. 1819, Tome II, pp. 294, 298.

[157] Sveno Nilsson. Om Försteningar och Aftryck af tropiska trädslag, Blad, ormbunkar och rörväxter m. m. samt trädkol, funna i ett Sandstenslager i Skåne. Kongl. Vetenskaps Akademiens Handlingar, 1820, pp. 108–122, 278–293.

which appeared in 1819 or 1820, the last named of which contains the earliest descriptions of the plant remains of the interesting locality of Hör, in South Sweden, afterward more carefully studied by Brongniart,[158] we find in the year 1820 three treatises of prime importance: Rhode's "Pflanzenkunde der Vorwelt,"[159] Schlotheim's "Petrefactenkunde," (*supra*, p. 371), and Sternberg's "Flora der Vorwelt" (*supra*, p. 371). Rhode studied the coal plants of Silesia, and was the predecessor of Göppert in that line of work. He discovered the now well-known fact that thick stems often silicify within while carbonizing without, which he discussed as well as the questions treated by Schlotheim and his predecessors relative to the real nature of plant impressions. He figured Lepidodendron, Sigillaria, and other coal plants, and his plates are still frequently quoted. Like Lehmann, he mistook certain verticillate forms for flowers, but represented them none the less faithfully. His work was never finished, being interrupted by the premature death of the author. Sternberg treated the subject of vegetable remains both from the geognostic and the botanical points of view, and his work was undoubtedly the most advanced contribution that had been made up to this date. We have already referred to it in a general way, and as its chief interest centers upon the system of classification which he proposed we must defer the more detailed account of it until this subject is reached. Less than an eighth of Schlotheim's "Petrefactenkunde" is devoted to plants, but it is systematically arranged, and the families, genera, and species are named according to the binomial method of Linnæus, giving the work a decidedly modern appearance. About the only other work referred to in it is his own "Flora der Vorwelt," the plates of which are reproduced, and others added. He had evidently not met with the paper of Steinhauer, and appeared not to be aware of the labors of Sternberg.

These works gave a new impetus to the science of fossil plants, and in the following year a number of papers appeared describing discoveries in special localities in Germany,[160] France,[161] England,[162] and America.[163] In this year also appeared Adolphe Brongniart's first and very important paper on the classification and naming of fossil plants,

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[158] Annales des Science Naturelles. Tome IV, p. 200. Pl. XI, XII. Paris, 1825.

[159] J. G. Rhode. Beiträge zur Pflanzenkunde der Vorwelt. Breslau, 1820.

[160] B. S. von Nau. Pflanzenabdrücke und Versteinerungen aus dem Kohlenwerke von St. Ingbert im baierischen Rheinkreis verglichen mit lebenden Pflanzen aus wärmeren Zonen. Denkschr. der köngl. Akad. d. Wiss. zu München, Band VII, 1821, S. 283.

[161] Alexandre Brongniart. Notice sur des végétaux fossiles traversant les couches du terrain houiller. Annales des Mines, Tome VI, 1821, pp. 359–370.

[162] Thomas Allan. Description of a vegetable impression found in the quarry of Craigleith. Trans. Roy. Soc., Edinb., Vol. IX, 1823, p. 235.

Patrick Brewster. Description of a fossil tree found at Niteshill, etc. *Loc. cit.*, p. 103, Pl. IX.

[163] Ebenezer Granger. Notice of vegetable impressions on the rocks connected with the coal formation of Zanesville, Ohio. Am. Journ. Sci., 1st ser., Vol. III, 1821, p. 5.

which has been quoted already (*supra*, p. 372), and will receive special attention further on.

Four important works appeared in 1822, viz., (1) a memoir by Adolphe Brongniart, contained in the "Description géologique des environs de Paris," by Cuvier and Alex. Brongniart (also in Cuvier's "Recherches sur les ossements fossiles," Tome V, pp. 640–674, éd. 1835), describing the fossil plants of the Paris basin; (2) Mantell's Fossils of the South Downs, or Illustrations of the Geology of Sussex, in which the plant remains, though meager, are mostly dicotyledonous, or fruits of Conifers, etc. (see Plates VIII and IX and pp. 157 and 262); (3) Martius, "De plantis nonnullis antediluvanis ope specierum inter tropicos viventium illustrandis;"[164] and (4) Schlotheim's "Nachtrag zur Petrefactenkunde," which, though chiefly devoted to animal fossils, contains an interesting chapter on fossil seaweeds.

Brongniart took up the subject of fossil seaweeds, or fucoids, the following year,[165] but with the exception of two or three unimportant papers nothing else appeared in 1823, though research was none the less active.

Much the same could be said for the year 1824, although the contributions of Buckland,[166] Sir Henry Thomas de la Beche,[167] and Dr. Mantell[168] in England, Defrance[169] in France, and Nilsson[170] in Sweden added to the stock of knowledge in this department. Sternberg published an important memoir in *Flora*,[171] and Martius began his great work on the palms,[172] which has at least proved an aid to paleobotany, and to which Unger eventually supplied the fossil department.

The year 1825 was characterized in England by an important illustrated work by Edmund Tyrell Artis, entitled "Antediluvian Phytology," which, notwithstanding Brongniart's criticism,[173] and the fact that most of his species have been obliged to give way, must ever remain one of the classics of paleobotany, though rather as a work of art than of science. The author discusses in a very rational manner the progress of ideas relative to geology, but shows the proximity of his time to the age of pure discussion by admitting that he had undertaken to prepare himself to write the work because "convinced of the importance of this

[164] Denkschriften der königlich-baierischen batanischen Gesellschaft in Regensberg, Band II, 1822, p. 121, Pl. II–X.

[165] Mém. de la Soc. d'Hist. Nat., Paris, Tome I, pp. 301–321, Pl. xix–xxi.

[166] Trans. Geol. Soc. London, ser. ii, Vol. I, Part I, p. 210.

[167] *Loc. cit.*, Pt. II, pp. 45, 162, Pl. VII, Figs. 2, 3.

[168] *Loc. cit.*, Part II, p. 421.

[169] Jacques Louis Marin Defrance. Tableau des corps organisés fossiles, précédé des remarques sur les pétrifications. Paris, 1824. (See pp. 123, 124, 126.)

[170] Kongl. Vetenskaps-Academiens Handlingar, 1824, pp. 143–148, Pl. II. Stockholm, 1824.

[171] Bd. VII, p. 689.

[172] C. F. Martius. Genera et species palmarum quas in itinere per Brasiliam annis 1817–1820. . . collegit. Monachii, 1824–1849.

[173] Hist. des vég. foss., Tome I, p. 6.

study in affording the materials on which the geologist may found his theoretical speculations." The plates are certainly beautiful and also faithful, and they have been largely drawn upon by later authors. A second edition of the work appeared in 1838.

Three important papers by Brongniart appeared during the same year in the "Annales des sciences naturelles" (Tome IV, pp. 23, 200, 417), one of which has just been referred to. Sir Alexander Crichton's memoir on the climate of the antediluvian world[174] attracted considerable attention and was copied into several of the scientific journals on the continent.

During 1826 few results were made known, and the only monograph of special note that appeared in 1827 was Jaeger's "Pflanzenversteinerungen,"[175] which was a praiseworthy effort, and although the illustrations fall below the standard erected by Schlotheim and Artis, the geognostic treatment has been considered able, and the work is still quoted.

The year 1828 is without question the most eventful one in the history of paleobotany, since it saw the issue of Brongniart's "Prodrome," and the commencement of his "Histoire des Végétaux fossiles" (*supra*, p. 372), which, taken together as they belong, form the solid basis upon which the science has since been erected. We will first consider the "Prodrome," which merely forms an introduction to the other work, not as it is, but as it was, designed by its author to be. The "Histoire" stopped before the cryptogamic series had been finished, but in the "Prodrome" he takes us through the phenogamic series also as he understood it. Brongniart's fundamental conception was that fossil plants were not the less plants, and that so fast as they really became known they should be placed in their proper position in the vegetable series and made to form an integral part of the science of botany. In his classification, which will be given in another place, he therefore had due respect for the natural system as then understood, but he nevertheless felt that geognostic considerations must be taken into the account, and he saw, with almost prophetic accuracy, that in passing up through the geologic series higher and higher forms of vegetable life presented themselves. This seems simple enough to us of this age, and might seem trite to the reader did we not find, several years later, some of the ablest authorities both in botany and geology warmly contesting it, as we shall presently see. Although unable to understand the complete continuity in the series, as modern evolution requires, and although affected by the Cuvierian idea of successive destructions and re-creations, still he insisted that each successive creation was superior to the one it had replaced, and that there had thus been, as it were, a steady progress from the

[174] Alexander Crichton. On the Climate of the Antediluvian World, etc. Annals of Philosophy, Vol. IX, pp. 97, 207. (See especially pp. 99-102.)

[175] Georg Friedrich Jaeger. Ueber die Pflanzenversteinerungen welche in dem Bausandstein von Stuttgart vorkommen. Stuttgart, 1827. (There is an abstract in French in the Ann. Sci. Nat., Paris, Tome XV, 1828, p. 92.)

lowest to the highest forms of vegetation. He believed in the gradual reduction of temperature in the climate of the globe from the earliest times, and in the purification of the atmosphere from a former excess of carbonic acid, favorable only to the lower types which then prevailed. He divided the geologic series into four great periods, the first extending through the Carboniferous, the second embracing the grès bigarré, or Buntersandstein, only, the third seeming to include the rest of the Trias, the Jurassic, and the Cretaceous, and the fourth completing the series. The table which he gives on page 219 is calculated to show the development of the higher types of vegetation in successively higher strata, and may profitably be compared with the one having the same form, which will be found below (*infra*, pp. 440–441). Of this table he remarks that in the first period there exist hardly anything but Cryptogams, plants having a more simple structure than that of the following classes. In the second period the number of the two following classes becomes proportionately greater. During the third period it is the Gymnosperms which specially predominate. This class of plants may be considered *intermediate between the Cryptogams and the true Phenogams* (Dicotyledons), which preponderate during the fourth period. The words italicized in the liberal translation here made are scarcely less than a prophecy, and one whose fulfillment is only now being tardily granted by systematic botanists. In this tabular exhibit Brongniart enumerates 501 species of fossil plants known to him, 240 of which belonged to the first period (Paleozoic), 25 to the second, 72 to the third, and 164 to the fourth. He also states the number of living species at 50,350. A comparison of these figures with those of our own time, as given in the table below, will afford a sort of measure by which to judge of the nineteenth century as an era of scientific discovery.

Brongniart propounded a theory for the primordial distribution of land vegetation over the globe which is well worth a passing notice, and is not weakened by modern theories of post-glacial distribution, which might also be true. His theory, in brief, was that it began on small islands, the only land then existing; that these islands became gradually united and consolidated into continents upon which a different vegetation, more varied, and more like the present vegetation could exist, and he says that it was not until after the formation of the chalk (*i. e.*, the beginning of the Tertiary) that such a continental vegetation seemed to have appeared. He concludes from this that it was from this period that large areas of the earth's surface began to be laid bare, and that true continents commenced to be formed. He regarded it as remarkable that great changes in both the flora and the fauna of the globe should have taken place almost simultaneously; that the age of Cycads should correspond with that of reptiles and the age of Dicotyledons with that of mammals (p. 221). But unless fresh discoveries of this last-named class of animals shall be hereafter made in the middle Cretaceous we must regard this second coincidence as now disproved.

The great work of Brongniart, his "Histoire des Végétaux fossiles," proceeds with only a brief historical introduction to the systematic elaboration of the fossil plants in the order laid down in the "Prodrome." One entire volume was finished and a second begun without completing the Cryptogams. Seventy-two quarto pages are all that appear in the published editions of the second volume, which are devoted to a thorough discussion of the Lycopodiaceæ. The first volume is illustrated by 166 plates, and 29 accompany the second volume.

Besides these works by Brongniart, which bear date 1828, no less than five other memoirs from his pen relating to fossil plants appeared in that year.[176] A number of other contributions to vegetable paleontology swell the extraordinarily rich literature of the subject in 1828, only one of which can be noticed in this hasty sketch. This is Anton Sprengel's "Commentatio de Psarolithis, ligni fossilis genere," the best treatise on fossil woods that had thus far appeared. He reviews the history of the subject from a rational stand-point, gives a systematic classification, and describes six species of *Endogenites*, illustrating internal structure in one plate. The work is a small octavo pamphlet of 42 pages, published at Halle, in Latin; but for one so unpretentious it has commanded a high tribute of respect.

In 1829 Phillips published Part I of his "Geology of Yorkshire," so well known to both geologists and paleontologists. Like most English writers, he was behind the writers of France and Germany in appreciating the revolution in modes of explanation which the logic of facts had wrought, and we find him saying (p. 16) that "of many important facts which come under the consideration of geologists the 'Deluge' is, perhaps, the most remarkable; and it is established by such clear and positive arguments that if any one point of natural history may be considered as proved, the Deluge must be admitted to have happened, because it has left full evidence in plain and characteristic effects *upon the surface of the earth*." But he proceeds to qualify this statement by the admission that organic remains "were certainly deposited in the rocks *before* the Deluge."

He enumerates (pp. 147, 148, 189, 190) and figures (Pl. VII, VIII) a number of Jurassic fossil plants from what he calls the Upper Sandstone, Shale, and Coal, which have formed an interesting chapter in the history of the Mesozoic flora of the globe. Brongniart's method of arranging these vegetable remains is adopted.

Passing over the year 1830, which was characterized by considerable activity, as evinced by numerous minor papers of Brongniart, Witham, and others, we will pause to consider the most important work of this time, which began to appear in quarterly numbers in 1831, viz., "The Fossil Flora of Great Britain," under the happy joint editorship of Dr. John Lindley, the eminent botanist, and William Hutton, the equally

[176] Annales des sciences naturelles, Vol. XIII, p. 335, XIV, p. 127, XV, pp. 43, 225, 435.

renowned geologist. This work continued to appear until 1837, when it was suspended. The whole is now bound in three shapely octavo volumes, and forms an indispensable part of the library of every paleobotanist. From such an authorship was certainly to be expected a work of the highest authority and merit, and, indeed, such it really is. The illustrations are as fine as could be attained for the octavo size, and the text is both ample and accurate; but the greater part of the introductory remarks in Volume I, as well as much of the general discussion throughout the work, is characterized by a most astonishing and apparently willful ignorance of the true principles of paleophytology as they were set forth by Brongniart, Sternberg, and even Schlotheim. One of the most remarkable aberrations of the book is the pertinacity with which the authors contend for the existence of cactaceous and euphorbiaceous plants in the coal-measures. It is true that Parkinson[177] had seen a fancied resemblance between certain stems and those of large cacti, and several similar guesses had been made by early authors,[178] who supposed they must find the counterpart of every fossil in the living flora, but all these imaginings had been long since laid aside only to be revived by the leading botanist of Europe.

The theory of a former tropical climate in England and temperate Europe is assailed, the existence of tree ferns in the Carboniferous is denied, and the relation of Calamites to the Equisetaceæ doubted, while to the now somewhat waning doctrine of atmospheric changes "much more probability is attached." The true secret of this sweeping skepticism is, however, not far to seek. It is found in the more general denial which is finally made of the conclusion to which an admission of these rejected theories would naturally lead, and had actually led M. Brongniart and others. The authors say: "Of a still more questionable character is the theory of *progressive development*, as applied to the state of vegetation in successive ages * * * in the vegetable kingdom, it cannot be conceded that any satisfactory evidence has yet been produced upon the subject; on the contrary, the few data that exist, appear to prove exactly the contrary." All the denials and assertions contrary to Brongniart's teachings are made to support this view. The existence of Cactaceæ, Euphorbiaceæ, and other Dicotyledons in the Carboniferous would negative development; the existence of a former tropical climate was a strong argument for the nebular hypothesis as well as for geologic progress; tree-ferns would argue such a former tropical climate; if Calamites could be shown to be a Juncus (Vol. I, p. xxx), a higher type would be found in Paleozoic strata and another point gained. Still another good point was thought to be gained by proving what is now admitted, that Coniferous plants occur in the coal. All botanists proper then held, as many still hold, that the Gymnosperms were a

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[177] Organic Remains, Vol. I, pp. 430, 439, Pl. V, Fig. 8, Pl. IX, Fig. 10.

[178] Volkmann. Silesia subterranea, p. 106; Walch, Naturgeschichte der Versteinerungen, Tab. Xa, Xb, Xc.

subclass of the Dicotyledons, co-ordinate with the dicotyledonous Angiosperms. But, curiously enough, Brongniart had forestalled this argument by making the Gymnosperms of lower type, intermediate between the Cryptogams and the angiospermous Phanerogams. By a special insight, characteristic of true scientific genius, he had used their lower geological position as a partial proof of their lower organization, *i. e.*, had postulated evolution as an aid to organic research—a method which is now becoming quite common, although unsafe except in the hands of a master.

Much stress is laid upon the fact "that no trace of any glumaceous plant has been met with, even in the latest Tertiary rocks," the authors thus freely employing the fallacy which they elsewhere warn others to avoid, that because a class of plants has not been found, therefore it did not exist in a given formation. But to cut off the possibility of a reply to the position they take they finally declare that, "supposing that Sigillarias and Stigmarias could really be shown to be cryptogamic plants, and that it could be absolutely demonstrated that neither Coniferæ nor any other dicotyledonous plants existed in the first geological age of land plants, still the theory of progressive development would be untenable, because it would be necessary to show that Monocotyledons are inferior in dignity, or, to use a more intelligible expression, are less perfectly formed than Dicotyledons. So far is this from being the case that if exact equality of the two classes were not admitted, it would be a question whether Monocotyledons are not the more highly organized of the two; whether palms are not of greater dignity than oaks, and Cerealia than nettles." Teleologic and anthropocentric reasoning like this pervades all the discussions in the work and largely vitiates the scientific deductions. The elaborate experiment of Dr. Lindley, described in the first dozen pages of the third volume, was obviously animated by the same spirit of uncompromising hostility to the development hypothesis that inspired the vagaries that characterize the introduction to the first volume. By showing that the higher types of plants when long immersed in water are earlier decomposed than ferns, conifers, and palms, he thought he had demonstrated that the reason why we find no Dicotyledons in the Carboniferous is simply because they had not resisted, and from their nature could not resist, the destructive agencies to be overcome in the process of petrifaction. One could wish that he might look down upon the four thousand species of fossil Dicotyledons now known, and realize how vain had been his experiment as well as all his former theorizing.

One work of special interest and value appeared in 1832, "Die Dendrolithen in Beziehung auf ihren inneren Bau," by C. Bernhard Cotta. This was a renewed attempt to classify systematically and describe scientifically the various kinds of fossil wood that had been discovered. Following in the footsteps of Sprengel, but provided with far more and better material, Cotta made a special study of the internal structure of all the trunks and stems in his collection, establishing new genera and species based thereon, some of which are still accepted, as, *e. g.*, *Psaronius*. He reduces the forms in which all vegetable remains occur to three general classes, viz., (1) mere impressions without any remnant of the original cause; (2) petrifactions proper, in which the original substance is replaced with precision by the particles which were in the solution in which the plant was immersed; and (3) true vegetable remains whose substance is still present though somewhat metamorphosed, as, *e. g.*, lignite. This classification may be profitably compared with that of Schultze, in the work which has already been noticed.[179] His *Dendrolithen* embrace more than did Sprengel's *Psarolithi*, and aimed to include all the objects of this general class with which he was acquainted.

Witham's "Internal Structure of Fossil Vegetables" (*supra*, p. 373), appeared in 1833, and is the most exhaustive treatise thus far produced on the histology of paleobotany. He was evidently unacquainted with Cotta's "Dendrolithen," and, so far as the work itself would indicate, with Sprengel's "De Psarolithis." He confined his investigations entirely to British fossils, to which he is able in most cases to apply the systematic names given by Brongniart and Lindley and Hutton. The classification adopted is that of Brongniart. He makes his study comparative, and devotes two plates to the illustration of the structure of various kinds of wood of living trees.

One other important work appeared in 1833, viz., Zenker's "Beiträge zur Naturgeschichte der Urwelt,"[180] which, while describing animal remains from several localities and horizons, devotes 23 of its 67 pages, and three of the six plates to the description and illustration of the remarkable Cretaceous plant beds of Blankenburg in the Harz district. This memoir is remarkable for being the first attempt systematically to treat dicotyledonous fossils, and notwithstanding the adverse fate which has overtaken nearly all the names given at that and earlier periods to plants of all kinds, Zenker's genus, *Credneria*, still stands, and seems likely to stand much longer, if not perpetually. Though less well known than the Œningen leaf-prints, this locality was known to Scheuchzer, Brückmann, and Walch, but its systematic study as well as the initial step in the investigation of dicotyledonous fossil plants was reserved for Zenker in the second quarter of the nineteenth century.

The year 1834 would be sufficiently memorable in the annals of paleobotany if it had witnessed nothing more than the appearance of the first memoir[181] relating to the subject, from the pen of Doctor Heinrich

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[179] Kurtze Betrachtung derer Kräuterabdrücke im Steinreiche, pp. 7–9.

[180] Jonathan Carl Zenker. Beiträge zur Naturgeschichte der Urwelt, etc. Jena, 1833.

[181] Ueber die Bestrebungen der Schlesier die Flora der Vorwelt zu erläutern. Schlesische Provincialblätter, August und September, 1834. Also in Karsten und Dechen's Archiv, Band VIII, 1835, pp. 232–249.

Robert Göppert, of Breslau, whose career we have already briefly sketched, and whose death since the first draft of that sketch was made occasioned an unavoidable shock notwithstanding the ripened age which our biographic notice showed him to have attained (*supra*, p. 373).

No important works on fossil plants appeared in 1835, and the principal production of 1836, in this line of research, was Göppert's "Systema Filicum Fossilium,"[182] which had probably been in preparation for many years. It was a masterly effort and fittingly betokened the great career of its author. The historical introduction remains the best review of paleobotanical science that has ever been written, and shows that the literature of the subject had long been a favorite pursuit of Dr. Göppert. Nearly all the figures of fossil ferns that had been drawn by the early authors were discussed and identified by the light of more recent knowledge. Rigid comparisons were instituted between fossil and living species, and systematic descriptions of the former so far as then known were introduced. In the forty-four plates that accompany the work are figured most of the Silesian species, which the author declares to be more numerous than those of any other country.

Göppert's contributions during the next year (1837) were numerous[183] and important, and, taken with the equally valuable ones of Brongniart,[184] render this year a good one for their branch of science.

The year 1838 was still more fruitful in published results, as many as a dozen memoirs having been produced in Europe. One of the most important of these has already been mentioned[185] (*supra*, p. 380), in which the first serious attempt was made to determine dicotyledonous genera by the aid of the nervation of their leaves.

In this year also appeared the eighth number of Sternberg's "Flora der Vorwelt," containing Corda's "Skizzen zur vergleichenden Phytotomie vor- und jetztweltlichen Pflanzen," whose merits have already been referred to (*supra*, p. 371).

The year 1839 produced the first contributions of both Geinitz (*supra*, p. 374) and Binney,[186] thus adding two important names to the roll of colaborers in this field. The Count of Münster's "Beiträge zur Petre-

[182] Systema Filicum Fossilium: Die Fossilen Farnkräuter. Nov. Act. Acad. Caes. Leop. Car., Tom. XVII, Suppl., pp. 1–76.

[183] Uebersicht der bis jetzt bekannten fossilen Pflanzen. In Germar's Handbuch der Mineralogie, 1837.

Idem. Two papers on fossil wood: Neues Jahrbuch für Mineralogie, 1837, p. 403, and Verhandl. d. schles. Gesell., 1837, pp. 68–76; and an important one on the process of petrifaction: Poggendorf's Annalen, Band XLII, 1837, S. 593.

[184] Comptes Rendus, Paris, 1837, Tome V, p. 403; Proc. verb. de la soc. philom., 1837, p. 99; Mém. de l'Acad. Roy., Tome XVI, 1838, p. 397.

[185] Sul sistema vascolare delle foglie, considerato come carattere distintivo per la determinazione delle filliti. N. Ann. d. Sc. Nat. Bologna, 1838 Ann. I, Tom. I, pp. 343–390, Pl. VII–XIII.

[186] "On a microscopic vegetable skeleton found in peat, near Gainsborough." British Association Report, 1839 (Part II), pp. 71, 72.

factenkunde" also began to appear in that year, to which several of the most prominent German paleobotanists contributed.

Three very important works appeared in 1840. Bowerbank's "Fossil Fruits and Seeds of the London Clay"[187] marked a great advance in the state of knowledge of the remarkable bodies studied by him, and which, since Parsons[188] called attention to them in 1757, and in fact for many years previous to that time, had excited the interest of both the learned and the unlearned. Of these remarkable forms Bowerbank established ten genera, all but two of which (Hightea and Cucumites) are accepted by Schimper in his "Traité de paléontologie végétale." The number of species distinguished is quite large, and the descriptions and illustrations are very thorough and exact. The work is intensely scientific, and the reader is rarely referred to other authors or to any of the collateral circumstances that would have so greatly aided him in understanding it properly. Exact localities are rarely given, though the island of Sheppey seems to have furnished a large share of the specimens.

The work of Steininger,[189] treating of the fossil plants of what he designates as the "pfälzisch-saarbrückische Steinkohlengebirge," may next be mentioned, in which 83 species of coal plants are described, with 17 illustrations. The work, however, is chiefly geognostic.

Rossmässler's treatise on the lignitic sandstone about Altsattel in Bohemia,[190] almost marks an epoch in the science of fossil plants from the resolute, and in many respects, successful manner in which the author attacks the problem of dicotyledonous leaves, which had thus far been regarded as beyond the power of science to harmonize with the living flora. He clearly realized the objections to the use of Sternberg's universal genus *Phyllites* for all plants of this class, and in stating these objections he says, among other things, that in the great quantity of leaves that will be distinguished in the course of careful investigations of Tertiary strata the species of this vague genus *Phyllites* cannot fail to increase so enormously that all resources for deriving specific names will be exhausted. He first proposed to himself to determine the true genera to which the leaves seemed to belong, and then to append the old name *phyllites* to these genera, as, *e.g.*, Leuco-phyllites, Daphno-phyllites, etc.; but the fear of responsibility, the comparatively unimportant and local character of his work, and the advice of friends deterred him from car-

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[187] James Scott Bowerbank. A History of the Fossil Fruits and Seeds of the London Clay. London, 1840.

[188] James Parsons. An Account of some Fossils and other Bodies found in the Island of Shepey. Phil. Trans., 1757, Vol. L, pp. 2, 396.

[189] J. Steininger. Geognostische Beschreibung des Landes zwischen der unteren Saar und dem Rheine. Ein Bericht an die Gesellschaft nützlicher Forschungen zu Trier. Trier, 1840.

[190] E. A. Rossmässler. Beiträge zur Versteinerungskunde. Erstes Heft. Die Versteinerungen des Braunkohlensandsteins, aus der Gegend von Altsattel in Böhmen. Dresden und Leipzig, 1840.

rying out his plan and decided him to employ under strong protest the old name. He described forty-eight Phyllites, all of which are so admirably figured as regards nervation that it has been no trouble for later writers to refer them to their proper genera. He also describes a palm (Flabellaria), several cones of Pinus, and a coniferous stem that he mistook for Stigmaria, though it is due to him to say that he recognized the entire novelty of finding a Stigmaria in the Tertiary formation.

In addition to these and some minor contributions during the year 1840, it was, as already shown, the one in which the earliest papers of both Unger[191] and Schimper[192] on fossil plants made their appearance.

The principal contribution made in 1841 was Göppert's "Gattungen der Fossilen Pflanzen,"[193] which appeared originally in six parts, with German and French text and many plates. It embraces a fundamental discussion of the existing knowledge of fossil plants. It must not be supposed that it is confined to the description of generic characters. The characteristic species of each genus are fully portrayed. The author still clings to the ancient floras, chiefly to the Carboniferous. The work has an unfinished appearance, and the parts have been put together by the publishers in a most slovenly manner, which, however, should not be allowed to detract from the true merits, as it certainly does from the usefulness, of this work.

A number of other papers by Göppert must be credited to 1841, the most important of which was his "Fossile Flora des Quadersandsteins von Schlesien,"[194] which he supposed to belong to the Tertiary system, while in connection with Beinert he published in the same year a memoir on the distribution of fossil plants in the Carboniferous formation.[195]

The little work of Alexander Petzholdt, "De Calamitis et Lithanthracibus" (Dresdæ et Lipsiæ, 1841), possesses merits not to be measured by its size. It has done much to clear up both subjects, and also to advance them, and the collection given of opinions which have been expressed by those best situated to know respecting the nature of the Calamitæ, and especially respecting the origin of coal, must continue to

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[191] *Supra*, p. 375, note 9.

[192] Baumfarne, Schachtelhalme, Cycadeen, Aethophyllum, Albertia * * * im bunten Sandstein der Vogesen; Hysterium auf einem Pappel-Blatte der Wetterauer Braunkohle. Lonhard und Bronn's Neue Jahrbücher, 1840, pp. 336–338. Communication dated 14. März, 1840.

[193] Die Gattungen der fossilen Pflanzen verglichen mit denen der Jetztwelt und durch Abbildungen erlautert (Les genres des plantes fossiles comparés avec ceux du monde moderne expliqués par des figures). Bonn, I–IV. Lfg., 1841, V–VI. Lfg., 1842–1845.

[194] Ueber die fossile Flora der Quadersandsteinformation in Schlesien als erster Beitrag zur Flora der Tertiärgebilde. Nov. Act. Acad. Cæs. Leop. Tom. XXIX, 1841, p. 97.

[195] Göppert & Beinert. Ueber Verbreitung der fossiler Gewächse in der Steinkohlenformation. Karsten & Dechen's Archiv., Band XV, 1841, p. 731.

have great historical value. As much may also be said for still another book of Petzholdt, published the same year, "De Balano et Calamosyringe (Additamente ad Palæologiam).

Although the first number of Unger's "Chloris Protogæa" appeared in 1841, still the work was not published until six years later, and contains preliminary matter of later origin and of such moment as to render it more proper to speak of the work as a whole in the chronological order of its final publication.

In 1842 numerous papers relating to fossil plants appeared in the current periodicals by Binney, Göppert, Gutbier, Kutorga, Unger, and others, all contributing to swell the literature of the science and supply the data for future generalization. Mr. Williamson's paper before the British Association of that year on the origin of coal (*supra*, p. 376) has already been referred to as a landmark to indicate the point of time at which he joined the growing band of workers in this field. Miquel's monograph of the Cycadaceæ,[196] although dealing chiefly in the living forms, takes account also of the fossil cycads, and forms a contribution to the subject that was much needed in its day. In Vanuxem's "Geology of New York," which forms Part III of the "Natural History of New York" (Albany, 1842), occur numerous figures of fossil plants, with some general remarks thereon.

Some dozen or more memoirs on fossil plants appeared in 1843, the most important of which were by Roemer[197] and Parlatore.[198] The first edition of Morris's "Catalogue of British Fossils"[199] (including fossil plants) also appeared in that year.

The number of contributions to the science of fossil plants in 1844 was considerably larger than in the previous year. It includes Schimper and Mougeot's "Monographie des plantes fossiles du grès bigarré de la Chaîne des Vosges," a work of considerable importance. In it are described and figured species of *Æthophyllum*, of surprising form and perfection, also *Yuccites* and other of the most ancient monocotyledonous types; Albertias, Voltzias, Schizoneuras, and Ferns.

Numerous short papers by Göppert relate to the lignite beds, and show that he was working up towards the subject of amber inclusions, which were soon to engross his attention; and one of these relates to the existence of amber in his own country,[200] and gives an historical ac-

[196] F. A. G. Miquel. Monographia Cycadearum. Trajecti ad Rheum. Fol. cum 8 tab.

[197] Friedrich Adolph Roemer. Die Versteinerung des Harzgebirges. Hanover, 1843, 4to.

[198] Filippo Parlatore. Intorno ai vegetali fossili di monte Bamboli e di monte Massi. Atti d. Georgofili d. Firenze, Vol. XXI, pp. 1–83. Firenze, 1843.

[199] John Morris. A Catalogue of British Fossils, comprising genera and species hitherto described with references to their geological distribution and to the localities in which they have been found. London, 1843. Second edition, considerably enlarged. London, 1854.

[200] Ueber das Vorkommen des Bernsteins in Schlesien. Uebersicht d. schles. Gesell., 1844, S. 228.

count of its discovery there, with a list of all the localities known to him. Besides giving a summary of the fossil flora of Silesia, in Wimmer's "Flora von Schlesien" (Breslau, 1844), Göppert prepared a laborious statistical paper[201] on the condition of the science at that date, which is highly interesting to consult now. The whole number of species then known to him was 1,778, of which 927 were vascular Cryptogams and 242 Gymnosperms.

Germar's great work on the Carboniferous flora of Wettin and Löbejün[202] began to appear in 1844 and continued in parts until 1853. Though treating of all the forms of life found in this district, the work is necessarily devoted mainly to plants, and the large folio plates display great thoroughness of treatment. To Dr. Andrä is due considerable of the text.

Probably no year since 1828 was more fruitful of results in paleobotany than 1845, and no year since has exceeded it, if we only speak relatively to the state of the science. Two of the greatest American contributors, Lesquereux[203] and Dawson (*supra*, p. 377, note 15), entered the ranks at this point, although their first papers gave little earnest of their future career. Besides some twenty minor papers and several small monographs and memoirs of permanent value, we have four large and important works that were either finished or well begun and fairly before the public on that year. Upon the first class we have here no space for comment. Among those of the second may first be mentioned Kurr's memoir on the Jurassic flora of Württemberg,[204] in which some dozen new species of Coniferæ, ferns, and lower Cryptogams are figured. His supposed discovery of true dicotyledonous (cupuliferous) wood has not been verified.

Two papers by Göppert are worthy of mention, one describing fossils from the coal measures of Siberia, collected by M. P. de Tchihatcheff, and published by that traveler in his "Voyage dans l'Altaï,"[205] with eleven plates, and one on the fossil flora of the middle Jura of Upper Silesia.[206]

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[201] Ueber den gegenwärtigen Zustand der Kenntniss fossiler Pflanzen, 1844. Leonh. u. Bronn's Neues Jahrbuch, 1845, S. 405.

[202] Ernst Friedrich Germar. Die Versteinerungen des Steinkohlengebirges von Wettin u. Löbejün im Saalkreise. (Petrificata stratorum lithanthracum Wettini et Lobejuni in circulo Salsae reperta.) Halle, 1844-'53, fol. (Printed in German and Latin).

[203] "Quelques recherches sur les marais tourbeux en général." Mémoires de la Société des sciences naturelles de Neuchatel, Tome III, 1845.

[204] Johann Gottlob Kurr. Beiträge zur fossilen Flora der Juraformation Württembergs. Stuttgart, 1845 (Einladungsschrift zu der Feier des Geburtsfestes Sr. Majestät Wilhelm von Württemberg in der königl. polytechnischen Schule zu Stuttgart den 27. September, 1845).

[205] Description des végétaux fossiles recueillis par M. P. de Tchihatcheff en Sibérie, traduit du manuscrit allemand par P. de Tchihatcheff et publié dans son "Voyage scientifique dans l'Altaï Oriental et les parties adjacentes de la frontière de la Chine, pages 379 à 390, planches 25 à 35.

[206] Ueber die fossile Flora der mittleren Juraschichten in Oberschlesien. Uebersicht der schles. Gesellsch. 1845, p. 139.

Adolphe Brongniart named the fossil plants of Murchison's Geology of Russia[207] and published an explanatory letter.

One other paper of the minor class may be mentioned, chiefly because it describes American material, viz., that of Dr. James Hall in his report upon the vegetable remains collected by Frémont's expedition in 1842.[208] Eleven species of fossil plants are described in this report, besides the figure (Pl. II, Fig. 4), and mention of a dicotyledonous leaf, which last diagnosis is undoubtedly in so far correct. The determination of the ferns is also correct, except in the case of his *Glossopteris Phillipsii* (Pl. II, Figs. 5, *5a*, *5b*, *5c*), which is not a fern but another dicotyledonous plant, as may be seen by the secondary veins and the absence of the characteristic forked nervation of Glossopteris. In these and other respects these figures do not agree with those of Brongniart ("Hist. veg. foss"., Pl. 61, bis Fig. 5) and Phillips ("Geol. Yorkshire," Pt. I, Pl. VIII, Fig. 8). This is not the place to enter into the diagnosis and state the true affinities of these leaves, and indeed from the figures alone this would be a somewhat hazardous task; as yet only a few of the types figured are in my hands, and of this species only one of the least perfect specimens, but this and other unfigured fragments fully confirm its reference to the Dicotyledons. Of the geological position of the locality from which this material was derived one can perhaps speak with greater certainty. It is at least certain that it is not Oolitic, as Dr. Hall supposed, and it is probably Cretaceous, perhaps Laramie group. If the latitude and longitude (lat. 41½°, long. 111°) were accurately taken this would make Muddy Creek a tributary of the Bear River at a point which is colored as Cretaceous on the new map of the United States Geological Survey prepared by Mr. W. J. McGee (1884). The report will at least serve to direct attention to this locality.

Among the larger works that appeared in 1845, we will first mention Unger's "Synopsis Plantarum Fossilium," which is a carefully-prepared catalogue of all the fossil plants known to him with references to the works in which first described. The orders and genera are briefly characterized, and the localities are stated for the species. At the end is a summary, from which we learn that he had been able to enumerate 1,648 species. This, as will be remembered, is 130 species less than Göppert had enumerated a year earlier. It probably was, however, a closer approximation to the true state of the science. A complete index and a good bibliography rendered the work convenient for reference, and we can readily imagine its extreme usefulness at that date.

Probably the most important work of this year was Corda's "Flora

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[207] Geologie de la Russie d'Europe et des montagnes de l'Oural, par Roderick Impey Murchison, Edouard de Verneuil, et le Comte Alexandre de Keyserling. Londres et Paris, 1845, Tome II, pp. 1–13.

[208] Report of the Exploring Expedition to the Rocky Mountains in the year 1842, and to Oregon and North California in the years 1843–'44. By Capt. J. C. Frémont, Washington, 1845, pp. 304–307, plates I and II.

der Vorwelt."[209] It is a large work in folio, with 128 pages of text and sixty magnificent plates, chiefly devoted to the illustration of the internal structure of petrified and carbonized trunks in various families of the vegetable kingdom and at different geological horizons, but mainly in the Carboniferous. As the only considerable work on this subject since Witham's (*supra*, p. 373), it was as much superior to that work as the aids to research were greater than they had been twelve years earlier.

In the same year also appeared Reuss's "Versteinerungen der böhmischen Kreideformation," to which Corda contributed the fossil plants in a chapter of sixteen quarto pages, with six plates executed with the same care and thoroughness that is characteristic of all his work.

One other masterly production, viz., Göppert's Amber-Flora, in Berendt's great work on amber,[210] will conclude the enumeration for the year 1845. His prolonged investigations into the lignite beds of Europe and his study of the amber found in Silesia naturally led to this broader undertaking and fittingly prepared him for it. He begins with a chapter on the amber tree. Of this he remarks that the pieces of wood that occur in and along with amber bear so close a resemblance to the specimens of lignite in his collection, that he does not for a moment hesitate, at least provisionally, to express the opinion that the amber of Prussia is probably derived from one species, which, from its similarity to the Coniferæ of the present epoch, he refers to the extinct genus Pinites, and which he designates as *Pinites succinifer*, and fully characterized in the systematic part of the work. This follows, beginning with a list of the species thus far found in amber, of which he enumerates fifty-three. He finds six other species of Pinites and twenty of Coniferæ. There are ten cellular plants (chiefly mosses and Hepaticæ), one fern, one gnetaceous species (Ephedrites), and twenty-one true Dicotyledons. The descriptions come next, and are accompanied by appropriate and very elaborate illustrations.

Very little idea of the true geologic age of these fossils is derivable from any of the statements contained in this work, either by Göppert or Berendt, and it is still quite the practice to refer these forms to the amber simply, without further attempt to fix their position. But in a paper read before the Silesian Society, May 11, 1853, Dr. Göppert expressed himself very clearly on this point. He said: "The manner in which this flora is composed, as well as the complete absence of one tropical or even subtropical form, points to the modern age of the amber formation, which we must unquestionably refer to the latest strata of the Tertiary formation, to the Pliocene division."[211] By this time the

[209] Beiträge zur Flora der Vorwelt, von August Joseph Corda, mit sechszig Tafeln Abbildungen. Prag., 1845.

[210] Georg Carl Berendt. Die im Bernstein befindlichen organischen Reste der Vorwelt. Erster Band, Berlin, 1845. I. Abtheilung: Der Bernstein und die in ihm befindlichen Pflanzenreste der Vorwelt (chiefly by Göppert).

[211] Jahresbericht d. Schles. Gesellschaft für vaterländische Cultur, 1853 (Breslau, 1854), pp. 46–62, (see p. 373).

amber flora had greatly increased, and 163 species are enumerated in this paper. This result was, however, in the main achieved through the indefatigable labors of Dr. Göppert.

In strong contrast with 1845 stands the next year, at least as regards the importance of the works produced relating to fossil plants. Dunker's monograph of the Wealden[212] is perhaps the leading contribution of 1846, and this embraces all departments of paleontology for that group. But the plants form a prominent feature. Fifty species of Wealden plants are enumerated as having been thus far found in Germany and England, nearly all of which are described and figured. In this last respect Dunker's work is all of a high order, which is nowhere more strongly displayed than in the treatise under consideration.

Göppert's papers were numerous in 1846, and at least one "Ueber die fossile Flora der Grauwacke oder des Uebergangsgebirges",[213] contained the germ of one of his future great works.[214]

Heer[215] and Bunbury (*supra*, p. 379, note 19) both commenced in 1846 to write on fossil plants.

The only great work devoted to paleobotany that appeared in 1847 was Unger's "Chloris Protogæa,"[216] which, as already stated, was published in ten numbers, the first of which came out in 1841. In the course of the preparation of these numbers his "Synopsis plantarum fossilium" appeared, which we have already noticed. The entire matter of this little work was introduced bodily, and apparently unchanged, into the larger one, forming its second part. The first part, or introduction, is entitled "Skizzen einer Geschichte der Vegetation der Erde." This is an able discussion of the leading problems as they presented themselves at that time and went far toward the solution of some of them. The body of the work is strictly descriptive, and here we find 120 species characterized, all new to science or consisting of corrected determinations of other authors. What specially distinguishes this work, however, from all that have thus far been reviewed is the very large percentage of dicotyledonous species, mostly from Parschlug, embraced in these descriptions. Considerably over one-half of the number belong to this subclass and to such genera as Ulmus, Alnus, Betula, Quercus, Acer, Rhus, Platanus, Ceanothus, Rhamnus, etc. He seems to have reached his determinations of these genera by an intuitive perception of the general and special resemblances of the fossil to the living leaves, with

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[212] Wilhelm Dunker. Monographie der Norddeutschen Wealdenbildung. Ein Beitrag zur Geognosie und Naturgeschichte der Vorwelt. Braunschweig, 1846.

[213] Uebersicht der Arbeiten der schlesien Gesellschaft, 1846, pp. 178–184 (expanded in the Zeitschrift d. deutsch. geol. Gesellsch. Band III, 1851, S. 185).

[214] Fossile Flora des Uebergangsgebirges, Nov. Act. Acad. Caes. Leop. Car. Nat. Cur. Band XXII, Suppl. Breslau & Bonn, 1852.

[215] The first paper of which we have a record is the one "Ueber die von ihm an der hohen Rhone entdekten fossilen Pflanzen," which appeared in the Verhandlungen der schweizerischen Gesellschaft for 1846, pp. 35–38.

[216] Franz Unger. Chloris Protogæa. Beiträge zur Flora der Vorwelt. Leipzig, 1847.

which, as a thorough botanist, he was perfectly familiar. He nowhere refers to any treatise on the nervation of leaves, and as those of Bianconi (*supra*, p. 380, note 27) are not included in his "Literatura nostri ævi," it is probably safe to infer that he was unacquainted with them. In drawing his figures he adopted the old method of figuring the stone as well as all the defects in the impression, which while requiring an immense amount of unprofitable labor, rendered the result much less clear and less valuable than it would have been had these features been omitted. The fifty plates, however, by which this work is illustrated constitute an enduring monument to the skill, energy, and industry of their author.

Pomel's paper on the Jurassic flora of France,[217] which appeared in the official report of the association of German naturalists and physicians for 1847, though unaccompanied by illustrations, proved a highly important contribution and gave a new impetus to the study of that formation from the vegetable side.

Some dozen or more other memoirs of greater or less import were contributed during 1847 by Binney,[218] Fr. Braun,[219] Bunbury,[220] Göppert,[221] Lesquereux,[222] Rouillier,[223] and others, none of which can be specially considered here.

About thirty papers and books, small and great, relating to fossil plants appeared in 1848, none of which, however, can be ranked as great works, unless it be Bronn's Index Palæontologicus,[224] which merely includes the plants with all other fossils in one alphabetical arrangement. The number, however, of what may be classed as second-rate productions was quite large. Among these we may count Unger's "Flora von Parschlug,"[225] Berger's thesis "De fructibus et seminibus

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[217] M. A. Pomel. Amtlicher Bericht der Versammlung der deutschen Naturforscher und Aertzte, 1847, pp. 332–354.

[218] Phil. Mag. Vol. XXXI, 1847, p. 259.

[219] Friedrich Braun. Die fossilen Gewächse aus den Gränzschichten zwischen dem Lias und Keuper des neu aufgefundenen Pflanzenlagers in dem Steinbruche von Veitlahm bei Culmbach. Flora, Regensburg, 1847, p. 81. (Enumerates 57 species of Rhetic plants.

[220] Quart. Journ. Geol. Soc. London, 1847, Vol. III, pp. 281, 423.

[221] Uebersicht der Arbeiten d. schles. Gesellschaft, 1847, pp. 70–73.

[222] Explorations dans le Nord de l'Europe pour l'étude des dépôts de combustibles minéraux. Bull. Soc. Sci. Nat. de Neuchâtel, Tome I, 1847, p. 471. *Idem* sur les plantes qui forment la houille. Bibl. Univ. Archives, Tome VI, p. 158. Genève, 1847.

[223] C. Rouillier. Etudes paléontologiques de Moscou, in Fischer de Waldheim's Jubilaeum semisecularem. Moscou, 1847. (Bois fossiles, pp. 20–24).

[224] Heinrich G. Bronn. Handbuch einer Geschichte der Natur. III. Band., III. Theil. Organisches Leben. Index Palæontologicus, oder Uebersicht der bis jetzt bekannten fossilen Organismen. Stuttgart, 1848–1849. A. Nomenclator palæontologicus, 1848. B. Enumerator palæontologicus, 1849.

[225] Die fossile Flora von Parschlug. Steiermärckische Zeitschrift, IX. Jahrg., I. Heft. 1848.

ex formatione lithanthracum,"[226] Binney "On the origin of coal,[227] three consecutive papers by Dr. J. D. Hooker in the Memoirs of the Geological Survey of Great Britain,[228] Debey, on the fossil plants of Aachen,[229] Göppert's prize essay on the formation of coal,[230] Raulin's "Flore de l'Europe pendant la période tertiaire,[231] Robert Brown's memoir on Triplosporites,[232] really announcing the discovery of the fruit of Lepidodendron, and Sauveur's "Végétaux fossiles de Belgique."[233] These works were all important additions to the literature of the science, and represented a large amount of original research.

The third volume of Bronn's Index Palæontologicus, namely, the *Enumerator*, did not appear until 1849. It contains Göppert's table of the vegetable fossils as known to him, arranged under their respective geological formations. All the species are enumerated in systematic order, but with an inconvenient appendix (pp. 5–72), and are not summed up at the end. The summary is, however, introduced in another part of the volume (p. 727), and shows that considerable progress had been made since 1847, when Unger made his synopsis in his "Chloris Protogaea," although, as already remarked, the 1,648 species there given is the same as given in his "Synopsis plantarum fossilium" (1845), which seems not to have been revised, while Göppert had already enumerated in 1844 (*supra*, p. 416) 1,778 species. From these figures we now have an advance to 2,055, or more than four times as many as were known to Brongniart in 1828, though only about one-fourth the number now known.

The great work of 1849 was Brongniart's "Tableau des genres de végétaux fossiles."[234] The author's views relating to the classification and

[226] Reinhold Berger. De fructibus et seminibus ex formatione lithanthracum. Dissertatio inauguralis quam consensu et auctoritate amplissimi philosophorum ordinis in alma litterarum universitate viadrina ad summas in philosophia honores rite capessendos die XVIII, M. Decembris, A. MDCCCXLVIII. H. L. Q. S. publice defendet Auctor. Vratislaviæ, 1848.

[227] Memoirs of the Literary and Philosophical Society of Manchester, Vol. VIII, 1848, p. 148.

[228] Vol. II, pp. 2—456.

[229] Verhandlungen des naturhistorischen vereines der preussishen Rheinlande, V. Jahrg., 1848, pp. 113, 126.

[230] Preisschrift. Abhandlung, eingesandt als Antwort auf die Preisfrage: * * * ob die Steinkohlenlager aus Pflanzen entstanden sind, etc. Eine mit dem doppelten Preise gekrönte Schrift. Haarlem, 1848, 4°, 300 S, 23 Taf., forming the 4e Deel, Tweede versameling, Verhandl. Holl. Maatschappen.

[231] Victor Raulin. Sur les transformations de la flore de l'Europe centrale pendant la période tertiaire. Annales des sciences naturelles de Paris, 3e série, Botanique, Tome X, 1848, p. 193.

[232] Annals and Magazine of Natural History, ser. II, Vol I, 1848, p. 376; Proc. Linn. Soc. I, 1849, p. 344; Trans. Linn. Soc., Vol. XX, Pt. I, 1851, p. 469, Pl. XXIII, XXIV. Cf. Comtes rendus des séances de l'Academie des sciences, Tome 67, 1868, pp. 421–426.

[233] J. Sauveur. Végétaux fossiles des terrains houillers de la Belgique, Académie royale des sciences, des lettres, et des beaux-arts de Belgique, Tome XXII, 1848.

[234] Tableau des genres de végétaux fossiles consideré sous le point de vue de leur classification botanique et de leur distribution géologique. Paris, 1849, 8°. Dictionnaire universel d'histoire naturelle.

distribution of the extinct genera and species of fossil plants are here systematically set forth and superbly illustrated. A memoir on the same subject[235] appeared in the "Annales des sciences naturelles" for the same year, in a manner summarizing his views and giving lists of fossil plants belonging to each horizon. In seeking to avoid all duplications that result from giving different names to different parts of the same plant, his enumeration is reduced to very modest proportions and falls inside of 1,600 species, while, by treating Œningen and Parschlug as Pliocene instead of Miocene, he greatly exaggerates the importance of the former horizon at the expense of the latter. But the era of Miocene exploration had only just begun, and that formation did not give evidence of its present overshadowing supremacy until the labors of Heer and Ettingshausen began to reveal its true character.

Pattison's "Chapters on Fossil Botany"[236] is a very superficial attempt to treat the subject in a popular way, and its only value is a table of British fossil plants, which, if it could be depended upon, would show the number then known to amount to 529, of which 279 were from the coal measures, 120 from the Tertiary, and 89 from the Oolite.

A large number of works and memoirs on vegetable paleontology appeared in 1850, perhaps exceeding that of any previous year. Most of these, however, were of modest pretensions, and only two can properly be classed among great works on the subject. These were Unger's "Genera et species plantarum fossilium"[237] and Göppert's "Monographie der fossilen Coniferen."[238]

As Unger had in 1845 published, in his "Synopsis," the first complete catalogue of fossil plants, so he was the first, in 1850, to publish a complete manual on the subject, for such is the nature of his "Genera et species." This work is a shapely octavo volume of 668 pages, written wholly in Latin, and describing in systematic order every species of fossil plant known to the author. The total number thus described is 2,421, a large advance upon any previous estimate. Among the good features of the work are an enumeration of the genera under their proper orders and classes in a table that precedes the descriptive part, the reproduction, brought down to date, of his previously published "Literatura nostri ævi," and a thorough species index at the end, distinguishing synonyms by printing them in italics. In his classification he follows the natural order of development, beginning with the lowest forms. He declines to follow the English authorities in

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[235] Exposition chronologique des périodes de végétation et des flores diverses qui se sont succédé à la surface de la terre. Ann. Sci. Nat. Bot., 3e sér., Tome XI, 1849, pp. 285–338.

[236] S. R. Pattison. Chapters on Fossil Botany. London, 1849, 12mo.

[237] Franz Unger. Genera et species plantarum fossilium. Sumptibus Academiæ Cæsareæ scientiarum. Vindobonæ, 1850.

[238] H. R. Göppert. Monographie der fossilen Coniferen. Eine im Jahre 1849, mit der goldenen Medaille und einer Premie von 150 Gulden gekrönte Preisschrift. Leiden, 1850. Naturkundige Verhandelingen van de Hollandsche Maatschappij der Wetenschappen te Haarlem. Tweede Verzameling, 6e Deel. Leiden, 1850.

treating Stigmaria as a dicotyledonous plant. He places the "Cycadeaceæ" between the Cryptogams and the Monocotyledons, but strangely separates them from the Coniferæ and Gnetaceæ, which he makes to follow the palms and precede the forms now referred to the apetalous division; though he does not recognize by special names the divisions of the Dicotyledons established by Jussieu. Still, in arranging the orders, he follows the system of A. L. de Jussieu, and not that of Adrien de Jussieu. No illustrations accompany this work.

In Göppert's "Monographie der fossilen Coniferen" we have another of those exhaustive works upon difficult subjects which characterize this author. When we say that it forms a quarto volume of 359 pages, with 58 plates, half of which are devoted to the illustration of internal structure as revealed by microscopic examination, we have given but a rude idea of the work. The first 67 pages relate entirely to living Conifers and fitly prepare the way for a thorough treatment of the fossil forms. To the treatise on fossil Conifers is prefixed an historical introduction of nearly a hundred pages, in which, as in the historical introduction to his "Systema filicum fossilium," he marshals the literature with great effect, and, as in the former case he found it impossible to confine himself to fern life, so in the present case he makes it the occasion for a thorough study of the history of man's acquaintance not merely with coniferous fossil wood, but with fossil wood in general, which for ages remained the only known form of vegetable petrifaction.

Besides the systematic description of all coniferous fossils known to him, the work contains a most valuable enumeration of localities where fossil wood, beds of coal, and fossil plants in general had been found from the year 1821 to the end of 1849, arranged primarily according to their position in the geological system. It also contains an arrangement of the species of Coniferæ according to geological horizons.

The remainder of the numerous productions of the year 1850 must be passed over in silence, as their bare enumeration would consume considerable space, and without glancing at their special merits would add little to the reader's knowledge respecting them. As has already been stated (*supra*, p. 379, 380) it was in 1850 that both Massalongo and Baron von Ettingshausen began their work in the domain of fossil plants, so that at this date no less than fourteen of those who have been mentioned as leaders of the science were living and actively engaged in extending its boundaries.

We have thus passed in review the literature of fossil plants from the earliest records down to the close of the first half of the nineteenth century. The plan was, and still is, to continue this survey down to the present time, though confining attention more and more, as the literature increases in volume, to the most important works. But for the present purpose the carrying out of this plan is manifestly impossible from considerations of both space and of time, and it must be postponed until the work to which it was intended as an introduction shall have been completed. This is specially to be regretted, as so little had been done down to 1850 to develop the paleobotanical resources of America. It is also true that at that date little had been done beyond the collection and accumulation of data for study. From the time when the practice of discussing imaginary problems without any data fell into disrepute the opposite and far more healthful tendency to treat facts as the end of research chiefly prevailed, until at length, at the time when we are compelled to close our record, a sufficiently large body of facts had been brought to light, and, through the organizing power of Unger, Brongniart, and Göppert, had been arranged for study and comparison, to render it somewhat profitable to speculate upon their probable meaning.

In the decade that followed some such speculation was indulged in very cautiously, but this always resulted in the clearer recognition of the need of still more facts, and undoubtedly tended strongly to stimulate research. Then commenced that systematic attack along the whole line of paleobotanical investigation. Ettingshausen's system of nervation for the determination of dicotyledonous leaves may be regarded as the result of the pressure, then irresistible, for the means of identifying the now vast accumulations of this important class of fossils. Heer's researches into the fossil floras of Switzerland and of the arctic regions, and Lesquereux and Newberry's investigations into the Dakota, Laramie, and Green River groups of the Western United States, together with Saporta's "Études" in the south of France, furnished more data than that of all the collections previously made from the later formations.

The work of exploration still goes on. Saporta has elaborated the Jurassic of France, Grand' Eury and Renault have thoroughly studied the Carboniferous of that country, as have Williamson and Carruthers that of England. Nathorst has opened up the subterranean floral treasures of Sweden, and Dawson those of British America, while Engelhardt, Hosius, Van der Marck, and Schenck have continued to investigate, without exhausting, the rich plant-beds of Germany. In America activity has not diminished, notwithstanding the advanced age of both the principal cultivators of this science. Large works, which have required years in preparation in the hands of both Lesquereux and Newberry, are either on the eve of publication or are far advanced toward completion. Professor Fontaine, of the University of Virginia, has an important work on the Rhetic flora of Virginia in press, and is collecting some most interesting material for a second from the lower Cretaceous or upper Jurassic of the same State. Large collections have lately been made by different parties of the United States Geological Survey, which are now in hand for examination, while fresh material is daily arriving at the National Museum from all parts of the country.

Between eight and nine thousand species (as species are made) of fossil plants are now known to science, and the time must be near at hand, if it has not already come, when this wide acquaintance with the ancient floras of the globe, if properly organized for study, will afford such aid to geological investigation as to command recognition, while the lessons which it supplies to the botanist and the biologist will be inestimable.

VIII. NOMENCLATURE AND CLASSIFICATION OF FOSSIL PLANTS.

Science does not consist in names, but it cannot well progress without them, and early in the history of every science a system of nomenclature always arises. Again, a knowledge of natural objects consists largely in a knowledge of their relations, to obtain which systematic attempts at their methodical arrangement are among the first steps. However humble such efforts may at first be, they nevertheless constitute the beginnings of scientific classification. The objects may be arranged before names are given to them or to the groups they are seen to form, as in Bernard de Jussieu's Garden of the Trianon. But usually the naming either precedes or closely accompanies the process of arrangement. Such at least has been the case with fossil plants. This fact, however, is to be here considered: That the science of botany proper antedated by far that of paleobotany. A few names were given to vegetable remains during the period when nobody believed that they either were themselves plants or represented plants. The reaction from this view, which took place at the beginning of the eighteenth century, in favor of the diluvian theory, carried its votaries much too far, and led them to think that every fossil plant must represent some known living one. This extremism had its fitting exemplification in Scheuchzer's now obviously ridiculous attempt to classify the fossil plants of his time under the same rubrics as the living plants. The timely appearance of Tournefort's "Élémens de Botanique," in 1694, in which about the first real system of botanical classification was drawn up, afforded Scheuchzer the desired opportunity, and without waiting for the appearance of a second edition of his "Herbarium diluvianum," he hastened to arrange all his species under Tournefort's twenty-one classes, and published them, in 1816, in his "Oryctographia Helvetiæ" (pp. 203–247). In spite of his zeal, however, a large residue of unassigned fossil plants remained as a special "Class unkantlicher Gewächsen oder dero Theilen, welche uns von der Sündfluth ubriggeblieben" (p. 236). This attempt was continued in the *Editio novissima* of the "Herbarium diluvianum," published in 1723 (Appendix).

In this rash scheme Scheuchzer was not followed. Lhwyd, in 1699, had applied the term *Lithoxylon* to fossil wood, which, with the exception of the impressions described by Major, mentioned on p. 389 (*supra*), was the only form of vegetable fossil known down to his time.

Volkmann (1720) adopts this term, and also *Lithophyllon*, while to all impressions of leaves and fronds he gives the general name of *Lithophytes*, but he goes a long way in the direction of Scheuchzer in accepting the *indigenous* theory (*supra*, p. 395). Schultze (1755) treats the whole subject of plant impressions from a strictly mineralogical point of view, designating his figures by the old indigenous names of Scheuchzer and Volkmann; but the three general classes of petrifactions which he describes without naming are of interest, as showing that he possessed a firm and rational grasp of the phenomena. They are: (1) Whole trees, large trunks, thick roots, and other similar woody matters transformed into stone; (2) impressions of twigs, leaves, flowers, etc., which consist either in whole or in part of the remains of the originals in a petrified state; (3) impressions of stems, plants, and shrubs in which no trace of their former parts is perceptible.

Walch (1769) was the first to offer anything like a nomenclature of fossil plants, and although most of his names have now disappeared from the text-books, they still served a useful purpose during a long embryonic period in the history of the science. He called petrified trunks by the terms *Lithodendron* and *Dendrolithus;* pieces of petrified wood *Lithoxylon*, and also *Stelechites;* petrified roots, *Rhizolithus*. If the fossil remains bore a sufficient resemblance to any living tree or plant, it was called by the name of that plant, with its terminal syllable changed into *ites*, as *Daphnites*, *Sandalites*, etc., a method which is still extensively employed in the creation of fossil genera of plants. Herbaceous plants were called *Phytolithi*, but he distinguished mere impressions of these as *Phytotypolithi*. Fossil leaves were *Lithobiblia*, *Bibliolithi*, or *Lithophylla*. *Phytobiblia* referred to the leaves of herbs as opposed to those of trees. He mistook the *Calamitæ* for great reeds, and applied to them this name, as also that of *Lithocalmi*, the first of which has come down to us notwithstanding the misnomer. Fossil fruits he denominated *Carpolithi*, which is another term that has survived in the long struggle for existence.

Parkinson (1804) contented himself by giving a simple classification in English, although he refers to the Latin names which had been given to his groups by previous authors. His terminology was, (1) fossil trees; (2) fossil plants; (3) fossil roots; (4) fossil stalks; (5) fossil leaves; (6) fossil fruits and seed-vessels.

Steinhauer (1818) made four classes: Fossil wood (*Lithoxylon*), fossil fruits (*Lithocarpi*), fossil leaves (*Lithophylli* [*sic*]), and fossil flowers, of whose existence he seemed doubtful. He describes ten species, all of which he classes under the one genus, *Phytolithus*. Considering the meagerness of this presentation it is somewhat surprising that Steinhauer should have actually been the first to apply specific names to fossil plants, and thus to bring them fairly within the circle of natural history sciences. It had thus taken more than a century to complete the cycle from the attempt of Scheuchzer to apply Tournefort's classification to fossil plants, through the "indigenous" and "exotic" stages incident to the diluvian theory and back to this humble beginning on a true scientific basis as a systematic science, and it is properly from the appearance of this unpretentious memoir in an American scientific serial that paleobotany as a systematic branch of natural history should date (*supra*, p. 403).

Baron von Schlotheim, in his "Flora der Vorwelt" (1804), had made no attempt to assign names to the forms he so admirably figured, but confines himself to questioning and criticising the "indigenous" and "exotic" names which they had received from the early authors. "If the author had established a nomenclature for the plants which he described," said Brongniart, "his work would have become the basis of all the works which have since been produced on the same subject."[239] But it was scarcely too late for him still to acquire this honor, for between this first work and the appearance of his "Petrefactenkunde" (1820) no important treatise on fossil plants other than Steinhauer's memoir was published, and in this second work, which, as we have already seen, so far, at least, as the treatment of vegetable remains was concerned, was merely the continuation of the first which had been interrupted by political troubles, a systematic nomenclature was adopted and carried out in detail (*supra*, p. 404). He styled the entire vegetable kingdom so far as fossils are concerned, Phytolithes, without, however, employing as Steinhauer had done, the term *Phytolithus* as a genus. Out of it he carves five classes, though he does not so denominate them. Under two of these larger divisions fall subordinate ones which may be called orders the other three remaining undivided with an ordinal and even generic rank of their own. The following is the outline of Schlotheim's system:

I. Dendrolithes.[240]
  - A. Lithoxylithes.
  - B. Lithanthracites.
  - C. Bibliolithes.

II. Botanilithes.

III. Phytotypolithes.
  - *a.*) Palmacites.
  - *b.*) Casuarinites.
  - *c.*) Calamites.
  - *d.*) Filicites.
  - *e.*) Lycopodiolithes.
  - *f.*) Poacites.

IV. Carpolithes.

V. Anthotypolithes.

Under his Dendrolithes and Botanilithes no species are introduced, but certain forms are described, compared, and discussed. Especially

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[239] Prodrome, p. 3.

[240] The anglicized forms are here employed as Schlotheim employed the German forms: *Dendrolithen, Lithoxylithen*, etc.

interesting are his notes on the Bibliolithes in which most of the dicotyledonous leaves, then known, are referred to. Of Palmacites he describes fifteen species under regular systematic names. Of Casuarinites he gives five species; of Calamites, ten; of Filicites, twenty-three; of Lycopodiolithes, five; of Poacites, four; of Carpolithes, fifteen, and of Anthotypolithes, one. The science of paleobotany could therefore start from this date with seventy-eight species described and figured.

Count Sternberg, in his "Flora der Vorwelt," established a large number of genera, which he founded upon the most thorough investigation, a large share of which have resisted the destructive agencies of subsequent research. Among these were *Lepidodendron*, *Flabellaria*, *Annularia*, *Nœggerathia*, and *Sphenopteris*. His determinations were modest and sound, and he was able only in a few cases to refer the fossil forms to living genera, as in *Osmunda*, *Asplenium*, etc. But the most important departure effected in this work was in establishing vegetable paleontology for the first time upon a geognostic basis. He assumed three periods of vegetation: (1) an insular period characterized by the great coal plants; (2) a period characterized by the predominance of cycadean types, and (3) a period introduced by fucoidal remains and characterized by dicotyledonous forms. It will be at once perceived that these three periods correspond substantially with the Paleozoic, Mesozoic, and Cenozoic ages of modern geology.

Passing over the system of Martius, published in 1822,[241] which, though having merits, has been received with less favor, we now come to that of Brongniart, the first draft of which also appeared in 1822.[242] In this memoir all fossil plants were divided into four classes, expressly so-called, viz., (1) stems whose internal organization is recognizable; (2) stems whose internal structure is not recognizable, but which are characterized by their external form; (3) stems joined to leaves or leaves only; (4) organs of fructification. The first class is divided into *Exogenites* and *Endogenites*, having the rank of genera. Under the second class, besides *Calamites* of Schlotheim, *Syringodendron* of Sternberg, and other genera, there occur for the first time the genera *Sigillaria* and *Stigmaria*. Sternberg's *Lepidodendron* is divided into *Sigillaria* and *Sagenaria*, to the latter of which Sternberg's name, *Lepidodendron*, is now generally preferred. Stigmaria is the equivalent of Sternberg's *Variolaria*. Under the third class *Lycopodites* is substituted for Schlotheim's *Lycopodiolithes*, *Asterophyllites* for his *Casuarinites*, and *Phyllites* for his *Bibliolithes*. Schlotheim's *Filicites* and *Poacites* are adhered to and the new genera, *Sphenophyllites* and *Ficoides*, are established. Under the fourth class Schlotheim's two genera, *Carpolithes* and *Antholithes*, are retained.

[241] C. F. Martius. De plantis nonnullis antediluvianis ope specierum inter tropicos viventium illustrandis. Denkschr. der königl. baierisch. botan. Gesellsch. in Regensburg, Band II, 1822, pp. 121–147, Pl. I and II.

[242] Mémoires du Muséum d'histoire naturelle, Paris, Tome VIII, 1822, pp. 209–210.

Without further discussing here the beautifully illustrated work of Artis (*supra*, p. 406) who attempted, for the most part unsuccessfully, to create several new genera, we may now profitably compare the method just reviewed with the one put forth six years later by the same author in his "Prodrome." On page 9 of that work he gives the key to his new classification in the following words: "La méthode que nous avons adoptée pour classer et dénominer ces fossiles, est fondée également sur ces rapprochements plus on moins intimes entre les plantes fossiles et les plantes vivantes." Laying aside the former method, based chiefly upon the nature of the fossil, *i. e.*, the part of the plant which happened to be preserved, he now makes bold to assign all these forms to some of the great natural divisions of the vegetable kingdom as established by the Jussieus and other botanists. But as already remarked (*supra*, p. 406), geognostic considerations and a firm faith in the laws of development led him to suggest some important modifications in this so-called natural method, as may be seen by comparing the following scheme from page 11 of the "Prodrome" and from page 20 of the "Histoire des végétaux fossiles":

I. Agams.
II. Cellular Cryptogams.
III. Vascular Cryptogams.
IV. Gymnospermous Phanerogams.
V. Monocotyledonous angiospermous Phanerogams.
VI. Dicotyledonous angiospermous Phanerogams.

In the present state of botanical science Brongniart's Agams would probably all be relegated to his second group, or Cellular Cryptogams, but in other respects this classification is pre-eminently sound, and seems likely to be vindicated by the future progress of the science as against some of the recent systems emanating from the highest authorities.

To these few general groups Brongniart proceeded to refer the fossil forms either as new and avowedly extinct genera, or, wherever possible, as extinct species of living genera. This was carried entirely through the system in his "Prodrome," and, so far as it went, the "Histoire" afforded ample justification for his determinations in the form of full descriptions and thorough illustrations. This latter work was in a manner completed by his "Tableau"[243] in 1849. The method of Brongniart has, with few exceptions, been adopted by subsequent paleobotanists, One of these exceptions, however, is too important to be passed over. although it has already been considered in certain of its bearings. This is the system of Lindley and Hutton. These authors, apparently in order to emphasize their dissent from the theory of development, reversed the order, placing the most highly developed forms first. They also placed the Coniferæ and Cycadeæ in the subclass Exogenæ, or

[243] Tableau des genres de végétaux fos-iles considéré sons le point de vue de leur classification botanique et de leur distribution géologique. Paris, 1849. (Dictionnaire universel d'histoire naturelle.

Dicotyledons, without intimating that they differ in any essential respect from oaks or elms.

The following is their system in outline:

Class I.—VASCULARES, or FLOWERING PLANTS.

Subclass 1. Exogenæ, or Dicotyledons.

Nymphæaceæ.
Laurineæ.
Leguminosæ.
Ulmaceæ.
Cupuliferæ.
Betulineæ.
Salicineæ.
Myriceæ.
Juglandeæ.
Euphorbiaceæ.
Acerineæ.
Coniferæ.
Cycadeæ.
Doubtful.

Subclass 2. Endogenæ, or Monocotyledons.

Marantaceæ.
Asphodeleæ.
Smilaceæ.
Palmæ.
Fluviales.
Doubtful.

Flowering plants which cannot be with certainty referred to either the monocotyledonous or the dicotyledonous classes.

Class II.—CELLULARES, or FLOWERLESS PLANTS.

Equisetaceæ.
Filices.
Lycopodiaceæ.
Musci.
Characeæ.
Algæ.

Plants the affinity of which is altogether uncertain.

Stigmaria is put in the Euphorbiaceæ, *Sphenophyllum* in the Coniferæ, *Annularia* and *Asterophyllites* in the Dicotyledons, *Nœggerathia* in the Palmæ, while *Sigillaria* and *Volkmannia* are classed with the last, or wholly uncertain group.

With the rapid increase of material for the study of fossil plants the possibility of referring them to living families and genera has increased until at the present time nearly all the remains of the former vegetation of the globe are readily assigned to their proper place in the general system adopted by botanists. Within a few years the number of dicotyledonous species has become so large that the attempt to identify them has been eminently successful. By the aid of a set of rules deduced from the prolonged study of the nervation of leaves the genera of fossil Dicotyledons have been in great part made known. The only prominent question which this increased knowledge has raised in the department of classification has been with reference to the order in which the divisions of Jussieu should stand. It is, however, now generally admitted that the order in which these three divisions of plants appeared was that of Adrien de Jussieu and not that of A. L. de Jussieu,[244] the Gamopetalæ constituting the most recent group of plants developed upon the globe. M. Schimper, while adhering to the old method in this respect for his systematic arrangement of the families, has nevertheless clearly shown that this does not represent the order of nature, and in his review of these groups[245] he has arranged them according to the natural method.

It is thus that after two centuries of floundering in turbid waters the science of paleobotany has at last found itself in condition to take its proper place as a department of botany—the botany of the ancient world—in which, whatever geology may gain from it, it must rest upon geology as its solid foundation.

IX. THE NATURAL METHOD AS INDICATED BY PALEOBOTANY.

The aid that the study of fossil plants affords in arriving at a natural classification of living plants is of prime importance, because it supplies at first hand the chief object for which all classification legitimately exists, viz., a knowledge of how existing forms came into being and why they are what they are.

Much as we may delight in the discovery of new and beautiful forms, and may admire the objects in our possession as products of nature and pets of our specialties, we must, as investigators of nature, feel a higher interest in the great problems of their origin and development, whose solution in strictly scientific ways constitutes the proper aim of science itself.

The method by which these problems can be most successfully attacked is the method of *classification*. Notwithstanding the contempt into which mere "systematists" have latterly fallen, the true scientific method is still and must ever be the systematic method. The real cause for the present disdain of systematists, lies in the mistaken spirit in which

[244] Adrien de Jussieu. Cours élémentaire d'histoire naturelle. Botanique. Paris, 1840, p. 395.

[245] Traité de Pal. vég., Tome I, pp. 83-87

system-making has been so commonly conducted. Systems of classification had come to be regarded as the end of science, when they are at best only the means. But it is not to be wondered at that this was so, since it was not until quite recently that science could be fairly said to have any end other than to collect facts and build systems. Not until the laws of genetic dependence among the forms of organized life, as taught by Lamarck in 1809 and enforced by Darwin in 1859, had begun to be recognized within the last twenty years, was any such grand result thought possible as that of ever finding out how existing forms have come to be what they are. With the growth of this conception all attempts at classification gradually became revolutionized in their spirit and aim, and from being merely logical and ideal they tended to become practical and real. Whereas formerly some collected facts for the sake of facts, and others built systems for the sake of systems, now all collect facts for the sake of systematizing them and systematize them in order to learn what they teach; for neither without facts nor without system can we ever arrive at truth.

It is customary with botanists to speak of *artificial systems* of classification as contrasted with the *natural system.* It is commonly supposed that the system of Linnæus was wholly artifical, and the impression equally prevails that that of Jussieu was the true natural one. But in the progress of human discovery no such sudden leap ever takes place. The truth is that all systems have aimed to be natural and that none have wholly succeeded. But there has been progress in the conception of what constitutes a natural system. The most that the older botanists aimed to secure was a *logical* system, and it was supposed that the logical necessarily represented the natural.

1. TYPES OF VEGETATION.

The vegetation of the globe has always been divided into certain obvious groups which may be called *types*, the word "type" being here used in a very general and indefinite way. These types of vegetation have various systematic values. The following table contains the principal ones, with a brief explanation accompanying each:

Synoptical View of the Types.

CRYPTOGAMS.—Flowerless plants.

- *Cellular Cryptogams.*—Devoid of vessels or vascular bundles; *e. g.*, sea-weeds, mosses.
- *Vascular Cryptogams.*—Having vascular bundles—fibers, ducts, etc.
  - *Filices.*—Ferns.
  - *Rhizocarpeæ.*—Inconspicuous plants, of interest chiefly as appearing to form the transition from the Cryptogams to the Phænogams through the Cycadaceæ; *e. g.*, Marsilia, Salvinia, Azolla.

CRYPTOGAMS.—Flowerless plants—Continued.

Equisetineæ.—Rush-like plants, with whorls of leafless branches; *e. g.*, Calamites, scouring rushes.

Lycopodineæ.—Plants with scaly stems or trunks; *e. g.*, Lepidodendron, club-mosses.

Ligulatæ.—Inconspicuous plants, of interest chiefly as appearing to form the transition from the Cryptogams to the Phænogams through the Coniferæ; *e. g.*, Isoetes.

PHÆNOGAMS.—Flowering plants.

Gymnosperms.—Plants having their ovaries open and the ovules and seeds naked or exposed.

Cycadaceæ.—Trees midway in general aspect between tree-ferns and palms; *e. g.*, sago palm.

Coniferæ.—The pine family; *e. g.*, pine, fir, cedar, yew, etc.

Gnetaceæ.—A small family of leafless plants, interesting chiefly as appearing to form the transition from the Equisetineæ to the Dicotyledons, through the Casuarinæ; *e. g.*, Ephedra antisyphilitica.

ANGIOSPERMS.—Plants having their ovules and seeds protected by closed ovaries.

Monocotyledons.—Plants that come up with a single blade, or cotyledon; stems endogenous; *e. g.*, grass, lily, palm.

Dicotyledons.—Plants that come up with two leaves, or cotyledons; stems exogenous.

Apetalæ or *Monochlamydeæ.*—Plants having but one floral envelope (a calyx but no corolla); *e. g.*, oak, willow.

Polypetalæ.—Plants having two floral envelopes (a calyx and a corolla), the corolla consisting of separate petals; *e. g.*, rose, magnolia, maple.

Gamopetalæ or *Monopetalæ.*—Plants having two floral envelopes, the corolla consisting of a single piece, or petal; *e. g.*, honeysuckle, catalpa, trumpet-flower.

The names contained in this table are the modern ones, and other terms with, perhaps, about the same meaning will be found in the systems of classification of the older botanists, while in some such systems quite different groups are recognized as primary.

2. THE LINNÆAN SYSTEM.

The history of the progress made by botanists proper, without the aid of paleontology, in the direction of the natural method, did space permit, would well repay examination. I shall confine myself to presenting the three principal systems in a much-abridged form, as perhaps the most satisfactory way in which that progress can be indicated. The systems to which I refer are those, respectively, of Linnæus, of A. L. de Jussieu and of Adrien de Jussieu. The first of these, the system of Linnæus, is introduced merely to show that it is not altogether an artificial one, but, like all the rest, an effort at real classification. More clearly to indicate this I have arranged it in logical form, and, for brevity's sake, have introduced a number of non-Linnæan terms:

The Linnæan system.

Cryptogamia					Cryptogamia.
Phæno-gamia.	Diclinae				Polygamia.
					Diœcia.
					Monœcia.
	Hermaphroditæ	Gynandria			Gynandria.
		Eleutherogynia	Desmandria		Syngynesia.
					Polyadelphia.
					Diadelphia.
					Monadelphia.
			Eleutheran-dria.	Anisan-dria.	Tetradynamia.
					Didynamia.
				Isandria	Polyandria.
					Icosandria.
					Dodecandria.
					Decandria.
					Enneandria.
					Octandria.
					Heptandria.
					Hexandria.
					Pentandria.
					Tetrandria.
					Triandria.
					Diandria.
					Monandria.

All who are familiar with the Linnæan system will, of course, observe that the order is here inverted. The names of the successively larger groups, with the exception of the terms "Cryptogamia" and "Phænogamia," are merely invented to obviate the necessity of describing those groups. This form of presentation clearly shows to how large an extent Linnæus aimed at a logical classification.

3. SYSTEMS OF THE JUSSIEUS.

We will next glance at the systems of the Jussieus. Bernard de Jussieu has merely left us his catalogue of the garden of Trianon, but this enigmatic list of names is regarded by modern botanists as containing the germ of all later systems. Guided by it, his nephew, Antoine Laurent de Jussieu, proceeded to elaborate the celebrated Jussiæan system, of which a mere outline is presented in the following table:

System of A. L. de Jussieu.

Acotyledons.	
Monocotyledons.	
Dicotyledons	Apetalæ.
	Monopetalæ.
	Polypetalæ.
	Diclinæ.

This system, as will be observed, rests primarily upon the number of cotyledons, and in making the Cryptogams co-ordinate with the Monocotyledons and the Dicotyledons fails to draw the great dividing line which Linnæus clearly perceived between the Cryptogamic and the Phænogamic series.

In re-elaborating it, his son, Adrien, adhered to this defect, but introduced some improvements. We will next glance at this latest form of the Jussiæan system:

System of Adrien de Jussieu.

- Acotyledons.
- Monocotyledons.
- Dicotyledons . . .
  - Diclinæ . . . .
    - Gymnosperms.
    - Angiosperms.
  - Hermaphroditæ . . .
    - Apetalæ.
    - Polypetalæ.
    - Monopetalæ.

In this case we see a very great advance in the recognition of the Gymnosperms. In transposing the Polypetalæ and Monopetalæ he also departed from the views of his father, and in this modern botanists have not followed him, although, as remarked above (p. 431), this change would undoubtedly be in the direction of a true natural system.

4. SYSTEM OF MODERN BOTANISTS.

From the systems of the Jussieus to that which prevails among botanists of the present day the transition is slight. Linnæus's Cryptogamic and Phænogamic series are restored; the terms "Exogens" and "Endogens" are introduced as synonymous with "Dicotyledons" and "Monocotyledons," of which they take precedence; the Gymnosperms are recognized, and A. L. de Jussieu's order is restored for the Polypetalæ and Monopetalæ, for which latter name that of "Gamopetalæ" is coming to be preferred, while for "Apetalæ" the term Monochlamydeæ is substituted by some. The system, then, is substantially as follows:

- Cryptogams.
- Phænogams.
  - Endogens, or Monocotyledons.
  - Exogens, or Dicotyledons.
    - Gymnosperms.
      - Cycadaceæ.
      - Coniferæ.
      - Gnetaceæ.
    - Angiosperms.
      - Apetalæ, or Monochlamydeæ.
      - Monopetalæ, or Gamopetalæ.
      - Polypetalæ.

All modern text-books invert the order and begin with the Phænogams, but whether advisable or not this is intended merely to facilitate study, the higher forms being easier of comprehension, and does not at all imply that our leading botanists believe this to have been the order in which plants have developed. This inversion of the order, however, shows how completely the notion of development is ignored in modern botany, and the system throughout rests upon the evidence furnished by the organs of the plants as they are understood. It is proper to say that at the present time quite a large body of the most thorough students of vegetal embryology and histology, especially in Germany, have rejected much of this system, and especially that which concerns the Gymnosperms. These they prove in the most satisfactory manner to constitute a lower type than any other of the Phænogams, and they conclude that they form a more or less natural transition from the Cryptogams to the Phænogams, between which they place them. This result is most gratifying to the paleontologist, for nearly or quite every work on fossil plants gives the Gymnosperms this position at the base of the Phænogamic series, so sagaciously assigned to it by Brongniart. Paleobotanists have been compelled to do this in the face of the prevailing botanical systems, because this is the position which they are found to occupy in the ascending strata of the earth's crust. It is astonishing that botanists could have remained so indifferent to such a weighty fact, and it is certainly most instructive to find the geological record, so long unheeded, confirmed at last by the facts revealed in living plants. There is no evidence that those who have thus confirmed it were in the least influenced by it, and Sachs is as silent as to paleontology as is Bentham or Gray.

The founders and perfectors of the prevailing system of botanical classification have not been influenced in any marked degree by the idea of development in vegetable life. Few of the earlier ones had ever heard of development, and those who had heard of it rejected it as a visionary theory. This system had become established long before the doctrine of the fixity of species had received a shock, for although Lamarck, himself a botanist, had sown the seed of its ultimate overthrow, still it required half a century for this seed to germinate, and it was during this half century that the Jussiæan system was supplanting the Linnæan and gaining a firm foothold.

It is our special task to examine this system by the light of the now universally accepted laws of development and to see in how far it conforms to those laws. We shall see that, with a few important exceptions and some unimportant ones, this purely logical classification is in substantial harmony with what we now believe to be the order demanded by the law of descent—an encouraging fact as showing that natural truth may often be correctly discerned by purely rational processes. Had Jussieu been told that the Monocotyledons and Dicotyledons were the direct descendants of the Acotyledons he would probably have treated the proposition with contempt. In his system the latter were placed before the former merely because they represented a lower grade of organization, and it was the relative grades of organization that determined the position of the minor as well as of the major groups throughout the Jussiæan system.

5. MODIFIED SYSTEM PROPOSED.

Now, therefore, that we have been compelled, from an entirely different class of evidence, to accept the fact of descent, we are glad to find that this does not wholly revolutionize the system arrived at from considerations of structure alone, while at the same time we must claim that this substantial agreement furnishes a strong corroboration of the theory of descent.

The following table may be taken to represent, so far as the tabular form will permit, the system of classification called for by the present known facts of structural botany and of paleontology.

Assumed natural system.

Cryptogams.			
Phænogams.	Gymnosperms.	Cycadaceæ.	
		Coniferæ.	
		Gnetaceæ.	
	Angiosperms..	Monocotyledons.	
		Dicotyledons.	Apetalæ.
			Polypetalæ.
			Gamopetalæ.

A glance at this table will show that the most important respect in which it differs from the one last examined is in the position and rank of the Gymnosperms. Whereas there the Gymnosperms and Angiosperms have only the rank of *subclasses* under the class Exogens, or Dicotyledons, they here assume the rank of *classes*, and the Monocotyledons and Dicotyledons are reduced to subclasses under the class Angiosperms. The Gymnosperms are thus taken out of the Dicotyledons entirely. This is done because the distinction of open and closed ovaries is regarded as a class distinction, and the Monocotyledons are as truly Angiosperms as are the Dicotyledons, since they possess the closed ovary; because the Gymnosperms are not dicotyledonous, the number of cotyledons varying from one to fifteen; and because, while all Gymnosperms are not strictly exogenous nor all Monocotyledons strictly endogenous, the woody structure of the Coniferæ differs fundamentally from that of all dicotyledonous plants. But a discussion of these points would carry us too far.

It will also be perceived that the order proposed by Adrien de Jussieu for the divisions of the Dicotyledons is here adopted, the reasons for which have already been referred to and will receive more special attention hereafter.

6. CLASSIFICATION OF THE CRYPTOGAMS.

Thus far we have considered the Cryptogams as an undivided group of plants; but they too are capable of subdivision. The classification of the Cryptogams, however, is still in its infantile stage and is the problem which is at this moment most earnestly claiming the attention of advanced botanists. The subject is too special to be entered into here, and I shall confine myself to naming a few of the groups which modern investigation has shown to throw some light upon the more general problem of descent in plant life.

That the first proper plants were cellular Cryptogams there is no question, and to that class still belong a great number and variety of forms, the seaweeds, fresh-water algæ, fungi, lichens, liverworts, mosses, etc. From these have in all probability descended the vascular Cryptogams, now chiefly represented by our ferns, club mosses, and scouring rushes. Leaving the cellular Cryptogams undivided, we will consider some of the groups of the vascular Cryptogams. The great preponderance of these forms of vegetal life throughout Paleozoic time renders this necessary, notwithstanding their insignificance at the present epoch.

As in the present, so throughout the past, the vascular Cryptogams are prominently divided into three great groups, which may be roughly designated as the fern group, the Calamite group, and the Lepidodendron group. Ancient ferns differed from those with which we are acquainted in being nearly all arborescent, or tree-ferns. The great Calamites of the coal-measures are now represented solely by our genus *Equisetum*, or scouring rush, while the *Lepidodendron* had degenerated into our little ground-pines and club-mosses (*Lycopodium*).

A careful study of the fossil remains of the Calamites and lepidodendroid growths of the Carboniferous period shows clearly that they were then much more closely related to each other than are the present Equisetaceæ and Lycopodiaceæ, and there can be little doubt that strictly intermediate forms existed. We may therefore class them together under a larger general group, to which we will give the name *Lepidophytes*. There is also a suggestive resemblance between some of the tree-ferns and certain of the Calamites, so that far back in that hoary antiquity of vegetable life we find a certain homogeneity and monotony, which show that those plant-forms as we now understand them were to a large extent undifferentiated and blended together.

Two small orders of cryptogamic vegetation, too rare to be frequent in a fossil state, and, indeed, unless formerly much more robust than now, too frail to admit of preservation except under the most favorable circumstances, possess for the modern cryptogamic systematist an extraordinary interest. These are the Rhizocarpeæ, or pepperworts, now chiefly represented by *Salvinia*, *Marsilia*, and *Azolla*, and the Ligulatæ, to which belong only *Isoetes*, the quillworts, and *Selaginella*. The reason for this special interest lies in the fact that the plants of these two orders, alone of all Cryptogams, possess characters which seem to mark the transition from the cryptogamic mode of reproduction to that of the Gymnosperms. In this the Rhizocarpeæ are supposed to approach more closely to the Cycadaceæ, while the Ligulatæ simulate rather the Coniferæ. On account of this exceptional prominence of these two orders I give them a separate place in the following table of classification of the Cryptogams:

Cellular Cryptogams.		
Vascular Cryptogams.	Filicineæ......	Filices (Ferns). Rhizocarpeæ.
	Lepidophytæ..	Equisetineæ. Lycopodineæ. Ligulatæ.

By uniting this table with the one last examined a somewhat complete view of the classification warranted by the present knowledge of plant life may be gained.

7. GEOGNOSTICO–BOTANICAL VIEW OF THE PLANT LIFE OF THE GLOBE.

We will now attempt to marshal in as convenient a form as possible the principal facts which paleòntology and modern botany afford, with a view to examining their bearings upon the problem of classification in general and upon those of descent and development in particular. In doing this we are compelled to depend upon the weight of evidence furnished by the *number of species* alone, since it is impossible to take account of the relative predominance of species, however great and important the differences may be in this respect. The number of species really marks the degree of variety or multiplicity, which certainly forms a rude index to the degree of abundance or prominence. Where a number of types are compared this difference in their degree of variety may fairly be assumed to apply to all alike, and the conclusions thus drawn will be measurably accurate; and in general this multiplicity of varying forms under larger types may be taken in a manner to represent the relative exuberance or luxuriance of the type, and thus roughly to indicate its relative predominance as a form of vegetation.

In all attempts to argue from paleontology allowance must, of course, be made for the imperfection of the geological record, and in no department is this imperfection greater than in that of plants. Yet it is certainly remarkable how large a portion of the earth's surface has, at one epoch or another, presented the conditions which have proved favorable to the preservation of vegetable remains. Our surprise at this is heightened when we contemplate the present state of the globe upon which that condition seems scarcely to exist. We know that the great land areas of our continents are wholly incapable of preserving the leaves that annually fall upon them, and it is only in the quiet beds of rivers that have reached their base level, or in their deltas, or else in localities where tufa-laden spring water flows over vegetation, or lastly, in our great swamps, that such a result is possible. This last condition is believed to furnish the key to the solution of the problem of most of the ancient vegetable deposits, but the limits of this paper forbid me to enter into a discussion of this subject.

The following table presents in a rough manner the history of the introduction of plant life upon the globe as revealed by the remains that have actually been discovered. It has been compiled from about 25,000 species slips which have been the product of nearly two years' labor in cataloguing the literature of Paleobotany. Although this work is by no means completed, still, it embraces nearly all the more recent and more important works on the subject, and hence cannot fall far short of affording a correct view of the present state of knowledge of the fossil flora of the globe.

Number of species of each of the principal types of vegetation that have been found fossil in sible to ascertain; together with the percentage that

Geological formations.			CRYPTOGAMS.											
			Cellular.		VASCULAR.									
					Ferns.		Rhizocarpeæ.		Equisetineæ.		Lycopodineæ.		Ligulateæ.	
			Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.
Present time			35,000	23.89	3,000	2.05	100	0.07	30	0.02	500	0.34	400	0.27
Cenozoic.	Quaternary		27	33.3	4	4.9			2	2.5				
Cenozoic.	Tertiary.	Amber	37	55.2										
Cenozoic.	Tertiary.	Pliocene			3	3.1								
Cenozoic.	Tertiary.	Miocene	168	5.5	87	2.9	6	0.2	18	0.6			2	0.06
Cenozoic.	Tertiary.	Oligocene	17	2.2	17	2.2	1	0.1	3	0.4				
Cenozoic.	Tertiary.	Green River	5	2.2	8	3.5	2	0.9	3	1.3	1	0.4	1	0.4
Cenozoic.	Tertiary.	Eocene	71	10.3	22	3.2			1	0.2				
Cenozoic.	Tertiary.	Paleocene	3	2.5	7	5.9								
Mesozoic.	Cretaceous.	Laramie	13	3.9	23	6.9	1	0.3	4	1.3	1	0.3	3	0.9
Mesozoic.	Cretaceous.	Senonian	23	6.5	73	20.6			1	0.3				
Mesozoic.	Cretaceous.	Turonian	1	20.0	1	20.0								
Mesozoic.	Cretaceous.	Cenomanian	8	3.3	38	15.5	1	0.4	1	0.4			1	0.4
Mesozoic.	Cretaceous.	Dakota	1	0.5	7	3.3								
Mesozoic.	Cretaceous.	Gault			10	27.8								
Mesozoic.	Cretaceous.	Urgonian			50	46.3	1	0.9	3	2.8	1	0.9		
Mesozoic.	Cretaceous.	Neocomian	10	25.6	12	30.8								
Mesozoic.	Jurassic.	Wealden	7	5.8	44	36.4								
Mesozoic.	Jurassic.	Coral	19	29.2	12	18.4								
Mesozoic.	Jurassic.	Oolite	39	9.3	133	31.7	1	0.3	14	3.3	3	0.7		
Mesozoic.	Jurassic.	Lias	13	9.7	44	32.8			4	3.0				
Mesozoic.	Jurassic.	Rhetic	8	6.3	69	54.3			5	3.9				
Mesozoic.	Trias.	Keuper			15	36.6			3	7.3				
Mesozoic.	Trias.	Muschelkalk	2	33.3	1	16.7								
Mesozoic.	Trias.	Bunter Sandstein			7	31.9			1	4.5				
Paleozoic.		Permian	6	1.8	186	55.4			26	7.7	9	2.7		
Paleozoic.		Carboniferous	17	1.2	627	42.4			143	9.7	368	24.9		
Paleozoic.		Subcarboniferous	5	3.7	64	47.4	1	0.8	20	14.8	25	18.5		
Paleozoic.		Devonian	33	17.6	79	42.0	3	1.6	16	8.5	28	14.9		
Paleozoic.		Upper Silurian	8	61.5	2	15.4			1	7.7	1	7.7		
Paleozoic.		Lower Silurian	40	90.9	1	2.3			1	2.3	2	4.5		
Paleozoic.		Cambrian	2	100.0										

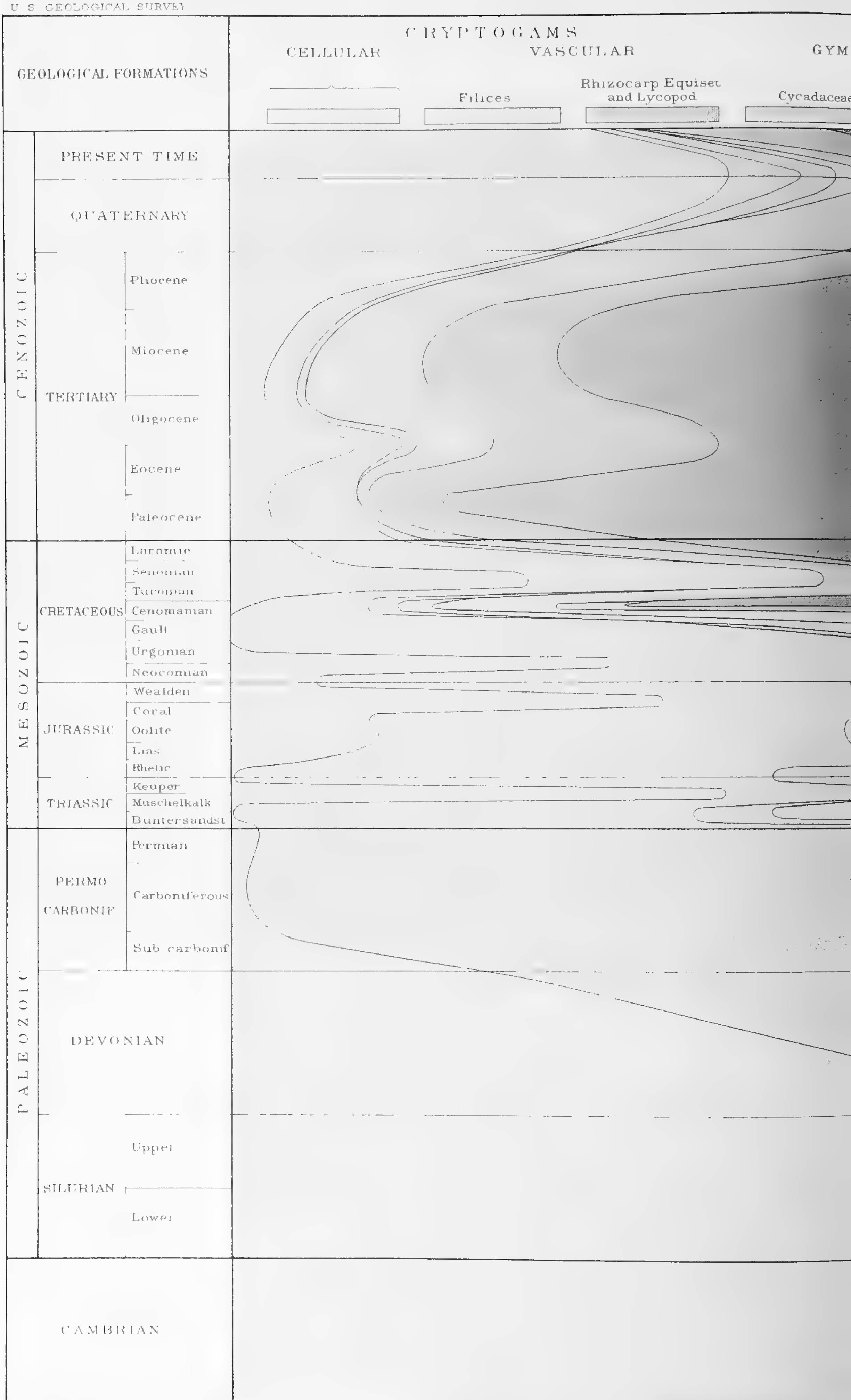
each geological formation, also the number existing at the present time as nearly as it is pos-
each type forms of the total flora of each formation.

PHÆNOGAMS.														Total.
GYMNOSPERMS.						ANGIOSPERMS.								
Cycadaceæ.		Coniferæ.		Gnetaceæ.		Monocotyledons.		Dicotyledons.						
								Apetalæ.		Polypetalæ.		Gamopetalæ.		
Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.
75	0.05	300	0.24	40	0.03	20,000	13.65	12,000	8.19	35,000	23.89	40,000	27.31	146,445
2	2.5	4	4.9	......	......	......	......	27	33.3	8	9.9	7	8.7	81
......	......	14	20.9	1	1.5	2	3.0	5	7.5	1	1.5	7	10.4	67
......	......	13	13.3	......	......	9	9.2	32	32.6	31	31.6	10	10.2	98
6	0.2	250	8.2	1	0.04	272	8.9	826	27.1	1,064	35.0	346	11.3	3,046
2	0.3	64	8.3	1	0.1	82	10.6	256	33.1	259	33.6	70	9.1	772
......	......	10	4.4	......	......	21	9.2	85	37.1	73	31.9	20	8.7	229
3	0.4	34	4.9	......	......	116	16.8	162	23.5	221	32.1	59	8.6	689
......	......	1	0.8	......	......	7	5.9	57	47.9	39	32.8	5	4.2	119
1	0.3	15	4.5	......	......	33	9.9	125	37.5	84	25.2	30	9.0	333
5	1.4	34	9.6	......	......	18	5.1	118	33.3	64	18.1	18	5.1	354
......	......	1	20.0	......	......	......	......	......	......	2	40.0	......	......	5
11	4.5	28	11.4	......	......	6	2.5	61	25.0	82	33.7	7	2.9	244
7	3.3	12	5.6	......	......	5	2.4	88	41.3	84	39.4	9	4.2	213
2	5.5	22	61.2	......	......	2	5.5	......	......	......	......	......	......	36
21	19.4	25	23.2	......	......	6	5.6	1	0.9	......	......	......	......	108
6	15.4	9	23.1	......	......	2	5.1	......	......	......	......	......	......	39
43	35.5	26	21.5	......	......	1	0.8	......	......	......	......	......	......	121
17	26.2	17	26.2	......	......	......	......	......	......	......	......	......	......	65
116	27.7	103	24.6	1	0.3	9	2.1	......	......	......	......	......	......	419
58	43.3	10	7.5	......	......	5	3.7	......	......	......	......	......	......	134
26	20.5	18	14.2	......	......	1	0.8	......	......	......	......	......	......	127
15	36.6	7	17.1	......	......	1	2.4	......	......	......	......	......	......	41
......	......	3	50.0	......	......	......	......	......	......	......	......	......	......	6
3	13.6	7	31.8	......	......	4	18.2	......	......	......	......	......	......	22
14	4.1	92	27.4	......	......	3	0.9	......	......	......	......	......	......	336
8	0.5	307	20.8	......	......	8	0.5	......	......	......	......	......	......	1,478
......	......	20	14.8	......	......	......	......	......	......	......	......	......	......	135
......	......	29	15.4	......	......	......	......	......	......	......	......	......	......	188
......	......	1	7.7	......	......	......	......	......	......	......	......	......	......	13
......	......	......	......	......	......	......	......	......	......	......	......	......	......	44
......	......	......	......	......	......	......	......	......	......	......	......	......	......	2

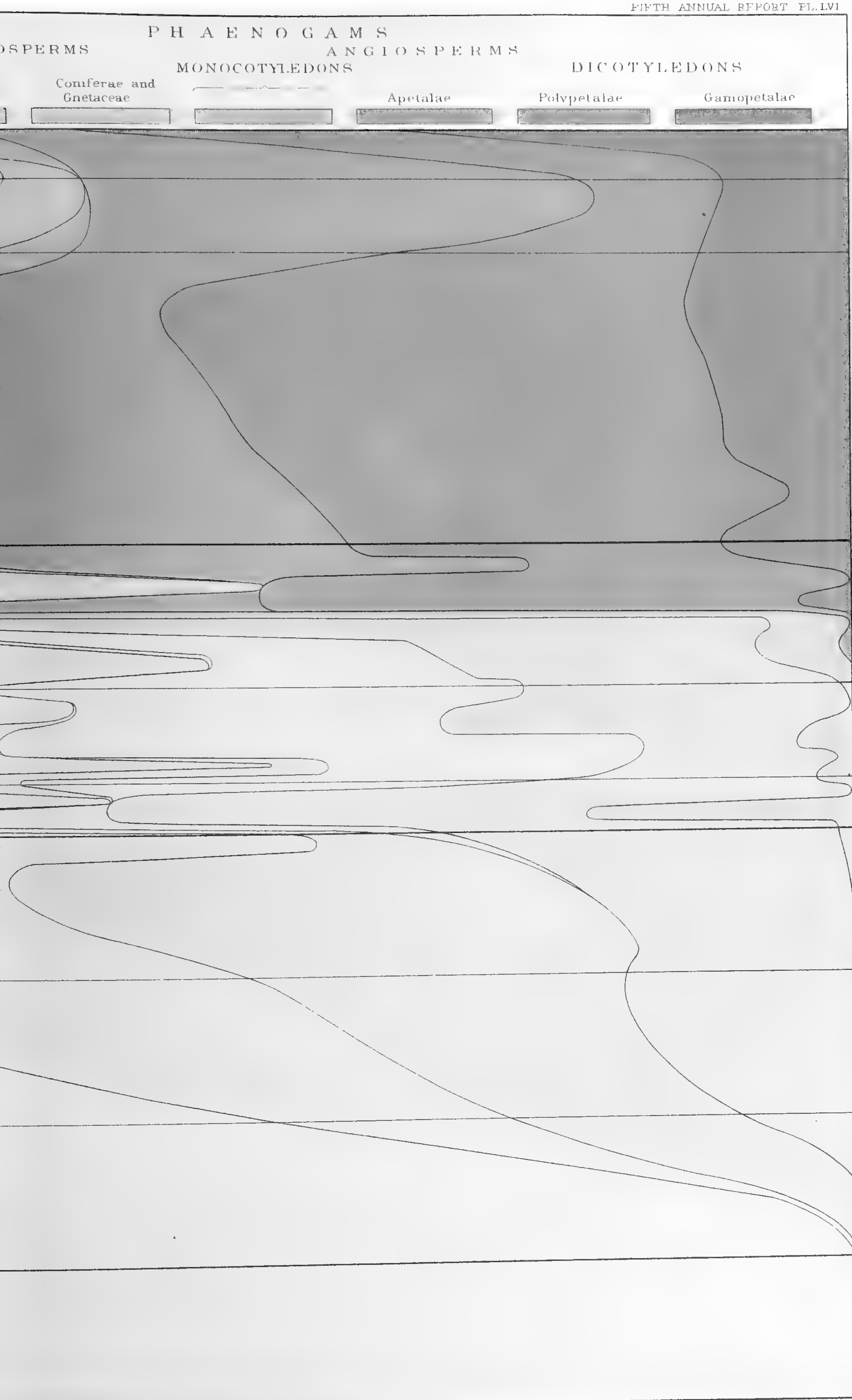
Before entering upon a general survey of the development of plant life as shown in this merely numerical exhibit, it will be necessary to refer the reader to three diagrams (plates LVI, LVII, LVIII), which have been prepared with a view to rendering the principal facts embraced in the table more readily intelligible, and then to discuss each of the diagrams separately, keeping the numerical data constantly in view. For the execution of these diagrams I am indebted to Ensign Everett Hayden, United States Navy, on duty at the National Museum in the Department of Fossil Plants, who has not only plotted and drawn them, but has aided me greatly in selecting from among the many possible modes of graphic illustration the ones which, as I believe, most successfully serve this purpose.

In all the diagrams an effort is made, of course in an approximate and very rude manner, to indicate time-measures in terms of thickness of strata, this being, however imperfect, certainly the only standard attainable. In a lecture delivered at the National Museum on February 24, 1883, on *Plant Life of the Globe, past and present*, enlarged diagrams having a similar object to those introduced here were used for illustration. The data then obtainable for their preparation were very defective, and the time-measures were taken from Dana's "Manual of Geology." Those who may remember them, from notes taken or otherwise, will observe that in this latter respect the accompanying diagrams differ widely from the ones presented on that occasion. Upon investigation it appears that the views of geologists generally have changed materially since the appearance of the last edition of that work, and recent observations have tended to show that the thickness formerly assigned to Mesozoic, and especially to Tertiary, strata was much too small in proportion to that assigned to Paleozoic, and especially to Silurian strata. After consultation upon this subject with the Hon. J. W. Powell, Director of the Survey, it was decided that nearly equal vertical space might be given to each of the following formations, or groups: 1, Cambrian; 2, Silurian; 3, Devonian; 4, Permo-Carboniferous; 5, Jura-Trias; 6, Cretaceous; 7, Eocene; 8, Mio-Pliocene. These have accordingly been taken as furnishing the scale of time equivalents, and all the diagrams have been drawn to this scale.

The development of vegetable life through geologic time may be discussed from three somewhat distinct points of view. We may, in the first place, consider each of the principal types of vegetation at each of the geologic periods in which it occurs solely with reference to its relative importance in the combined flora of that epoch. This is undoubtedly the most important point of view from which the subject can be contemplated, and has accordingly been considered first. It is clear that the data for this must consist, not in the actual number of species at each horizon, but in the proportion, or percentage, which this number forms of the total number found at such horizon. Diagram No. I is, therefore, based upon these percentages as given in the foregoing table.


GEOLOGICAL FORMATIONS
CRYPTOGAMS
CELLULAR
VASCULAR
Filices
Rhizocarp Equiset and Lycopod
GYM
Cycadaceae
PRESENT TIME
QUATERNARY
CENOZOIC
TERTIARY
Pliocene
Miocene
Oligocene
Eocene
Paleocene
MESOZOIC
CRETACEOUS
Laramie
Senonian
Turonian
Cenomanian
Gault
Urgonian
Neocomian
JURASSIC
Wealden
Coral
Oolite
Lias
Rhetic
TRIASSIC
Keuper
Muschelkalk
Buntersandst
PALEOZOIC
PERMO CARBONIF
Permian
Carboniferous
Sub carbonif
DEVONIAN
SILURIAN
Upper
Lower
CAMBRIAN

E H del



Julius Bien & Co Lith

In the second place, we can consider each type of vegetation by and in itself, with a view to determining the geological age in which it first made its appearance, the general nature of its progress through time, and the period of its maximum actual development as an element of the vegetation. Such a presentation, however, when based on the number of species actually found at each horizon, exhibits very great fluctuations, due to the irregularities in the record. These irregularities depend chiefly upon conditions quite independent of the real presence or abundance of the plants in any formation. These conditions are many, but the principal ones may be embraced under three heads: 1. The plants must have existed at the period in question. This is the legitimate assumption and alone gives value to the diagram. 2. The conditions for their preservation and then for their subsequent exposure must have occurred. Any one can see how exceedingly irregular must be these delicate conditions at different ages of the world. 3. The localities in which they are embedded must have been discovered and worked by the paleontologist. This is the great contingency which stands in the way of our acquaintance with any flora, but although doubtless more potent than the one last named, it possesses the merit of possible removal through the industry of man.

With all these detractions from its value this form of illustrating the geological record is nevertheless presented in Diagram No. II.

In the third place, we may, by a legitimate exercise of the rational method of science, construct a scheme of illustration, based indeed upon these facts as indispensable landmarks, yet recognizing the law of uniformity in natural processes that constitutes the primary postulate of science itself, which shall, to a large extent, eliminate the error of the defective record and present a rational and highly probable view of the true development. By a second act of ratiocination the probable period of first appearance of each type of vegetation may be deduced from the fact as to the earliest point at which it has actually been discovered, and thus an approach far nearer, at least, to the true history of plants than is possible by the last-named method may be made. Diagram No. III presents the subject from this third point of view.

Discussion of Diagram No. I.—In this diagram the Cryptogams are represented in buff tints and the Phanerogams in purple, with deeper shades for the successively higher types of each series. The diagram is based upon the assumption of the proportionate representation of types in the known floras of each age. Collectors of fossil plants never select. They take everything they find and make no attempt to find particular forms. If, therefore, the chances of preservation of different kinds of plants were equal the chances of finding any particular kind would depend upon its actual degree of abundance in the given flora. Conversely, the degree to which any type of plants is represented in the collections made would be a fair measure of such abundance or of the relative prominence of the type in the flora of the given epoch. However imperfectly such a flora was represented in the collections, this relation would theoretically hold, and thus the imperfection of the geological record would be eliminated so long as it was only contemplated from this relative stand-point. And although it is not true that all kinds of plants stand an equal chance of preservation, still the classification of plants according to their adaptability to preservation is wholly different from their systematic botanical classification and traverses the latter in such a manner as rarely to coincide with its boundary lines or to exclude any entire group from the possibility of being represented in the fossil state. Nevertheless, such omissions, or at least very disproportionate representations, will occur and must be allowed for. The theory also fails where a flora is only very meagerly represented, and the smaller the representation the less applicable the principle. This accounts for certain great irregularities in the diagram, which are greatest in the least adequately represented formations. Such defects will be readily rectified by the intelligent student of the diagram, and it was thought better to leave this to his judgment than to attempt to overcome the defects by an arbitrary reduction of irregularities. The numerical table will aid in making the proper allowance in each case by indicating, as the diagram cannot do, the poorly-represented horizons. Upon the whole this diagram may be regarded as trustworthy in intelligent hands and as fairly indicating all that is claimed for it.

That vegetable life should have preceded animal life is a fair deduction from all that we know of these two kingdoms of nature, and, not to speak of the much-disputed *Eozoon Canadense* of Canadian so-called Azoic rock, we at least have *Oldhamia* in the Cambrian, whose organic character is quite generally admitted. This and other facts give weight to the view that the dark carbonaceous substance found in the Laurentian has been the result of accumulated vegetable matter of marine origin, but too frail in structure to admit of preservation in any other form. Graphite, too, which is a pure form of carbon, and thus almost demonstrates vegetable origin, is found below the Silurian. But, dismissing these speculations and admitting the somewhat doubtful vegetable character of *Oldhamia*, we actually have organized plants, marine algæ, preserved in the Lower Silurian and even at its base. Such are *Bilobites rugosa*, *Chondrites antiquus*, and *Sphaerococcites Scharyanus*. The Cellular Cryptogams are thus fairly introduced at points lower than that of the appearance of any higher type of vegetation, and by the close of the Silurian fifty species had made their appearance, constituting 85 per cent of all the life of that epoch as thus far found. Not only in this case, but all through the series, the order in which these great types of vegetation are here drawn up agrees substantially with that of their appearance on the globe, as shown by actual specimens collected and determined. If the system of classification had been based exclusively upon paleontological data, there would be no force in this, but, as I have shown, it is in large measure that of botanists proper who never argue from paleontology, and most of the points in which it differs from accepted botanical systems have been independently confirmed by structural botanists.

More remarkable still, perhaps, than the early appearance of marine algæ is that of certain well-organized vascular plants that must have inhabited the land. Among the earliest forms of terrestrial vegetation we find the ferns, those graceful forms whose green, airy fronds are still the delight of every judge of natural beauty. We have at least one well-authenticated species in the Silurian—*Eopteris Morierii* of Saporta—found by Morière a few years ago at the base of the Middle Silurian, a gilt figure of which its namer has made the frontispiece of one of his last works.[246] The fern may be almost taken to represent the primary form of the vegetative process. Its delicate spray resembles, most of all plant-forms, the exquisite frost-work which we see on our windows on a cold morning. The physicists tell us that these latter are the result of molecular activities and consist in the deposit of solidified molecules of invisible vapor. Plant-growth consists in the deposit of solidified carbon molecules upon the growing surfaces of plants. Perhaps, then, we should not wonder at the resemblance between the earliest forms of plant life and those other forms which nature creates by the action of the same principle, and which the chemist can imitate in certain modes of precipitation.

In the Devonian we have 79 species of ferns, and this type of vegetation reaches its maximum in the Carboniferous epoch, which, if we extend it to include the Subcarboniferous and the Permian, furnishes 877 species, forming nearly 45 per cent of the total flora of that epoch. There are good reasons for supposing that during this age the ferns were nearly all arborescent and really formed a large part of the Carboniferous forests. From this time forward they declined both in number and vigor until, at the present time, they are only 2 per cent of the vegetation of the globe, and in nearly all cases consist of low herbaceous plants, almost valueless except for their singular beauty.

Let us next consider the type which is here denominated the *Equisetineæ*. At the present time the natural order *Equisetaceæ* embraces all the plants of this group, and they are very few indeed and insignificant in size, but in the Carboniferous age they formed nearly 10 per cent of the vegetation, and furnished the great Calamites, which clearly show that they were no mean element in the forest growth of that period. Certain plants of this group—*Sphenophyllum primævum*, *Annularia Romingeri*—were found by Mr. Lesquereux in the Cincinnati group of the Silurian, an horizon, perhaps, lower than that of *Eopteris*, and we must therefore regard this type as of exceedingly ancient origin. The Calamites disappear entirely in Mesozoic time and the type dwindles into insignificance.

[246] Le Monde des Plantes avant l'apparition de l'homme. Paris, 1879. (See pp. 35, 166.)

The *Lycopodineæ*, now represented by the natural order *Lycopodiaceæ*, and constituting little more than one-third of 1 per cent of the living vegetation of the globe, embraced in the Carboniferous epoch the lepidodendroid group. About four hundred species of these plants have been described from the Subcarboniferous to the Permian, and during their reign they formed nearly one-fourth of the vegetation of the globe. They were the largest forest trees of their time, and sometimes attained a great size, though, of course, nothing approaching the giants of our present forests. This ancient, or archaic, type disappears entirely with the Permian, and never reappears. Its degenerate descendants continue down to the present, chiefly in the form of club mosses, of which considerable variety exists.

The two remaining groups of cryptogamic plants, the *Rhizocarpeæ* and the *Ligulatæ*, possess little paleontological importance, although the number of species, including spore-cases, that have been referred to the former of these orders has now reached seventeen, four of which are Paleozoic (Devonian and Subcarboniferous) and four Mesozoic. These, as well as most of the Miocene species, belong to the genus *Salvinia* or one nearly allied to it (*Protosalvinia* Dawson), although one *Pilularia* has been found at Œningen, and a true *Marsilia* occurs in an undescribed collection now in my hands, made by Captain Bendire in the Miocene of the John Day River region, Oregon, and which I propose to call *Marsilia Bendirei*, should there prove to be no inaccuracy in this determination.

As regards the *Ligulatæ*, they are still less frequent in the fossil state, and are thus far represented only by the two very dissimilar genera, Selaginella and Isoetes. Unless, as has been affirmed, the former of these genera has its representatives in the Carboniferous, the group is not found lower than the Cenomanian of Atane, Greenland, where Heer has detected his *Selaginella arctica*. Mr. Lesquereux has described three species of this genus in the Laramie group, and the same author has found a true *Isoetes* in our Green River Eocene, at Florissant, Colorado. Two more species of Isoetes from the Miocene of Europe exhaust the enumeration, making in all only seven species of Ligulatæ.

We have thus rapidly glanced at the relative development of each of the cryptogamous types of vegetation, and will next consider that of the phanerogamous types. As already shown, the Gymnosperms stand lowest, and have probably, in some still undiscovered way, descended from the Cryptogams. Of these we place the Cycadaceæ lowest on account of their endogenous growth, circinate estivation, and other characteristics which seem to ally them to the ferns. Still, as the lines are now drawn by the best authorities, the Cycadaceæ cannot be traced below the Carboniferous, while the archaic progenitors of the Coniferæ extend far down into the Silurian. If we refer the *Medullosæ* to the ferns, as Renault and Grand' Eury would have us do, only three cycadaceous plants occur in the Carboniferous; but one of these is a true

Pterophyllum from the coal measures of China, and there is probably a second from Europe. Fourteen species occur in the Permian, including the typical genera *Dioonites* and *Clathraria*. It is not, however, until the Keuper is reached that this type of vegetation assumes a leading part, and throughout the Jurassic it continues to be the most abundant form of plant life. In the Lias it forms 43 per cent of the flora of that formation, though this may be accidentally exaggerated. It was 28 per cent of the Oolitic flora and more than 35 per cent of that of the Wealden. From this point, however, its decline was rapid and uninterrupted until in the living flora only 75 species of cycadaceous plants are known to botanists. Of these North America can claim but a single one, the sago-palm (*Zamia angustifolia*) of our extreme Southeastern States.

Passing to the Coniferæ, we find the *Cordaites Robbii* of Dawson from the Devonian of Canada recurring in the Upper Silurian of Hérault. This genus was formerly supposed to be the prototype of the Cycadaceæ, but, as already remarked, this opinion is now abandoned by the best authorities, and the genus referred to the Coniferæ. The evidence upon which this change rests cannot be presented here, but it is proper to say that the savants who have marshaled it have done so in such a manner as to render their conclusion akin to irresistible. But its adoption has carried with it a train of consequences which cannot be escaped. Not *Cordaites* alone, or with its spore-bearing parts (*Cordaianthus*) and its fruit (*Cordaicarpus*), but *Nœggerathia*, *Trigonocarpus*, *Cardiocarpus*, *Rhabdocarpus*, *Sternbergia*, *Artisia*, etc., must all follow in its wake and be gathered, one and all, into the great family of the Coniferæ. It is thus, as shown by our table and diagram, that this type assumes such a commanding position far back in Paleozoic time, forming about one-fourth of the vegetation of the Permo-carboniferous epoch. Doubtless this effect is exaggerated by duplications caused by giving different names to separate parts of the same plant, but this occurs throughout the series only to a less obvious degree.

The true Coniferæ, which have some representatives in the Paleozoic, replace the *Cordaiteæ* entirely in the lower Trias and thereafter vie with the Cycadaceæ for supremacy, which they do not fairly attain until the lower Cretaceous is reached. Being of a higher type of structure than the latter by reason of their exogenous mode of growth and other peculiarities, they refuse to succumb in competition with the now rising Angiosperms and continue to hold their own through much of the Tertiary. At the present time the number of known species (300) would denote a great decline, but this is in large part made up by the wonderful predominance and territorial expansion of these persistent forms. Although from the point of view of the number of species alone, the present Coniferæ would form but one-fourth of 1 per cent of the vegetation of the globe, we in fact find vast tracts of country covered with pine, fir, and spruce forests, excluding almost completely all other types. But that the pine family is now waning there can be no doubt. Important forms have wholly disappeared, and others that once were abundant have now nearly vanished from the earth. Of this last truth an example of unusual interest is furnished by the genus *Sequoia*. Of the score or more of species that made up so large a part of American Tertiary forests our well-known "big tree" of the Sierras (*S. gigantea*) and our California red-wood (*S. sempervirens*) now stand alone and continue the combat against fate—the closing struggle of a dying race.

Of the *Gnetaceæ* I need not here speak, as its paleontological record is almost *nil*, and its importance depends upon circumstances wholly disconnected from its prevalence as a type of vegetation.

We come now to the Angiosperms. A great step forward had been taken, and in her solicitude for her offspring Nature had, as it were, built a house over the hitherto unprotected germs of plant life. The closed ovary marks an era in the march of vegetal development.

The earliest form in which the Angiosperms appeared was that of the Monocotyledon. Issuing from the seed and from the ground as a single spear or blade, the plants of this type grow up chiefly by an internal circulation which can only deposit nutrition at the apex (endogenous growth). As the lowest type of Angiosperms we find them, according to our scheme of classification, occupying also the earliest position in the stratified deposits of the earth's crust.

The existence of Monocotyledons in the Carboniferous and Permian was long disputed, although Corda, after the most exhaustive study of their structure, was obliged to refer two species of endogenous wood to that subclass. This determination has been thus far sustained, and to these have been added *Palæospathe Sternbergii*, Unger, in the Carboniferous, and two other species in the Permian. The very problematical *Spirangium* has generally been regarded as the fruit of some Xyris-like Monocotyledon, and this view has been quite recently defended by Nathorst. Its occurrence in the Carboniferous is now also abundantly established by its discovery at Wettin, at Saint Etienne, and at Pittston, Pennsylvania. Certain lily-like forms, called *Yuccites*, are found in the lower Trias, and through the remaining Mesozoic these forms increase slowly and are reinforced by screw-pines and a few sedge-like plants. The monocotyledonous vegetation, however, does not receive any marked character until the advent of the great palm family, which dates from the Middle Cretaceous. From this time, notwithstanding the rivalry of the now dominant Dicotyledons, this type progressed, reaching its relative maximum in the Eocene. Overslaughed by the higher growths, it thenceforward declined, but still numbers some 20,000 species and forms over one-eighth of the total flora of the present epoch.

The step from the Monocotyledon to the Dicotyledon is very great, and it seems to have required a vast period of time to accomplish it.

Not only must a new form of growth from the seed and from the ground be developed, and a sort of bilateral symmetry be introduced, but in addition to this, and, as I believe, in great part due to it, the exogenous mode of circulation and tissue growth must supplant the endogenous one, whereby the stem may increase in thickness as well as in length. These great mechanical problems were worked out during Mesozoic time and in the Middle Cretaceous, represented in this country by the Dakota group, and in Europe by the Cenomanian epoch, the great type of plant life appeared which was destined to dominate the world and sink all other forms into insignificance. But the most astonishing fact is that this young giant was born, as it were, full grown. In this lowest horizon at which any Dicotyledons appear[247] we have already obtained more than three hundred species belonging to all three of the great divisions of the subclass, and exhibiting ample, luxuriant foliage. They embrace many of our most familiar forms, the poplar, the birch, the beech, the sycamore, and the oak. Here appears the fig tree, the true laurel, the sassafras, the persimmon, the maple, the walnut, the magnolia, and even the apple and the plum. We must conclude, then, that the Dicotyledons had a much earlier origin than is shown by our defective record, and that they had been long developing through the Mesozoic ages.

If now we follow the advancing wave of plant life from this point upward we shall see that from the new vantage-ground furnished by the closed ovary, the perfect flower, and the exogenous trunk, its march was rapid and steady until we reach the Miocene Tertiary, the culminating point in the paleontological series. Here the species actually found are numbered by thousands, and the higher types greatly predominate over the lower ones. But from this point the record begins to fail, and can no longer be trusted. Very little is found in the Pliocene, and still less in the Quaternary; but this cannot indicate an actual decline in these types of vegetation. It must be due to the approach of a state of things which rendered the preservation of vegetable remains difficult, a condition, as already remarked, which is especially characteristic of the present state of the globe. The march of the Dicotyledons was uninterrupted, and still continues. The figures given in the numerical table represent, in round numbers, the estimates of Messrs. Bentham and Hooker, as given in their "Genera Plantarum," and may, therefore, be taken as the most reliable that can be obtained. The three divisions of the Dicotyledons combined amount to 87,000 species, and constitute nearly 60 per cent. of the flora of the globe.

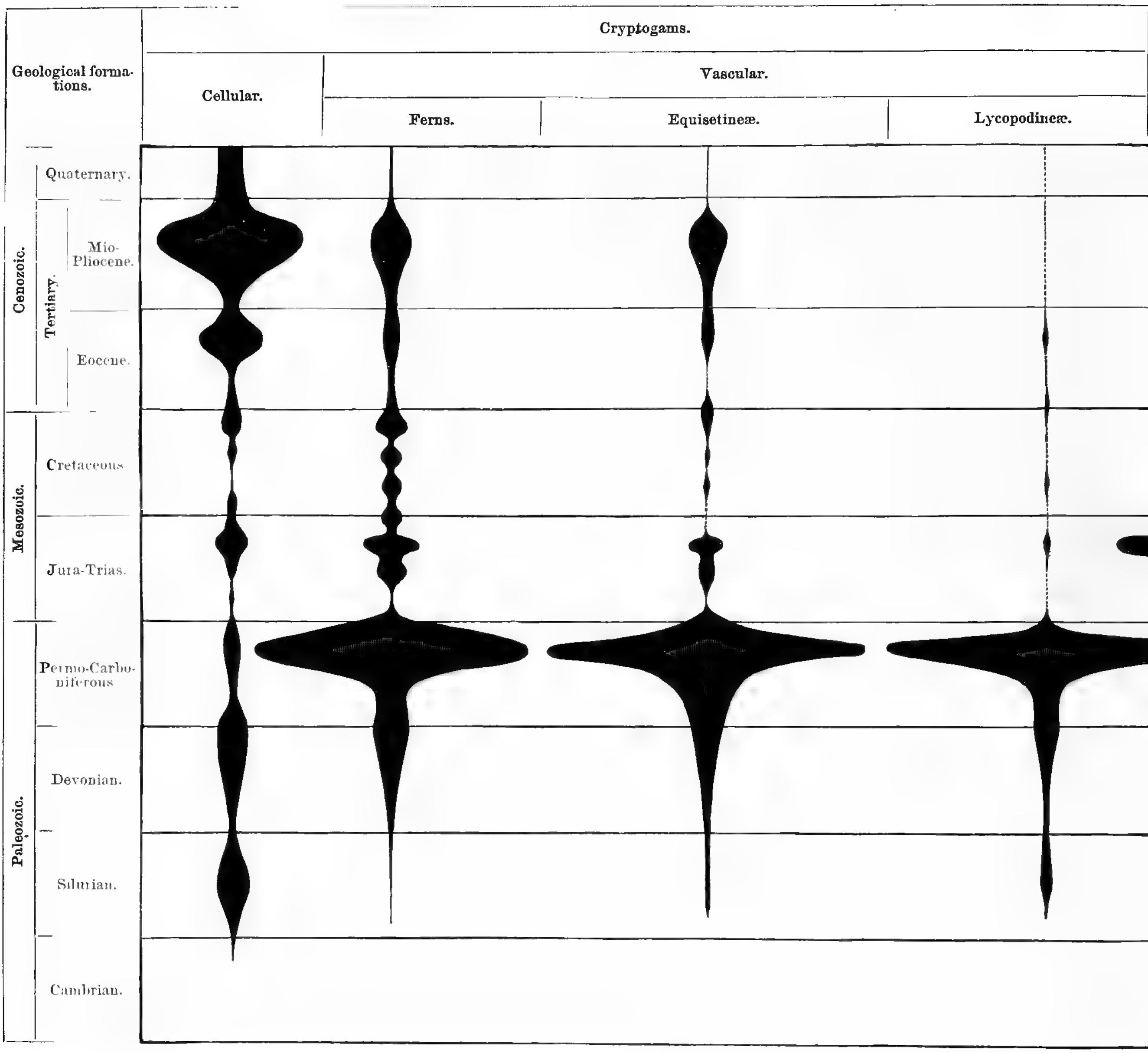
With regard to the three divisions of the Dicotyledons, although they are all represented in the lowest formation at which any considerable number are found, still the Apetalæ constitute a larger proportion of the Dicotyledons in the Cenomanian (45 per cent) than in the Miocene (37

[247] If we accept the solitary *Populus primæva*, Heer, from the Urgonian beds of Kome, Greenland.

per cent), and very much larger in the Tertiary than in the living flora (14 per cent), while the Gamopetalæ, which constitute only 5 per cent in the Cretaceous, reach 15 per cent in the Miocene, and 46 per cent in the living flora, here exceeding the Polypetalæ. From these facts it is evident that the order of development is such as I have here given it, and that the type of the future is to be not the Polypetalæ but the Gamopetalæ. These conclusions are independently corroborated by a large mass of evidence of other kinds, but space forbids me to adduce it in detail. I may simply say, however, that just as the closed ovary of the Angiosperm in general furnished a condition for the development of that class at the expense of the unprotected Gymnosperm, so the two floral envelopes of the Polypetalæ and Gamopetalæ enabled those divisions to outstrip the Apetalæ with its single floral envelope; and since this advantage is proportional to the degree of protection secured, the Gamopetalæ, with their tubular corollas are manifestly better adapted to survive in this respect than the Polypetalæ. This is the chief argument, and, putting it with that from paleontology, it seems sufficiently conclusive without detailed support.

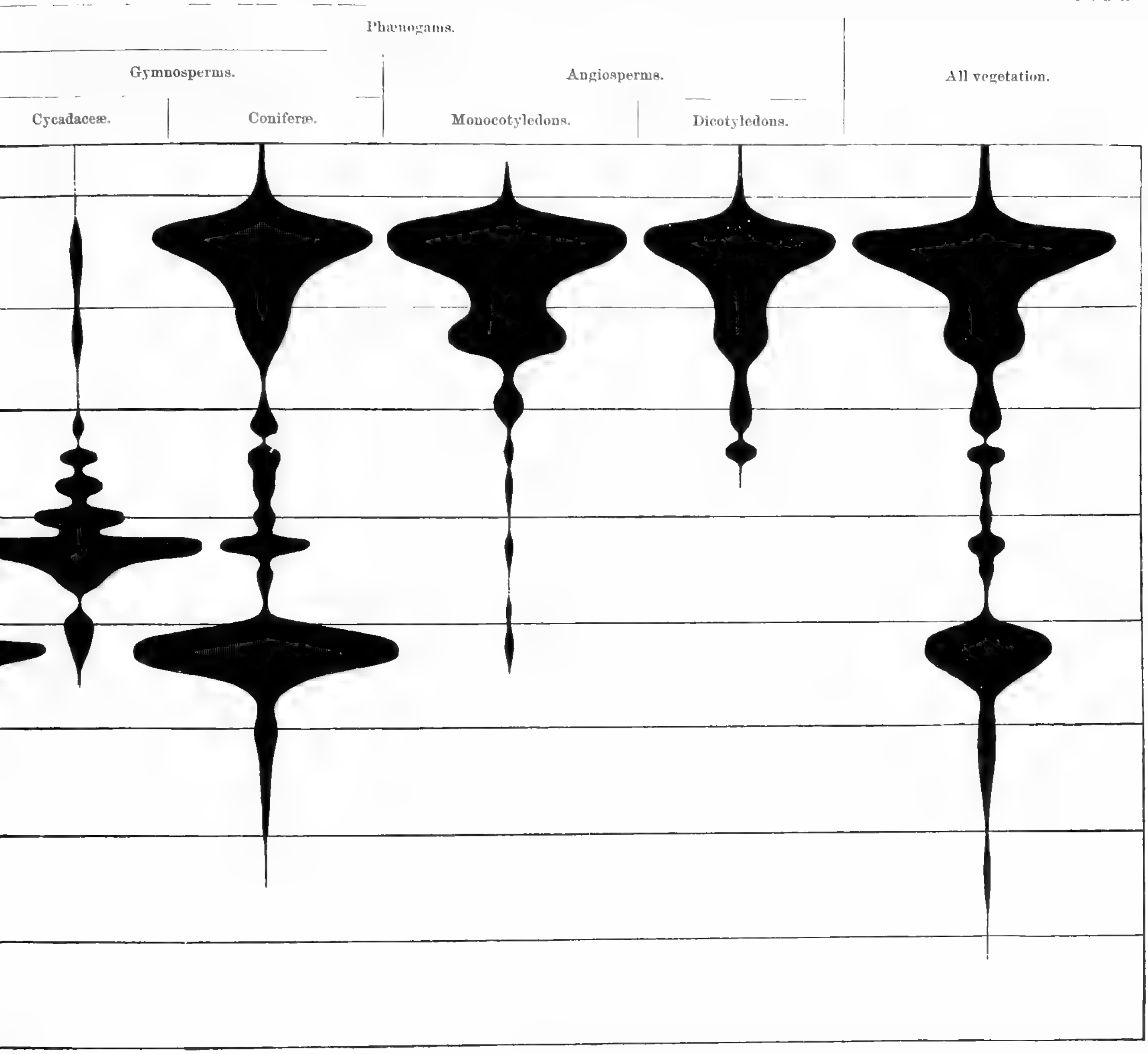
Discussion of Diagram No. II.—In this diagram the time equivalents are the same as in the last, but only the more important types are represented. The Rhizocarpeæ, Ligulatæ, and Gnetaceæ are omitted, and the Dicotyledons as a whole are shown, disregarding their subdivision into Apetalæ, Polypetalæ, and Gamopetalæ. A figure is added representing the total of all the formations, and this is probably the most important of them all, as least affected by the gaps and fluctuations in the record. No account could, of course, be taken of the living flora, as is done in Diagram No. I, for while between the fossil and the living floras there is a similarity in the proportion that the types in each bear to the sums of such floras, no such analogy holds between the number of species actually known in any fossil flora and the number in the living flora. This, at least, is true of the total floras and of all the types except, perhaps, the Cycadaceæ and the Coniferæ. But even here the comparison would fail to express the rapid decline which these forms have evidently undergone, at least so far as the number of their species, which represents their diversity, is concerned.

While the diagram is of little service as a means of representing the true development of each type of vegetation or of the general flora of past ages, it has considerable value as an exponent of the true character of the phyto-geologic record. It shows more clearly and more strikingly than any words or figures could do the great differences that characterize the different periods of geologic time in their susceptibility to deposit, preserve, and afterwards expose to scientific investigation the vegetable forms that constituted the floras of those periods. While this is well shown for the several dominant types it is especially obvious in the figure illustrating the entire flora. Here are brought prominently into view, first, the age of island vegetation in the Carbon-



DIAGR

SHOWING THE OBSERVED ORIGIN AND DEVELOPMENT OF



M No. 2.

HE PRINCIPAL TYPES OF VEGETATION IN GEOLOGIC TIME.

iferous; next, the second and still greater age of extensive marsh, vast low plains cut by shallow estuaries or partially or wholly cut off from the sea and forming brackish or fresh water deposits, which culminated in the Miocene; then, the two intermediate periods of only less favorable conditions occurring in the Brown Jura and the Cenomanian, respectively; and, finally, the long intermediate ages of less favorable or wholly unfavorable conditions and the abrupt termination of the entire period of plant deposition which accompanied the age of mountain building towards the close of the Tertiary. The almost complete absence of vegetable remains in the Trias, the lower Cretaceous, and the Turonian of both continents points to the probable general subsidence of land areas at those epochs, at least for such portions of the earth's surface as have been explored by paleontologists. But the great relative abundance of such life in the middle and again in the extreme upper Cretaceous shows that those must have been great land areas at all times—areas which are now either under the sea or belong to some of the still scientifically "unexplored regions" of the globe. The proof of this is made conclusive by the fact that new and higher types come forth abruptly in these floras which must have required ages of most favorable conditions for their prior development.

Discussion of Diagram No. III.—This diagram is simply the application of the rational scientific method to the incomplete facts afforded by the present infantile state of the science of fossil plants. It does not pretend to give the exact history of plant development, but only to constitute a certain advance in this direction beyond what the fragmentary data out of which it is constructed can alone furnish. For example, it is certain that the earliest record discovered by man of the existence of any type of vegetation cannot mark the absolute origin of that type, and it is therefore necessary in every case to project the type downward to an unknown distance. If the real facts could be indicated we should see during these unrecorded periods the actual transformations which must also be assumed to have taken place in each case before the fully-developed type could appear. This we are unable to represent, and must merely indicate the early history of each type by its downward projection to an assumed point of origin. Neither can it be supposed that the great fluctuations shown in the diagram last considered are due altogether or chiefly to fluctuations in the degree of vigor, territorial expansion, or local prominence of the given form of vegetable life. They are the results of varying geological conditions or of human good fortune, while the modifications in the forms themselves take place slowly and at uniform rates either in the ascending or the descending scale. Recognizing this law of uniformity, no fluctuations in any homogeneous type have been admitted, but simply a more or less regular development in each from its assumed point of origin to its supposed period of maximum predominance, followed by an equally uniform decline to the present epoch when its condition relative to past epochs is also indicated. The only exception to this rule has been made in the case of the Cellular Cryptogams, whose heterogeneous character has doubtless caused it to undergo considerable fluctuation. One such is assumed in the Carboniferous, in which, though one of the great periods of vegetable deposition, the actual number of Cellular Cryptogams falls below that of either preceding or subsequent periods. This seems to argue that there was a reduced representation of this form of plant life in that age, and this is shown in the figure presented for that type.

The three facts which this diagram aims chiefly to bring out, not shown in either of the preceding diagrams, are, first, the true origin, or geological age of first appearance of each type of vegetation; second, the period of its maximum development; and, third, the rank it occupies in the living flora relative to its maximum. These are all delicate points to fix in a manner that will satisfy all the conditions of the problem. The evidence from all sides has to be cautiously weighed, care taken not to give undue weight to any nor to undervalue any. These are not questions that can be hastily settled. They require to be pondered long and well. It is by no means claimed that substantial truth has been reached in every case. No two persons, however competent, would probably exactly agree upon all the points, and I am sure that at different times with increasing evidence I have modified my own conclusions. But this is far from confessing that the attempt is valueless, and it is certain that great value should be attached to the enlarged conceptions of vegetal development that flow from such a study.

Descent of plants.—But we need not stop here. The great law of development does not allow us to contemplate these types as independent of one another. Each class of plants must be regarded as the descendants of some ancestral form more or less different from it. The multiple origin of existing forms, whether of plants or animals, is repugnant to modern scientific thought. It is the discovery of facts that has rendered it so. The multiple and varied of the present must be regarded as due to divergences in the past. The forms we have have come down to us along divergent lines from common ancestral forms. These are the *lines of descent*, and plants have their lines of descent as well as animals or human families. Of this we are practically certain, but just what those lines are and where they diverged—these are the great problems of phytogeny.

The lines of descent in the animal kingdom have been laid down by various eminent zoölogists with considerable confidence and unanimity. In plant life they have scarcely ever been attempted. The problem is loaded with extraordinary complications and cannot be satisfactorily attacked until we shall possess far more knowledge than we possess at present.

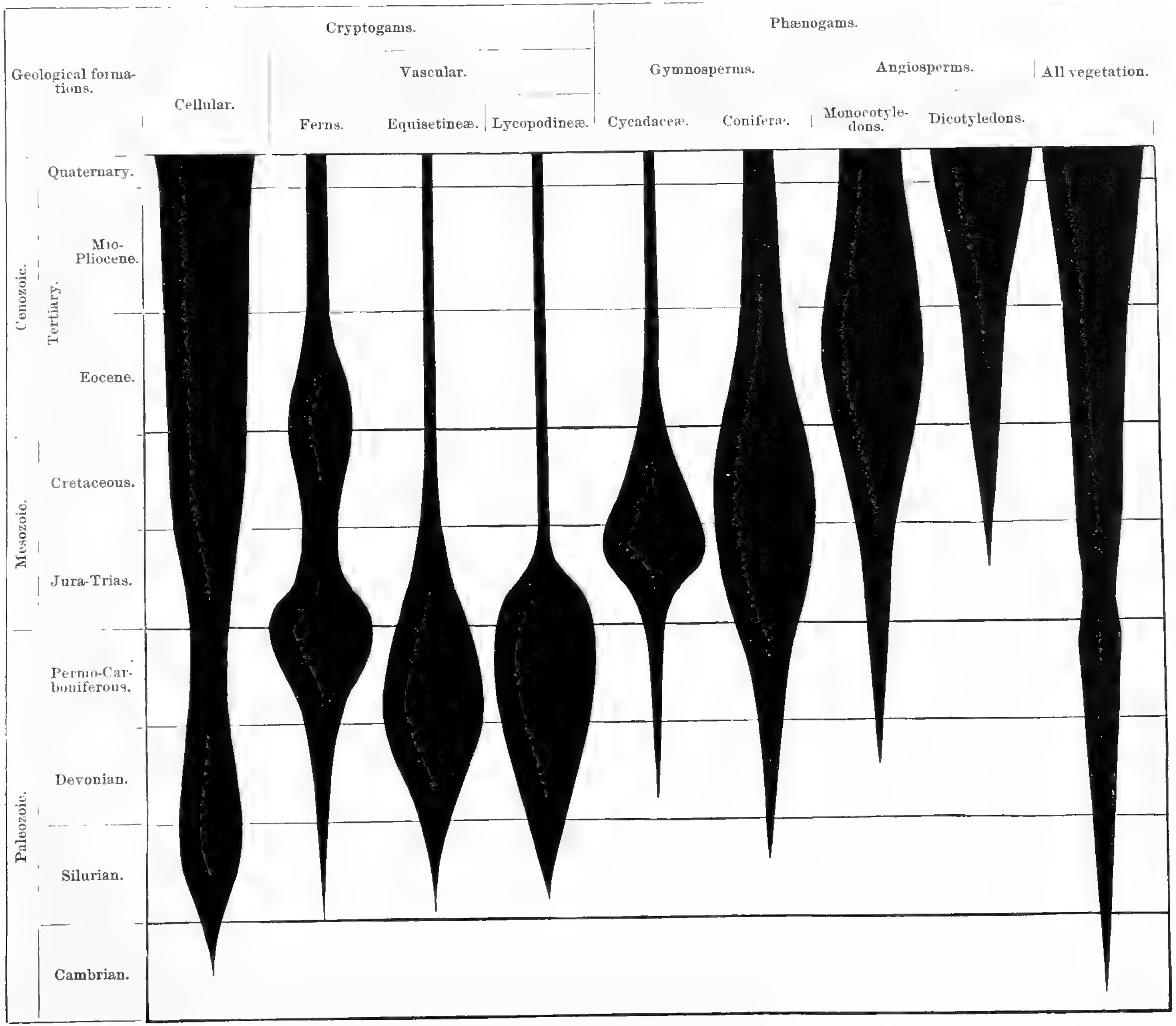


DIAGRAM No. 3.

SHOWING THE ASSUMED ORIGIN AND DEVELOPMENT OF THE PRINCIPAL TYPES OF VEGETATION IN GEOLOGIC TIME.

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