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On the Vegetation of the Carboniferous Period, as compared with that of the present day. By Dr. Hooker, Botanist to the Geological Survey of the United Kingdom.

There are few persons who have devoted any time to the study of fossil plants, especially those of the coal formation, and have not been particularly interrogated on the value of their results, compared with those derivable from the investigation of animal remains. What that value may be, is daily asked of the naturalist, while in the field, by the uninitiated yet curious looker-on, who eagerly offers his aid as a collector in exchange for information upon the materials he gives or offers to procure. It is no less frequently proposed by the young geologist, who, though skilled in seizing the characters presented by a comparatively indestructible shell or bone, is at a loss to appreciate those afforded by the always compressed and more or less mutilated fragments of what were originally perishable plants.

It is with a view of instructing such enquirers that the following introductory observations are thrown together. Relating exclusively to the more obvious features of that formation which conspicuously abounds in fossil vegetables, to their most prominent characters, and to the botanical value of those features only, they can have no claim upon the attention of the experienced palæontologist. They are little more than the first impressions received by a naturalist, who, having been almost exclusively occupied with an existing Flora, is called upon to contrast with it the fragmentary remains of another Flora, whose species are, without an exception, different from those now living, which represent in part the vegetation of a period indefinitely antecedent to the present, and have been succeeded by still other plants, equally diverse from both, and which have likewise perished.

From the very outset it must be borne in mind, that whatever light future investigations of hitherto unexplored coal-fields may throw upon this most difficult subject, we can never hope thereby to arrive at any great amount of precision in determining the species of vegetable remains, nor to ascertain the degree of value due to the presence or absence of certain forms, such as the animal kingdom so conspicuously affords. Still less can we expect that they will prove equally appreciable indices of the climate and other physical features of that portion of the surface of the globe upon which they once flourished.

The great extent of the vegetable kingdom is hardly to be appreciated except by the professed botanist; and he must be an advanced student who knows as much of its main features as he may acquire of the animal creation during the course of an ordinary education. Every one, for example, is familiar with the divisions of the class Animalia into beasts, birds, fish, reptiles, shells, &c.; but much study is required to attain an equal amount of acquaintance with the parallel divisions of plants into exogenous, endogenous, &c. The technical terms, too, employed in the one case are, very many of them, universally intelligible; whilst the majority of those applied to the more conspicuous organs of plants must be acquired by a special study. Lastly, the external organs of vegetables, and especially such as are generally available in the fossil state, are not the same guides to the affinity of the objects themselves, to their habits, or to the nature of the area they occupied, which the similarly conspicuous organs of animals are. Thus, were fossil vegetables much more perfect than they are, the information to be derived from their study will never hold a rank of equal importance to the geologist with that afforded by animal remains.

It is partly owing to these circumstances that the study has been comparatively neglected; partly also because a far more comprehensive knowledge of the existing forms of plants is required to make any progress in fossil botany, than of recent zoology to advance equally in palæontology; for, whilst an acquaintance with a single class of animals (the shells for instance) enables the student to understand and distinguish whole formations, he cannot, without being somewhat conversant with all classes of living plants, appreciate the value of the most perfect series of them in a fossil state.

Turning from this discouraging view of fossil botany in general to that of the particular formation to whose consideration the remainder of these pages will be devoted, it is satisfactory to find that it presents facilities for the investigation of its vegetable remains such as is afforded by no other. This is mainly due to the vast accumulation of specimens, and to many of them being presented under very different conditions in the under-clay, in the shales, in nodules of ironstone, and in the sand-

stone. Had it not been for these favourable circumstances, the study of coal fossils would have been apparently hopeless; for, whilst the clays and ironstone and sandstone scarcely ever contain more than one large class (ferns) in a fit state for determination, the shales preserve only the outlines of another (*Sigillariæ* and *Lepidodendrons*), whose affinities could hardly be guessed without a microscopical examination of their internal tissues, as these are preserved in the ironstones and sandstones. Considering of how exceedingly lax and compressible a tissue the coal-plants were composed, it is not wonderful that instructive specimens are rare; but to appreciate to its full extent how universal is the compression and how complete the mutilation of almost every individual, it is necessary to study the whole bed or deposit, *in situ*. Thus will be seen a layer of mineralized organic matter, exceeding in bulk and in area whatever any other formation may present in equal purity; for throughout the whole mass of the coal there will not be found one pebble or even grain of sand: it is a deposit of vegetable matter, so homogeneous that not a trace remains of the outward form of that incalculable number of species and specimens of plants to whose decay it owes its existence.

Plants, whose tissues are so lax as to be convertible after death into a mass of such uniform structure as coal, evidently would not retain their characters well during fossilization, under whatever favourable circumstances that operation may be conducted. We consequently find that few specimens are available for scientific purposes. Of the ferns, whose remains preponderate in the carboniferous Flora, only one surface of the leaves or fronds, and that invariably the least important (botanically speaking), is exposed to view; and their mutilation is so great that the identification of contiguous specimens is frequently impossible, much more so of those from different parts of the same or from other coal-fields. Were the species and genera identical with those now in existence, this difficulty would be lessened, for we should then know the variations in form which the individuals might be likely to assume, or, at any rate, what dissimilarity between the isolated fragments was due to their belonging to different parts of the same plant. The naturalist is thus hampered in the outset by his inability to answer questions relating to systematic and specific botany. And when he turns to a general review of the whole, and seeks to reclothe the globe with the vegetation to whose decomposition we are indebted for coal, he labours under no lighter difficulties: the most casual inspection of such a wreck suffices to show that the number of species, genera, and even orders, of which scarce a trace remains, must far outnumber those which are recognizable. Of the latter, again, but a small percentage is known in a tolerably complete state, only the larger and

better preserved specimens retaining those organs and appendages which the most skilful botanist requires to examine in the living vegetable before he can pronounce decidedly on its affinities. The female flowers or fruit are distinguishable in very few cases, and they are so rare that but one genus of coal-plants has thereby been referred with any certainty to its proper position in the natural system. They occur in the form of cones (aggregations of seed-vessels) or of isolated seed-vessels. Their form alone is generally preserved, their interior having been wholly destroyed, or presenting a crushed and shapeless mass of disorganized tissue. The solitary nuts, again, may have grown in cones or separately: they have never been found attached nor in a position relatively to any leaf, branch, or cone, that would justify their having belonged with certainty to either. Of male flowers no traces remain. Leaves and scales occur abundantly, but almost invariably detached, as is generally the bark of the stems or trunks, so that the very outline of the vegetable is frequently lost. Hence arises the necessity, in the infancy of this science, of describing the different portions, perhaps of one plant, as species, and of arranging them provisionally into genera; the word genus signifying, not a natural group of species, but a set of organs; and being synonymous in many cases with a shorter and more expressive Latin word, long in use and better understood. As an example, the genera *Strobilites* and *Lepidostrobus* may be cited, whose species are various cones (*strobili*), in some cases of *Lepidodendron*, in others possibly of other plants, widely different; even the order to which they belong being distinct from that including *Lepidodendron*.

This arrangement of portions of specimens under various genera is highly detrimental to the progress of systematic botany, but is not equally disadvantageous to the geologist, whose object it is to determine the relationship of strata, by means of a comparison of their contained species, without so particular a reference to their affinities. The identification of these is always open to question, from the errors into which the imperfection of the specimens necessarily leads. Two specimens of one plant, the one more perfect than the other, are frequently described as different: this is eminently the case in the *Sigillariæ*, the markings upon the surface of whose bark differ from those on the similar surface exposed by the removal of that bark, while in many specimens it is exceedingly difficult to determine whether the latter be present or not. The markings also vary extremely in different parts of the same trunk; insomuch that fragments which had been regarded as characteristic of six or eight separate species, have been more recently found to belong to one, that one presenting a surface equal to those six or eight fragments collectively, whereon the

supposed species were founded. Again, as the specific characters used in dividing this genus are drawn from what are considered very unimportant features in recent plants, namely the scars left by the fallen leaves, it is evident that several distinct species may be merged into one, in the absence of other distinctions beyond that solitary character which does not suffice to recognize analogously marked living vegetables.

The last obstacle which demands a passing allusion, because tending to retard our knowledge of coal fossils, is, that they cannot be investigated independently. Representing the earliest known Flora, the individuals composing it are, as might be expected, more unlike those now living, than what any subsequent formation contains. The succeeding beds present us with plants, which occupy, in point of organization, as in date of creation, a middle position; and it is in many cases through the investigation of these alone that a clue can be gained to the relationship existing between the earliest known and the now living vegetable forms. It is not so to an equal extent in the animal kingdom. A knowledge of recent shells, for instance, can be brought to bear upon those of the Silurian formation (independently of any study of their allies in the more modern strata) far more effectually than an equal acquaintance with living plants can, upon those preserved in our coal-fields. Many and sufficiently obvious are the reasons for this: the Silurian rocks contain but one or few orders of animals, the carboniferous many of plants. There is a greater external similarity between the shells of all periods—they are better preserved, and their external characters afford surer indications of their affinities, habits, and localities.

An examination of the coal vegetation being merely a comparison of its tribes of plants with those we are more familiar with, the first object of the naturalist is, to reduce all the strange individual forms he here for the first time sees, to the same classes and orders with existing ones. When their affinities cannot be traced, he seeks to ally them to living analogues, and thus, reproducing the whole Flora, he regards it as probably characteristic of such physical features of soil, surface, and climate, as accompany what he has determined to be the existing types of the by-gone Flora. The general laws now affecting vegetable life, are the only ones available in this comparison, and therefore are adopted as correct; but to appreciate the extent of their application, a very comprehensive knowledge of the distribution of plants is necessary. Slight local causes may very materially modify the operation of these laws; and so plastic is vegetation under their influence, that we find what appear to be entirely analogous positions with regard to heat, light, soil, and moisture, tenanted by whole genera, and even orders of plants, of very opposite botanical characters, and that

such localities present a greater disparity of vegetation than do other countries more remote in geographical position, and with less similarity in their conditions.

It is the case with very many species of existing plants, that they vary so considerably at various parts of the area over which they are dispersed, as to draw all but those who know the intermediate links (which may be comparatively scarce) into a belief, that the extreme varieties are specifically distinct. This is eminently true of ferns, which have very wide ranges, and are exceedingly sportive. If the difficulty be great with living plants, of which complete specimens or whole individuals are procurable, it must be far more so with fragmentary fossils; and the coal formation being characterized by ferns to a very remarkable degree, it follows, that with only imperfect specimens, all attempts towards determining the species and limiting them must be very vague. The amount of variation also is fluctuating, and it bears no necessary reference to botanical affinity; for whilst nine species of a genus may be constant to their characters wherever they occur, a tenth may vary so widely that its extremes will appear far more dissimilar than are any two of the other nine.

The knowledge of recent botany, which is needful to throw light upon the study of fossil plants and the origin of coal, must be both varied and extended; though a profound acquaintance with any particular branch is not required to make a very considerable progress. Those points with which the student should be most familiar are some of them purely botanical; whilst others are more general, and refer to the dependence of vegetation upon the condition of the area it covers.

Some acquaintance with systematic botany is the first requisite: through this alone can any approximation to the living affinities of the fossil be obtained. It should embrace not only a knowledge of the principal groups or natural order under which all plants are arranged, but a familiarity with vegetable anatomy; for when the stem or trunk alone is preserved, which is often the case, a minute examination of its tissues is the sole method of determining its position in the natural series.

A solution of the difficulties which this special knowledge will tend to remove is of the highest interest to botanists, though comparatively preliminary to the object of the geologist, whose inquiry is, what were the general features of such a vegetation as has effected the formation of a seam of coal, both as regards quantity and kind. As regards quantity, inasmuch as the growth was either wonderfully rapid, or more tardy, but prolonged under uniform conditions; and as regards kind, from certain species, genera, or orders, being particularly adapted by their quick growth, their gregarious habits, and their continued appropri-

ation of certain areas to produce those vast accumulations, the explanation of whose origin is still an unsolved problem. Other questions, which a study of living plants alone can answer, refer to the sorts of plants best calculated to thrive in such a uniform soil as the underclay, upon which each bed of coal rests, and into which some of the vegetables have certainly been rooted. What form of surface is best fitted to retain so mobile a débris as the coal was previous to its compression and hardening; what degree of dryness would be most favourable to such an accumulation, consistently with an energetic growth of vegetation.

The above considerations pre-suppose some general ideas of the vegetations both of the tropics and cooler latitudes, of mountain-chains, table-lands, valleys, and æstuaries, more especially of countries characterized by equable or by excessive or extreme climates, as compared with continents, and of humid and desert districts; in short, of all the complex associations with, or dependence of botanical characters upon, surface, soil, and climate, which the globe presents.

The want of this kind of information amongst many naturalists, and the neglect of its application by others, have caused those utterly contradictory opinions which have been expressed regarding the origin of coal,* and unnecessarily complicated the subject. The botanist must not seek to force a plant into a natural order, the habits of whose existing species are incompatible with those conditions under which a more comprehensive view of the coal formation may assure him it must have vegetated; nor can the geologist put forward any theory which will explain the features of that formation, if it be grounded on views opposed to those few certain data, which a study of the botany of the period in question has afforded.

There is another branch of this investigation of equal importance to the geologist and botanist, namely, the identification and comparison of the species from different and sometimes remote coal-fields, or from the various strata of the same field. This is as difficult as any of the points which occupy the botanist; and all questions connected with the geographical distribution of the plants of that period being dependent on the results thus obtained, it is one which requires extreme caution in the working. The obvious tendency in the student is to regard as

* The looseness of the speculations hitherto advanced on the relationship of the coal flora to such physical conditions as climate, cannot be better illustrated than by the fact that the *Sigillariæ* (which have undoubtedly contributed largely to the formation of coal) are considered by some naturalists to be allied to the order *Euphorbiaceæ*, by others to *Cacti*, and by the majority to ferns. The necessary conclusion to which those who place them in the first two orders would lead us, is, that they were inhabitants of singularly arid and desert countries; whilst, if ferns, they are characteristic of diametrically opposite conditions, a moist soil and a humid atmosphere.

identical the similar fossils in the various strata exposed in one mine; and as different the plants from remote coal-fields. From recent observations, it appears that subsequent movements may have isolated portions of what once formed a continuous bed of coal, characterized by a uniform vegetation throughout, and that hence a slight dissimilarity between the plants of each portion may be attributable to a difference in the conditions to which it was exposed in each. On the other hand, it must be borne in mind, that at the present day a change in position is almost surely accompanied by a very considerable change in vegetation. The labour of identification too is not confined to the comparison of specimens, but includes the determination of their names when previously described. This is often all but impossible, from the nature of the specimens, and the difficulty of presenting them, in an available form, without plates. Hence it happens, that the labour of individual observers is overlooked. It is, perhaps, impossible to employ similar materials to better purpose than has the author of the "Flore Fossile" those upon which he laboured; and yet the difficulty of naming the species by that work is very great, and must be so; for the specimens to be compared are, like the originals, mere fragments, and the genera of *Ferns* adopted are far from being properly defined, though as judiciously as the materials would permit. On the contrary, many of these are not supported by the examination of living analogues; whilst others are unavoidably founded on isolated portions of plants, whose appearances whilst living and affinities are alike unknown, whether amongst their contemporaries by which the world was then inhabited, or those hitherto unrecognised allies that may now surround us.

The foregoing remarks admit of illustration, to a certain extent, by particular instances. This may be useful, because indicating to the student those errors into which he is most liable to fall. Since, however, he may not be aware how closely the course of investigation pursued in the examination of a living Flora ought to be followed in studying a fossil one, it is, perhaps, well to enumerate those steps by which a knowledge of both can be obtained.

As a field for botanical research there is none so novel as the coal formation, the few yards of shaft being more than equivalent to the longest voyage, in respect of the amount and kind of difference between the vegetation the naturalist is acquainted with and that he seeks to understand. Whatever be the nature of the vegetation to which the botanist is transported, he commences by observing:—1. What are the orders, genera, and species of plants characterising the Flora; their mutual affinities, and their relations to those of other countries; their numbers, and the relative proportions which the natural groups under which they arrange themselves, bear to each other. 2. The geographical distribu-

tion of the species, &c.; their extension over the surface of the country, and the replacement of one kind by another. 3. The relations which may be traced between the species and the soil to which some are peculiar, whilst others are common to it, and to very different soils; the quantity of moisture, heat, and light they require, and the effects of a diminution or increase of any of these elements. 4. The reciprocal influence of the whole mass of the vegetation upon the surface it covers; the new soil, or alteration of the old, produced by its decay; the extent and composition of accumulations of dead matter; the particular kinds of plants contributing most largely to, and the consequent nature of, such deposits; the conservative influence of the vegetation upon this deposit, which may be retained by roots, and sheltered by foliage from the action of elements, which, in the absence of these protections, would rapidly sweep it away.

An enumeration of these points, viewed in their bearing on the subject of the Coal-flora, will show how limited is our knowledge of any one of them, compared with what might be acquired from a very superficial examination of any recent flora, or with what the geologist may obtain from an inspection of the animal remains in many strata.

1. Of the mutual affinities of the groups under which the majority of the genera of coal-plants arrange themselves, little more can be said, than that the *Ferns* occupy the lower end of the series, and the *Coniferæ* possibly the highest; but this depends upon the view taken of the affinities of *Sigillariæ*, the most important group. These are classed by some observers amongst *Ferns;* by others, with *Coniferæ;* another considers them as linking these two widely-different families; whilst a fourth ranks them much higher than either. The affinities of another group, *Calamites*, are entirely unascertained. Of the whole amount of species in each, no conjecture can be formed; or any but a very rough one of the number into which those with which we are familiar, as of common occurrence, should be divided. The ferns far out-number, probably, all the others; but this again materially depends on the value accorded to the markings of *Sigillariæ*, as means of dividing that genus; for if the slight differences hitherto employed be insisted upon, the number of the so-called species may be unlimitedly increased.

2. With regard to the geographical distribution of the species, &c., it appears that an uniformity once existed in the vegetation throughout the extra-tropical countries of the northern hemisphere, to which there is now no parallel; and this was so, whether we consider the coal plants as representing all the flora of the period, or a part only, consisting of some widely-distributed forms that characterized certain local conditions. Nor is this uniformity less conspicuous in what may be called the vertical distribution, the fossils in the lowest coal-beds of one field,

very frequently pervading all the succeeding beds, though so many as thirty may be interposed between the highest and the lowest.

3. Of the relations between the soil and the plants nourished by it, little more is recognizable, than that the *Sigillariæ* have been particularly abundant on the under-clay, which, judging from the absence of any other fossils but *Sigillariæ* roots (*Stigmaria*), seems to have been either, in itself, unfriendly to vegetation, or so placed (perhaps from being submerged) as to be incapable of supporting any other. The latter is the most probable, because both *Sigillariæ* and their *Stigmaria* roots occur in other soils besides under-clay, and are there accompanied by *Calamites*, *Ferns*, *&c.* The *Coniferæ*, again, are chiefly found in the sandstones; and their remains being exceedingly rare in the clays, shales, or ironstones, it may be concluded that they never were associated with the *Sigillariæ* and other plants which abound in the coal seams; but that they flourished in the neighbourhood, and were at times transported to these localities. The quantity of moisture to which these plants were subjected must remain a question, so long as some authors insist upon the *Sigillariæ* being allied to plants now characteristic of deserts, and others, to such as are the inhabitants of moist and insular climates. The singularly succulent texture and extraordinary size of both the vascular and cellular tissue of many, possibly indicate a great amount of humidity. The question of light and heat involves a yet more important consideration, some of the coal-plants of the Arctic regions being considered identical with those of Britain. How these can have existed in that latitude, under the now-prevailing distribution of light and heat, has not been hitherto explained: they are too bulky for comparison with any vegetables inhabiting those regions at the present time, and of too lax a tissue to admit of a prolonged withdrawal of the stimulus of light, or of their being subjected to continued frosts.

4. The consequence of the existence of the coal-plants has been the formation of coal; but how this operation was conducted is a question still unsolved. The under-clay, or soil upon which the coal rests, and upon which some of the plants grew, seems in general to have suffered little change thereby, further than what was effected by the intrusion of a vast number of roots throughout its mass. The shales, on the other hand, are composed of inorganic matter, materially altered by the presence of the vegetable matter which they contain. The iron-clays again present a third modification of this mixture of organic and inorganic matter, often occurring in the form of nodules. These nodules seem to be the result of a peculiar action of vegetable matter upon water charged with soil and a salt of iron, the iron-stone nodules of existing peat-bogs appearing altogether analogous to those of the carboniferous period, whether in form or in chemical constituents.

Here, then, the botanist recognizes in one coal-seam a vegetable detritus under three distinct phases, and which has been acted upon in each by very different causes. In the under-clay there are roots only:* these permeate its mass, as those of the water-lily and other aquatic plants do the silt at the bottom of still waters.

The coal is the detritus either of those plants whose roots are preserved in the under-clay, or of those, together with others which may have grown amongst them, or at a distance, and have been afterwards drifted to the same position.

Above the coal is the third soil, bearing evidence of the action of a vigorous vegetation; this is the shale, which has all the appearance of a quiet deposit from water charged with mineral matter, and into which broken pieces of plants have fallen. Here there is so clear a divisional line between the coal and shale, that it is still a disputed point whether the plants, contained in the latter, actually grew upon the former, or were drifted to that position in the fluid which deposited the mineral matter. Amongst the shales are also interspersed, in many cases, innumerable stumps of *Sigillariæ*, similar to those whose roots occur in the under-clay, and which are themselves found attached to those roots in soils similar to the under-clays, but unconnected with any seam of coal. These stumps are almost universally erect, are uniformly scattered over the seams, and otherwise appear to have decidedly grown on the surface of the coal: the shales likewise seem deposited between these stumps. The rarity of *Sigillariæ* roots (*Stigmariæ*) in this position, is probably due to their being incorporated with the coal itself, though they sometimes occur above that mineral and between the layers of shale. The seams of iron-stone (or black-band) are the last modifications of soil by vegetable matter, to which allusion has been made: when these are uniform beds or layers, they may be supposed to be the deposit from water charged with iron and soil which has percolated through the peat, and in so doing absorbed a great deal of vegetable matter. The layers of nodular iron-stone are simple modifications of these, and may be caused by the sedimentary particles contained in the fluid, which, instead of being deposited in a uniform stratum, are aggre-

* The absence of other parts of plants, and indeed of any plant but the roots of *Sigillariæ*, in the under-clay, appears a fact of considerable importance. In the first place, it indicates that that soil was in a condition unsuited to the growth of other vegetables (as mentioned above), whose seeds might have accompanied those of that genus on its previously-naked surface. In the second place, this absence of other fossils in the under-clay is opposed to the theory of the drift-origin of the vegetable matter comprising coal; for there is no interstratification of coal with this subjacent deposit, which might have been expected to occur over some portion of an extensive coal-field; whereas, the gradual decay of these plants, whose roots struck into the under-clay, would produce a uniform bed of peat, perhaps adapted to the growth of those ferns and other plants which are fossilized in the superincumbent shales.

gated round broken bits of vegetable matter (as fern leaves, stems or cones) which served as nuclei.

Now, though each of these points admits of some explanation when taken independently, and some illustration from the action of an existing vegetation upon soil, &c., it is very difficult to understand their combined operation over so enormous a surface, for instance, as one of the American coal-fields, and even more to account for their regular recurrence, according to some fixed law, in every successive coal-seam throughout the whole carboniferous formation. These are problems of the highest order and unsuited to this sketch, the remainder of which shall refer to the plants themselves, and especially to those botanical characters according to which the Coal Flora has been grouped and named, and to an illustration of these several points by a comparison of them with what are afforded by recent plants.

ON THE PROBABLE EXTENT OF THE FLORA OF THE COAL FORMATION IN BRITAIN.

No fewer than 300 species of plants have been enumerated as belonging to the Coal Flora of Great Britain; but whether this gives any approximation either to what was the amount of their species at one period, or even to all those which contribute to form the coal, it is impossible to say. It need hardly be observed, that a collection of the fragments imbedded in our most recent deposits is no index to the general mass of the vegetation, nor are the remains necessarily those of the commonest plants, or even of such as would *à priori* be judged the best suited for becoming fossilized. That hitherto unknown species do exist in an available state for the botanist cannot be doubted: they are of frequent occurrence; but that these are not so numerous as might be expected from the enormous magnitude of a coal-field, is evident, from the great uniformity that prevails throughout the formation. It may indeed be a query, whether the number of species still to be discovered will equal in amount that of the so-called species, which being founded on imperfect specimens, will ultimately prove to belong to previously described forms.

That the vegetation of the carboniferous period, whether confined to the coal veins or not, was highly luxuriant, cannot be disputed. The enormous bulk of carbon accumulated, and the prevalence of ferns in all the fields, and the great size to which so many soft-tissued plants attained, all prove this fact. A luxuriant vegetation is, however, no index to a varied one; and, as many of our modern woods and even great areæ of tropical forests consist of but a few species multiplied *ad infinitum*, so may the forests of the carboniferous period have been composed of but a few *Sigillariæ* and *Lepidodendrons*, sheltering an under-

growth of a limited number of kinds of fern,* for a very limited number of them (comparatively speaking) if as protean as some of their allies are in our day, would embrace all the known species of the Fossil Flora.

In the temperate latitudes particularly, a recent Flora, marked by a preponderance of ferns, is almost universally deficient in species of other orders; as is thus shown. 1. Where one species prevails over a considerable area, as the bracken (*Pteris aquilina*) does in parts of Britain, and the *P. esculenta* in Van Diemen's Land and New Zealand, it generally monopolizes the soil, choking plants of a larger growth on the one hand, and admitting no under-growth of smaller species on the other. 2. A luxuriant vegetation of many species of ferns, continued through a great many degrees of latitude or longitude, especially in the temperate regions of the globe, generally indicates a uniformity of temperature throughout that area, and a paucity of species of flowering plants. A comparison of the vegetations of Tasmania and New Zealand illustrates this. The former of these islands, barely 200 miles long, contains four times as many species of flowering-plants as New Zealand, whose total length is 900 miles. On the other hand, this latter country possesses more than four times as many kinds of fern as Tasmania, and they are so uniformly distributed over its area, that almost all those which are found at the southern extremity of the island prevail also at the northern. The West Indian and Pacific Islands again present a Flora remarkably rich in ferns, and in both these instances we have very many of the species uniformly spread over an enormous surface, in the one instance, from the Windward Islands to Mexico, and in the other from New Zealand to the Society and Sandwich Islands. Take on the other hand the campos of Brazil, the sandy flats of Southern Africa, and the somewhat similar plains of Australia, and sterile though they appear at first sight, they will be found to abound in many kinds of flowering plants, but unaccompanied with ferns.

This prevalence of ferns has been long adduced in proof of the climate of the carboniferous period being temperate, equable and humid; and so it no doubt was; but I am not aware that it has been hitherto regarded as probable evidence of the paucity of other plants, and the general poverty of the whole Flora which characterized that formation. If, however, the laws of existing vegetation are to be considered as having had equal force at that time when the fossil one

* This preponderance of ferns over flowering plants is common to many tropical islands, and not confined to the smaller of them, as St. Helena and the Society group. In extra-tropical islands, too, as New Zealand, I have collected as many as 36 kinds of fern in an area not exceeding a few acres: they gave a most luxuriant aspect to the vegetation, which presented scarcely a dozen flowering plants and trees besides. An equal area in the neighbourhood of Sydney (in about the same latitude) would have yielded upwards of 100 flowering plants and but two or three ferns.

flourished, we must conclude that the predominance of ferns in general, and of certain species of *Pecopteris* (a fern apparently allied to our *Pteris*) over a great area, together with the remarkable similarity of the English fossils with those of North America, are all indications that the Flora of that period was poor in number of species.

Let it not be supposed that this prevalence of an order, which in point of complexity of structure is low in the system of plants, is a fact favourable to the hypothesis that the vegetation of which it appears to form a large part, was less highly developed than what succeeded it. We know too little of the structure of the ferns of that day, to pronounce them either more or less complete than their allies of the present time; while of the *Lycopodiaceæ* * it may be safely asserted, that they were of a form and stature far more noble, and in structure more complicated than any plants of that order now existing.

ON THE MOST PREVALENT GENERA OF PLANTS BELONGING TO THE COAL FORMATION, AND THE CHARACTERS EMPLOYED IN THEIR CLASSIFICATION, AND THAT OF THE SPECIES THEY CONTAIN.

§ *Ferns, General Remarks.*

Numerous as are the dissimilar groups of plants (whether genera or orders) scattered through the various strata of the coal formation,

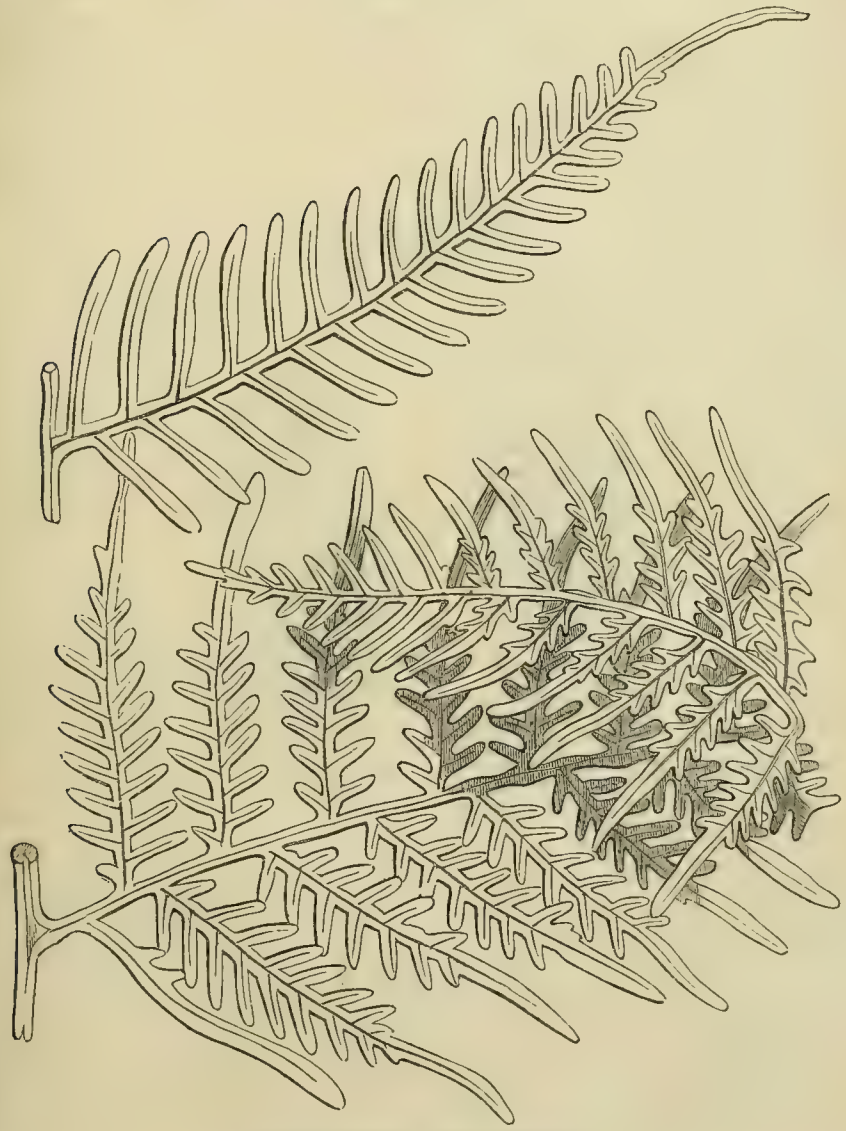
Fig. 1.

Pecopteris heterophylla (Coal-fields, Newcastle).

* See "Essay on the Structure and Affinities of *Lepidostrobus*," in the present volume of Survey Reports.

there is but one which presents any obvious or recognizable close relationship with an order now in existence. Such is that of the ferns. These were not only undoubted ferns, such as we have now living, but one of the many fossil genera included under this order is probably identical with a living one, though none of the species comprised in it are alive now. The genus here alluded to is *Pecopteris* (Fig. 1), the fossil representative, if not congener, of the modern *Pteris* (Fig. 2).

Fig. 2.

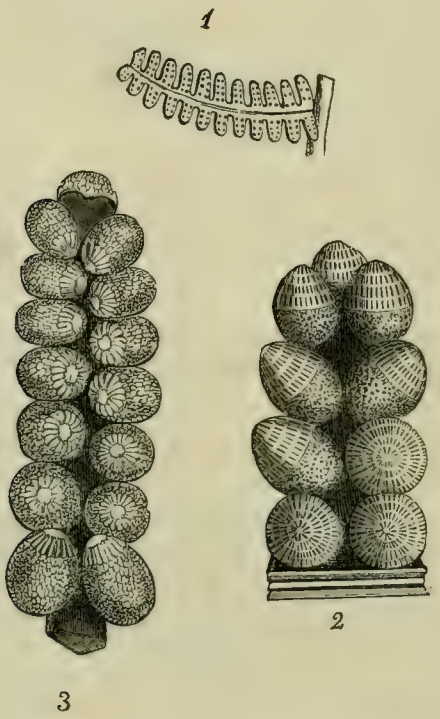


Pteris esculenta (New Zealand).

It is not improbable that there are other genera of living ferns fossilized in the shales of the coal formation, but if so they are not so well preserved, probably from not offering the facilities for petrifaction (in a determinable condition) that *Pecopteris* does. The perfect state in

which this genus is often found is attributable partly to its characteristic fructification being copiously produced, to its fronds being of a hard texture and coriaceous consistence, and to the absence of hairs or glands upon the under surface where the spores are produced, and to the large size, smoothness, and evenness of the involucre, or organ protecting these spores. A few other ferns of this formation present the fructification well preserved, and especially the genus *Senftenbergia* of Corda* (Fig. 3, 1 & 2), which is allied to the recent *Aneimidictyon* (Fig. 3, 3); but in no case except *Pecopteris* can the genus be thereby, even provisionally, identified with any living one.

Fig. 3.



The ferns are a group of plants, whose genera and species vary extremely in the form of their fronds, and are sometimes so bizarre that without the organs of fructification it is impossible to ascertain even on the order they sometimes belong to. Now the fruit is so universally present and abundant in recent ferns, that there is no difficulty in defining the limits of the order as it now exists; but in the case of fossil ferns, in most species of which the fruit is of rare occurrence, and partially obliterated by fossilization, it is impossible to decide whether

* Corda "*Flora der Vorwelt*," Tab. 57, fig. 2. I have introduced a copy of Corda's figure of the remarkable fructification of this plant; as from the scarceness and high price of that work it must be inaccessible to most of our readers.

many of the genera put into the order (as *Asterophyllites*,* *Sphenophyllum*, &c.) really belong to it or not, until some evidences be gained from their fructification.

This absence of fructification not only prevents our defining the limits of the fossil ferns as an order, but deprives the botanist of one of the most important generic characters that the plants comprised in it afford. As will be hereafter shown, it is generally impossible to trace the affinities of a fern without the fruit, and often even to refer it to the section or subdivision in which it should be placed.

There are two other points which cannot fail to strike the observer of fossil ferns: they are, the absence of a singular aspect of fronds in a state of incipient vernation, that is curled up like a crozier, as the fronds of all are in a young state. In the perennial existing species, fronds in this state may be seen on the plants at all seasons, and even in the annuals they are visible for many months; so that it were difficult to select a season of the year during which a modern fern Flora could be fossilized without very many such fronds being preserved, as well as fully expanded ones; but in the coal formation these are excessively rare. That they do occur is evidence that the evolution of the leaves followed the same law then as now; while this extreme infrequency would seem to indicate, either that the majority of the species were annual, and fossilized at an advanced season of the year, possibly coinciding with a sudden depression of the surface; or that they were perennial, and the old fronds dropping from time to time off the parent trunk, were subsequently fossilized.

Again, the almost universal absence of any defined termination to the stalks (stipites) of the fronds, or of any such masses of woody roots or rhizomata as those of modern ferns, is highly remarkable.† In the case of recent species we find long and strong under-ground woody roots, or more frequently great knotty masses above the surface of the earth, from out of which the fronds spring. But in the case of fossil ferns, there is hardly such a thing known as a specimen presenting two fronds attached to one stem. This may readily be explained on the supposition that the ferns are all fragments, transported to the position they now occupy, an hypothesis gravely objected to by many close observers on geological grounds. Another suggestion which offers itself is that the fronds are the deciduous ones of tree-ferns; this is much more plausible, though almost necessarily involving the con-

* My friend, Mr. Bunbury, informs me that he is possessed of American specimens of this genus with the organs of fructification preserved.

† Several authors have figured small ferns, in which both the fronds, their axis of support, and root, are well preserved; but the species are very scarce, much smaller, and of a different character to the prevailing forms of the coal formation.

clusion that *Sigillariæ* are the trunks of those tree-ferns, a subject to which I shall revert at a future part of this essay. A third and the only other explanation that I can propose is, that the roots were planted in the peat, and with that are now turned to coal, thus being as effectually obliterated as are the roots of those numerous upright stumps of *Sigillariæ* which I consider to have undoubtedly grown on the surface of the coal, and spread their roots into, or along the surface of its mass.

No fewer than one hundred and forty species of ferns are enumerated as having inhabited those few isolated areæ in England over which the coal has been worked, at the time when the latter was formed. This is a strange contrast to our existing Flora, which boasts but 50 species of that order, upon a surface of incomparably greater extent than what we have examined of the carboniferous period. It is, indeed, doubtful whether all the fronds now in Great Britain would equal in number those contained in the largest seams; so that under whatever light the predominance of the ferns be regarded, whether in amount of species or specimens, they indicate a climate far different from the present. I have before said, that it is only in the tropics, and in the equable, moist, higher latitudes of the southern hemisphere, that any remarkable luxuriance of ferns is met with. A climate warmer than ours now is would probably be indicated by the presence of an increased number of flowering plants, which would doubtless have been fossilized with the ferns; whilst a lower temperature, equal to the mean of the seasons now prevailing, would assimilate our climate to that of such cooler countries as are characterized by a disproportionate amount of ferns. This then is an argument unfavourable to the theory of central heat having warmed the surface, or of the direction of the poles being so altered as to have exposed Great Britain to a tropical climate, and demanding only a different disposition, and perhaps proportion of land and water to that now existing; judging from the southern hemisphere, where it is seen that the relative proportions of land and water modify the Flora most materially.

With regard to the distribution of these fossil ferns out of Britain, it appears that their ranges were as wide as are those of the present day; perhaps more so, when we consider how extremely difficult is the determination, and no less the identification of the species and specimens, and that the general tendency is probably to the multiplication of species. Of the British species, about 50 are known to occur in the coal-beds of North America, some of them ranging there from the latitude of Nova Scotia to 35° S., and abounding in these and various other intermediate coal-fields. On the continent of Europe again there are about as many of the British species.

Again, turning to the living ferns, we find that of the 50 inhabiting

Great Britain, little more than a half are found in North America. A greater similarity between the climates of these countries is required to account for the preponderance of the species common to both during the carboniferous epoch, and possibly the presence of land between the two to have favoured the transmission of seeds from one to another. That such an aid as an intermediate land was necessary, however, may be disputed, on the ground that the *Lycopodia* of Europe are all found in North America, their spores being apparently no smaller nor easier wafted than are those of the ferns.

Nothing satisfactory has been elicited regarding the vertical distribution of the species, beyond the fact that no decided difference between those of the uppermost and lowermost beds has been hitherto ascertained. A few of the species are found in the Old Red Sandstone, but none enter the superior beds, as the Oolite, &c.

Ferns—Botanical Remarks, &c.

Habit.—Upon this point we absolutely know nothing. Although the fronds occur in countless myriads throughout all the beds, they offer no characters, either relative or individual, by which we can pronounce whether they were terrestrial or epiphytal (growing on trunks of trees), if the stems were erect, inclined, or creeping; nor, what is most remarkable of all, do the fronds ever occur attached; so that we are ignorant whether any or all of these kinds belonged to tree-ferns, or were humble individuals, with stems scarcely rising above the ground.

This ignorance of the habit of the plants is a most serious drawback, and till it is removed we have little hope of gaining a clear idea of the features of that vegetation to which they so largely contributed. It may be urged in favour of a great proportion being arborescent, that none are found attached, as stated above, to roots or slender stems; and that some may have belonged to *Sigillariæ*, with whose foliage we are otherwise unacquainted. Against this supposition, again, stands the extreme rarity of any acknowledged tree-fern stems in the coal-beds, and that whether drifted or deposited on the spot, the fronds must, if arborescent, have been accompanied by such stems.

The infrequency of fructification upon the fronds of the fossil ferns belonging to this formation appears as possibly another argument in favour of many of those appertaining to tree-ferns; for, while the herbaceous and caulescent ferns of New Zealand are scarcely ever barren, the arborescent species are almost invariably so. I think I am safe in saying that of two or three kinds of New Zealand tree-fern, not one specimen in a thousand bears a single fertile frond, though all abound in barren ones.

Fructification.—The sporules (fruit or seeds) of the ferns are invariably produced on the under-side of the frond, and as that is all but universally the concave surface, and generally presents other inequalities beyond those caused by the organs of reproduction, it becomes firmly attached to the rock during petrifaction, and very rarely exposed to view. Hence, when the frond is coriaceous, it cannot even be determined whether the plant was in fruit or not, except in such rare case as that of *Pecopteris lonchitica*, to which I have already alluded. When, however, the texture of the frond is membranous, the position of the sori (or clusters of spores) is indicated by a prominence on the upper and exposed surface. This stamping through is usually the only apparent sign of fertility in fossil ferns, and is conspicuous in several British species (as *Pecopteris obtusifolia*); also in three American species, indicated by Mr. Bunbury,* who has lately drawn attention to the circumstance. Lindley and Hutton were, I believe, the first to point this out as the probable cause why the fructification of fossil ferns should be very seldom apparent, even supposing fruiting specimens more frequent than they really are.† Goeppert ‡ again finds that in producing artificially fossilized ferns, the under surface invariably remains attached to the matrix, which separates from the upper.

It is, unfortunately, impracticable to class the most perfect specimens of living ferns without the aid of characters derived from their sori. Much more is this the case with the imperfect ones of the fossil. The former indeed are almost universally rejected from the Herbarium, many species being in every other respect identical.

In illustration of this fact two wood-cuts have been prepared, each displaying how great a difference may occur in fructification unaccompanied by any disparity in the outline, form, surface, texture, or venation of the frond.

The first (Fig. 4) represents a portion of a frond whose outline and venation answer either for a species of *Leptogramma* (A) or of *Asplenium* (B), genera which are precisely alike in those points; but if the fructification be regarded, it will be seen, that the sori of the portion, marked (B) and enclosed in the black line, are covered with a protecting scale (involucre or indusium) as is more distinctly shown in the magnified portion, whilst those of the rest of the figure are naked. Now this absence of an involucre in *Leptogramma* is not accidental in that fern, but a constant character, separating both it and many allied species (all equally wanting the involucre) from *Asplenium*, and a similar group which possess that organ.

* Fossil Flora sub *Neuropteris undulata*, t. 83.

† "Quarterly Journal of London Geolog. Soc.," vol. ii. p. 85.

‡ "Systema Filicum Fossilium," p. 293.

At Fig. 5 again a portion of a fern frond is figured, which, when out of fruit, would be referred indiscriminately to one of four species, differing only in the form, protection, or position of their sori. Thus, at

Fig. 4.

Fig. A, the sori are placed on the middle of a venule, and are unprovided with an involucre: were the whole frond thus characterized it would be that of *Goniopteris crenata.* At B the sori are elongated, covering the whole venule; it is *Stenogramma aspidioides.* Fig. C shows the sori to be situated at the middle of a vein (as in A), but they are here covered with an involucre, and not exposed; such is the case with *Nephrodium glandulosum.* The sori at D again are naked and round (as at A), but instead of being placed in the middle of a

venule, they occur only where two venules meet: were the whole frond so furnished it would represent *Meniscium cuspidatum.**

Thus we have four plants, wholly indistinguishable except by their

Fig. 5.

* To illustrate still further the confusion which the absence of fructification might entail, it may be mentioned that three of these ferns are natives of Java, and would, if petrified without the fructification being displayed, be unsuspectingly referred to one species; the fourth, a native of Jamaica, would, if similarly fossilized, be adduced as an instance of the similarity in the vegetable productions of the Old and New World at the epoch when they both flourished! Yet four more really and truly distinct plants cannot well be.

fructification, which proves them to belong to different groups of the order. It has been already remarked that the fruit is rarely present in fossil ferns; whence it may be presumed, that did the four ferns just described occur fossil, the probability is great that whatever formation they inhabited, or however widely separated they were in geographical position, they still would all be included under one species.

Fig. 6.

Again, very many existing species of ferns have the fertile frond quite distinct from the barren ones in size and shape. The *Niphobolus rupestris* of New Zealand is an instance: a wood-cut of it (Fig. 6) is added. In such a case the absence of any fructification on the one hand, and the severance of both the fertile and barren fronds from the

caudex previous to fossilization, would effectually prevent the two parts being recognised as portions of one plant.

The tendency in this case is towards the multiplication of species, while in the former we should unite what are nearly totally distinct.

Venation. In the absence of those characters afforded by fructification which are acknowledged to be of the very highest value in this order, if indeed they are not the only ones by a study of which the primary groups of ferns are to be united, the venation, or arrangement of the nerves, is adopted. This character is considered by many of secondary importance, and one by which the primary groups may be divided into minor groups without violence to nature, especially according to whether the veins after branching join again, or continue free to the margin of the frond. Now, there are doubtless many sub-orders both of fossils and recent ferns distinguished by the organs of fructification, each of which again is sub-divided by characters in the venation; but instead of adopting the primary characters (of fructification) in the formation of these sub-orders, the secondary ones (of venation) are employed: it follows, then, that every such group (and they are genera) of fossil ferns may contain species generically widely apart. The genera must, of course, be wholly artificial, and include plants belonging to separate sub-orders, as would be proved did their fructification occur.

Even venation is a character to be used with caution; for though the presence or absence of an involucre to the sorus is constant in one species, and so are the form and position of the sori, the venation is found occasionally to vary materially in different parts of the same plant, or even the same frond. Hence, while some sub-orders of ferns may be trenchantly divided according to the branching of the nerves, others cannot, because the individual species at times assume both forms in one frond.

This is remarkably the case with the *Diplazium Malabaricum*,* of whose fronds two states are figured (Fig. 7). In the upper and older portions it will be seen that the veins, after branching, meet; while in the lower the branches run free to the margin of the frond. Fossil fragments of this fern would be included under two genera, those as resembling Fig. A to *Callipteris*, and those veined in B to *Digrammaria*. It would be out of place to exhibit through what transition stages the passage between A and B is effected: any one frond, however, of this par-

* This plant has caused no little perplexity to the students of existing ferns. So protean are its fronds, that different states of this one fern have been made into two separate genera, *Anisogramma*, Pres., and *Digrammaria*, Presl. Mr. John Smith, of Kew, to whom I owe many illustrative specimens of these points, has separated this plant from *Diplazium*, and given it the name of *Callipteris*.

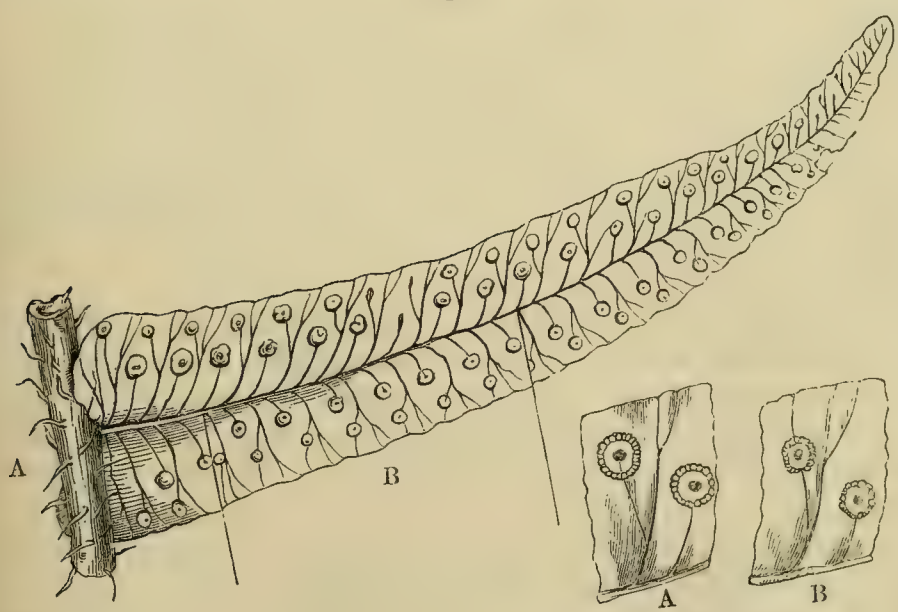
ticular species shows it, and would afford material, if fossilized, for many bad species.

Generally speaking, however, venation is a character of the greatest

Fig. 7.

importance; and to show how closely it should be scrutinized, an illustration is added (Fig. 8) of a form of frond and fructification common to two very different ferns, which are permanently and effectually distinguishable by the length of one branch of a repeatedly branched vein.

Fig. 8.



The general character of the frond of both A and B is to have the veins alternately simple and branched, the simple one is in both produced only half-way towards the margin, and bears a sorus on its point,

the longer is in both three times branched, and bears a sorus on the first or right-hand branch. But whereas in A (*Cyclopeltis Presliana*, Sm.) the said first right-hand branch or venule is not produced to the margin of the frond, and bears its sorus on the point, in B (*Cycl. semicordata*, Sm.) the same venule is produced to the margin, and has the sorus on its middle. Now this arises from no difference of specimens, but of species, and it is the only character by which a plant exclusively inhabiting the Old World can be distinguished from one confined to the New.

Though such an anomaly as that of a *growing* fern bearing fronds with two different types of venation is readily recognized amongst recent plants whose whole frond is presented to the eye, it is not so in the petrified specimen, of which isolated fragments must be classed under different genera according to the arrangement of the veins. This is probably a fertile agent in dismembering genera, an error no less grave than that to which so slight a character as that distinguishing *Cyclopeltis Presliana* from *C. semicordata*, would, if overlooked, lead; for hence we might specifically unite the widely different ferns of two more differently circumstanced countries than Europe and North America.

Lastly, many recent ferns are of so dense and leathery a texture that their venation cannot be ascertained without much trouble, arising from the necessity of macerating the frond and dissecting out the veins. When such are petrified, they cannot be referred with propriety to any previously established genus, the characters afforded by texture, and comparative denseness of substance, being of specific importance only.

The conclusion to be drawn from the above resumé of the value of the characters drawn from the venation of fossil ferns is that the prevailing tendency of dwelling too much upon it leads to the dismemberment of species, and placing the individual parts under different genera.

Outline and Division of Fronds.—A character considered next in importance to venation, both amongst recent and fossil ferns. It is seldom of more than sectional or specific value, and frequently not that, the species of a genus being frequently grouped into those with simple fronds, those with the fronds lobed, deeply divided, once, twice, and so forth.

In some cases of living ferns even the amount of variation is very startling, for instance the *Polypodium pustulatum* (Fig. 9), where the fronds are sometimes entire, at others deeply lobed; or still more remarkably in the case of *Lindsæa cordata* (Fig. 10, p. 414), whose fronds vary so extraordinarily, that did the various forms occur petrified, and detached from the parent plant, it would be impossible to deny specific

value to some dozen, or more, of such isolated fragments as would alone be found. Further instances of variation of form in the same plant are given at Figs. 1 and 6 of the illustrative wood-cuts.

Fig. 9.

On the whole, it is probable that the irregularity of outline and division, prevalent in recent ferns, is the most fertile source of error in our investigations amongst the fossil, because the individual fronds are universally detached, and are seldom seen entire, so that we are ignorant to what portion of the plant the fragments belong. The result is of course the multiplication of species to a degree only commensurate with the protean nature of the species.

The zoologist is not equally hampered with the three classes of difficulties described above. Take the mollusca for instance; there is hardly an instance of two shells, identical in appearance, yet belonging to different genera of that order, and only distinguishable by the animal they contain, or by one organ of that animal; far less of four genera of shells so circumstanced, and each the type, not of a genus, but of groups—groups, too, differing in geographical distribution as well as in their most important characters.

Fig. 10.

Outline again, a fallacious guide to the determination especially of generic affinity amongst plants, is of eminent importance in the animal kingdom, where the habits of the different groups, all locomotive, demand peculiar modifications of the hard parts, whether of the external or internal skeleton.

Surface.—The presence or absence of hairs or scales on the surface of the fronds, and sometimes of glands also, affords characters of the greatest constancy for distinguishing species, being often available when the outline of the fern is so variable, that by it alone the species cannot be traced. The larger and most characteristic hairs or scales occur

chiefly at the base of the frond-stem or stipes, a part of the plant invariably wanting in the fossil. Smaller scales, hairs, and glands are most frequently confined to the under surface of the frond, which, from various causes, and this amongst others, is almost invariably the one that is united to the rock in petrified ferns, and therefore unavailable for botanical examination.

Sigillaria.

Perhaps the most important plant in the coal formation, forming a conspicuous feature in almost every field, appearing in all the strata, and distributed from Spain to Scotland and from Virginia to Newfoundland in America. Upwards of 60 species have been described; with how little precision may be inferred from the fact mentioned above, that many of them have been proved mere varieties, in a solitary case even four being reduceable to one.* Under the names of "bottoms" and "bell-moulds" the stumps of *Sigillaria* are well known to the colliers, as dangerous associates of the shale roofs in the workings, immediately above the coal. They are generally but a few feet high, though sometimes two yards broad at their expanded bases, they are truncated at the top, and retain their position in the shales after the removal of the coal upon which they rested, being supported by the pressure of the atmosphere and the cohesion of their smooth sides. Unless propped, they, after a time, lose their hold and fall in, sometimes severely injuring the workmen. So common are they, that I have in many South Wales and other collieries counted five or six in the space of a few fathoms, always suggesting the idea of the erect stumps of trees in a forest.

In the shales surrounding the bases of these stumps are found prostrate stems, bearing markings similar to what sometimes appear on the stumps. It is, however, generally the case that the markings of the stumps are very obscure or wholly obliterated, as usually occurs on the lower parts of the stems of those plants which at an earlier stage bear deciduous organs. This absence of marking has been urged in proof of these stumps not being *Sigillariæ* at all; but we know no other genus to which they can be referred; and in the noble erect specimens discovered and examined by Mr. Binney, the gradual evanescence of the scars or even flutings of the trunk at a few feet above the root, is very decidedly shown in most instances, though in some they may be traced almost to the base.

That the *Sigillariæ* were of a very brittle and probably lax tissue, is I think evident by the constantly truncated upper end of the stumps in the shales, their never being prostrated entire, and the singular com-

* Mr. Binney, of Manchester, showed me a *Sigillaria*, in which the characters of *S. catenulata*, *reniformis*, *organum*, and *alternans* were all displayed, a fact he has alluded to in the Manchester Philosophical Magazine for October, 1844.

pression of the prostrate portions. I am not aware that they have ever been found prolonged upwards from the roof of one coal-seam *through* another one, as the coniferous * fossil discovered by Mr. Binney was. This may be owing either to their generally lower stature, or more probably to their not being capable of surviving the geological changes which that harder-wooded plant did.

External Form of Sigillariæ.—It is highly singular that this fossil should be of such universal occurrence and yet be unaccompanied by any evident traces of branches, leaves, flowers, or fruit, and that till very recently the probability of its roots being *Stigmariæ* was called in question by most. Except, however, we assume that some *Lepidodendrons*, which almost universally accompany *Sigillariæ*, were the branches of that genus, or that the fern fronds deposited round their bases were their foliage, we cannot hazard a conjecture of the appearance of the growing plant.

In favour of certain so-called species of *Lepidodendron* having been the young state, or the branches, of the older *Sigillariæ*, it may be urged, that though abundant along with the latter genus, they are very seldom found erect, or as it were growing, that there is no real line of distinction between the two genera, and that some plants may be indiscriminately referred to either. Opposed to this theory, however, is the fact, that the *Sigillariæ* seldom or never show any tendency to ramify, or present scars of fallen branches.

Above the sudden enlargement of the base, this genus presents a columnar trunk of nearly equal diameter, very different from the gradually tapering *Lepidodendron*, and more like the caudex of a tree-fern. The great size and peculiar form of the scars also rather resemble those left by the fall of a frond than by a leaf such as the *Lepidodendron* bore. Another fact, favouring this view of their having simulated modern tree-ferns in mode of growth, is the absence of any hitherto recognized specimens of very small *Sigillariæ* which, from being of considerably less diameter than the old, would answer to the young † of that genus, and also the absence of slender *Stigmariæ* roots. In short, it ap-

* This remarkable case of an erect fossil many feet long having deposited around it as many feet of sandstone, followed by underclay, a bed of coal, shale, and other successive deposits, is a startling proof of the rapidity with which the coal-beds were formed, of the rapid decomposition of those which constituted the coal in comparison with the coniferous wood, and of the probable composition of that deposit of very soft tissued plants.

† This absence of young specimens may be otherwise accounted for by supposing on the one hand, that the shale deposit was drifted, and that the old specimens alone withstood the effects of the transport; and on the other, to me more probable, hypothesis, that they grew on the spot, and the older specimens alone fell and were fossilized. I was once inclined to consider some of the *Lepidophylla* as the foliage of *Sigillariæ*, but the specimens I have seen of certain fossils with those attached, and the figure given by Brongniart, "Hist. Veg. Foss.," vol. ii. t. 23, fig. 6, are against this supposition.

pears far from impossible, that the *Sigillariæ* was strictly Acrogenous (increasing not laterally but in length) in its growth, that it at first assumed nearly its full diameter, as a tree-fern or palm does, throwing out at the same time its stout *Stigmariæ* roots, which we know to be of a very uniform diameter in all stages, and throughout their whole length (points which will be dwelt upon in a separate essay). It may further be conjectured, that the *Sigillaria*, as it grew upwards with some rapidity, threw off the lowest fronds successively, leaving the broad scars on the stems.

I do not attempt to enter into any further or more rigid comparison between tree-ferns and *Sigillariæ*, confining the above only to what may subsist between the mode of growth of these two very distinct tribes of plants, which does not necessarily indicate a close botanical affinity between them.

The succulent nature of the *Sigillariæ*, which I have elsewhere dwelt upon, can hardly be considered an objection to these trunks having been the supports to the fern fronds* so abundantly scattered about their roots; for it may be remarked, that the *stipites* (stems of the fronds themselves) appear to have been of a succulent texture likewise, if we may judge of their invariable compression in the shales, and the rarity of their occurrence in the nodules of iron-stone, &c., in a state that shows structure. Succulent caudices (subarborescent) and stipites, too, are further characteristic of some of our largest and most coriaceous-fronded recent ferns, as the *Marattiaceæ* and *Daneaceæ*. In these tribes, the succulence of their organs is remarkably contrasted with the woodiness of those of most other ferns, the fronds of which are already assumed (on characters drawn from the fructification only) to occur in the coal formation.

A yet more remarkable and anomalous structure in *Sigillariæ* than either that of their stigmaroid roots or fluted stems was pointed out to me by Mr. Binney, of Manchester, to whom I am mainly indebted for all I know of the most important features of this genus, and whose investigations of their habit, mode of growth, and of their connexion with the *Stigmariæ* are beyond praise.† This is the curious crucial mark

* This is, I believe, the opinion of Mr. Binney, who mentioned it to me with some hesitation arising from his never having found the fronds attached, and from his having had no opportunity of comparing the *Sigillariæ* with existing tree-ferns.

† In the Manchester Museum there is a room almost entirely devoted to illustrating the botany of the coal formation. The original specimens of some *Sigillariæ* and models of others of the natural size, collected and transported with great labour, and arranged under Mr. Binney's direction, present to the eye the grandest features of the coal flora. Accustomed as I had been to see these fossils *in situ*, both in the pits and in quarries, I had previously no adequate conception of their gigantic size, nor of the rapidity with which coal may have been formed, if the tissues of these vegetables were as lax as I suppose them to have been.

which quarters the base of the trunk. The *Sigillaria* generally divides into four main roots at the base, which unite to form that crown of the dome described by Lindley and Hutton; and it is along the line of union of these four roots that these strongly marked lines run, all meeting at the centre of the dome. I know of nothing analogous to this either in recent or fossil botany.

Of the foliage of *Sigillariæ* little or nothing is known; the *S. lepidodendrifolia** not appearing to be a typical, if at all a species, of the genus. The scars are, especially in the larger species, much too broad to be regarded as the point of attachment of leaves like those of *Lepidodendron*.

Internal Structure of Sigillariæ.—The beautiful plate and excellent description of the anatomy of *Sigillaria elegans* given by M. Brongniart† are, though as regards the specimen most satisfactory, far from completing our knowledge of the genus. The drawing of the entire plant is evidently not that of a fluted *Sigillaria* of the common form. It may belong to a young plant of this genus upon which the organs indicated by the scars were very closely packed; but this is a supposition only; and until the figured fossil is better known, or some of the fluted species are found to contain structure, we must hold that the tissues of *Sigillaria* proper are to be described. M. Brongniart's plant is no doubt allied to this genus, and very distinct from *Lepidodendron:* there is a probability, too, of its belonging to the same plant as *Stigmaria*, which is evidenced by the similarity of the arrangement of the vascular tissues in both. This tissue in *Stigmariæ* is broken into wedges, indicating a higher organization than is found in *Lepidodendron*, and a still more complex arrangement in the trunks of which *Stigmariæ* are the root. Such we find in M. Brongniart's *S. elegans*, wherein are two distinct series of bundles of vascular tissue; one disposed in wedges separated by medullary? rays,‡ the other in as many bundles, each placed at the back or small end of one of these wedges.

The great bulk of *Sigillariæ* seems to have been inimical to the preservation of their tissues, the process of decay being generally effected on a grand scale in the substance of a plant evidently almost entirely composed of a lax tissue. The remains of a central column are, however, sufficiently obvious in the upright stems of many *Sigillariæ*,

* "Brongn. Hist. Veg. Foss.," p. 426, t. 161.

† "Archives du Musée d'Hist. Nat." vol. i. p. 404.

‡ The tissue of the axis of this plant and of its rays is wanting. This is generally the case in the spaces corresponding to what are filled with cellular tissue in analogously formed vegetables. In all carboniferous fossils that I have examined the cellular tissue is best preserved at the coaly circumference. I have, however, observed it elsewhere; and in one *Stigmaria* it occupies nearly all the broad space intervening between the circumference and vascular column.

these have been called "*Endogenites*," are scarcely two inches in diameter, and are generally obliquely placed in the substance of specimens five feet and upwards in girth. That this slender column represented all the vascular tissue of this plant, I cannot doubt, from examination of *Stigmariæ*, whose vascular column often assumes the same appearance.

Affinities.—These have been very much discussed by various naturalists, who have eagerly seized upon the few botanical characters the very imperfect fossils present.

In noticing its outward appearance, little allusion was made to the *S. lepidodendrifolia*, the only species of the genus whose foliage has been described, and which, if really a congener of *S. Organum*, &c., would, doubtless, ally all these plants closely to *Lepidodendron* itself. But I am inclined to pronounce M. Brongniart's figure of this plant* to be a true *Lepidodendron*, though possessed of scars more resembling those of many *Sigillariæ*, for it wants the fluted stem. The leaves of this *S. lepidodendrifolia* seem to be what was considered a species of grass or sedge, and placed in the genus *Cyperites*.

Did the great *Sigillariæ* bear leaves like those of *Lepidodendron*, they could hardly escape petrifaction in the shales, especially where the *Cyperites* so abound; but there is nothing whatever in the shales which we can recognise as having been in any probability an organ of or appendage to *Sigillariæ*.

One point which must not be overlooked, namely, the possibility of the scars upon young *Sigillariæ* being quincuncially or spirally arranged, as in *Lepidodendron*, and afterwards owing to the dilatation of the trunk being disposed in lines. The reverse of this is sufficiently obvious in some recent *Coniferæ*, as the *Pinus Webbiana*, where the young leaf-scars are disposed in parallel lines, which become disturbed through age, and appear ultimately arranged in the old branches, as shown in the accompanying wood-cut (Fig. 11).

Fig. 11.

That there are *Lepidodendrons* generically distinct from *Sigillariæ* cannot be doubted; for specimens of the former genus, many feet long, are known, having their scars spirally arranged throughout; but this is not inconsistent with the hypothesis that other plants in a certain state, apparently belonging to the

* *Sigillaria lepidodendrifolia*, "Brong. Hist. Veg. Foss.," vol. ii. t. 161.

one genus, ought really to be referred to the other, and that the *Sigillaria elegans*, whose structure M. Brongniart has ably illustrated, may be amongst them.

Although the *S. elegans* here referred to displays no fluting, it is possible that in an older state it might, and that the arrangements of the vascular tissue into separate wedge-shaped bundles, may indicate such a fluting, each ridge answering to one of the wedges; a conjecture the more probable, from the mass of vessels which supply the leaves, and which lead to scars on the ridges being placed exactly opposite to the wedge-shaped bundles.

The opinions previously held of the affinities of *Sigillariæ* are very various, and no less vague, being grounded upon supposed resemblances in their external characters, to certain natural orders of living plants. Thus Artis*, Lindley, and Hutton,† and more recently Corda,‡ have referred them, with more or less confidence, to *Euphorbiaceæ*.

Schlotheim § to *Palmæ*.

Von Martius to *Cacti*.

Brongniart, originally, ‖ and

Sternberg to *Ferns*.¶

In the earlier years of the study of fossil plants, when their affinities were scarcely known, it was no wonder that observers sought the affinities of *Sigillariæ* amongst *Dicotyledones;* but now that each successive observation tends to prove that every order of that class,** except *Cycadeæ* and *Coniferæ*, were absent from the coal-fields, it is not a little bold to persist, as M. Corda has done, and on very insufficient grounds, in ranking them among *Euphorbiaceæ*. The absence of true woody fibre in any part of these plants, pointed out by Mr. Bunbury†† is conclusive against *Sigillariæ* being allied to *Euphorbiaceæ:* I may add, that the same objection affects M. Corda's reference of *Lepidodendron* to *Semperviveæ*.

Their reference to *Palmæ* by Schlotheim, is yet more unsatisfactory. The central column is of itself a fatal objection, and it is further exceedingly improbable that such numerous *Palmæ* would be petrified without the occurrence of structural specimens.

The arguments in defence of their being *Cacti* are nearly what other writers have thought conclusive as to their being *Euphorbiaceæ*.

* Artis, Antediluv. Phytol., t. 3, 10, 18.

† Lindley and Hutton, Fossil Flora, I. pp. 94—110; t. 31—36; II. p. 13; III. p. 47, t. 166.

‡ Corda, Flora der Vorwelt, p. 34. § Schlotheim, Essai, p. 23, t. 12.

‖ Brongniart, Mem. Mus. d'Hist. Nat., v. 8, t. 1, f. 7.

¶ Sternberg, Vers. I. p. 4, t. 38. Vers. II. p. 209, t. 15.

** See M. Brongniart's excellent remarks on this subject in the "Annales des Sciences Naturelles," 3rd Series, vol. v. p. 52.

†† Quarterly Journal of Geological Society, vol. ii. p. 120.

Judging from the great preponderance of *Filices* in the coal measures, the probabilities are somewhat in favour of *Sigillariæ* belonging to that class; and this opinion has accordingly the most advocates. Lindley and Hutton* indeed adopted it at first, but rejected it afterwards on the examination of *Caulopteris;* † a most decided tree-fern.

The latest observations, however, on this subject, are those of M. Brongniart, who after an examination of the *S. elegans*‡ slightly modifies his opinion, placing the genus between *Lycopodiaceæ* and *Cycadeæ*, but nearest to the latter.

Assuming the *S. elegans* to be a true *Sigillaria*, it appears to afford slender grounds for the adoption of the above view, as regards its uniting such diverse and distinct orders as *Cycadeæ* and *Lycopodiaceæ*. It is true that it departs signally from the ordinary structure of the latter order, which however itself exhibits various modifications of the arrangements of scalariform tissue; but it requires stronger evidence than the more perfect structure and regular arrangement of the bundles of vascular tissue to ally it to *Cycadeæ*, with which, in general appearance, habit, fluting, markings, stigmaroid roots, absence of accompanying foliage, and many other points, it has nothing in common.

The *Cycadeæ*, on the other hand, and especially the *Zamia integrifolia*, which M. Brongniart instances as peculiarly favourable to his views, possess broad vessels perforated with very large circular apertures § (not seen in *Sigillariæ*), and they want the double zone of bundles of vascular tissue and diverging fascicles of *Sigillariæ*.

That the *Sigillariæ* were allied to *Lycopodiaceæ* is evident, their tissues and scarring being very like those of *Lepidodendron*, in which, however, there is but one series or zone of vascular tissue. In both, the great mass of the woody axis is formed of large tubular vessels identical in structure, and in both, fascicles are given off from the central mass to the scars on the circumference, which fascicles consist of slenderer tubes than the axis does. In *Lepidodendron* there are no medullary rays, the vascular zone being continuous and surrounded by

* Fossil Flora, Introduction to, vol. i.

† Fossil Flora, tab. 42, sub *Caulopteris primæva*, et tab. 54, sub *Sigillaria pachyderma*.

‡ Archives du Muséum, t. i. p. 426.

§ A very similar tissue is exceedingly common in the coal-beds: all the mineral charcoals (commonly called mother-coals in S. Wales) present it abundantly, and appear wholly formed of such vessels held together by fragments of medullary rays. In specimens of charcoals from the Virginian coal-mines given me by Mr. Lyell, the same tissue occurs; but it was only during the passage of this sheet through the press that I had the good fortune to meet with a fragment of the fossil wood to which these charcoals belong. In examining the collection of Mr. Darker, an acute observer and excellent lapidary, he showed me relics of a small rolled nodule of fossil wood from the coal-seams of the Yard Mine, Durham, in which I at once recognized this tissue, of which I had been long in search. The nodule was little larger than a hasel-nut, and originally covered with quartz crystals Mr. Darker had himself conjectured its probable alliance to *Cycadeæ*.

those slender vessels from which the fascicles diverge and run to the scars. In *Sigillaria elegans*, again, there are medullary rays; and M. Brongniart states that the fascicles which run to the scars in that plant originate in the inner zone of slender vascular tissue. I am however more inclined to suppose that they belong to a system of vessels exterior to the main body of the woody tissue, for if they passed out by the medullary rays they would be alternate with the latter, instead of being placed immediately opposite to them.

In *Stigmariæ* the bundles of slender vessels are distinctly seen arising from behind the woody zone and passing out by the medullary rays to which they are opposite, not alternate, as in *Sigillaria elegans*.

It is not by solitary characters, and least of all by such as the arrangement of the tissues in the axis affords, that genera of plants are referred to their natural orders. Amongst recent plants we see many instances of plants indisputably belonging to one natural family having the peculiar woody tissues of another and far distant group in the system; but these are mere analogical resemblances and by no means indications of affinity.

We may conclude then that the *Sigillaria elegans* was not far from *Lycopodiaceæ*, and especially from *Lepidodendron*: — that it was of much completer structure and higher organization than either is incontestable; but the indications of a relationship with any individual group higher in the series, or with *Cycadeæ* in particular, appear to me far too feeble to justify our considering it as tending to unite these two natural orders. It is a plant which (until we know its foliage or fructification) must be considered as belonging to the great family of ferns (including *Lycopodiaceæ*), displaying a relationship, though only of analogy, to *Cycadeæ* in one point, and to *Euphorbiaceæ* and *Cacti* in others.

Lepidodendron. — The anatomy of this genus has been well illustrated by Lindley and Hutton,* by Witham,† and more recently by M. Brongniart,‡ whose analysis has left little to be desired regarding the structure of its stem. Under the remarks upon *Lepidostrobus* which follow this Essay will be found notices of a few remarkable points connected with the occurrences of cylindrical specimens of the trunk of this genus containing cones in their hollow axes; and of the sculpture of its surface as it appears before that compression to which the specimens are almost invariably subjected previous to or during their petrifaction.

Of the stems, branches, leaves, and fructification, we have thus a very satisfactory knowledge; but the nature of their roots is not ascertained. Mr. Dawes, of West Bromwich, to whom I am indebted for much information regarding the structural characters of coal-fossils, is

* Lindley and Hutton. † Witham. ‡ Brongniart.

inclined to regard the species of *Halonia* as roots of *Lepidodendron*, on which opinion I have no remarks to offer.

Nearly forty species of *Lepidodendron* are described; and the characters of the majority of them are drawn from the arrangement and form of the scars on the stem. There are, besides, seven or eight species of *Lepidostrobus*, some of which (perhaps all) are parts of one or other of the *Lepidodendrons*. *Halonia*, another genus of the *Lepidodendreæ*, is composed of three species, possibly the roots of these or others of the same genus. Some *Lepidophylla* are certainly its leaves: a few of the carboniferous *Lycopodites* are founded on its slender terminal branches; and one or more *Trigonocarpi* (as I shall show in some remarks upon *Lepidostrobus*) are probably the seed-vessels (sporangia) of the same.

This reduction of genera to species, and in some cases of genera contained in one order (as *Trigonocarpum*, which is placed in *Scitamineæ* by Unger) to the species of another, materially diminishes our ideas of the great amount of species preserved in the coal. Such a reunion is not, however, available in practice, nor is it here for the first time forced on our attention; though it is not sufficiently considered, in the hurry of describing new forms, that the result of further discoveries amongst those already described, is to reduce the many supposed species to fragments of a few certain ones. Hence, the object of the fossil botanist should be now, in preference to describing what appear new species, and thus increasing the synonomy, to throw more light on the old, about *all* of which we know, botanically speaking, very little.

But it is not merely by the reduction of genera, founded on the parts of plants, that this is to be carried into effect. No one accustomed to study existing individuals, can regard the characters adopted for distinguishing the *Lepidodendrons*, without comparing their validity with those drawn from the same parts of their living analogues. Applying this rule to *Lepidodendron*, it will be seen that if the species of that genus were as prone to vary in the foliage as are those of *Lycopodium*, our available means for distinguishing them are wholly insufficient. Take, for example, the noblest of the genus *Lycopodium*, the *L. densum* of New Zealand, which in stature, and probably in general habit, &c., approaches nearer to *Lepidodendron* than any of its congeners. In this species, not only do the shape and arrangement of the leaves vary in different specimens, but leaves from different parts of the same individual are very unlike. The three accompanying cuts represent as many states or varieties of this plant, gathered by myself in New Zealand, where multitudes of specimens of all were growing intermixed. Of these, the dense fastigiate one (Fig. 12) is the most common; and

this is represented with the cones at the ends of the branches, borne as the *Lepidodendrons* did theirs, and all of a uniform size.* The same variety, however, repeatedly occurred with some of its branches, as in (Fig. 13), clothed with slender patent squarrose leaves; whilst others had

Fig. 12.

the branches slender, as in (Fig. 14), and covered with small and closely appressed leaves. In figure (13) the whole habit is widely different; and the leaves from three parts of the plant are so dissimilar, that had

* Though this species bears cones whose size, shape, &c., is constant, the majority of the species are extremely variable in this respect, as were the *Lepidostrobi:* this is illustrated in my remarks on the latter genus.

we only portions of branches, &c., such as we possess of *Lepidodendron*, it were impossible to recognize the plant. At letter *a* is shown the base of the stem, covered with closely imbricating leaves; at letter *b*, a portion from the middle, with very long tapering appressed leaves; at letter *c*, the branch, with its elongated spreading and squarrose foliage.

Fig. 13.

The third modification of this plant is represented at (Fig. 14), in which the branches are uniformly slender, and clothed with similar appressed leaves throughout; but the arrangement of these leaves is exceedingly variable; for at letter *a* they are closely imbricated and cover all the

stem, whilst at *b* they are disposed in whorls, separated from one another by more than the length of the leaf itself.

Fig. 14.

It may well be asked how the botanist can pronounce these dissimilar forms to belong to one plant. This can only be done by comparing a large series of perfect specimens, or by growing the different varieties from the seeds of one. The plant has, however, some constant characters and a certain habit, the value of which is at once perceived and admitted by the skilful botanist, though the uninitiated eye cannot seize it.

Ulodendron.—This very remarkable genus scarcely differs from *Lepidodendron* in internal structure: its external aspect widely departs from that of any plant, recent or fossil, with which I am acquainted. I have seen in collections, specimens which have been fossilized, apparently erect, or at any rate, under very different circumstances from those preserved in the shales over the coal. They present the appearance of a large unbranched zigzag trunk, with two rows (opposite one another) of alternating cup-shaped deep depressions, one at every projecting angle of the trunk. Some idea of the appearance of these specimens might be gathered from the accompanying wood-cut. Mr. Dawes showed me a specimen preserved in sandstone, with a large organ which he considers to be a cone inserted into one of the cup-shaped depressions. I could not, however, form any conclusion concerning the real nature of this highly interesting example.

Fig. 15.

Knorria. — A genus of which very little is known. Dr. Lindley* pronounces the *K. taxina* to be certainly coniferous, comparing it with a leafless branch of the common Yew; to me it appears to have quite as much resemblance to the stem of a *Lycopodium*, especially of *L. phlegmaria.*†

The *K. Sellonii* again, is remarkably similar to what I have considered as much compressed specimens of *Stigmaria ficoides*, which are very much compressed but not entirely flattened, and in which the cellular tissue has collapsed, leaving the vascular bundles which meet the circumference at the areolæ projecting beyond the surface:—this, however, is only a suggestion.

Calamiteæ.

I have in vain sought for any traces of structure in carefully prepared species of this genus; or for evidence of their being *Equisetaceæ* in the presence of those siliceous stomata with which that order abounds, and which would surely have been preserved in the fossil state.

Very fine specimens of this genus were pointed out to me on a cutting of the Manchester and Bolton Railway by Mr. Binney: they were

* Lindley and Hutton, Fossil Flora, sub. *K. taxina*, tab. 95.

† Compare the figure of the stem of this plant given in Brongniart's Hist. Veg. Foss., tab. 7, fig. 11, with Lindley and Hutton's figure v. 2, t. 95.

standing erect as they grew in a forest of *Sigillaria*, distinctly proving that what have been taken for leaves by the authors of the Fossil Flora, are in reality roots.

M. Brongniart* ranks them, I am not aware upon what ground, with dicotyledonous plants, allied to *Lepidofloyos*, whose tissue has been illustrated by Corda.

Cycadeæ.

The only evidence I have seen that this order existed during the carboniferous period, rests on that afforded by the charcoal (or mother-coal), and rolled nodule of fossil wood, both alluded to at p. 421; and it is confirmed by the curious observations of Brongniart† upon *Noggerathia.*

On the Order *Coniferæ*, and some obscure ones supposed to be allied to *Filices*, I have no remarks to make: future collectors will doubtless throw some light upon their true nature, especially when it is considered how much these last few months have done for the *Lepidodendrons*, *Lepidostrobi*, and *Stigmaria.* Our provincial collections, and even the still rudimentary one of the Geological Survey, abound in specimens suggestive of most interesting points, yet to be worked out. These, it is trusted, will form the materials for a succession of essays in the Memoirs of the Geological Survey of the United Kingdom.

I cannot conclude these desultory, and I fear unsatisfactory remarks, the fruits of one short year's study in the vast field of inquiry to which they relate, without expressing a hope, that my observations on the discouraging aspect of the science will not deter the beginner from pursuing his investigations: still less that they will lead the geologist to reject such information as the botanist can supply, because it has hitherto been encumbered with loose speculations on the affinities of the genera, distribution of the species, and value of the characters which the latter display. Too much has been expected from the botanist, who wants materials for those bold generalizations which the fossils of the animal kingdom so abundantly supply. Except to individuals who have great facilities for this study, the collection and examination of the waifs and strays of a by-gone Flora is a forbidding pursuit. It can be undertaken to advantage only by him to whom the existing Flora is in some measure familiar, and such an one cannot see the rapid advances in palæontology which are due to the exertions of the zoologist, without feeling a conviction, that some undistinguishing geologist will expect more definite and immediate results from his labours than the specimens at his command may ever afford.

* Brongniart, Annales des Sciences Naturelles, Ser. 3rd, vol. 5, p. 52.

† Brongniart, Annales des Sciences Naturelles, l. c.

The very desire to give a definite answer to the many puzzling questions proposed to the observer, has mainly increased the prevailing readiness to draw arbitrary conclusions from the characters which the outward appearance of a fossil affords: against this the student cannot be too frequently warned. The earliest inquirers saw (and some see still) the acorn, bean, hasel-nut, &c., in the strata of the coal formation, parts of plants belonging to orders which are not acknowledged by the sober geologist to have existed at that period. So the rude collier, denying a vegetable origin to the ferns of the shale, beholds in them merely the effort of a creative power which has fashioned stones in the likeness of plants; whilst his more reflective master recognizes fossil snakes in *Lepidodendron* and mail-clad crocodiles in *Sigillariæ*. He who acknowledges all to be vegetables has advanced a step further, but there he too may stop, if he does not pursue his investigations with due caution; for the measure of success which will reward his study will be proportionate to the comprehensiveness of the view he takes of the whole vegetation of the period in question, whether such view be the result of his own experience, or adopted from the conclusions of others. Let him remember that as remote districts on the globe are peopled, not only by different species of plants but by different prevailing natural orders, so the outward forms of one locality are imitated in the other by objects which have no further relationship, and nothing else in common. In this respect, intervals in time are marked by the same changes as intervals in space. Let him likewise bear in memory, that the two most experienced and distinguished observers have attained the same conclusion regarding the general features of the coal Flora, which I shall give in their own words. Goeppert,† in his resumé of the characters and affinities of *Stigmariæ*, says:—

"———— d'ou s'ensuit une nouvelle preuve pour l'opinion deja emanée tant de fois, que la vegetation actuelle et la primitive ne forment q'une seule Flore, dans laquelle les familles separées forment actuellement un ensemble harmonieux, au moyen de formes intermediaires multipliées qui se trouvent tantot dans le monde actuel, tantot dans le monde primitif."

M. Brongniart, the most successful cultivator of the science, after a careful review of the whole vegetation of the coal, excludes all existing orders of flowering plants except *Coniferæ* and *Cycadeæ*, and thus concludes his essay on *Noggerathia*:— ‡

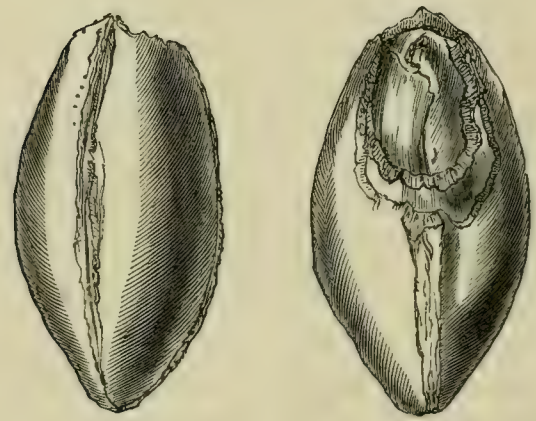
* The tail-piece represents a very singular fossil fruit of the coal formation, possibly belonging to the highest order of plants of any known during that epoch. It was discovered by Mr. Wilson, of Barnsley, in the Oak's Quarry sandstone, and is apparently the *Trigonocarpum ovatum*, Lindley and Hutton (Fossil Flora, t. 142 A.)

† Goeppert, Genera des Plantes Fossiles, under *Stigmaria*, p. 29.

‡ Annales des Sciences Naturelles, Ser. 3, vol. 5, p. 61.

" Ainsi, tout semble nous porter à conclure, des recherches faites jusqu'à ce jour, que la végétation terrestre de l'epoque houillère était limitée a deux des grandes divisions du regne végétal; les Cryptogames acrogènes ou vasculaires, et les Phanérogames dicotylédones gymnospermes."

Fig. 16.



On some Peculiarities in the Structure of STIGMARIA. By Dr. HOOKER, F.R.S., &c., Botanist to the Geological Survey of the United Kingdom.

MUCH as has been said and written upon the structure and appearance of *Stigmaria*, and long as this genus has been recognized as the prominent feature in all discussions regarding the origin of coal, there are still some very important points in its history which have hitherto escaped observation. Of these, the most remarkable is the nature of the surface previous to compression, and of the bases and attachment of the rootlets.

The surface of the *Stigmaria* has hitherto been supposed to be nearly even and uniform, interrupted only by shallow scars, variously described as circular by some, oblong by others, and lanceolate by still a third class of observers, according to the state of the specimens they have examined. The depth of these scars seldom exceeds $\frac{1}{10}$th to $\frac{1}{8}$th of an inch, in which respect the appearance of the surface of this fossil is so constantly the same, that no geologist has at first sight recognized the specimens figured at Plate 1, as belonging even to the genus *Stigmaria*.

The above-mentioned two specimens are fragments of plants which have evidently been preserved under little or no compression: the perfectly circular outline and uniform depth and figure of the cavities, together with the cylindrical form of the organ they contain, all attest this positively; whilst the depression of the surface between these cavities, and the wrinkled substance, seem to indicate that a slight collapse of the tissues composing the plant has taken place.

After having convinced myself that the specimens of *Lepidodendron*, figured at Plate 8, fig. 12, and that the portion of bark enclosed in the fossil,* Plate 10, fig. 7, and indicated by the daggers, were the only specimens that had come under my observation displaying any approach to the original and unmutilated state of that genus, I was more than ever assured of the extreme laxity of the tissues of the coal-plants, and persuaded in my own mind that the ordinary run of specimens of all were calculated to lead to erroneous views of their original appearance. Being thus prepared to find familiar forms under a new aspect, I was not a little gratified, when inspecting the cabinet of Miss Jukes, of Birmingham, to recognize the specimen of *Stigmaria ficoides*, figured at Plate 1, fig. 3, and which was obligingly lent for the use of the Survey. On my return to town I found that a similar, but more perfect and much

* See Memoirs of Geolog. Survey, in Essay on *Lepidostrobus*.

larger, specimen had been sent to the Museum, by Mr. Ormerod, and figured for me by Mr. Baily. In this latter the cavities are of somewhat less diameter, and contain the obconical or flaggon-shaped bases of the rootlets, whose summits are level with the mouth of the cavity, and are depressed at the apex.

In neither of these cases could I gain any information upon the particular circumstances under which these valuable specimens were preserved, to which however they must owe their singularly perfect condition. The precise locality of the specimen, Fig. 3, is unknown: Mr. Ormerod's was found overlying the white coal in the Peel Quarries, Lancashire.

Comparing these with the usual state of the plant, figured at Plate 2, fig. 4, the amount of collapse of the tissue which shall bring the base of a cavity a full half-inch deep, to the surface, must appear startling; but it is not really so remarkable as that the whole cylinder, including the vascular axis, should be reduced by pressure from the thickness of three or four inches to that of an inch, or even a few lines, or to a mere flake, as is generally the case with this plant when preserved (if this deserves the name of preservation) in the shales above the coals.*

While upon this branch of the subject I may allude to the singular difference in the appearance of the surface in different parts of the same *Stigmaria*. In the Bolton railway trees, to which Mr. Binney conducted me, the *Sigmaria* roots extended uninterruptedly for upwards of 20 feet, and at different points along that distance from the trunk of one individual we had many opportunities of marking the appearance of the surface: this, which was characteristic of *S. ficoides* throughout the greater part of their length, when within a few feet of the tree was seen to be materially altered. The roots themselves here became broader, more vertically compressed, the scars densely packed, and forming transversely elongated areolæ, the fossil thus possessing all the characters of *S. conferta* of Corda.†

Though so much swollen below, the surface of attachment between the base of the rootlet and of the cavity into which it is inserted must have been but limited and the union slight; for in several instances these organs are loose in the cavity, and resemble so closely a nut in its shell, that this fossil has been taken for a fruit with many nuts borne on a pitted receptacle. In the admirable and very complete account of the genus, published by M. Goeppert,‡ there is a figure (Table XIII.), representing the outline of the rootlet as produced within the

* The *Stigmaria* is rare in the shales above the coal; but I have observed it to occupy that position in the Oakwood level of Cwm Afon (in S. Wales). I have elsewhere (p. 396) given my views on the subject of the prodominance of this vegetable in the underclay.

† Corda, Flora der Vorwelt, Tab. 13.

‡ Goeppert.

circumference of the stem, and circumscribed by a dark line: this line probably indicates the surface of the deep cavity, to the base of which the rootlet is attached.

The apices of those bases of the rootlets are marked with a circular depression, and so is the lower extremity of the rootlet figured at Plate 2, fig. 1, suggesting the possibility of the point of the latter (rootlet) having been jointed unto the basal portion, at the level of the aperture through which it emerges from the root. These corresponding depressions may, however, have been caused by the collapse of the cellular tissue at the fractured end, and thus indicate no articulation at all. In none of M. Goeppert's figures is any such articulation represented, but there is something of the sort in Corda's Tab. XII., Fig. 4.

For the highly interesting specimen of a rootlet in which the cellular tissue is preserved, the Museum is indebted to Mr. Warington Smyth (Mining Geologist to the Geological Survey). It is figured at Plate 2, Fig. 1, and consists of the silicified lower portion of a rootlet, whose sides have collapsed, so as to reduce its originally cylindrical form to that of an irregularly four-sided prism. The substance is formed of a network of exceedingly delicate cellular tissue, (Plate 2, Figs. 2 and 3,) composed of hexagonal cells; and it is traversed throughout its length by a dark line, (Fig. 2 *a*,) no doubt indicating the prolongation of one of those slender bundles of vascular tissue which issue from the medullary rays of the axis, (*a* of Figs. 6 and 7,) and thence proceed to the mamillæ on the surface of the specimen, figured at Fig. 4, or the bases of the cavities in the figures in Plate 1.

This very simple structure of rootlet is similar to that of several *Lycopodia*, and indeed of many other plants, both Monocotyledonus and Dicotyledonus, so far as can be ascertained without a further knowledge of the axis of the organ; of whose structure, however, there can exist no reasonable doubt, since it may be confidently assumed to consist of a bundle of vessels, similar to those represented at Fig. 7 *a*.

In M. Goeppert's* figure (Table XIII. Fig. 8, E *d*) this axis is represented as formed of such tissue, surrounded by cellular tissues disposed in two concentric rings, between which a black line is interposed. There is no appearance of any similar arrangement in the specimen I have examined, the net-work being continuous from the vascular axis to the circumference. As there appears to be a rupture of the tissue to a considerable extent in M. Goeppert's figure near this line, and as where there is no such disunion the cellular tissue is continuous across the line, I am inclined to regard the latter as a coaly deposit, consequent possibly upon the process of petrifaction having been arrested at that point.

Mr. Henry Beckett of Wolverhampton having forwarded to the Geo-

* Goeppert, l. c. t. xvi. fig. 48.

logical Survey most beautiful specimens of the vascular axis of *Stigmariæ*, they were sliced for examination by Mr. Cuttle, and some of the points they perfectly illustrate are drawn by Mr. Bone.

Plate 2, fig. 4, represents the surface of the specimen in which the axis Fig. 14 is contained. There was not the slightest appreciable distinguishing characters between the markings of this and that specimen containing the very different looking axis Fig. 5. I shall therefore describe them as specifically the same, for in microscopical characters also they are identical.

The axis consists of a broad cylinder, composed of parallel elongated tetragonal or hexagonal tubes, of equal diameter throughout, for the greater part of their length obtuse and rounded at either extremity, and everywhere marked with crowded parallel lines, which are free or anastomising all over the surface. The tubes towards the axis are of the smallest diameter: they gradually enlarge towards the circumference, where the largest are situated, though bundles of smaller tubes occasionally occur among the larger (Fig. 7 *d*). The cylindical axis (which may for convenience be called the woody system of the plant) is divided into elongated wedge-shaped masses, rounded at their posterior or inner extremity by numerous medullary rays of various breadths, some much narrower than the diameter of the tubes, others considerably broader, but none are conspicuous to the naked eye, except towards the outer circumference.

The medullary rays, even the narrowest, are traversed by bundles of tubes half the diameter of the largest vessels of the axis (or wood) or even less (Plate 2, figs. 6, 7 *a*, and 8.) The transverse lines on their surface are generally finer and less crowded. These bundles evidently originate in the cellular axis of the stem, and do not belong to the wedges of vascular tissue (or wood) between which they run, as they appear to have done in M. Brongniart's* specimen of the plant, both from his figure and description. I cannot, however, but conclude the latter to be erroneous, because M. Goeppert, whose specimens appear to have been in this respect more perfect than any hitherto illustrated, represents the bundle of vessels which proceed from the axis, run between the wedges of wood, and communicate with the rootlets (leaves, *Goepp.*) as originating in isolated bundles, irregularly scattered in the medullary axis of the stem. Of the existence of these bundles there are some indications in my own specimens, though for the most part they have been destroyed with the cellular tissue of the plant, which indeed often takes place with the system of vessels from which the leaves, rootlets, or scales of the cones in these fossils are supplied. It is so in the stems of *Lepidodendron*, in the axis of the *Lepidostrobi*, in the

* Archives du Museum d'Hist. Nat. v. i. p. 405, t. 29, f. 3 d.

portion of the *Sigillariæ* figured by M. Brongniart, and in other fossils contained in the Museum of the Survey, and is probably owing to their great delicacy, for they are much more membranous in appearance than the similarly marked vessels of the wood.

The most important circumstance thus developed is the existence of a double system of vessels in *Stigmaria*, first shown by Goeppert, and the consequent approach in this respect to *Diploxylon*,* Corda. In *Diploxylon*, however, the inner system forms a continuous cylinder, concentric with and in juxta-position to the wedges of wood forming the outer; whilst in *Stigmaria* the same inner system is broken up into scattered bundles apparently unsymmetrically arranged in the medullary axis or pith of the plant.

In *Lepidodendron* again there is the same double vascular system; but that, from which the bundles arise which proceed to the leaves, is placed externally to the wood, where it forms a continuous zone with a well-defined inner edge (in juxta-position with the outer circumference of the inner zone) and a sinuous outer edge, from which the diverging bundles are given off. Such is also the arrangement in the axis of *Lepidostrobus*.

Sigillaria elegans differs from all the above. The woody system is (as in *Stigmaria*) broken up into wedge-shaped plates, separated by medullary rays; and another vascular system (from which, possibly, the leaves are supplied) forms † a series of bundles in the medullary axis of the stem, each placed opposite the wedges of wood. The bundles which immediately supply the leaves again are also placed opposite the wedges of wood, but externally to them, in this respect differing from *Stigmaria*, where they are opposite the medullary rays, and from *Lepidodendron*, where they form a continuous zone. It is, however, doubtful to M. Brongniart whether in his *Sigillariæ* the system of vessels which supplies the leaves really communicates with that immediately surrounding the pith. To me that structure appears improbable, from the position of both being alternate with the medullary rays through which the vessels should pass. This then is a very important point to clear up; for if the inner and outer bundles of tissue in *Sigillariæ* communicate through the medullary rays, then will the arrangement be nearly identical with that of *Stigmaria*. If, according to Brongniart's views, on the other hand, the outer bundles from which the leaves are supplied have no communication with the innermost, and form an independent

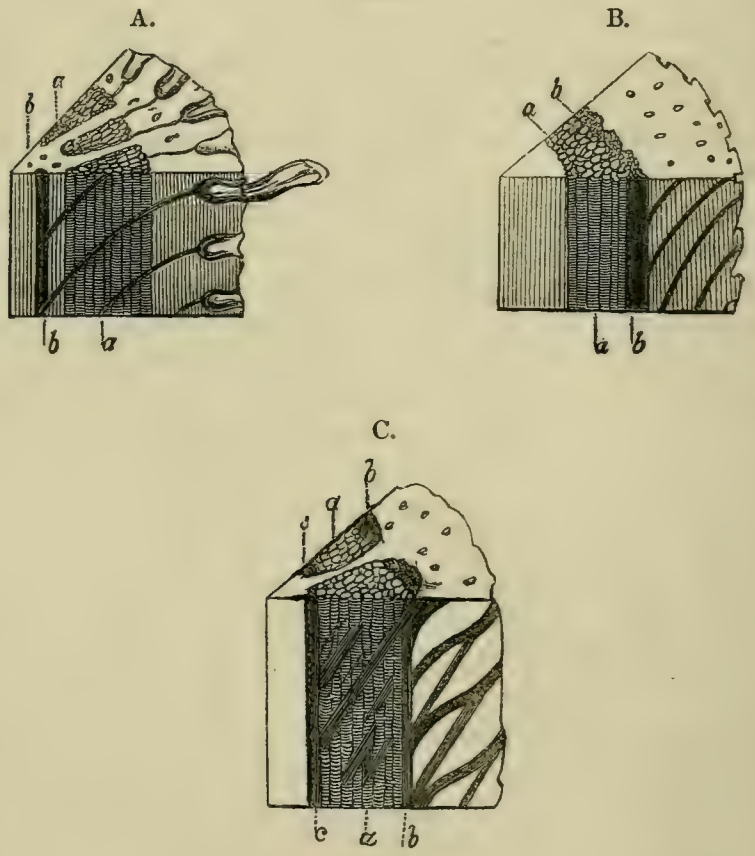
* Corda, Flora der Vorwelt, p. 34, tab. xi.

† On this point M. Brongniart is not satisfied, not having seen the bundles which traverse the cutical portion in the medullary rays, which might be expected if they communicated with the system of vessels within the wood and immediately surrounding the pith.

series concentric with but exterior to the wood, then will the arrangement coincide with that of *Lepidodendron* in these important points, and the *Sigillaria* in question may be pronounced a *Lepidodendron* with the vascular system broken up into wedges divided by medullary rays, and further possessed of a third system of vessels placed in juxta-position to and within that of the wood.

The accompanying wood-cuts explain these arrangements of the tissues in *Stigmaria* (A.), *Lepidodendron* (B.), and *Sigillaria* (C.), the latter both according to M. Brongniart's view, and in the light wherein I regard it. In all, the letter *a* indicates the vascular tissue of the wood; *b*, that from which the leaves are supplied; and *c* indicates the third series in *Sigillaria*.

Fig. 1.



Under any circumstances, the most complex of these plants is the *Sigillaria*, in which the vascular tissue surrounding the axis is as independent of the foliage and as free, as are the similar vessels in *Lycopodium*, which also pass down the pith within the wood, and send off no bundles to the leaves.

Should the conclusion of M. Brongniart hold good, and the vascular system of the axis *c* give origin to the bundles *b*, then will there be some botanical evidence of *Stigmaria* constituting a part of *Sigillaria*. If, on the other hand, it does not prove correct, still its failure would afford neither proof nor even presumptive evidence against these genera holding the respective place of root and stem.

As, however, I have elsewhere stated, I consider Mr. Binney's discoveries to be conclusive upon the origin of *Stigmaria*. That gentleman had the kindness himself to conduct me to the spot where the great fossil trees were, and we cleared the soil from the roots of several well-marked *Sigillariæ*, which roots were indisputably the plant called *Stigmaria*.

M. Goeppert, who holds this genus to be an individual plant, generically distinct from any other, refers it to the *Lycopodiaceæ* as its nearest allies, but suggests the probability of its being intermediate between that order and the *Cycadeæ*. This exact coincidence with the opinion of M. Brongniart respecting the affinities of *Sigillariæ* is sufficiently striking, especially since these authors entertain different views of the nature of *Stigmaria*. I have, under my general remarks on *Sigillariæ*, expressed doubts of the correctness of this opinion, in reference to the connexion of two such widely different families by so slender and fallacious a character as the arrangement of the tissues in the stem. The points by which *Sigillaria* (and *Stigmaria*) is allied to *Lycopodiaceæ*, especially through the *Lepidodendra*, are probably quite sufficient; but when we consider that the *Cycadeæ* have sexes, a complicated reproductive system, and a perfect seed with embryo, radicles, albumen, &c., whilst *Lycopodiaceæ* are asexual, have no reproductive system of male and female flowers, and increase by spores, it will be evident that it is by modifications of these important organs that the intermediate family would be indicated. The noble Tree-fern departs from its humble congeners in assuming the aspect of a Palm, and the *Cephalotus* (or Pitcher-plant of New Holland) has the leaf of *Nepenthes;* but the Tree-fern does not unite the Ferns with the Palms, and the *Cephalotus* is not the less a rosaceous plant because it has the pitcher of *Nepenthes;* and so we may find that the *Stigmaria* is no less a fern from its tissues being modified in arrangement. A still better illustration is furnished by some of the natural order *Magnoliaceæ*, that have the woody tissue closely resembling *Coniferæ,* and the parasitical *Myzodendrons* of Cape Horn, whose wood is like that of the ferns in many respects. These are genera certainly departing from their immediate allies in these characters, but not therefore allied to the plants which in those particulars they resemble.

The symmetrical quincuncial arrangement of the scars has been considered by very many observers to be all but conclusive against the

theory of *Stigmaria* being a root. We know, however, very little of the roots of living plants, their importance in systematic botany being trifling. There is, however, no good cause for supposing that symmetry should not pervade the subterraneous as well as the superior organs of plants; and in the case of the roots of some *Palmæ* in common use, but of unknown origin, we have an arrangement of rootlets round a prostrate root (analogous to the root of *Stigmaria*), as symmetrical as in *Stigmaria* itself.

M. Goeppert has recognised, in the majority of those species of *Stigmaria* which are founded on variations in the form and disposition of the sexes, only one. That such a view is concurrent with the fact of the genus representing merely a root, is obvious; for such an organ cannot be expected to afford specific characters. M. Corda, on the contrary, has given the name of *Stigmaria ficoides* to the dissection of a plant which evidently bears no very close relationship to the characteristic fossil of our British under-clay, and which is, doubtless, the true *S. ficoides* of authors. M. Corda's *S. ficoides* is, on the other hand, possibly a stem, and not a root.

There are in the Museum of Practical Geology so many *Stigmaria* specimens, the majority having only the external characters preserved (though in not a few the internal tissues, and in some both, are admirably displayed), that I can confidently affirm, that specimens figured by Corda (Tab. XII.), do belong to the same genus, and probably species, as M. Brongniart's dissections in the *Archives*. In proof of this assertion I would adduce the figures and dissections of Plate 2, Bot. figs. 5—13, all having been made from the one specimen, fig. 4.

Explanation of Plates.

Plate 1, figs. 1 and 2. Two views of a specimen of *Stigmaria*, fossilized without compression, and showing the pits or cavities from which the rootlets emerge in an unmutilated condition. The bases of these rootlets are generally retained within the cavity. Specimen from Peel Quarry, Lancashire, above the white-coal seam,—Mr. Ormerod's cabinet. Fig. 3, specimen of a similarly preserved fossil, from the cabinet of Miss Jukes, of Birmingham.

Plate 2, fig. 1, rootlet of *Stigmaria ficoides*. Fig. 2, horizontal section of ditto, very highly magnified, showing at *a* the position of the vascular axis. Fig. 3, cellular tissue from ditto, more highly magnified. Fig. 4, portion of *Stigmaria ficoides*, showing the scars as they usually appear, and enclosing an axis from which the dissections 5—13 were taken. Fig. 5, horizontal section of axis in fig. 4, of natural size. Fig. 6, posterior ends (those towards axis) of the vascular tissue (*b*) forming the wood, divided by broad and narrow medul-

lary rays (*a*). Fig. 7, anterior (or circumferential) end of vascular axis; *a*, vessels passing through the medullary rays to the rootlets; *b*, vascular tissue of wood; *d*, bundles of small vessels towards circumference. Fig. 8, very highly magnified view of one of the narrow medullary rays (fig. 6 *c*), forming a bundle of tubes of less diameter than those forming the wood. Fig. 9, vertical section through the axis of fig. 5. Fig. 10, magnified portion of fig. 9, showing at *a* the longitudinal vessels of the wood; at *b*, the horizontal ones passing through the medullary rays. Fig. 11, another magnified portion from the circumference of the same; *a*, the longitudinal vessels displaced by the horizontal ones, *b*, which are fractured in the fossil, and pass upwards towards the rootlets at *b'*. Fig. 12, section of the axis (fig. 5) taken at right angles to the medullary rays. Fig. 13, very highly magnified portion of ditto, showing the longitudinal vessels of the wood, *a*, displaced by the horizontal ones, *b*, whose mouths are cut across, issuing through the medullary rays. Fig. 14, horizontal section of another axis, from a specimen marked externally as in fig. 4, and whose structure accords with that of figs. 5—13.

Remarks on the Structure and Affinities of some LEPIDOSTROBI. By Dr. HOOKER, F.R.S., &c., Botanist to the Geological Survey of the United Kingdom.

The numerous detached petrified cones which are scattered through the various strata of the coal formation, being obviously organs of fructification, and having therefore belonged to some of the arborescent plants whose remains they accompany, are objects of peculiar interest to the fossil-botanist and geologist. Such of them as are preserved in the nodules of iron-stone, or are otherwise mineralized without pressure, alone offer the means of ascertaining to what existing families of plants they are most nearly allied; for in those that are crushed flat in the shales the internal structure is wholly destroyed. Many of the better preserved specimens have been sliced, polished and examined with the greatest care; but this expensive operation has hitherto thrown little light upon the true nature of the objects thus investigated.

This is because the three following conditions for their complete illustration has never been displayed by one specimen, and the most important point—the nature of the organs of fructification—has hitherto wholly escaped observation in all. Every cone being an aggregation of organs of some kind, it becomes necessary to ascertain not only the arrangement of these organs, but the nature of the tissues composing them, and (even more essential) their contents, before satisfactory conclusions can be drawn as to their relationship to any of the vegetable remains they accompany, or to whatever existing order of plants they are allied:—

1. The arrangement of the individual organs of fructification, of which the cone is an aggregation, and the nature of the scales supporting them. These are characters sometimes displayed on the fracture of the specimen by ordinary means, though rarely, from the parts appearing to have suffered partial decay previous to or during petrifaction. The imbricating apices of the scales, which lie over one another like those of a pine-cone, are generally removed with the matrix wherein the fossil is imbedded, as is seen by contrasting plate 8, fig. 1, with fig. 3, in the former of which the apices of the scales have persisted, whilst in the latter they are uniformly broken away. The mutilated is the more usual state of the surface, for reasons which shall be afterwards detailed.

2. The tissues, or anatomical structure of the various organs composing the cone; viz., of the central axis, which is a continuation of the

stem of the plant;—of the scales, which, being inserted into the axis, support the individual male or female organs;—and of the latter themselves. These tissues can only be displayed by slicing fossils in the very best state of preservation, and in such as are changed into a more or less transparent mineral. Specimens of this description are exceedingly rare, and have not hitherto been described.

3. The two above considerations are secondary to the remaining one, the nature of the contents of the cones. There may be stamens or male organs,—ovaria, or female ones;—or lastly, capsules containing reproductive spores (which are peculiar to plants having no sexual system); for these three kinds of organs all occur arranged in the form of cones, undistinguishable from one another by any external marks. Up to the present time no carboniferous fossil cone has ever been known to supply this great desideratum, without which we can arrive at no exact conclusion as to whether these curious objects are clusters of flowers, or fruits, or are the spore-bearing organs of flowerless vegetables as mentioned above.

Sections of numerous fossil cones have been prepared for the Geological Survey, with the view of illustrating these several points. Many have hardly repaid the trouble and expense of slicing, whilst others, which from external characters had been considered the least profitable, have, on the contrary, turned out the most instructive. It is a fact, that neither the most experienced lapidaries, or collectors, nor the geologists, mineralogists or botanists, have been able to decide in the majority of cases by the external appearance of a fossil cone how its internal and microscopical tissues shall be preserved. As an instance, it may be mentioned, that the most beautiful of all the *Lepidostrobi* which I have seen (that figured at plate 8, fig. 1) is utterly worthless as a structural specimen. This circumstance, combined with the rarity and singularly elegant forms of these plants, must ever render their collection and investigation among the most attractive and curious branches of Fossil Botany.

The circumstances under which these structural specimens occur are not the least interesting points in their history. All are found in the seams or nodules of clay iron-stone, and are very highly mineralized, sometimes containing crystals of iron, and the cavities in their substance being filled with white carbonate of lime and magnesia. Those which are most complete always form the nuclei to nodules of clay iron-stone—such are those figured at plate 7 and plate 8, fig. 1; but in these the internal tissues are nearly obliterated. Others again, including all in which the spores are preserved, have occurred as broken frustules, *within* stems of *Lepidodendron elegans* and other species of that genus.

I have examined as many as thirty specimens of cylindrical truncheons

of *Lepidodendron*, each from two or three inches to a foot long and from two to five inches in diameter, from the Staffordshire coal-fields, all of them containing one or more fragments of *Lepidostrobi*.* These *Lepidostrobi* are of various lengths, they run parallel to the stem in which they are enclosed, are of all ages, and in various stages of decomposition.

In one large stem, figured at plate 9, fig. 2, and plate 10, fig. 1, the remains of upwards of thirty *Lepidostrobi* are crowded together with broken-up portions of the bark and of other parts of the *Lepidodendron* itself. When they are solitary, which is very frequently the case, they resemble the vascular axis of the *Lepidodendron*, and are usually taken for such; but a very slight examination suffices to shew their true nature.

Usually the fragments of *Lepidostrobi* are not more than half an inch long, and very frequently are mere discs; so that though there is often the appearance of one several inches long, and traversing the whole length of the fragment of *Lepidodendron*, it will generally be found that this is owing to two being placed each at an extremity of the truncheon, and opposite to one another. That all were exceedingly brittle cannot be doubted, for no modern cone of any natural order could be broken up into the shallow discs which many of these fossils present. This brittleness of *Lepidostrobi*, combined with that of *Lepidodendron*, is in consonance with the remark I have elsewhere made, that the tribes of plants that were converted into coal, were all of a singularly compressible and succulent texture.

It is difficult to account for the presence of these fragments of *Lepidostrobi*, and especially of so many in one *Lepidodendron* stem as are shewn in plate 10, fig. 1. We can but conjecture that the trunks of the latter were erect stumps whose interior was hollowed out by decay, that these stumps were covered with water, charged, so to speak, with myriads of broken fragments of *Lepidostrobi* and other vegetable matter, which were washed by the fluid into the stumps. These points, however, demand a separate consideration, and will be better understood by a reference to the figures in plate 9, and those of transverse sections of the same fossils in plate 10, bearing in mind that the *Lepidodendron* stems or stumps are stuffed throughout with fragments similar to those figured in plate 10.

1. The stumps appear to have been rooted and erect, and to have received the cone fragments into their cavity, as fern fronds find their way into the axis of *Sigillariæ*. Were the stumps mere prostrate por-

* There is in Lord Stamford's Museum, at Enville Hall, a very valuable collection of coal-fossils, made by Mr. Beckett, of Wolverhampton: amongst them is a cylindrical specimen of *Lepidodendron*, containing three species of shells labelled *Unio aquilinus*, *Modiola carinata*, and *Mytilus triangularis*.

tions of stems, it is evident that cones would have lain horizontally in them, and that no washing or drifting could have induced the fragments of these cones to lie with their axis parallel to them, or could have introduced so many into one trunk ; and the latter would certainly have been materially compressed had they received on one side the pressure of the superincumbent shales.

2. The stumps must have been submerged, and the fragments quietly deposited from the water. Had the cones fallen into the stumps from an overhanging forest, they would have alighted in all manner of irregular positions, and in some cases overlain one another, which I have never seen to be the case.

3. The deposit appears to have been effected by the gradual subsidence of the water, and not by a sudden rush or current. This again is proved by the non-interference of the cones, and their uniformly vertical position with respect to the *Lepidodendron*, a fact to which I cannot too strongly call attention. It might be expected, that however tranquilly they were deposited, some irregularity should occur in their arrangement, and such may yet be observed, though in the various sections I have had the advantage of seeing made under my own direction none has been noticed.

It is hard to account for the accession of so large a volume of water as should submerge these stumps and deposit the fragments, and yet exhibit no evidence of drifting in its course. The sudden fall of a tropical torrent of rain, on a *Lepidodendron* forest, in which were hollow stumps of these trees, must at once suggest itself. This would both carry down the *Lepidostrobi* from the trees and float up the fragments on the ground, depositing them together in the stumps. Another effect of such a fall would be to break down some of the older trees, whose decaying stumps would be prepared to enclose other *Lepidostrobi* on the precipitation of the next similar torrent.

It may be asked, why the same agent that produced all the deposits over the coal, should not both have filled the trees and enveloped the whole in silt. To this I would answer, that the action does not appear to have been sufficiently violent, that the beds of iron-stone nodules, or continuous seams of clay iron-stone in which this kind of fossil occurs, bear no evidence of having contained the remains of a luxuriant forest vegetation, similar to what the coal-shales present; and that the repetition of such phenomena as I have assumed to have filled the stumps with fragments, is very likely to have impregnated the iron-charged mud with carbonized matter in a state of the most subtle comminution, which is the character of the carboniferous iron-stone wherein these specimens are imbedded.

The extreme fragility of the *Lepidostrobi*, displayed by these speci-

mens, is to me very satisfactory, as the *Lepidodendrons*, of which they are the fruit, no doubt partook of this character, which is eminently favourable to a rapid decomposition and intimate union with the silt or mud which is the basis of the clay iron-stone in the one case, and the formation of a homogeneous bed of vegetable matter, such as the coal presents, in another. The extraordinary abundance of the fragments, too, indicates a most vigorous vegetation, for they must indeed have been profusely scattered to be deposited in such numbers within narrow cylinders, into which no current appears to have been directed.

It is worthy of remark, that no fern leaves are contained in any of these *Lepidodendron* stems; and their absence is the more singular, from their being commonly deposited, along with branches of *Calamites*, &c., in the erect stumps of *Sigillaria* resting on the coal-shales. This is no doubt connected with the well-known fact of the *Sigillaria* stumps being filled with sandstone, or the same materials as those composing the stratum above the shales they root into; whilst the fossil *Lepidodendron* of the clay iron-stone seams is of the same mineral as that wherein it is imbedded. Were the fragments of *Lepidostrobi* washed into their enclosing stumps by any current, that agent would in all probability have transported the remains of other plants to the same spot.

The perfect preservation in which these fragments occur must be attributed to the protection afforded them by the surrounding *Lepidodendron* bark. That the circumference of the latter has been subjected to pressure may be inferred from the flattening of the prominences to which the leaves were attached. This pressure was moreover very considerable, as may be proved by comparing the evenness of their surface with that of a piece of *Lepidodendron* bark fossilized without pressure and embedded within the stem along with the *Lepidostrobi* (plate 10, fig. 1). From this it may be seen that the scars of the surface occupied the faces of diamond-shaped projections, elevated a full $\frac{1}{6}$ of an inch and more above the surface of the stem, and that they were separated from one another by deep grooves which dilate inwards: in other words, the prominences are broader at their bases than on their surface.

To illustrate this beautiful and hitherto unobserved character of *Lepidodendron* bark, I have figured (plate 8, fig. 12), a unique specimen preserved in a very hard and tough iron-stone, for the loan of which the Geological Survey is indebted to Mr. Cooper, of Bilston. It is not known to what favourable combination of circumstances this fossil owes its rare and perfect state of preservation: it is the only specimen of the kind that I have seen, and, like the *Stigmaria* fragments figured at plate 1, it throws a new light upon the subject it illustrates. In this the surface that bore each leaf projects a full $\frac{1}{8}$ of an inch beyond that of the stem itself, and is perforated by a tubular cavity through

which the bundle of vessels that diverged from the vascular axis of the stem to the leaf passed out.

The uniformity of the surface of the *Lepidodendrons* figured at plate 8, is an argument for their having been erect when fossilized, and proves that the deposition of the *Lepidostrobi*, &c., into their interior was effected by, comparatively speaking, tranquil waters. Had the specimens been drifted, or exposed to the action of a rushing current, on one side or the other, they must have shown it by the obliteration of some of the scars, or probably the adherence of other fossils to their surface. Again, had the stems been prostrate, the same pressure that flattened the once prominent scars, would have compressed the cylinder also.

The above are the only observations I have to offer upon these specimens relatively to the formation wherein they were found, and the circumstances under which they appear to have been fossilized: the remainder refer to the botanical characters of the *Lepidostrobi* themselves, to the strong evidence these specimens contain of their belonging to the *Lepidodendrons* that enclose them, and to the proofs which the discovery of their spores and tissues yield of both being allied to the existing genus *Lycopodium*.

*Description of the Specimens.**

Plate 3. This and the following plate represent the fragment of a *Lepidodendron*, enclosing in its once hollowed axis several *Lepidostrobi*. The specimen was received through Mr. Jukes from Mr. Lowe, of Wolverhampton, who obtained it from the iron-stone seams in the neighbourhood of that town.

Fig. 1. External surface of the fossil, displaying the markings of the *Lepidodendron Harcourtii* of the natural size.

Fig. 2. Lower surface of the same, showing the fractured surfaces of a mature and very young *Lepidostrobus*.

* It is with regret that I find myself obliged to introduce here a detailed description of the specimens, of which the plates are faithful and beautiful copies; but to understand all the points of structure in these interesting fossils, it is essential that the reader be familiar with these. Perhaps there is no more tedious and perplexing task than that of restoring a fossil plant of the coal formation. No solitary specimen among the many prepared at great cost and labour by the Geological Survey has fully illustrated any of the various points now, I hope satisfactorily, cleared up. The restoration of a *Lepidostrobus* is effected by taking a cell here and a cell there out of many individuals, and the tubes of vascular tissue, spores, &c., from various other cones. The adaptation of these to one another, and arrangement of the whole, are, after all, a mental operation. It is, however, imperative on the restorer to give every feature he has availed himself of in detail; that the experienced observer may pronounce on the justice of his views, or point out the error of his judgment; and that the tyro may know how to proceed in following similar investigations.

Fig. 3. Magnified view of the four somewhat distorted scars on the surface of fig. 1.

Plate 4, Fig. 1. Opposite surface of the fossil from that figured in Plate 3, showing a large *Lepidostrobus*, whose base rests on the curved crest of what was perhaps a branch supporting the cone.

Fig. 2. Upper fractured surface of the fossil, showing the large mature cone *a*, and a somewhat smaller one lying parallel to it. The point, where lines, drawn from the daggers *a* and *b* would intersect, indicates the position of the very perfect apex of one of the sporangia which are arranged round the axis.

Fig. 3 represents four scales (two restored) from the surface of the cone *a*.

Fig. 4. Sporangia chipped off the cone *a*.

Fig. 5. Magnified view of a sporangium, restored according to the appearances presented by the apex of the sporangium of the smaller cone seen in fig. 2.

Plate 5. Vertical sections from the *Lepidostrobus* figured in Plates 3 and 4, taken through the axes of the cones.

Fig. 1. A vertical section taken from the cone, Plate 4, figs. 1 and 2 *a*, in the direction of the dagger *a*, cutting through the axis and portions of several sporangia on either side. The axis retains hardly a trace of organization beyond a little cellular tissue on its outer margin. There are no remains of the bases of the scales supporting the sporangia, which were once inserted into the axis. The sporangia are large and long, occupying nearly the whole semidiameter of the cone, and slightly curved, with the convexity upwards, as shown at Plate 4, fig. 4. Their walls are of extreme tenuity, formed of a single row of parallel cells (seen at Plate 6, fig. 4 *c* and 10), and they contain the spores.

Fig. 2 is a magnified view of some of the tissues of the walls of the sporangia *b*, and the vascular tissue of the scales *a*, the latter composed of tubular vessels which communicate from the apices of the scales and the axis of the cone.

Fig. 3 shows the dorsal portion (that nearest the axis) of a sporangium, whose position is indicated by the intersection of lines drawn from the daggers *a b*, of fig. 1. Towards the back of this are seen numerous spores from the opaque mass which fills the greater part of the sporangium.

Fig. 4 is a portion of the same, so magnified as to define the spores.

Fig. 5. Dorsal portions of two other sporangia, indicated in fig. 1 by the daggers *b c*, between the bases of which some escaped spores are enclosed in a transparent mineral *x*.

Fig. 6. The portion marked *x* in fig. 5, magnified equally with fig. 4.

Fig. 7. A group of spores from fig. 5, very highly magnified, exhibiting their characteristic trisection by opaque lines.

Fig. 8. A smaller group of more advanced spores from fig. 3, still more highly magnified.

Fig. 9. Individual spores selected from figs. 4 and 6. They are generally tetrahedral bodies, divided into three by broad transparent spaces. The youngest, *a*, *b*, *c*, are immature, and present spurious projections at their three angles, which spines are continuous with the transparent spaces and acute, deformed by prolongations of the contiguous apices of the three sporules comprising the spore. Letter *d* indicates a more mature spore, with the spines very nearly obliterated. At letter *e* is a still more matured spore, whose angles are rounded, and in which the transparent spaces are broader, indicating that the spore has all but broken up into three sporules.

Fig. 10. A vertical section, of the natural size, of a portion of the cone, Plate 4, fig. 2 *a*. In this the tissues of the axis are preserved. This axis is hollow in the centre from the obliteration of the once cellular (?) tissue filling it.

Fig. 11. A semi-diameter of the axis of fig. 10, showing at *a* the tubes of vascular tissue, which once formed a continuous zone round the pith; *b*, the system of vascular tissue exterior to the former, which gives off the bundles *c* to the scales of the cone. The arrangement of these tissues will be best observed by referring to the wood-cut of these parts in *Lepidodendron*, at p. 436 of this volume.

Fig. 12. Tubes of the perpendicular vascular tissues *a*, of fig. 11. These are marked with horizontal rings, sometimes free, at others anastomosing at various points.

Fig. 13. Slender tubes *b*, of the vascular system, *c* of fig. 11, supplying the scales. They are surrounded by cellular tissue *d*, formed of elongated utriculi. The tubes are much more delicate and slender than those of the other system of vessels.

Plate 6. Horizontal sections of the cones, Plates 3 and 4.

Fig. 1. Slice of the mature, *a*, and immature, *b*, cones, seen in Plate 3, fig. 2.

Fig. 2. A portion of the coaly bark close to the surface of the *Lepidodendron*, showing its cellular tissue.

Fig. 3. A highly magnified portion of the cone, fig. 1 *a*, showing a section of the apex of one scale, with several others imbricating over it.

Fig. 4. Still more highly magnified view of a portion of a similar scale, edged by the walls of a sporangium *c*. The scale is chiefly formed of cellular tissue, enclosing in its centre a mass of vascular tissue *a*, which turns up to the ascending apex of the scale at *b*.

Fig. 5. Vessels seen at fig. 4 *b*, as they ascend towards the apices of the scale, fig. 4, and are consequently cut across by the lapidary. These vessels are figured at Plate 5, fig. 2 *a*, and Plate 8, figs. 6, 7, and 11 *a*.

Figs. 6 and 7. Portions of the crystallized cellular tissue of the axis of the cone, fig. 1 *a*, in which the circular holes, *a*, indicate the position of the vascular bundles supplying the scales, which are vertically sliced in Plate 5, fig. 11 *c*.

Figs. 8 and 9. Magnified portions of the small mutilated cone, fig. 1 *b*, showing the positions of the spores which are retained in the young cone, but of which there are no traces in the large cone, fig. 1 *a*.

Fig. 10. A portion of the walls of a sporangium, cut obliquely by a horizontal line, so that at one portion, *a*, the lateral cells are divided according to their long axis, whilst at the other, *b*, the cells forming the floor, are cut across their short axis.

Fig. 11. Ripe spores from the small cone, fig. 1 *b*, one of them, *a*, divided into four cohering sporules.

Fig. 12. Other spores more advanced, *a*, ready to separate; *b*, the sporules detached from one another; 3, a sporule detached wholly, probably in a state once ready for germination.

Fig. 13. Horizontal section of another part of the cone figured at Plate 3, fig. 2. This is crushed on one side, but tolerably perfect on the other, and there displaying some ripe sporangia, with a few spores in each.

Fig. 14. Magnified view of the axis.

Fig. 15, Portions of three sporangia, with a few spores scattered at their bases.

Fig. 16. More highly magnified view of portions of these sporangia and their contained spores.

Fig. 17. Spores from the same, in various stages of development.

Fig. 18. Some spores very highly magnified, all young, and the component sporules not only separated, but bounded by a transparent space, and the whole surrounded by a jagged border, probably the effect of crystallization.

Plate 7, illustrates a beautiful specimen of *Lepidostrobus ornatus*, preserved in a nodule of iron-stone. The specimen is from Glamorganshire, is preserved in the Bristol Museum, and liberally placed at the service of the Survey, not only for illustration, but for slicing, by Mr. Stutchbury, with the approbation of the directors of that institution.

Fig. 1. *Lepidostrobus ornatus*, Lindl. and Hutt., of the natural size.

Fig. 2. Vertical slice, taken through the axis, showing that the apex is undeveloped, and the cones hence hardly mature.

Fig. 3. Vertical slice of lowest scales and sporangia.

Fig. 4. Horizontal slice of semi-diameter of cone through the middle.

Fig. 5. Vascular tissue of the scales supporting the sporangia.

Fig. 6. Cellular tissue of ditto, restored from cells in various scales.

Fig. 7. Cellular tissue comprising the walls of one of the sporangia.

Fig. 8. Ideal representation of a horizontal section of a restored cone, showing eight scales, radiating round, and inserted into the axis, each bearing a sporangium.

Fig. 9. Ideal representation of a vertical section of two sporangia and their supporting scales, the latter traversed by vascular tissue.

Plate 8, Fig. 1. Fragment of a cone of *Lepidostrobus ornatus*, in which the apices of the scales are admirably preserved. Specimen from Mr. Beckett of Wolverhampton.

Fig. 2. Apices of scales of ditto magnified.

Fig. 3. Upper extremity of a *Lepidostrobus* from which the apices of the scales are removed. In the collection of Miss Jukes, of Birmingham.

Fig. 4. Vertical section of the same, showing that the axis has fallen away, as also the apices of the scales.

Fig. 5. Magnified view of the fractured terminations of the scales, each with a prominence in its hollow, which is the projecting bundle of vascular tissue, shown at fig. 11 *a*.

Fig. 6. Portion from another specimen of *L. ornatus*, showing the union of the walls of the sporangium *c*, with the scale *d*, at the point *b*; *c* is the vascular axis of the scale.

Fig. 7. More highly magnified portions of fig. 6, showing the disposition of the cells at the junction of the walls of the sporangium, *c*, with the scale, *d*. At letter *a* is seen the vascular tissue of the latter, and at *e* an escaped spore.

Fig. 8. Vertical slice of another *Lepidostrobus ornatus*.

Fig. 9. Mutilated apex of ditto, with spores escaped and mineralized in a transparent medium.

Fig. 10. Spores from the same, some of them broken up into their component sporules.

Fig. 11. Restored view of axis of cone, *x*, with two supporting scales, *b*, transversed by vascular tissue, *a*, the lower one bearing a sporangium, *s*, with its contained spores. The apices of the scales are represented broken off, as at figs. 3, 4, and 5, but restored by dotted lines, as in figs. 1 and 2.

Fig. 12. Fragment of *Lepidodendron elegans*, preserved in iron-stone, without any material compression, and hence showing the surface scars as prominent bodies. It is in the collection of Mr. Cooper, of Bilston, who procured it near that town.

Plate 9, Fig. 1. Specimen of *Lepidodendron elegans* in the cabinet of

Mr. Cooper, of Bilston, containing three tolerably perfect *Lepidostrobi*, and the remains of very many others, all vertically disposed in its axis —of the natural size.

Fig. 2. A much larger specimen of the same fossil, *reduced one-third*, from Mr. Beckett, of Wolverhampton, containing more or less perfect fragments of upwards of thirty cones of *Lepidostrobus ornatus*, besides other vegetable matter.

Plate 10, Fig. 1. A horizontal section of the fossil represented in Plate 9, fig. 1, showing the arrangement of the *Lepidostrobi* in its axis.

Fig. 2. Magnified view of semi-diameter of a very young cone, whose position in Fig. 1, is indicated by the two arrows. It is also probably the upper end of a cone, and contains sporangia full of spores.

Fig. 3. Spores and sporules from the same, of various ages and sizes, all rather mutilated.

Figs. 5 and 6. Fragments of vessels forming the vascular axis of the scales, in the same specimen.

Fig. 7. Horizontal view of Plate 9, Fig. 2, *of the natural size*, showing the numerous fragments of cones, and a curved portion of the bark of *Lepidodendron*, the position of which is indicated by the four arrows.

If the several points thus obtained be, so far as they refer to the structure of the cones, singled out and arranged, it will be seen that in the aggregate they afford a very complete knowledge of every part of the genus *Lepidostrobus*, which may be thus described :—

Cone variable in length, cylindrical, obtuse at both ends, gradually tapering towards the apex, formed of a perpendicular axis, around which are arranged horizontal scales, each bearing a sporangium, or hollow vessel filled with spores.

Axis cylindrical, consisting chiefly of cellular tissue, traversed by tubular vessels, which compose the vascular tissue. Vascular tissue of wood, Plate 5, fig. 11 *a*, forming a continuous ring enclosing the pith of the axis, composed of long hexagonal tubes, whose sides are marked with free or anastomosing transverse lines. Around this vascular tissue of wood are arranged bundles of smaller and more delicate tubes, Plate 5, fig. 11 *b*, which radiate outward to the basin of the scales.

Scales horizontal, 8-16 in a whorl, composed of two parts. Firstly, a slender pedicel, inserted into the axis and supporting the sporangium, Plate 8, fig. 11 *b*, formed of vascular tissue, through the axis of which runs the bundle of vascular tissue, fig. 11 *a*. Secondly, a broad dilated apex, at right angles to the pedicel, fig. 11 *c*, produced upwards into a triangular acute point, fig. 2, and downwards into a blunt lobe, fig. 11 *e*, also traversed throughout its length by a continuation of the vascular bundle of the pedicel. This dilated apex is formed of very loose cellular tissue laxer, especially towards the centre, which is generally

hollow; the anterior portion of this body is hence frequently removed, as seen at Plate 8, figs. 3 and 5, leaving a pitted surface to the cones.

Sporangia oblong, resting on the pedicel, and each attached by its lower face towards the apex of the latter by a small surface. Some, perhaps all, of these sporangia are furnished with ribs, Plate 4, fig. 5. Walls formed of a single layer of transversely elongated cells, Plate 6, figs. 4 and 10, and Plate 8, fig. 6 *a*. Mode of dehiscence or bursting to allow the escape of the spores unknown.

Spores consisting of three, or rarely four sporules, which are afterwards separated from one another, the immature produced at their angles into acute spines, the older suborbicular.

The two cones, from which the above general views have been deduced, are apparently from different species, and I shall therefore characterize them as such. Further, as they seem to have belonged to the fossil *Lepidodendron* enclosing them, I shall for the future notice them as really the fruit of that genus.

1. LEPIDODENDRON *elegans*. Cone slender, $\frac{3}{4}$ inch in diameter, 4-10 inches long, sporangia 8 in a whorl.

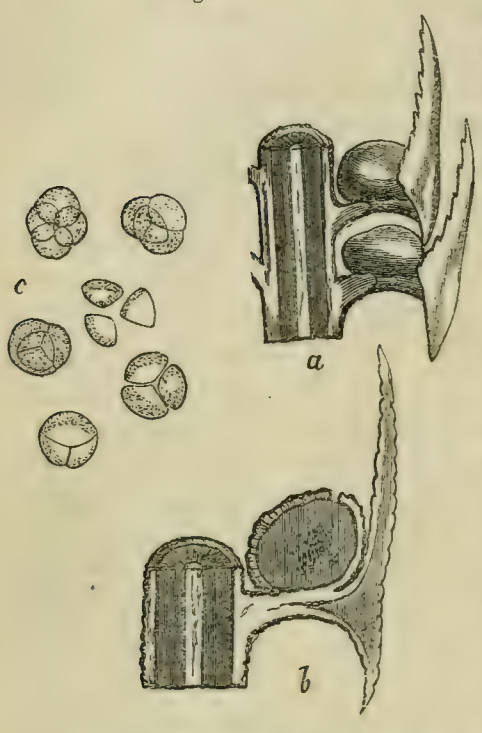
2. LEPIDODENDRON *Harcourtii*? Cone broad, $1\frac{1}{2}$ inch in diameter, sporangia about 16 in a whorl.

If, now, these cones be examined with reference to the known contemporaneous fossils which accompany them, it will appear impossible to deny their having the reproductive organs of *Lepidodendron*, not only from their association with the fragments of that genus, because the arrangement of the tissue in the axis of the cone entirely accords with that of the stem of *Lepidodendron;* just as we find, in modern cones of *Lycopodiaceæ* and *Coniferæ*, that the axis is a continuation of the branch which bears leaves, modified into organs adapted to support and protect the parts of fructification.

The most positive evidence that can be adduced of *Lepidostrobi* being a genus allied to *Lycopodium*, is afforded by the spores, the presence of which not only removes them from *Cycadeæ*, *Coniferæ*, or any other order of flowering plants, but directly refers them to the family of *Lycopodiaceæ* and *Coniferæ*. In both, the original spore divides into three or nearly four sporules, which are angular, and form the reproductive system of the plant. Not only do these groups coincide in the essential character of their spores, but, in many minor points, the strongest similarity exists between them. The arrangement of the scales is the same in both, and so are the scales themselves in general features, especially towards their dilated apices. The situation of the sporangia, too, is alike, and their attachment by a very narrow surface to the scale.

To illustrate this properly, the following illustrations (fig. 1), were prepared. That at Plate 8, fig. 11, should be compared with this wood-cut, where the only material difference between them is in the shape of the sporangium. The spores *c*, from *L. Selago*, should be compared with those of Plate 5, figs. 7, 8, 9; Plate 6, figs. 11 and 12; Plate 8, fig. 10; and Plate 10, fig. 3.

Fig. 1.



Previous to the investigations of M. Brongniart, the prevailing opinion with regard to these cones was, that they belonged to plants of the Pine tribe. Their great size and the presence of coniferous wood in the coal formation both favour this supposition.

It is, however, well known to the botanist, not only that cones are far from being peculiar to one natural order of plants, but that their extreme form is no indication, either of their contents, or of the affinities of the plants which produced them. Accordingly, we find that Dr. Lindley, the first English observer who published any extended views on the affinities of these plants, suggests the probability of their being referable either to *Coniferæ, Lycopodiaceæ,* or more probably still to *Cycadeæ*.*

The scales, to whose arrangement the production of a cone is due, are in no essential respect different from those that occur on other parts of the plant. The doctrine of morphology teaches us, that the cone is nothing more than the leafy apex of a branch, whose leaves are modified in form, generally to the end that they shall perform the office of protecting organs to reproductive bodies; this is the case with the Pine cone, that of the *Lycopodium* or club-moss, and many other plants.

Cases are however not unfrequent, of what may be termed false cones, which have no relation to the reproductive organs of the plant. In some species, they are common, and are naturally produced, as in the well-known cone-bearing willow, and in the larch, which produces barren cones, unconnected in every way with those containing the seeds.

* Lindley and Hutton, Fossil Flora, t. 11, sub. *L. variabilis.*

The normal arrangement of the leaves of a plant is spiral around the branch: when the latter is very short, and the leaves also short and crowded, the whole branch becomes a cone; this is frequently seen on the apices of the branches of some plants, and is also artificially effected in others, by an injury to the branch, which prevents its elongation. In Tierra del Fuego there is a genus, several species of which have the branches punctured by an insect; the consequence is, that the wounded portion is arrested in its tendency to prolong, the sap is thrown into the leaves, which become broader and otherwise of different appearance from the usual form of leaf, and lap over one another, so as to produce a cone.

I have thus long dwelt upon the formation of spurious cones, because some of the so-called *Lepidostrobi* may be of this nature,—witness the *Lepidodendron oocephalum*, * of which it is impossible to say whether it be a *Lepidostrobus* or the apex of a branch crowded with short leaves.

The Fuegian plant mentioned above illustrates this subject, and a wood-cut of two species of the genus alluded to (*Pernettya*, allied to the "Heaths") is added. Both were collected at Cape Horn, where the plants were invariably thus coniferous in the diseased branches, while the healthy bore little bell-shaped flowers. Instances of this sort

Fig. 2.

are not very uncommon on individual species, but a general tendency in the development in question is sufficiently curious. Were the above figured plants to occur fossil, the probability is, that their cones would be regarded as the undoubted reproductive organs, and the plants themselves be provisionally referred to *Coniferæ;* in further evidence of which opinion the cold climate they inhabit might be adduced, and

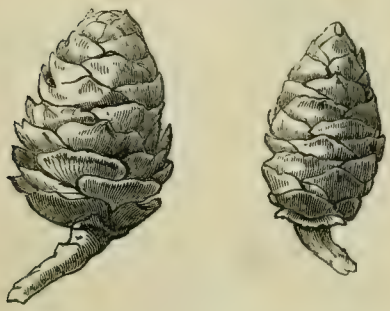
* Lindley and Hutton, Fossil Flora, v. iii., t. 206.

their general similarity to some really coniferous and totally different plants of Tasmania.

Cones, again, instead of being fruit-bearing organs, are frequently mere aggregations of male flowers. This is the case especially with the *Cycadeæ*, the cones of one species of which (*Dion edule* of Mexico) entirely resemble those of the truly coniferous genus *Araucaria*.

Proteaceæ are an order whose species abound in, and are almost confined to, Australia and South Africa, and whose (hermaphrodite) flowers are very frequently arranged in cones. Such cones would, if fossilized, and in the absence of any other evidence, be considered to have belonged to a coniferous plant. An illustration is added of such a Proteaceous cone, which, without examination, is calculated to deceive, even when recent, and if petrified, would assuredly be considered as belonging to a pine.

Fig. 3.



Lycopodiaceæ are the last (though not the only other) cone-bearing genera I shall mention; but as *Lepidostrobi* are to be directly compared with these, I omit any further mention of them here.

The size, form, and arrangement of their parts, together with the general disposition of previous observers to class the *Lepidostrobi* among *Coniferæ*, did not deceive M. Brongniart, who rightly conjectured them to belong to *Lycopodiaceæ*, and that too without any of that direct evidence, afforded by the specimen in the museum of the Geological Survey. Dr. Lindley, with his usual sagacity, had previously referred the cones to *Lepidodendron*, though ignorant of the nature of those tissues which also it has been our good fortune to obtain. In this opinion M. Brongniart concurs, and proceeds, in a review of the characters afforded by both *Lepidodendron* and *Lepidostrobus*, to cite his reasons for allying them to *Lycopodiaceæ*, rather than to *Coniferæ*, under which the authors of the Fossil Flora of Great Britain had arranged *Lepidodendron*.*

From the curious dichotomous ramification of the stem, M. Brong-

* The extreme perplexity of this subject may be gathered from the hesitation with which so excellent a botanist as Dr. Lindley always speaks of the affinities of *Lepidodendron*. In the introduction to the *Fossil Flora*, he regards it as *Lycopodiaceous*; under *Halonia gracilis* (Tab. 86), as probably *coniferous*; *Lepid. Harcourtii* (Tab. 89, 90) is pronounced intermediate between *Lycopod.* and *Coniferæ*; *Lep. selaginoides* (Tab. 113) is, he continues, rather *Coniferous* than *Lycopodiaceous*; and finally, under *Lep. elegans* (Tab. 118) and *Megaphyton approximatum* (Tab. 116), the *Lepidodendreæ* are definitively referred to *Coniferæ*.

niart inferred that *Lepidodendron* could not be a *Dicotyledonous* plant. The arrangement of its tissues clearly forbade its belonging to *Monocotyledones*. The cylindrical form of many of their (erroneously so called) cones was conclusive against their belonging to any coniferous plant, where these organs are always truly conical; whilst the form of these organs and the arrangement of their parts entirely tallied with *Lycopodiaceæ*.

In the details of M. Brongniart's description of the genus *Lepidostrobus*, there are some errors which, with the aid of more copious and perfect specimens, may now be corrected. It is satisfactory to know, that these rectifications throw light upon certain important points, in which it was supposed that this genus differed from any existing vegetable, presenting a most anomalous feature.

The first error then relates to the arrangement of the sporangia upon the supporting scales; they were imagined to be borne on the under-surface of the scales,* a misconception probably arising from mistaking the base for the apex of the cone, as shown at Fig. 2 *a* of Tab. 23.—(*Végétaux Fossile*, vol. ii.)

M. Brongniart further supposed the horizontal portion or pedicel of the scale, to be very broad, and to surround the base and two sides of the sporangium, which was thus enclosed between its own scale and axis, on all but the upper surface. In the specimens I have examined, on the contrary, the pedicel of the scale is exceedingly slender in comparison to its dilated apex, and of far less breadth than the sporangium, whose point of attachment to it is so small, that it can seldom be divided during slicing by the lapidary.

Lastly, M. Brongniart hesitates on pronouncing the *L. ornatus* of Lindley and Hutton to be *Lycopodiaceous*. If, however, as I suppose, the specimen, figured at Plate 7, is rightly referred to that plant, its affinities are undoubtedly with the other *Lepidostrobi*.

With regard to the number of species of *Lepidostrobus*, comprised in the Plates 3, 4, 7, 8, 9, 10, I do not recognize more than two, with any degree of certainty. One of them is that contained in the trunk of *Lepidodendron* (figured at Plates 3 and 4), and which is probably identical with the fragments figured in *Végétaux Fossile*, (vol. ii., t. 23, fig. 5 *a*, *b*). The second is the very long cylindrical cone, included within the trunk of *Lepidodendron elegans* (figured at Plate 8, fig. 1), and to which, in all probability, should be referred the cones Plates 7, 8, figs. 3 and 8, and Plate 10. This is allowing for great variation in the length of the cone, in one species, not more, however, than may be seen in very many of their existing allies the *Lycopodia* as the

* Végétaux Fossile, v. ii., p. 52.

accompanying wood-cut of the cones of the *L. Magellanicum* will show. The internal structure, form of the sporangium, the length of the apices of the scales, and breadth of the cones, are very nearly alike in all the specimens. To this *L. ornatus* (Brongniart's Figs. 1, 2, and 4 of vol. ii., Tab. 23), should, possibly, be referred.

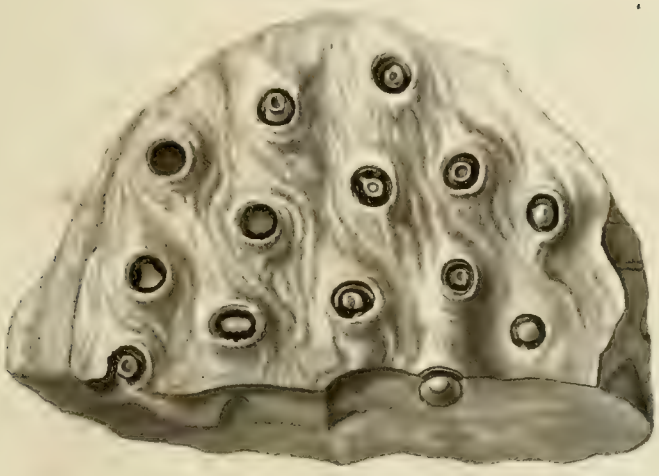
Fig. 4.

The beautiful little nut, of which a wood-cut is added,* is most probably a sporangium, belonging to this cone of *Lepidodendron elegans*; though differing in shape, its sculpturing corresponds with that of sporangium, removed and restored from *Lepidostrobus*, Plate 4, fig. 5.

The young state of this species is the very elegant specimen contained in a nodule of clay-iron-stone, figured at Plate 7. Besides the more conical and shorter form of the cones, they are distinctly attenuated to the apex, as if hardly matured. The apices of the scales, too, do not appear to be produced downwards to the degree of those of the former species.

Fig. 5.

* From the collection of John Gray, Esq., of Dudley. It is fossilized in a nodule of iron pyrites.



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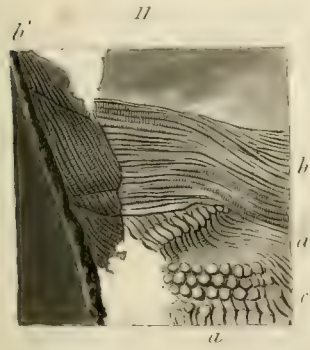
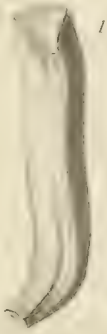
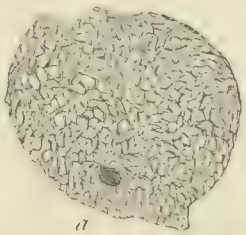
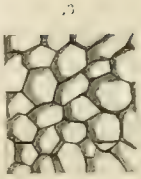
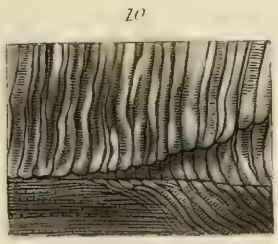
ROOTLETS *of* STIGMARIA.

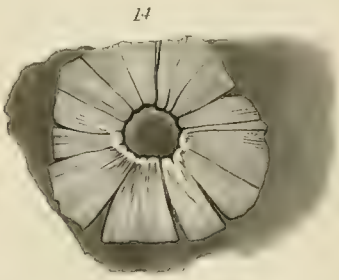


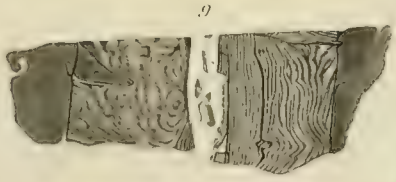


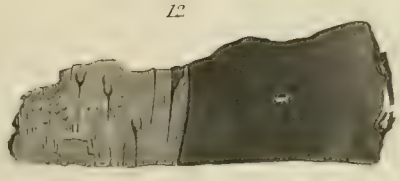


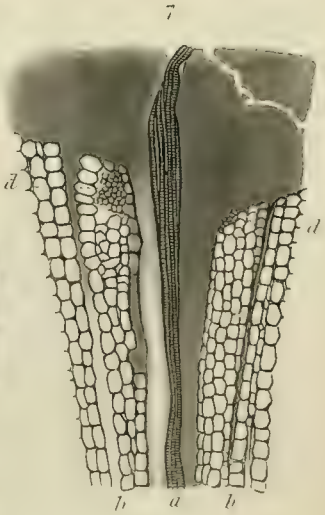


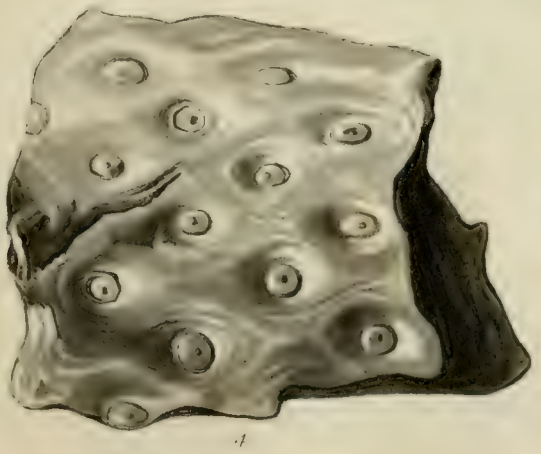


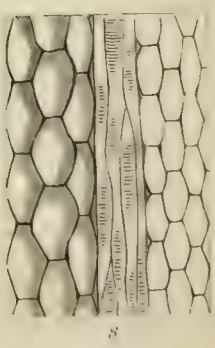




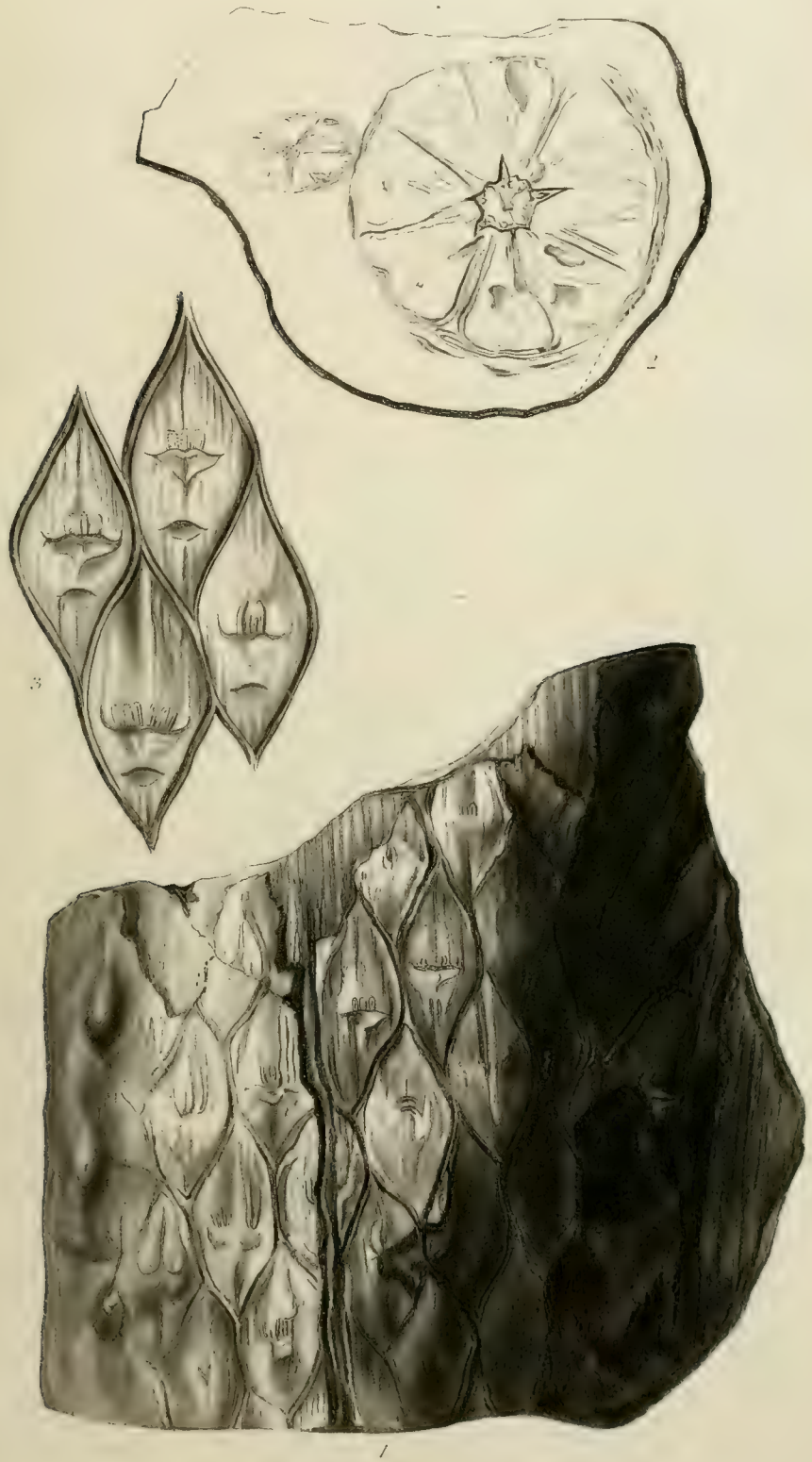






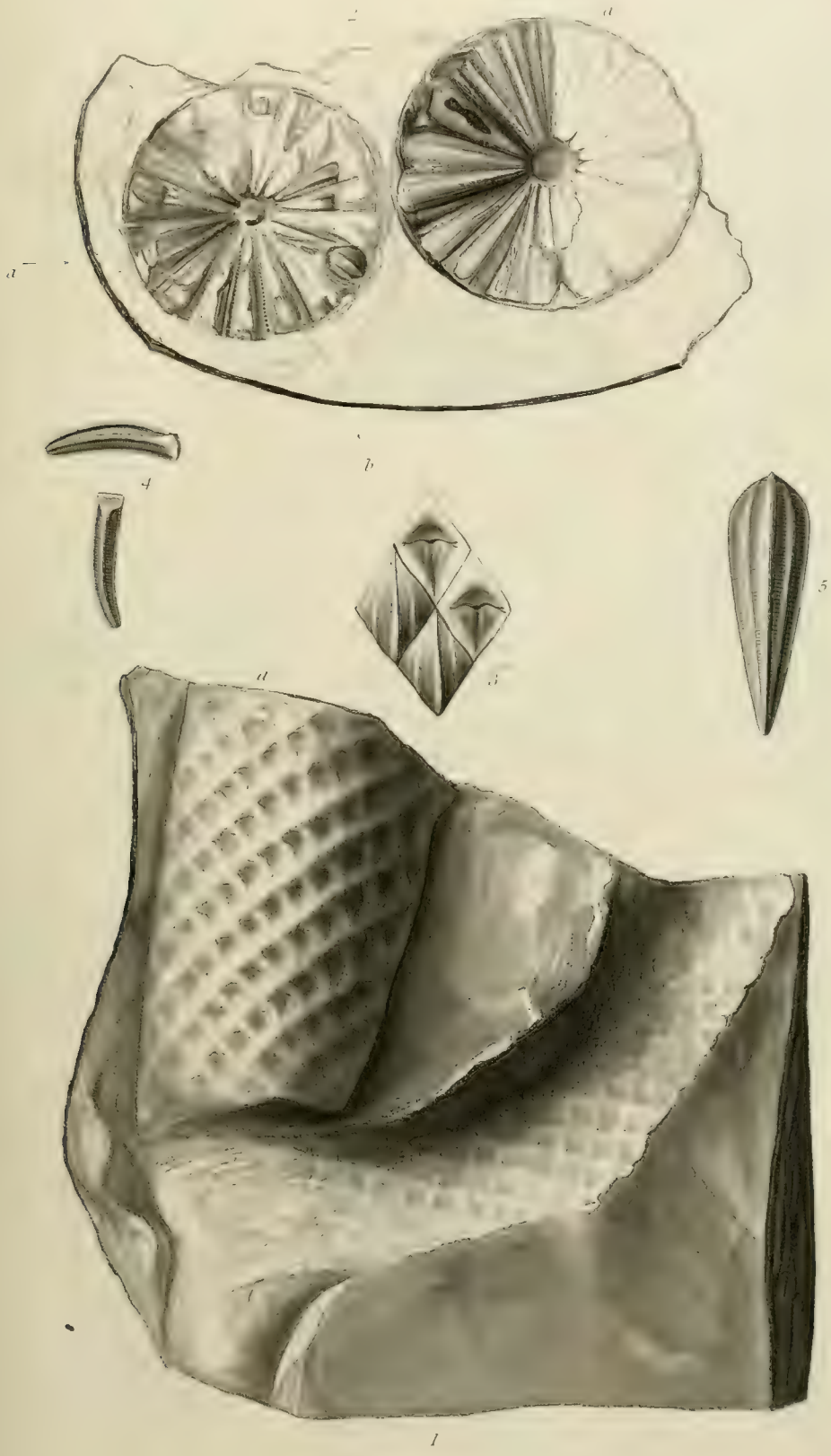


STIGMARIA FICOIDES



LEPIDODENDRON *and* LEPIDOSTROBUS

W.H.Baily del

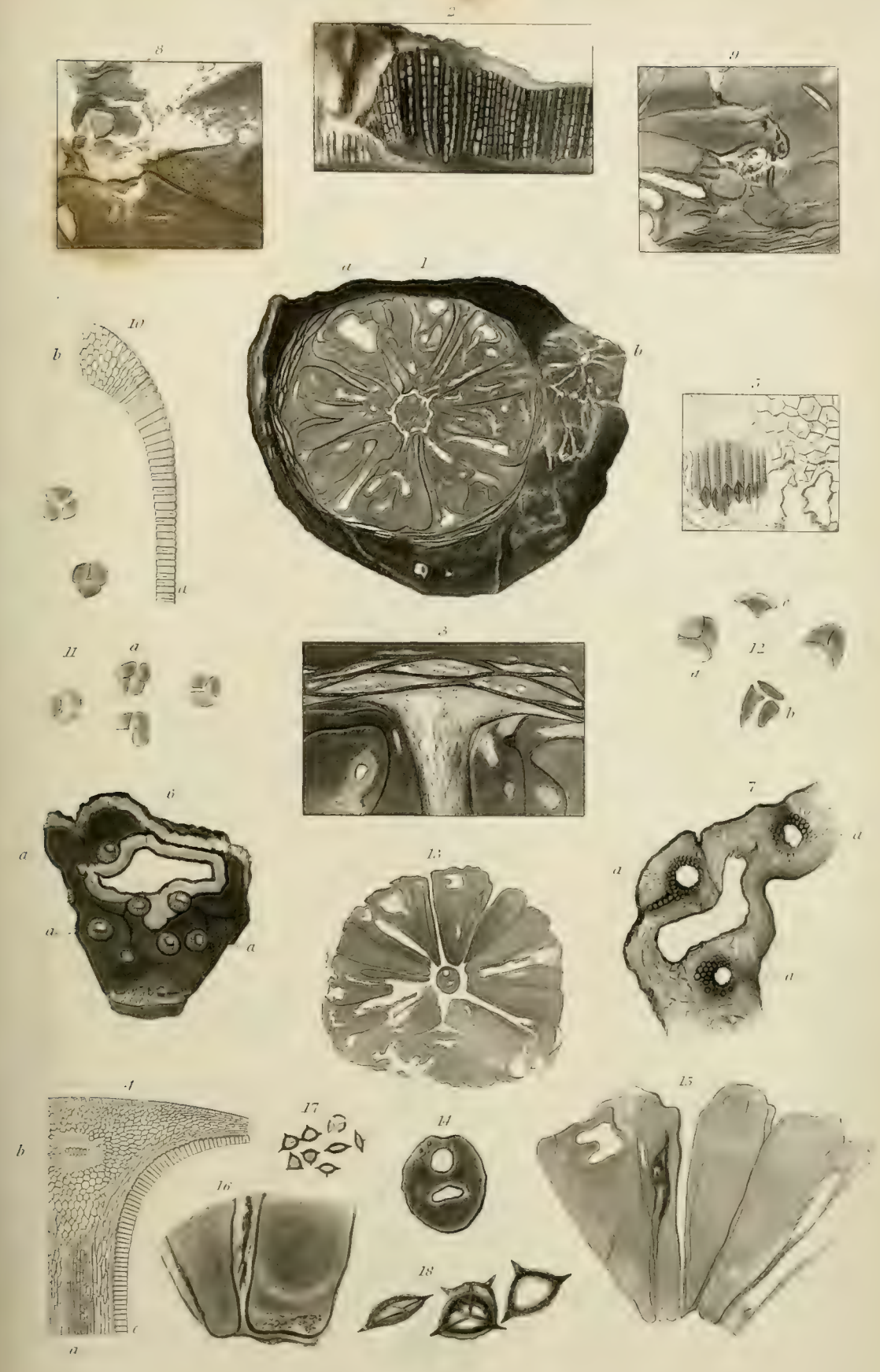


LEPIDOSTROBUS

Geological Survey of the United Kingdom.

Plate V.

LEPIDOSTROBUS



LEPIDOSTROBUS

Geological Survey of the United Kingdom.

Plate VII

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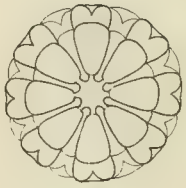

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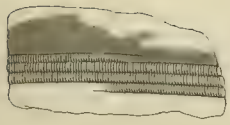

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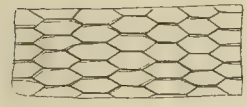

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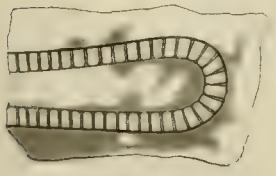

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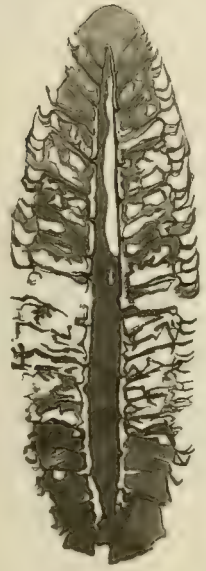

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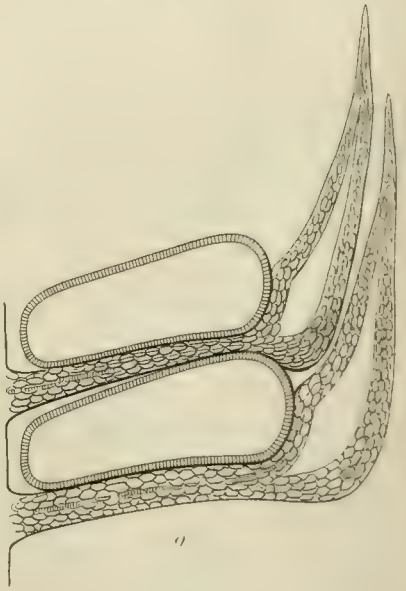

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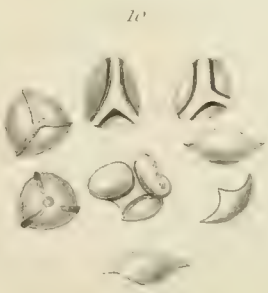
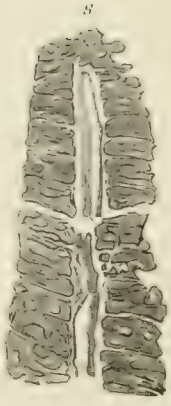
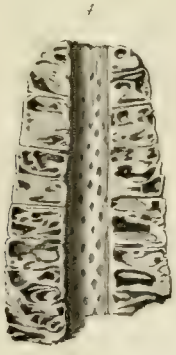
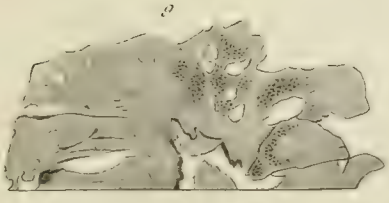
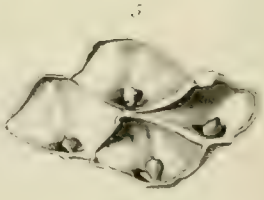
LEPIDOSTROBUS ORNATUS

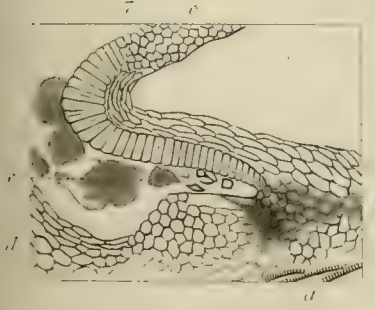


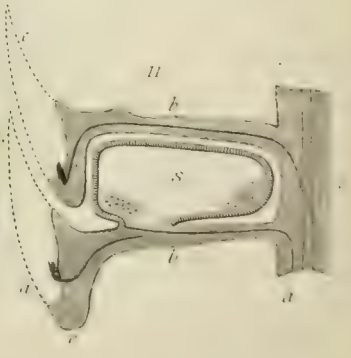












LEPIDOSTROBUS ORNATUS *and* LEPIDODENDRON ELEGANS.

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LEPIDODENDRON ELEGANS

C.R.Bone del. J.D.Hooker

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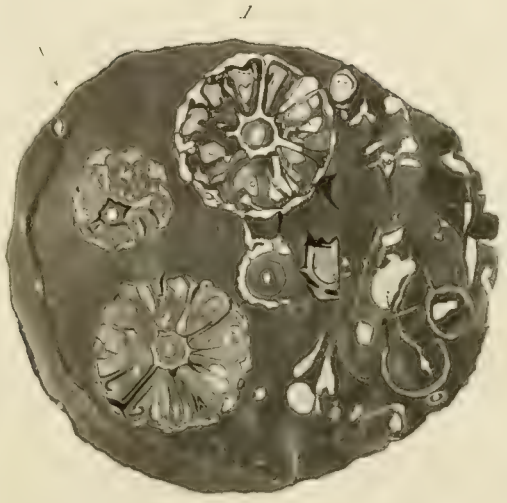

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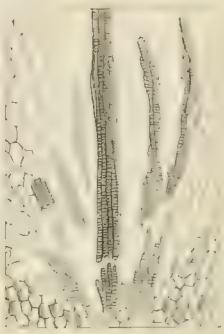

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LEPIDOSTROBI *in* LEPIDODENDRON