Separated Set

CHAPTER XX.

THE CARBONIFEROUS SYSTEM—*Continued.*

THE FLORA OF THE COAL FORMATION.

I HAVE already endeavoured to introduce the reader into the jungles and forests of Carboniferous Acadia; but in order that he may fully appreciate the nature of the wondrous vegetation of that ancient time, the producer of all our stores of mineral fuel, it will be necessary that we shall pass in review the several genera of Coal formation plants, and endeavour so to restore them that, in imagination, we may see them growing before us, and fancy ourselves walking beneath their shade. While thus endeavouring to introduce the ordinary reader and the student of Geology and Palæontology to an acquaintance with the Coal Flora, I shall take advantage of the abundant material within my reach to restore some of the species more completely than has hitherto been possible, and thus to present to geologists what I trust may prove a more full and accurate synopsis of the leading features of the Carboniferous Flora than any at present accessible.

The modern flora of the earth admits of a grand twofold division into the *Phænogamous,* or flowering and seed-bearing plants, and the *Cryptogamous*, or flowerless and spore-bearing plants. In the former series, we have, first, those higher plants which start in life with two seed-leaves, and have stems with distinct bark, wood, and pith—the *Exogens ;* secondly, those simpler plants which begin life with one seed-leaf only, and have no distinction of bark, wood, and pith, in the stem—the *Endogens ;* and, thirdly, a peculiar group starting with two or several seed-leaves, and having a stem with bark, wood, and pith, but with very imperfect flowers, and wood of much simpler structure than either of the others—the *Gymnosperms.* To the first of these groups or classes belong most of the ordinary trees of temperate climates. To the second belong the Palms and other trees found in tropical climates. To the third belong the Pines and Cycads. In the second or Cryptogamous series we have also three classes,—(1.) The *Acrogens*, or ferns and club-mosses, with stems having true vessels marked on the sides with cross bars—the scalariform vessels. (2.) The *Anophytes*, or mosses and their allies, with stems and leaves, but no vessels. (3.) The *Thallophytes*, or lichens, fungi, sea-weeds, etc., without true stems and leaves.

In the existing climates of the earth we find these classes of plants variously distributed as to relative numbers. In some, pines predominate. In others, palms and tree-ferns form a considerable part of the forest vegetation. In others, the ordinary exogenous trees predominate, almost to the exclusion of others. In some Arctic and Alpine regions mosses and lichens prevail. In the Coal period we have found none of the higher Exogens, and only a few obscure indications of the presence of Endogens; but Gymnosperms abound, and are highly characteristic. On the other hand, we have no mosses or lichens, and very few algæ, but a great number of ferns and Lycopodiaceæ or club-mosses. Thus the Coal formation period is botanically a meeting place of the lower Phænogams and the higher Cryptogams, and presents many forms which, when imperfectly known, have puzzled botanists in regard to their position in one or other series. In the present world, the flora most akin to that of the Coal period is that of moist and warm islands in the southern hemisphere. It is not properly a tropical flora, nor is it the flora of a cold region, but rather indicative of a moist and equable climate. Still we must bear in mind that we may often be mistaken in reasoning as to the temperature required by extinct species of plants differing from those now in existence. Farther, we must not assume that the climatal conditions of the northern hemisphere were in the Coal period at all similar to those which now prevail. As Sir Charles Lyell has shown, a less amount of land in the higher latitudes would greatly modify climates, and there is every reason to believe that in the Coal period there was less land than now. Farther, it has been shown by Tyndall that a very small additional amount of carbonic acid in the atmosphere would, by obstructing the radiation of heat from the earth, produce almost the effect of a glass roof or conservatory, extending over the whole world. Again, there is much in the structure of the leaves of the Coal plants, as well as in the vast amount of carbon which they accumulated in the form of coal, and the characteristics of the animal life of the period, to indicate, on independent grounds, that the carboniferous atmosphere differed from that of the present world in this way, or in the presence of more carbonic acid,—a substance now existing in the very minute proportion of less than one-thousandth of the whole, a quantity adapted to the present requirements of vegetable and animal life, but probably not to those of the Coal period.

We shall commence our survey of the Coal flora with the higher forms of plant-life, which are also those most akin to the plants of the present world.

Class of Gymnosperms.

1. *Coniferæ or Pines.*

Four species of pines have been recognised in the Coal formation of Nova Scotia and New Brunswick. They are known principally as drift trunks imbedded in the sandstones, and these are so abundant as to indicate that extensive pine forests existed, perhaps principally in the uplands, higher than the Coal swamps. The trunks are also frequently so well preserved, owing to the infiltration of carbonate of lime or silica into their cells, that their most minute structures can be observed as readily as in the case of recent wood. They may all be included in the genus *Dadoxylon*, a name which means simply pine-wood. The wood of these trees, however, more resembles that of the Araucarian pines of the southern hemisphere than that of our ordinary pines.

One of the species, *D. antiquius*, is closely allied to *D. Withami* of Great Britain, and, like that species, belongs to the Lower Carboniferous Coal measures. Its structure is of that character for which Brongniart proposed the generic name "*Palæoxylon.*"* Another species, *D. Acadianum*, is found abundantly at the Joggins and elsewhere in the condition of drifted trunks imbedded in the sandstone of the lower part of the Coal formation and the upper part of the Millstone-grit series. The third species, *D. materiarium*, is very near to *D. Brandlingii* of Great Britain, and may possibly be only a variety. It is especially abundant in the sandstone of the Upper Coal formation, in which vast numbers of drifted trunks of this species occur in some places. The fourth species, *D. annulatum*, presents a very peculiar structure, probably of generic value. It has alternate concentric rings of discigerous woody tissue, of the character of that of *Dadoxylon*, and of compact structureless coal, which either represents layers of very dense wood or, more likely, of corky cellular tissue. In the latter case, the structure would have affinities with that of certain *Gnetaceæ* or jointed pines, and of Cycads.

Though coniferous trees usually occur as decorticated and prostrate trunks, I have recorded the occurrence of one erect specimen, in a sandstone a little above the "Main Coal," at the Joggins. It probably belonged to the species last named. Tissues of coniferous trees are very rare in the coal itself. Most of the tissues marked with discs on the cells like those of pines, found in the coal, belong to *Sigillaria* and

* Ancient wood.

Calamodendron. From the abundance of coniferous trees in sandstones above and below the coal, and their comparative absence in the coal and coal-shales, it may be inferred that these trees belonged rather to the uplands than to the coal-swamps; and the great durability and small specific gravity of coniferous wood would allow it to be drifted, either by rivers or ocean-currents, to very great distances. I am not aware that the fruits of pine-trees occur, unless some of those called *Trigonocarpa* are of this character. Nor has any foliage of these trees been found, except at Tatamagouche, in the continuation of the Upper Coal formation, where I have found leafy branchlets which I have named *Araucarites gracilis*, and which may possibly have belonged to *Dadoxylon materiarium*.

The casts or pith-cylinders known as *Sternbergiæ* are abundant in some of the sandstones, especially in the Upper Coal formation. I have shown that in Nova Scotia, as in England, some of these singular casts belong to *Dadoxylon*;* but as the pith-cylinder of *Sigillaria* and of *Lepidophloios* was of a similar character, those which are destitute of woody investment cannot be determined with certainty, though in general the transverse markings are more distant in the *Sternbergiæ* of *Sigillaria* and *Lepidophloios* than in those of *Dadoxylon*.

In a paper communicated to the Geological Society of London in 1846, to which Professor Williamson, in his able Memoir in the Manchester Transactions (vol. ix., 1851), assigns the credit of first suggesting that connexion between these curious fossils and the conifers which he has so successfully worked out, I stated my belief that those specimens of Sternbergiæ which occur with only thin smooth coatings of coal might have belonged to rush-like endogens; while those to which fragments of fossil wood were attached presented structures resembling those of conifers. These last were not, however, so well preserved as to justify me in speaking very positively as to their coniferous affinities. They were also comparatively rare; and I was unable to understand how casts of the pith of conifers could assume the appearance of the naked or thinly coated Sternbergiæ. Additional specimens, affording well-preserved coniferous tissue, have removed these doubts, and, in connexion with others in a less perfect state of preservation, have enabled me more fully to comprehend the homologies of this curious structure, and the manner in which specimens of it have been preserved independently of the wood.

My most perfect specimen is one from the coal-field of Pictou†

* Proceedings of the American Association, 1837, Canadian Naturalist, vol. ii. Paper on Structures of Coal, Quart. Journ. Geol. Soc. 1860.

† Presented to me by Mr Hogg of Pictou Island.

the cell walls (C, *c*). It is not distinguishable from that of *Pinites* (*Dadoxylon*) *Brandlingii* of Witham, or from that of the specimens figured by Professor Williamson. The wood and transverse partitions are perfectly silicified, and of a dark-brown colour. The partitions are coated with small colourless crystals of quartz and a little iron pyrites, and the remaining spaces are filled with crystalline laminæ of sulphate of barytes.

Unfortunately this fine specimen does not possess enough of its woody tissue to show the dimensions or age of the trunk or branch which contained this enormous pith. It proves, however, that the pith itself has not been merely dried and cracked transversely by the elongation of the stem, as appears to be the case in the Butternut (*Juglans cinerea*), and some other modern trees, but that it has been condensed into a firm epidermis-like coating and partitions, apparently less destructible than the woody tissue which invested them. In this specimen the process of condensation has been carried much farther than in that described by Professor Williamson, in which a portion of the unaltered pith remained between the Sternbergia cast and the wood. It thus more fully explains the possibility of the preservation of such hollow-chambered piths after the disappearance of the wood. It also shows that the coaly coating investing such detached pith-casts is not the medullary sheath, properly so called, but the outer part of the condensed pith itself.

The examination of this specimen having convinced me that the structure of Sternbergiæ implies something more than the transverse cracking observed in Juglandaceæ, I proceeded to compare it with other piths, and especially with that of *Cecropia peltata*, a West Indian tree, of the natural family Artocarpaceæ, a specimen of which was kindly presented to me by Professor Balfour of Edinburgh, and which I believe has been noticed by Dr Fleming, in a paper to which I have not had access. This recent stem is two inches in diameter. Its medullary cylinder is three-quarters of an inch in diameter, and is lined throughout with a coating of dense whitish pith tissue, one-twentieth of an inch in thickness. This condensed pith is of a firm corky texture, and forms a sort of internal bark lining the medullary cavity. Within this the stem is hollow, but is crossed by arched partitions, convex upward, and distant from each other from three-quarters to one and a quarter inch. These partitions are of the same white corky tissue with the pith lining the cavity; and on their surfaces, as well as on that of the latter, are small patches of brownish large-celled pith, being the remains of that which has disappeared from the intervening spaces. Each partition corresponds with the upper margin of one of the large triangular leaf-scars, arranged in quincuncial order on the surface of the stem.

Inferring from these appearances that this plant contains two distinct kinds of pith tissue, differing in duration and probably in function, I obtained, for comparison, specimens of living plants of this and allied families. In some of these, and especially in a species labelled "*Ficus imperialis*," from Jamaica, I found the same structure; and in the young branches, before the central part of the pith was broken up, it was evident that the tissue was of two distinct kinds: one forming the outer coating and transverse partitions opposite the insertions of the leaves, and retaining its vitality for several years at least; the other, occupying the intervening spaces or internodes, of looser texture, speedily drying up, and ultimately disappearing.

The trunks above noticed are of rapid growth, and have large leaves; and it is probable that the more permanent pith tissue of the medullary lining and partitions serves to equalize the distribution of the juices of the stem, which might otherwise be endangered by the tearing of the ordinary pith in the rapid elongation of the internodes. A similar structure has evidently existed in the Coal formation conifers of the genus Dadoxylon, and possibly they also were of rapid growth and furnished with very large or abundant leaves.

Applying the facts above stated to the different varieties or species of Sternbergia, we must, in the first place, connect with these fossils such plants as the *Pinites medullaris* of Witham. I have not seen a longitudinal section of this fossil, but should expect it to present a transverse structure of the Sternbergia type. The first specimen described by Professor Williamson represents a second variety, in which the transverse structure is developed in the central part of the pith, but not at the sides. In my Pictou specimen the pith has wholly disappeared, with the exception of the denser outer coating and transverse plates. All these are distinctly coniferous, and the differences that appear may be due merely to age, or more or less rapid growth.

Other specimens of Sternbergia want the internal partitions, which may, however, have been removed by decay; and these often retain very imperfect traces, or none, of the investing wood. In the case of those which retain any portion of the wood sufficient to render probable their coniferous character, the surface markings are similar in character to those of my Pictou specimen, but often vary greatly in their dimensions, some having fine transverse wrinkles, others having these wide and coarse. Of those specimens which retain no wood, but only a thin coaly investment representing the outer pith, many cannot be distinguished by their superficial markings from those that are known to be coniferous, and they occasionally afford evidence that we must not attach too much importance to the character of their markings. A very instructive specimen of this kind from Ohio, with which I have been favoured by Professor Newberry, has in a portion of its thicker end very fine transverse wrinkles, and in the remainder of the specimen much coarser wrinkles. This difference marks, perhaps, the various rates of growth in successive seasons, or the change of the character of the pith in older portions of the stem.

The state of preservation of the Sternbergia casts, in reference to the woody matter which surrounded them, presents, in a geological point of view, many interesting features. Professor Williamson's specimen I suppose to be unique, in its showing all the tissues of the branch or trunk in a good state of preservation. More frequently, only fragments of the wood remain, in such a condition as to evidence an advanced state of decay, while the bark-like medullary lining remains. In other specimens, the coaly coating investing the cast sends forth flat expansions on either side, as if the Sternbergia had been the midrib of a long thick leaf. This appearance, at one time very perplexing to me, I suppose to result from the entire removal of the wood by decay, and the flattening of the bark, so that a perfectly flattened specimen may be all that remains of a coniferous branch nearly two inches in diameter. A still greater amount of decay of woody tissue is evidenced by those Sternbergia casts which are thinly coated with structureless coal. These must, in many cases, represent trunks and branches which have lost their bark and wood by decay; while the tough cork-like chambered pith drifted away to be imbedded in a separate state. This might readily happen with the pith of Cecropia; and perhaps that of these coniferous trees may have been more durable; while the wood, like the sap-wood of many modern pines, may have been susceptible of rapid decay, and liable, when exposed to alternate moisture and dryness, to break up into those rectangular blocks which are seen in the decaying trunks of modern conifers, and are so abundantly scattered over the surfaces of coal and its associated beds in the form of mineral charcoal.

Some specimens of Sternbergia appear to show that they have existed in the interior of trunks of considerable size. I have observed one at the South Joggins, which appears to show the remains of a tree a foot in diameter, now flattened and converted into coal, but retaining a distinct cast of a wrinkled Sternbergia pith. (Fig. 160, E.)

Are we to infer from these facts that the wood of the trees of the genus Dadoxylon was necessarily of a lax and perishable texture? Its structure, and the occurrence of the heart-wood of huge trunks of similar character in a perfectly mineralized condition, would lead to a different conclusion; and I suspect that we should rather regard the mode of occurrence of Sternbergia as a caution against the too general inference, from the state of preservation of trees of the Coal formation, that their tissues were very destructible, and that the beds of coal must consist of such perishable materials. The coniferous character of the Sternbergiæ, in connexion with their state of preservation, seems to strengthen a conclusion at which I have been arriving from microscopic and field examinations of the coal and carbonaceous shales, that the thickest beds of coal, at least in Eastern America, consist in great part of the flattened bark of coniferous, sigillarioid, and lepidodendroid trees, the wood of which has perished by slow decay, or appears only in the state of fragments and films of mineral charcoal. This subject, however, will be introduced in the next section of this chapter. In my researches in microscopic coal structures, I have also ascertained that some Sternbergiæ are pith cylinders of Sigillariæ. (Fig. 161, M).

The most abundant locality of Sternbergia with which I am acquainted occurs in the neighbourhood of the town of Pictou, immediately below the bed of erect calamites described in the Journal of the Geological Society (vol. vii., p. 194). The fossils are found in interrupted beds of very coarse sandstone, with calcareous concretions, imbedded in a thick reddish brown sandstone. These gray patches are full of well-preserved Calamites, which have either grown upon them, or have been drifted in clumps with their roots entire. The appearances suggest the idea of patches of gray sand rising from a bottom of red mud, with clumps of growing Calamites which arrested quantities of drift plants, consisting principally of Sternbergia and fragments of much decayed wood and bark, now in the state of coaly matter, too much penetrated by iron pyrites to show its structure distinctly. We thus probably have the fresh growing Calamites entombed along with the debris of the old decaying conifers of some neighbouring shore; furnishing an illustration of the truth, that the most ephemeral and perishable forms may be fossilized and preserved contemporaneously with the decay of the most durable tissues. The rush of a single summer may be preserved with its minutest striæ unharmed, when the giant pine of centuries has crumbled into dust or disappeared.

2. *Sigillariaceæ or Sigillarioid Trees.*

1. *Genus Sigillaria.*—The Sigillariæ, so named from the seal-like scars of fallen leaves stamped on their bark, were the most important of all the trees of the coal-swamps, and those which contributed most

susceptible of rapid decay than most kinds of wood, and too impervious to fluids to be readily penetrated by mineral matter, they were admirably fitted for the production of the raw material of coal.

I have endeavoured to represent the structures above referred to in Fig. 161.

The species to which I have referred was only one of many more or less resembling it, but differing in details; and according to these special differences, they may be arranged in the following genera, which may, however, be much modified by the progress of discovery. Opposite each genus I have given the species representing it in Nova Scotia.

(1.) Favularia, *Sternberg* . . .	Sigillaria elegans, *Brongn.*
	—— tessellata, *Brongn.*
	—— Bretonensis, *Dawson.*
(2.) Rhytidolepis, *Sternberg* . .	—— scutellata, *Brongn.*
	—— Schlotheimiana, *Brongn.*
	—— Saullii, *Brongn.*
	—— Dournaisii, *Brongn.*
	—— Knorrii, *Brongn.*
	—— pachyderma, *Brongn.*
	—— flexuosa, *L. & H.?*
	—— elongata, *Brongn.*
(3.) Sigillaria, *Brongn.*	—— reniformis, *Brongn.*
	—— Brownii, *Dawson.*
	—— lævigata, *Brongn.*
	—— planicosta, *Dawson.*
	—— catenoides, *Dawson.*
	—— striata, *Dawson.*
	—— eminens, *Dawson.*
(4.) Clathraria, *Brongn.*	—— Menardi, *Brongn.*
(5.) Leioderma, *Goldenb.* . . . . (Asolanus, *Wood*).	—— Sydnensis, *Dawson.*
(6.) Syringodendron, *Sternb.* . .	—— organum, *L. & H.*

Of these, seven are probably new species, and the remainder can be identified with reasonable certainty with European species. The differences in the markings in different parts of the same tree are, however, so great, that I regard the greater part of the recognised species of *Sigillariæ* as merely provisional. Even the generic limits may be overpassed when species are determined from hand specimens. A fragment of the base of an old trunk of *Sigillaria* proper would necessarily be placed in the genus *Leioderma*, and a young branch of

Favularia has all the characters of the genus *Clathraria.* It is, however, absolutely necessary to make some attempt at generic distinction among the diverse forms included in the genus *Sigillaria;* otherwise it will be impossible to reconcile the conflicting statements of authors as to the dimensions, habit of growth, foliage, roots, and fructification of these singular plants;—such statements usually applying to one or more of the subordinate generic types. I shall therefore notice separately, and with especial reference to their function in the production of coal, the several generic or subgeneric forms, beginning with that which I regard as the most important—namely, *Sigillaria* proper, of which, in Nova Scotia, I regard the species which I have named *S. Brownii* as the type. Other species are represented in Figs. 161, B to K.

In the restricted genus *Sigillaria* the ribs are strongly developed, except at the base of the stem; they are usually much broader than the oval or elliptical tripunctate areoles, and are striated longitudinally. The woody axis has both discigerous and scalariform tissues, arranged in wedges, with medullary rays as in exogens;* the pith is transversely partitioned in the manner of *Sternbergia;* and the inner bark contains great quantities of long and apparently very durable fibres, which I have, in my descriptions of the structures in the coal, named "bast tissue." The outer bark was usually thick, of dense and almost indestructible cellular tissue. The trunk when old lost its regular ribs and scars, owing to expansion, and became furrowed like that of an old exogenous tree. The roots were *Stigmariæ* of the type of *S. ficoides.* (Fig. 30, *d*, p. 180.) I have not seen the leaves or fruits attached; but, from the association observed, I believe that the former were long, narrow, rigid, and two-or-three-nerved (*Cyperites*), and that the latter were *Trigonocarpa*, borne in racemes on the upper part of the stem. These trees attained to a great size. I have seen one trunk four feet in diameter, and specimens of two feet or more in diameter are common: some of these trunks have been traced for thirty or forty feet without branching. The greater number of the erect stumps preserved at the Joggins appear to belong to this genus, which also seems to have contributed very largely to the formation of coal. Judging from the paucity of their foliage, the density of their tissues, and the strong structural resemblance of their stems and roots to those of Cycads, I believe that their rate of growth must have been very slow.

The genus *Rhytidolepis*, in which the areoles are large, hexagonal, and tripunctate, and the ribs narrow and often transversely striate, ranks as a coal-producer next to *Sigillaria* proper, and is equally

* Quart. Journ. Geol. Soc., paper on Structures of Coal.

abundant in the Coal measures. These trees seem to have been of smaller size and feebler structure than the last mentioned, and are less frequently found in the erect position; but they are very abundant on the roofs of the coal beds. Judging from such specimens as I have seen, their roots were less distinctly stigmarioid than in the last genus, though this appearance may arise from difference of preservation. Their leaves were of the same type as in the last genus; and their stems bear rings of irregular scars, which may mark stages of growth, or the production of slender racemes of fruit in a verticillate manner. The woody axis of the stems of this genus was composed of scalariform and coarsely porous tissues, much like those of modern Cycads. I figure, as an illustration of the genus, a fragment of *S. Bretonensis* (Fig. 161, F).

The genus *Favularia* is represented in Nova Scotia principally by the typical species *S. elegans* of Brongniart. The admirable investigations of the structure of the stem of this species by Brongniart, with the further illustrations given by Corda, Hooker, and Goldenberg, still afford the best general views of the structure of *Sigillariæ* which we possess. It is to be observed, however, that Brongniart's specimen was a young stem or a branch, and that it affords a very imperfect idea of the development of discigerous and bast tissues in the full-grown stems of *Sigillaria* proper. The trees of this genus appear to have been of small growth; and they branched in the manner of *Lepidodendron*, the smaller branches being quite destitute of ribs, and with the areoles elliptical and spirally disposed. The stems show joints or rings of peculiar scars at intervals, as in the last genus. The leaves differ from those of the other genera, being broad and with numerous slender parallel veins, almost in the manner of *Cordaites* (Fig. 161, B[1]).

The genus *Clathraria* is evidently closely allied to the above, and is possibly founded on branches of trees of the genus *Favularia*. It is a rare form in Nova Scotia.

Of the genus *Leioderma* or *Asolanus* I know but one species, independently of those specimens of old trunks of the ordinary *Sigillaria* in which the ribs have disappeared. My species, *S. Sydenensis*, is founded on specimens collected by Mr Brown at Sydney, Cape Breton, which are especially remarkable for the curious modification which they present of the Stigmarian root. The specimens described by Mr Brown under the name of *S. alternans*,* and which have been copied by Geinitz and Goldenberg, belong, I believe, to this species.

* Quart. Journ. Geol. Soc., vol. v. p. 354. *et seq.* See also my paper on "Conditions of Accumulation of Coal," Quart. Journ. Geol. Soc., vol. xxii. p. 147, and Pl. vii, Figs. 28, *a*, *b*, *c*.

On the genus *Syringodendron* of Sternberg I have no observations to make. I have seen only fragments of stems; and these seem to be very rare.

I include under *Sigillariæ* the remarkable fossils known as *Stigmaria*, being fully convinced that all the varieties of these plants known to me are merely roots of *Sigillaria;* I have verified this fact in a great many instances, in addition to those so well described by Mr Binney and Mr Brown. The different varieties or species of *Stigmaria* are no doubt characteristic of different species of *Sigillaria*, though in very few cases has it proved possible to ascertain the varieties proper to the particular species of stem. The old view, that the *Stigmariæ* were independent aquatic plants, still apparently maintained by Goldenberg and some other palæobotanists, evidently proceeds from imperfect information. Independently of their ascertained connexion with *Sigillaria*, the organs attached to the branches are not leaves, but rootlets. This was made evident long ago by the microscopic sections published by Goeppert, and I have ascertained that the structure is quite similar to that of the thick fleshy rootlets of *Cycas*. The lumps or tubercles on these roots have been mistaken for fructification; and the rounded tops of stumps, truncated by the falling in of the bark or the compression of the empty shell left by the decay of the wood, have been mistaken for the natural termination of the stem.* The only question remaining in regard to these organs is that of their precise morphological place. Their large pith and regular areoles render them unlike true roots; and hence Lesquereux has proposed to regard them as *rhizomes*. But they certainly radiate from a central stem, and are not known to produce any true buds or secondary stems. In short, while their function is that of roots, they may be regarded, in a morphological point of view, as a peculiar sort of underground branches. They all ramify very regularly in a dichotomous manner, and, as Mr Brown has shown, in some species at least, give off conical tap-roots from their underside.

In all the *Stigmariæ* exhibiting structure which I have examined, the axis shows only scalariform vessels. Corda, however, figures a species with wood-cells, or vessels with numerous pores, quite like those found in the stems of *Sigillaria* proper; and, as Hooker has pointed out, the arrangement of the tissues in *Stigmaria* is similar to that in *Sigillaria*. After making due allowance for differences of preservation, I have been able to recognise eleven species or forms

* For examples of the manner in which a natural termination may be simulated by the collapse of bark or by constriction owing to lateral pressure, see my papers, Quart. Journ. Geol. Soc., vol. x. p. 35, and vol. vii. p. 194.

of *Stigmaria* in Nova Scotia, corresponding, as I believe, to as many species of *Sigillaria*.* At the Joggins, *Stigmariæ* are more abundant than any other fossil plants. This arises from their preservation in the numerous fossil soils or *Stigmaria* underclays. Their bark, and mineral charcoal derived from their axes, also abound throughout the thickness of the coal beds, indicating the continued growth of *Sigillaria* in the accumulation of the coal.

Our knowledge of the fructification of *Sigillaria* is as yet of a very uncertain character. I am aware that Goldenberg has assigned to these plants leafy strobiles containing spore-capsules: but I do not think the evidence which he adduces conclusive as to their connexion with *Sigillaria;* and the organs themselves are so precisely similar to the strobiles of *Lepidophloios*, that I suspect they must belong to that or some allied genus. The leaves, also, with which they are associated in one of Goldenberg's figures seem more like those of *Lepidophloios* than those of *Sigillaria*. If, however, these are really the organs of fructification of any species of *Sigillaria*, I think it will be found that we have included in this genus, as in the old genus *Calamites*, two distinct groups of plants, one cryptogamous, and the other phænogamous, or else that male strobiles bearing pollen have been mistaken for spore-bearing organs.

I cannot pretend that I have found the fruit of *Sigillaria* attached to the parent stem; but I think that a reasonable probability can be established that some at least of the fruits included, somewhat vaguely, by authors under the names of *Trigonocarpum* and *Rhabdocarpus*, were really fruits of *Sigillaria*. These fruits are excessively abundant and of many species, and they occur not only in the sandstones, but in the fine shales and coals and in the interior of erect trees, showing that they were produced in the coal-swamps. The structures of these fruits show that they are phænogamous and probably gymnospermous. Now the only plants known to us in the Coal formation, whose structures entitle them to this rank, are the *Conifers*, *Sigillariæ*, and *Calamodendra*. All the others were in structure allied to cryptogams, and the fructification of most of them is known. But the Conifers were too infrequent in the Carboniferous swamps to have afforded numerous species of *Carpolites;* and, as I shall presently show, the *Calamodendra* were very closely allied to *Sigillariæ*, if not members of that family. Unless, therefore, these fruits belonged to *Sigillaria*, they must have been produced by some other trees of the coal-swamps, which, though very abundant and of numerous species, are as yet quite unknown to us. Some of the *Trigonocarpa* have been claimed

* See Paper on Accumulation of Coal, Journ. Geol. Soc., vol. xxii.

for Conifers, and their resemblance to the fruits of *Salisburya* gives countenance to this claim; but the Conifers of the Coal period are much too few to afford more than a fraction of the species. One species of *Rhabdocarpus* has been attributed by Geinitz to the genus *Næggerathia;* but the leaves which he assigns to it are very like those of *Sigillaria elegans*, and may belong to some allied species. With regard to the mode of attachment of these fruits, I have shown that one species, *Trigonocarpum racemosum* of the Devonian strata,* was borne on a rhachis in the manner of a loose spike, and I am convinced that some of the groups of inflorescence named *Antholithes* are simply young *Rhabdocarpi* or *Trigonocarpa* borne in a pinnate manner on a broad rhachis and subtended by a few scales. Such spikes may be regarded as corresponding to a leaf with fruits borne on the edges, in the manner of the female flower of *Cycas;* and I believe with Goldenberg that these were borne in verticils at intervals on the stem. In this case it is possible that the strobiles described by that author may be male organs of fructification containing, not spores, but pollen. In conclusion, I would observe that I would not doubt the possibility that some of the fruits known as *Cardiocarpa* may have belonged to sigillarioid trees. I am aware that some so-called *Cardiocarpa* are spore-cases of *Lepidodendron;* but there are others which are manifestly winged nutlets allied to *Trigonocarpum*, and which must have belonged to phænogams. It would perhaps be unwise to insist very strongly on deductions from what may be called circumstantial evidence as to the nature of the fruit of *Sigillaria;* but the indications pointing to the conclusions above stated are so numerous that I have much confidence that they will be vindicated by complete specimens, should these be obtained.

All of the Joggins coals, except a few shaly beds, afford unequivocal evidence of *Stigmaria* in their underclays; and it was obviously the normal mode of growth of a coal-bed, that, a more or less damp soil being provided, a forest of *Sigillaria* should overspread this, and that the Stigmarian roots, the trunks of fallen *Sigillariæ*, their leaves and fruits, and the smaller plants which grew in their shade, should accumulate in a bed of vegetable matter to be subsequently converted into coal—the bark of *Sigillaria* and allied plants affording "bright coal," the wood and bast tissues mineral charcoal, and the herbaceous matter and mould dull coal. The evidence of this afforded by microscopic structure I have endeavoured to illustrate in a former paper.†

The process did not commence, as some have supposed, by the

* "Flora of the Devonian Period," Quart. Journ. Geol. Soc., vol. viii. p. 324.

† "On the Structures in Coal," Quart. Journ. Geol. Soc. 1859.

growth of *Stigmaria* in ponds or lakes. It was indeed precisely the reverse of this, the *Sigillaria* growing in a soil more or less swampy but not submerged, and the formation of coal being at last arrested by submergence. I infer this from the circumstance that remains of Cyprids, Fishes, and other aquatic animals, are rarely found in the underclays and lower parts of the coal-beds, but very frequently in the roofs, while it is not unusual to find mineral charcoal more abundant in the lower layers of the coal. For the formation of a bed of coal, the sinking and subsequent burial of an area previously dry seems to have been required. There are a few cases at the Joggins where *Calamites* and even *Sigillariæ* seem to have grown on areas liable to frequent inundation; but in these cases coal did not accumulate. The non-laminated, slicken-sided and bleached condition of most of the underclays indicates soils of considerable permanence.

In regard to beds destitute of Stigmarian underclays, the very few cases of this kind apply only to shaly coals filled with drifted leaves, or to accumulations of vegetable mud capable of conversion into impure coal. The origin of these beds is the same with that of the carbonaceous shales and bituminous limestones already referred to. It will be observed in the section that in a few cases such beds have become sufficiently dry to constitute underclays, and that conditions of this kind have sometimes alternated with those favourable to the formation of true coal.

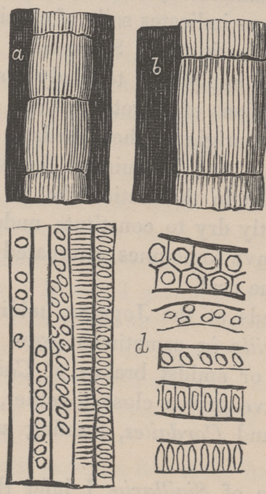
There are some beds at the Joggins, holding erect trees *in situ*, which show that *Sigillariæ* sometimes grew singly or in scattered clumps, either alone or amidst brakes of *Calamites*. In other instances they must have grown close together, and with a dense undergrowth of ferns and *Cordaites*, forming an almost impenetrable mass of vegetation.

From the structure of *Sigillariæ* I infer that, like Cycads, they accumulated large quantities of starch, to be expended at intervals in more rapid growth, or in the production of abundant fructification. I adhere to the belief expressed in previous papers that Brongniart is correct in regarding the *Sigillariæ* as botanically allied to the *Cycadaceæ*, and I have recently more fully satisfied myself on this point by comparisons of their tissues with those of *Cycas revoluta*. It is probable, however, that when better known they will be found to have a wider range of structure and affinities than we now suppose.

There are some reasons for believing that the trees described by Corda under the names of *Diploxylon*, *Myelopithys*, and *Heterangium*, and also the *Anabathra* of Witham, are *Sigillariæ*. Much of the tissue described by Goeppert as *Araucarites carbonarius* is probably also Sigillarian.

2. *Calamodendron* or *Calamitea.*—These plants are much less known than the proper Sigillarias, and it is perhaps doubtful if they should not form a separate family. In the meantime I place them here, simply because they seem to approach more nearly to *Sigillariæ* than any other plants in their structure. They were of less massive growth than *Sigillariæ*, being rarely more than a few inches in diameter; they had stems fluted lengthwise like *Sigillaria*, but more distinctly divided into nodes or joints by the scars of branches which were borne in whorls, and carried their narrow, slender leaves. In their habit of

Fig. 162.—*Calamodendron.*



(*a, b*) Casts of axis in sandstone, with woody envelope, reduced.
(*c, d*) Woody tissue, highly magnified.

growth they thus resembled the pine tribe, and they seem to have had a larger amount of true wood in their stems than was the case with *Sigillaria.* This cylinder of wood contained a thick pith, which was constricted at intervals into joints, and had also a longitudinal striation on the outside; and as this pith from its ready decay admitted sand into the interior of the stem, while the wood was entire or in process of conversion into coal, we often have a stem of *Calamodendron* represented merely by a cast of the pith in stone. In this case the pith cylinder may be easily mistaken for a plant of the genus *Calamites*, which, as we shall immediately find, was quite a different thing. I believe that the statements often found in geological books to the effect that the *Calamites* were smooth externally, and that the supposed jointed stems are only casts of the pith, are true of *Calamodendron* only, and proceed from confounding that genus with *Calamites*.

A *Calamodendron* as usually seen is a striated cast with frequent cross lines or joints; but when the whole stem is preserved, it is seen that this cast represents merely an internal pith-cylinder, surrounded by a woody cylinder composed in part of scalariform or reticulated vessels, and in part of wood-cells with one row of large pores on each side. External to the wood was a cellular bark, and the outer surface seems to have been simply ribbed in the manner of *Sigillaria*. It so happens that the internal cast of the pith of *Calamodendron*, which is really of the nature of a *Sternbergia*, so closely resembles the external appearance of the true *Calamites* as to be constantly mistaken for them. Most of these pith-cylinders of *Calamodendron* have been grouped in the species *Calamites approximatus*; but that species, as understood by some authors, appears also to include true *Calamites*,* which, however, when well preserved, can always be distinguished by the scars of the leaves or branchlets which were attached to the nodes.

Calamodendron would seem, from its structure, to have been closely allied to *Sigillaria*, though, according to Unger, the tissues were differently arranged, and the woody cylinder must have been much thicker in proportion.

The tissues of *Calamodendron* are by no means infrequent in the coal, and casts of the pith are common in the sandstones; but its foliage and fruit are unknown. They probably resembled those of *Sigillaria*.

Class of Cryptogams.

1. *Equisetaceæ.*

1. *Calamites.*—These curious plants are by no means to be confounded with those last noticed. Their stems were slender, ribbed and jointed externally, and from the joints there proceeded, in some of the species, long, narrow, simple branchlets; and, in others, branches bearing whorls of small branchlets or rudimentary leaves. The stem was hollow, with thin transverse floors or diaphragms at the joints, and it had no true wood and bark, but only a thin external shell of fibres and scalariform vessels. The *Calamites* grew in dense brakes on the sandy and muddy flats, subject to inundation, or perhaps even in the water, and they had the power of budding out from the base of the stem, so as to form clumps of plants, and also of securing their foot-

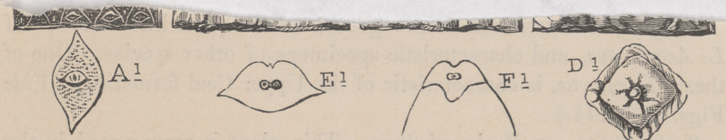
* See Geinitz, "Steinkohlen formation in Sachsen."

Fig. 163.—*Calamites.*

A, Calamites Suckovii, restored.
A¹, Foliage.
A², Ribs and scars.
A³, Roots.
A⁴, Base of stem.
B, Calamites Cistii, restored.
B¹, Leaves.
B², Leaf enlarged.
C, Leaves of C. nodosus.
C¹, Whorl enlarged.
D, Structure of stem.
E, Vessels magnified.

these, *L. parvus*, is characteristic of the Upper Coal formation. (*Vide* Figs. 170, 171.)

3. *Cordaites* or *Pychnophyllum.*—This plant is represented in the Coal formation chiefly by its broad striated leaves, which are extremely abundant in the coal and its associated shales. Some thin coals are indeed almost entirely composed of them. The most common species is *C. borassifolia*, a plant which Corda has shown to have a simple stem with a slender axis of scalariform vessels resembling that of *Lepidophloios;* for this reason, notwithstanding the broad and parallel-veined leaves, I regard this genus as belonging to *Lycopodiaceæ*, or some allied family. It must have been extremely abundant in the Carboniferous swamps; and, from the frequency of



A, Lepidodendron decurtatum; A^1, areole enlarged.
B, Lepidodendron, old bark.
C, Lepidodendron, old bark, of another species.
D, Lepidophloios tetragonus, $\frac{2}{3}$. D^1, Areole.
E, Lepidophloios platystigma, $\frac{2}{3}$. E^1, Areole.
F, Lepidophloios platystigma, $\frac{2}{3}$, differently preserved. F^1, Areole.
G, Lepidophloios parvus, $\frac{2}{3}$. G^1, Leaves, $\frac{2}{3}$. G^2, Part of leaf. G^3, Areole, natural size.

Fig. 168.—*Lepidodendron corrugatum.*

A, Restoration.
B, Leaf, nat. size.
C, Cone and branch.
D, Branch and leaves.
E, Various forms of leaf areoles.
F, Sproangium.
G, Scalariform vessel, magnified.
H, I, K, L, M, Bark with leaf-scars.
N, Do. of old stem.
O, Decorticated stem (Knorria).

are particularly rare, and *L. undulatum* is the most common species. In the Middle Coal formation, *L. rimosum*, *L. dichotomum*, *L. elegans*, and *L. Pictoense* are probably the most common species; and *L. corrugatum* is the characteristic *Lepidodendron* of the Lower Carboniferous, in which plants of this species seem to be more abundant than any other vegetable remains whatever.

To the natural history of this well-known genus I have little to add, except in relation to the changes which take place in its trunk in the process of growth, and the study of which is important in order to prevent the undue multiplication of species.

Lepidodendron corrugatum, Dawson.—I give below a description of this species, and may refer to the figures in Fig. 168 for further illustration. I do not know any other species in Nova Scotia which has precisely the same habit of growth; but *L. plicatum* and *L. rimosum* show a tendency to it. The present species is exclusively Lower Carboniferous, and occurs on that horizon in New Brunswick, in Pennsylvania, and, I believe, also in Ohio; though the beds holding it in the latter State have been by some regarded as Devonian.

L. undulatum, Sternberg.—I think it not improbable that several closely allied species are included under this name. On the other hand, all the large areoled *Lepidodendra* figured in the books must have branches with small scars, which in the present state of know-

Fig. 169.—*Lepidodendra of Middle Coal Formation.*

perfect state of preser

ed from

those prepared for my paper (Fig. 175).

ledge, it is impossible to identify with this species. I suppose that *L. elegans* resembles the present species in its mode of growth, at least if the large-scarred specimens attributed to it are really of the same species. *L. dichotomum* (= *L. Sternbergii*) also resembles it to some extent (Fig. 169, E).

L. Pictoense, Dawson.—This species I described as follows, from young stems, in my "Synopsis of the Coal-plants of Nova Scotia:"—"Areoles contiguous, prominent, separated in young stems by a narrow line, long-oval, acuminate; breadth to length as 1 to 3, or less; lower half obliquely wrinkled, especially at one side. Middle line indistinct. Leaf-scar at upper end of areole, small, triangular, with traces of three vascular points, nearly confluent. Length of areole about 0·5 inch."

Additional specimens from Sydney show that in old trunks of this species the areoles do not enlarge, but the bark becomes split into strips. I have reason to think that a new species from Nova Scotia, which I shall describe in the sequel, *L. personatum*, agrees with it in this respect (Fig. 169, A, B).

The *Lepidodendra* resemble each other too closely to admit of good sub-generic distinction. The grounds on which the distinction of *Sagenaria* and *Aspidiaria* is founded are quite worthless, the apparent position of the vascular scars in the areoles depending on accidents of preservation much more than on original differences. The genus *Knorria* includes many peculiar conditions of decorticated *Lepidodendra*.

In regard to the accumulation of coal, *Lepidodendra*, when present, appear under the same conditions with *Sigillariæ*, the outer bark being converted into shining coal, and the scalariform axis appearing as mineral charcoal of a more loose and powdery quality than that [illegible] On the planes of lamination of the coal the [illegible] scarcely be distinguished from that [illegible] further

Lepidodendron corrugatum, Daws[illegible]

of this species, and may refer to the figures in [illegible]

illustration. I do not know any other species in N[illegible] coals like cannel-coals, which have been formed wholly under subaqueous conditions, the mineral charcoal is deficient.*

A consideration of the decay of vegetable matter in modern swamps and forests shows that all kinds of tissues are not, under ordinary circumstances, susceptible of the sort of carbonization which we find in the mineral charcoal. Succulent and lax parenchymatous tissues decay too rapidly and completely. The bark of trees very long resists decay, and, where any deposition is proceeding, is likely to be imbedded unchanged. It is the woody structure, and especially the harder and more durable wood, that, becoming carbonized and splitting along the medullary rays and lines of growth, affords such fragments as those which we find scattered over the surfaces of the coal.† These facts would lead us to infer that mineral charcoal represents the woody debris of trees subjected to subaërial decay, and that the bark of these trees should appear as compact coal along with such woody or herbaceous matters as might be imbedded or submerged before decay had time to take place.

My method of preparing the mineral charcoal for examination was an improvement on the "nitric-acid" process of previous observers, and the results gave very perfect examples of the disc-bearing tissue restricted in the modern world to conifers and cycads, but which existed also in the *Sigillariæ* of the Coal period. With this were scalariform vessels, like those of ferns and club mosses, and several other kinds of woody tissue. On careful comparison, it was found that all these tissues might be referred to the following genera of plants common in the Coal measures: *Sigillaria*, including *Stigmaria*, *Calamites*, *Dadoxylon*, and other conifers, *Lepidodendron*, *Ulodendron*, ferns, and possibly some other less known plants. Another form of tissue observed was a large spiral vessel, possibly belonging to some endogenous plant. The perfect state of preservation of these tissues may be inferred from the following figures, selected from those prepared for my paper (Fig. 175).

I shall first notice in detail the structures preserved in the layers of shining compact coal, and afterwards those found in the mineral charcoal.

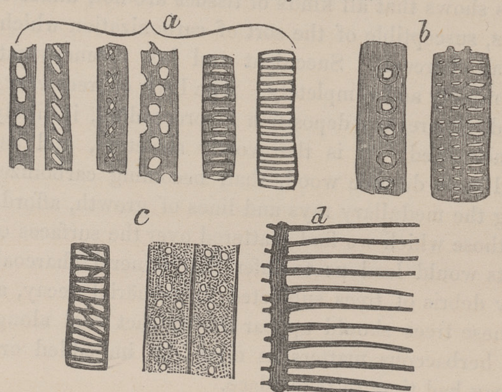
I. The compact coal, constituting a far larger proportion of the mass than the "mineral charcoal," consists either of lustrous conchoidal *cherry* or *pitch coal*,—of less lustrous *slate coal*, with flat

* American Journal of Science. See also Goeppert, "Abhandlung uber Steinkohlen;" also a paper by the author, "On Fossils from Nova Scotia," Quart. Journ. Geol. Soc. 1846.

† See paper of 1846, previously cited.

fracture,—or of coarse coal, containing much earthy matter. All of these are arranged in thin interrupted laminæ. They consist of

Fig. 175.—*Tissues from Coal.*



(*a*) Tissues of axis of Sigillaria. (*b*) Tissues of Calamites?
(*c*) Tissues of Ferns. (*d*) Scalariform vessel of Lepidodendron.

vegetable matter which has not been altered by subaërial decay, but which has undergone the bituminous putrefaction, and has thereby been resolved into a nearly homogeneous mass, which still, however, retains traces of structure and of the forms of the individual flattened plants composing it. As these last are sometimes more distinct than the minute structures, and are necessary for their comprehension, I shall, under the following heads, notice both as I have observed them in the coals in question :—

1. The laminæ of pitch or cherry coal, when carefully traced over the surfaces of accumulation, are found to present the outlines of flattened trunks. This is also true, to a certain extent, of the finer varieties of slate coal; but the coarse coal appears to consist of extensive laminæ of disintegrated vegetable matter mixed with mud.

2. When the coal (especially the more shaly varieties) is held obliquely under a strong light, in the manner recommended by Goeppert, the surfaces of the laminæ present the forms of many well-known coal-plants, as *Sigillaria*, *Stigmaria*, *Cordaites*, *Lepidodendron*, *Lepidophloios*, and rough bark, perhaps of conifers.

3. When the coal is traced upward into the roof-shales, we often find the laminæ of compact coal represented by flattened coaly trunks and leaves, now rendered distinct by being separated by clay.

4. In these flattened trunks it is the outer cortical layer that alone constitutes the coal. This is very manifest when the upper and under

bark are separated by a film of clay or of mineral charcoal, occupying the place of the wood. In this condition the bark of a large Sigillaria gives only one or two lines in thickness of coal; *Stigmaria*, *Lepidodendron*, and *Ulodendron* give still less. In the shales these flattened trunks are often so crushed together that it is difficult to separate them. In the coal they are, so to speak, fused into a homogeneous mass.

5. The phenomena of erect forests explain to some extent the manner in which layers of compact coal and mineral charcoal may result from the accumulation of trunks of trees *in situ.* In the sections at the South Joggins, the usual state of preservation of erect *Sigillariæ* is that of casts in sandstone, enclosed by a thin layer of bark converted into compact, caking, bituminous coal, while the remains of the woody matter may be found in the bottom of the cast in the state of mineral charcoal. In other cases the bark has fallen in, and all that remains to indicate the place of a tree is a little pile of mineral charcoal, with strips of bark converted into compact coal. Lastly, a series of such remains of stumps, with flattened bark of prostrate trunks, may constitute a rudimentary bed of coal, many of which exist in the Joggins section. In short, a single trunk of *Sigillaria* in an erect forest presents an epitome of a coal-seam. Its roots represent the Stigmaria underclay; its bark the compact coal; its woody axis the mineral charcoal; its fallen leaves, with remains of herbaceous plants growing in its shade, mixed with a little earthy matter, the layers of coarse coal. The condition of the durable outer bark of erect trees concurs with the chemical theory of coal, in showing the especial suitableness of this kind of tissue for the production of the purer compact coals. It is also probable that the comparative impermeability of bark to mineral infiltration is of importance in this respect, enabling this material to remain unaffected by causes which have filled those layers consisting of herbaceous materials and decayed wood, with earthy matter, pyrites, etc.

6. The microscopic structure of the purer varieties of compact coal accords with that of the bark of *Sigillaria.* The compact coals are capable of affording very little true structure. Their cell-walls have been pressed close together; and pseudo-cellular structures have arisen from molecular action and the segregation of bituminous matter. Most of the structures which have been figured by microscopists are of this last character, or at the utmost are cell-structures masked by concretionary action, pressure, and decay. Hutton, however, appears to have ascertained a truly cellular tissue in this kind of coal. Goeppert also has figured parenchymatous and perhaps bast-tissues obtained from its incineration. By acting on it with nitric

acid, I have found that the structures remaining both in the lustrous compact coals and in the bark of *Sigillariæ* are parenchymatous cells and fibrous cells, probably bast-fibres.

7. I by no means desire to maintain that all portions of the coal-seams not in the state of mineral charcoal consist of cortical tissues. Quantities of herbaceous plants, leaves, etc., are also present, especially in the coarser coals; and some small seams appear to consist entirely of such material,—for instance, of the leaves of *Cordaites* or *Poacites*. I would also observe that, though in the roof-shales and other associated beds it is usually only the cortical layer of trees that appears as compact bituminous coal, yet I have found specimens which show that in the coal-seams themselves true woody tissues have sometimes been imbedded unchanged, and converted into structureless coal, forming, like the coniferous trees converted into jet in more modern formations, thin bands of very pure bituminous material. The proportion of woody matter in this state differs in different coals, and is probably greatest in those which show the least mineral charcoal; but the alteration which it has undergone renders it almost impossible to distinguish it from the flattened bark, which in all ordinary cases is much more abundant.

II. In the mineral charcoal, which affords the greater part of the material showing distinct vegetable structures, the following kinds of tissue are those ordinarily observed:—

a. *Bast tissue, or elongated cells from the liber or inner bark of* Sigillariæ *and* Lepidodendron, *but especially of the former.*—This kind of tissue is abundant in a calcified state in the shales associated with the coals, and also as mineral charcoal in the coals themselves, and in the interior of erect *Sigillariæ*. It is the kind of tissue figured by Brongniart as the inner layer of bark in *Sigillaria elegans*, and very well described by Binney (Quart. Journ. Geol. Soc. vol. xviii.) as "elongated tissue or utricles." Under the microscope many specimens of it closely resemble the imperfect bast tissue of the inner bark of *Pinus strobus* and *Thuja occidentalis;* and like this it seems to have been at once tough and durable, remaining in fibrous strips after the woody tissues had decayed. It is extremely abundant at the Joggins in the mineral charcoal of the smaller coal-seams. It is often associated with films of structureless coal, which represent the dense cellular outer bark which, in the trunk of *Sigillaria*, not only surrounded this tissue, but was intermixed with it.

b. *Vascular bundles of Ferns.*—These may be noticed by all close observers of the surfaces of coal, as slender hair-like fibres, sometimes lying separately, in other cases grouped in bands half an inch or more in diameter, and embedded in a loose sort of mineral charcoal. When treated with nitric acid, each bundle resolves itself into a few scalariform vessels surrounded with a sheath of woody fibres, often minutely porous. This structure is precisely that of macerated fern-stipes; but, as already stated, there may have been some other coal-plants whose leaves presented similar bundles. As stated in my former paper "On the Vegetable Structures in Coal," this kind of tissue is especially abundant in the coarse and laminated portions of the coal, which we know on other evidence to have been made up, not of trunks of trees, but of mixed herbaceous matters (Fig. 175, C).

c. *Scalariform vessels.*—These are very abundant in the mineral charcoal, though the coarser kinds have been crushed and broken in such a manner that they usually appear as mere debris. The scalariform vessels of *Lepidodendron*, *Lepidophloios*, and *Stigmaria* are very coarse, and much resemble each other. Those of ferns are finer, and sometimes have a reticulated structure. Those of *Sigillaria* are much finer, and often have the aspect of wood-cells with transversely elongated pores like those of *Cycas*. Good examples of these are figured in the paper already referred to (see also Fig. 175, A and D).

d. *Discigerous wood-cells.*—These are the true bordered pores characteristic of *Sigillaria*, *Calamodendron*, and *Dadoxylon*. In the two former genera the discs or pores are large and irregularly arranged, either in one row or several rows; but in the latter case they are sometimes regularly alternate and contiguous. In the genus *Dadoxylon* they are of smaller size, and always regularly contiguous in two or more rows, so as to present an hexagonal areolation. Discigerous structures of *Sigillaria* and *Calamodendron* are very abundant in the coal, and numerous examples were figured in my paper above cited. I have indicated by the name *Reticulated Tissue* certain cells or vessels which may either be reticulated scalariform vessels, or an imperfect form of discigerous tissue. I believe them to belong to *Stigmaria* or *Calamodendron* (Figs. 162 and 175, A.)

e. *Epidermal tissue.*—This is a dense cellular tissue representing the outer integuments of various leaves, herbaceous stems, and fruits. I have ascertained that the structures in question occur in the leaves and stipes of *Cordaites* and ferns, and in the outer coat of *Carpolites* and *Sporangites.* With this I may include the obscure and thick-walled cellular tissue of the outer bark of *Sigillaria* and *Lepidodendron* and other trees, which, though usually consolidated into compact coal, sometimes exhibits its structure.

I would here emphatically state that all my observations at the Joggins confirm the conclusion, which I arrived at many years ago from the study of the coals of Pictou and Sydney, that the layers of clear shining coal (pitch or cherry coal) are composed of flattened trunks of trees, and that of these usually the bark alone remains; further, that the lamination of the coal is due to the superposition of layers of such flattened trunks alternating with the accumulations of vegetable matter of successive years, and occasionally with fine vegetable muck or mud spread over the surface by rains or by inundations. In connexion with this, it is to be observed that the density and *impermeability* of cortical tissues not only enable them to endure after wood has perished or been resolved into bits of charcoal, but render them less liable than the wood to mineral *infiltration*.

Rate of Growth of Carboniferous Plants.—Very vague statements are often made as to the supposed rapid rate of growth of plants in the Carboniferous period. Perhaps the most trustworthy facts in relation to this subject are those which may be obtained from the coniferous trees. In some of these (for instance, *Dadoxylon materiarium*, *D. annulatum*, and *D. antiquius*) the rings of growth, which were no doubt annual, are distinctly marked. On measuring these in a number of specimens, and comparing them with modern species, I find that they are about equal in dimensions to those of the Balsam Fir or the Yellow Pine of America. Assuming, therefore, similarity in habit of growth and extent of foliage to these species, we may infer that, in regard to coniferous trees, the ordinary conditions of growth were not dissimilar from those of Eastern America in its temperate regions at present. When, however, we compare the ferns and *Lycopodiaceæ* of the Coal formation with those now growing in Eastern America, we see, in the much greater dimensions and luxuriance of the former, evidence of a much more moist and equable climate than that which now subsists; so that we may suppose the growth of such plants to have been more rapid than it is at present. These plants would thus lead us to infer a warm and insular climate, perhaps influenced by that supposed excess of carbonic acid in the atmosphere which, as Tyndall and Hunt inform us, would promote warmth and moisture by impeding terrestrial radiation. With this would also agree the fact that the conifers have woody tissues resembling those of the pine trees of the milder climates of the southern hemisphere at present.

If we apply these considerations to *Sigillaria*, we may infer that the conditions of moisture and uniformity of temperature favourable to ferns and *Lycopodiaceæ* were also favourable to these curious plants. They must have been perennial; and the resemblance of their trunks to those of Cycads, together with their hard and narrow leaves, would lead us to infer that their growth must have been very slow. A similar inference may be drawn from the evidences of very slow and regular expansion presented by the lower parts of their stems. On the other hand, the distance, of a foot or more, which often intervenes between the transverse rows of scars, marking possibly annual fructification, would indicate a more rapid rate of growth. Further, it may be inferred, from the structure of their roots and of their thick inner bark, that these, as in Cycads, were receptacles for great quantities of starch, and that the lives of these plants presented alternations of starch-accumulation and of expenditure of this in the production of leaves, wood, and abundant inflorescence. They would thus, perhaps for several years, grow very slowly, and then put forth a great mass of fructification, after which perhaps many of the individuals would die, or again remain for a long time in an inactive state. This view would, I think, very well harmonize with the structure of these plants, and also with the mode of their entombment in the coal.

From the manner of the association of Calamites with erect *Sigillariæ*, I infer that the former were, of all the plants of the Coal formation, those of most rapid dissemination and growth. They appear to have first taken possession of emerging banks of sand and mud, to have promoted the accumulation of sediment on inundated areas, and to have protected the exposed margins of the forests of *Sigillariæ*.

In applying any conclusions as to the rate of growth of Carboniferous plants to the accumulation of coal, we must take into account the probable rate of decay of vegetable matter. When we consider the probable wetness of the soils on which the plants which produced the coal grew, the density of the forests, and the possible excess of carbonic acid in the atmosphere of these swamps, we must be prepared to admit that, notwithstanding the warmth and humidity, the conditions must have been favourable to the preservation of vegetable matter. Still the hollow cylinders of bark, the little fragments of decayed wood in the form of mineral charcoal, and the detached vascular bundles of ferns, testify to an enormous amount of decay, and show that, however great the accumulation of coal, it represents only a fraction of the vegetable matter which was actually produced. It has been estimated that it would require eight feet of compact vegetable matter to produce one foot of coal; but if we reckon the whole vegetable matter actually produced in the process, I should suppose that five times that amount would be far below the truth, even in the most favourable cases; while there is evidence that in the Carboniferous period many forests may have flourished for centuries without producing an inch of coaly matter.

Summary of Conclusions.—In illustration of the bearing of these facts on the questions relating to the materials of the coal, I give the following table, representing in a condensed form the results of my observations on the coals of the South Joggins:—

Table showing the Relative Frequency of Occurrence of Genera of Plants and Animals in the Coals of the South Joggins.

Name of Fossils.		Division 3. 23 coals.	Division 4. 49 coals.	Division 6. 9 coals.	Total. 81 coals.
Plants.					
Sigillaria	occurs in	13	34	2	49
Cordaites........................	”	15	26	...	41
Filices (mostly *Alethopteris lonchitica*)	”	4	17	2	23
Lepidodendron and Lepidophloios........................	”	1	15	...	16
Calamites	”	4	12	...	16
Carpolites, etc....................	”	2	9	...	11
Asterophyllites	”	1	2	...	3
Calamodendron	”	...	1	...	1
Structures.					
Vascular bundles of ferns ...	”	8	22	...	30
Bast tissue (*Sigillaria*)	”	2	16	2	20
Epidermal tissue (*Cordaites*, etc.)...........................	”	6	6	...	12
Scalariform (*Sigil.*, *Stig.*, *Lepidod.*, etc.)........	”	1	9	1	11
Discigerous (*Sigillaria* and *Dadoxylon*, etc.)...........	”	1	8	1	10
Reticulated (*Calamites*, Ferns, etc.)	”	...	2	1	3
Animals.					
Fishes (*Palæoniscus*, *Rhizodus*, etc.)	”	1	16	1	18
Naiadites (*Anthracomya*, etc.)	”	...	16	1	17
Spirorbis carbonarius	”	...	16	...	16
Cythere	”	...	13	1	14
Insects (?)	”	...	3	...	3
Reptiles (*Dendrerpeton*, etc.)	”	...	1	...	1
Pupa vetusta and *Xylobius sigillariæ*	”	...	1	...	1

The number of coals reckoned in this coal-field may vary according to the manner in which the several layers are grouped; but as arranged in the sectional list given in a previous chapter it amounts to eighty-one in all. Of these, 23 are found in Division 3 of Logan's section, being the upper member of the Middle Coal formation; 49 are found in Division 4 of Logan's section, being the lower member of the Middle Coal formation; 9 occur in Division 6 of Logan's section, or in the equivalent of the Millstone-grit. In the latter group few of the coals were sufficiently well exposed to enable a satisfactory examination to be made. I have grouped the remains under three heads—External Forms of Plants, Microscopic Structure of Plants, and Animal Remains—and have arranged the forms under each in the order of their relative frequency of occurrence. No mention is made of *Stigmaria*, which occurs in nearly every coal or its underclay.

The following are the conclusions, based on the above table and on examinations of the Coal of Pictou and Sydney:—

"1. With respect to the plants which have contributed the vegetable matter of the coal, these are principally the *Sigillariæ*, with *Cordaites*, Ferns and *Calamites*. With these, however, are intermixed remains of most of the other plants of the period, contributing, though in an inferior degree, to the accumulation of the mass. This conclusion is confirmed by facts derived from the associated beds,—as, for instance, the prevalence of *Stigmaria* in the underclays, and of *Sigillariæ* and *Calamites* in the roof-shales and erect forests.

"2. The woody matter of the axes of *Sigillariæ* and *Calamiteæ* and of coniferous trunks, as well as the scalariform tissues of the axes of the *Lepidodendreæ* and *Ulodendreæ*, and the woody and vascular bundles of ferns, appear principally in the state of mineral charcoal. The outer cortical envelope of these plants, together with such portions of their wood and of herbaceous plants and foliage as were submerged without subaërial decay, occur as compact coal of various degrees of purity; the cortical matter, owing to its greater resistance to aqueous infiltration, affording the purest coal. The relative amounts of all these substances found in the states of mineral charcoal and compact coal depend principally upon the greater or less prevalence of subaërial decay, occasioned by greater or less dryness of the swampy flats on which the coal accumulated.

"3. The structure of the coal accords with the view that its materials were accumulated by growth, without any driftage of materials. The *Sigillariæ* and *Calamiteæ*, tall and branchless, and clothed only with rigid linear leaves, formed dense groves and jungles, in which the stumps and fallen trunks of dead trees became resolved by decay into shells of bark and loose fragments of rotten wood, which currents would necessarily have swept away, but which the most gentle inundations or even heavy rains could scatter in layers over the surface, where they gradually became imbedded in a mass of roots, fallen leaves, and herbaceous plants.

"4. The rate of accumulation of coal was very slow. The climate of the period, in the northern temperate zone, was of such a character that the true conifers show rings of growth not larger or much less distinct than those of many of their modern congeners.* The *Sigillariæ* and *Calamites* were not, as often supposed, composed wholly, or even principally, of lax and soft tissues, or necessarily short-lived. The former had, it is true, a very thick inner bark; but their dense woody axes, their thick and nearly imperishable outer bark, and their scanty and rigid foliage, would indicate no very rapid growth or decay. In the case of *Sigillariæ*, the variations in the leaf-scars in different parts of the trunk, the intercalation of new ridges at the surface representing that of new woody wedges in the axis, the transverse marks left by the stages of upward growth—all indicate that several years must have been required for the growth of stems of moderate size. The enormous roots of these trees, and the conditions of the coal-swamps, must have exempted them from the danger of being overthrown by violence. They probably fell, in successive generations, from natural decay; and, making every allowance for other materials, we may safely assert that every foot of thickness of pure bituminous coal implies the quiet growth and fall of at least fifty generations of *Sigillariæ*, and therefore an undisturbed condition of forest-growth enduring through many centuries. Further, there is evidence that an immense amount of loose parenchymatous tissue, and even of wood, perished by decay; and we do not know to what extent even the most durable tissues may have disappeared in this way; so that in many coal-seams we may have only a very small part of the vegetable matter produced.

"*Lastly*, the results stated in this paper refer to coal-beds of the Middle Coal measures. A few facts which I have observed lead me to believe that, in the thin seams of the Lower Coal measures, remains of *Cordaites* and *Lepidodendron* are more abundant than in those of the Middle Coal measures. In the upper Coal measures similar modifications may be expected."

* Paper on Fossils from Nova Scotia, Quart. Journ. Geol. Soc. 1847.