THE STORY OF A PIECE OF COAL

WHAT IT IS, WHENCE IT COMES, AND WHITHER IT GOES

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PREFACE.

The knowledge of the marvels which a piece of coal possesses within itself, and which in obedience to processes of man's invention it is always willing to exhibit to an observant enquirer, is not so widespread, perhaps, as it should be, and the aim of this little book, this record of one page of geological history, has been to bring together the principal facts and wonders connected with it into the focus of a few pages, where, side by side, would be found the record of its vegetable and mineral history, its discovery and early use, its bearings on the great fog-problem, its useful illuminating gas and oils, the question of the possible exhaustion of British supplies, and other important and interesting bearings of coal or its products.

In the whole realm of natural history, in the widest sense of the term, there is nothing which could be cited which has so benefited, so interested, I might almost say, so excited mankind, as have the wonderful discoveries of the various products distilled from gas-tar, itself a distillate of coal.

Coal touches the interests of the botanist, the geologist, and the physicist; the chemist, the sanitarian, and the merchant.

In the little work now before the reader I have endeavoured to recount, without going into unnecessary detail, the wonderful story of a piece of coal.

E.A.M.

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THE ORIGIN OF COAL AND THE PLANTS OF WHICH IT IS COMPOSED.

From the homely scuttle of coal at the side of the hearth to the gorgeously verdant vegetation of a forest of mammoth trees, might have appeared a somewhat far cry in the eyes of those who lived some fifty years ago. But there are few now who do not know what was the origin of the coal which they use so freely, and which in obedience to their demand has been brought up more than a thousand feet from the bowels of the earth; and, although familiarity has in a sense bred contempt for that which a few shillings will always purchase, in all probability a stray thought does occasionally cross one's mind, giving birth to feelings of a more or less thankful nature that such a store of heat and light was long ago laid up in this earth of ours for our use, when as yet man was not destined to put in an appearance for many, many ages to come. We can scarcely imagine the industrial condition of our country in the absence of so fortunate a supply of coal; and the many good things which are obtained from it, and the uses to which, as we shall see, it can be put, do indeed demand recognition.

Were our present forests uprooted and overthrown, to be covered by sedimentary deposits such as those which cover our coal-seams, the amount of coal which would be thereby formed for use in some future age, would amount to a thickness of perhaps two or three inches at most, and yet, in one coal-field alone, that of Westphalia, the 117 most important seams, if placed one above the other in immediate succession, would amount to no less than 294 feet of coal. From this it is possible to form a faint idea of the enormous growths of vegetation required to form some of our representative coal beds. But the coal is not found in one continuous bed. These numerous seams of coal are interspersed between many thousands of feet of sedimentary deposits, the whole of which form the "coal-measures." Now, each of these seams represents the growth of a forest, and to explain the whole series it is necessary to suppose that between each deposit the land became overwhelmed by the waters of the sea or lake, and after a long subaqueous period, was again raised into dry land, ready to become the birth-place of another forest, which would again beget, under similarly repeated conditions, another seam of coal. Of the conditions necessary to bring these changes about we will speak later on, but this instance is sufficient to show how inadequate the quantity of fuel would be, were we dependent entirely on our own existing forest growths.

However, we will leave for the present the fascinating pursuit of theorising as to the how and wherefore of these vast beds of coal, relegating the geological part of the study of the carboniferous system to a future chapter, where will be found some more detailed account of the position of the coal-seams in the strata which contain them. At present the actual details of the coal itself will demand our attention.

Coal is the mineral which has resulted, after the lapse of thousands of thousands of years, from the accumulations of vegetable material, caused by the steady yearly shedding of leaves, fronds and spores, from forests which existed in an early age; these accumulated where the trees grew that bore them, and formed in the first place, perhaps, beds of peat; the beds have since been subjected to an ever-increasing pressure of accumulating strata above them, compressing the sheddings of a whole forest into a thickness in some cases of a few inches of coal, and have been acted upon by the internal heat of the earth, which has caused them to part, to a varying degree, with some of their component gases. If we reason from analogy, we are compelled to admit that the origin of coal is due to the accumulation of vegetation, of which more scattered, but more distinct, representative specimens occur in the shales and clays above and below the coal-seams. But we are also able to examine the texture itself of the various coals by submitting extremely thin slices to a strong light under the microscope, and are thus enabled to decide whether the particular coal we are examining is formed of conifers, horse-tails, club-mosses, or ferns, or whether it consists simply of the accumulated sheddings of all, or perhaps, as in some instances, of innumerable spores.

In this way the structure of coal can be accurately determined. Were we artificially to prepare a mass of vegetable substance, and covering it up entirely, subject it to great pressure, so that but little of the volatile gases which would be formed could escape, we might in the course of time produce something approaching coal, but whether we obtained lignite, jet, common bituminous coal, or anthracite, would depend upon the possibilities of escape for the gases contained in the mass.

Everybody has doubtless noticed that, when a stagnant pool which contains a good deal of decaying vegetation is stirred, bubbles of gas rise to the surface from the mud below. This gas is known as marsh-gas, or light carburetted hydrogen, and gives rise to the *ignis fatuus* which hovers about marshy land, and which is said to lure the weary traveller to his doom. The vegetable mud is here undergoing rapid decomposition, as there is nothing to stay its progress, and no superposed load of strata confining its resulting products within itself. The gases therefore escape, and the breaking-up of the tissues of the vegetation goes on rapidly.

The chemical changes which have taken place in the beds of vegetation of the carboniferous epoch, and which have transformed it into coal, are even now but imperfectly understood. All we know is that, under certain circumstances, one kind of coal is formed, whilst under other conditions, other kinds have resulted; whilst in some cases the processes have resulted in the preparation of large quantities of mineral oils, such as naphtha and petroleum. Oils are also artificially produced from the so-called waste-products of the gas-works, but in some parts of the world the process of their manufacture has gone on naturally, and a yearly increasing quantity is being utilised. In England oil has been pumped up from the carboniferous strata of Coalbrook Dale, whilst in Sussex it has been found in smaller quantities, where, in all probability, it has had its origin in the lignitic beds of the Wealden strata. Immense quantities are used for fuel by the Russian steamers on the Caspian Sea, the Baku petroleum wells being a most valuable possession. In Sicily, Persia, and, far more important, in the United States, mineral oils are found in great quantity.

In all probability coniferous trees, similar to the living firs, pines, larches, &c., gave rise for the most part to the mineral oils. The class of living *coniferae* is well known for the various oils which it furnishes naturally, and for others which its representatives yield on being subjected to distillation. The gradually increasing amount of heat which we meet the deeper we go beneath the surface, has been the cause of a slow and continuous distillation, whilst the oil so distilled has found its way to the surface in the shape of mineral-oil springs, or has accumulated in troughs in the strata, ready for use, to be drawn up when a well has been sunk into it.

The plants which have gone to make up the coal are not at once apparent to the naked eye. We have to search among the shales and clays and sandstones which enclose the coal-seams, and in these we find petrified specimens which enable us to build up in our mind pictures of the vegetable creation which formed the jungles and forests of these immensely remote ages, and which, densely packed together on the old forest floor of those days, is now apparent to us as coal.

[Illustration: Fig. 2.—*Annularia radiata.* Carboniferous sandstone.]

A very large proportion of the plants which have been found in the coal-bearing strata consists of numerous species of ferns, the number of actual species which have been preserved for us in our English coal, being double the number now existing in Europe. The greater part of these do not seem to have been very much larger than our own living ferns, and, indeed, many of them bear a close resemblance to some of our own living species. The impressions they have left on the shales of the coal-measures are most striking, and point to a time when the sandy clay which imbedded them was borne by water in a very tranquil manner, to be deposited where the ferns had grown, enveloping them gradually, and consolidating them into their mass of future shale. In one species known as the *neuropteris*, the nerves of the leaves are as clear and as apparent as in a newly-grown fern, the name being derived from two Greek words meaning "nerve-fern." It is interesting to consider the history of such a leaf, throughout the ages that have elapsed since it was part of a living fern. First it grew up as a new frond, then gradually unfolded itself, and developed into the perfect fern. Then it became cut off by the rising waters, and buried beneath an accumulation of sediment, and while momentous changes have gone on in connection with the surface of the earth, it has lain dormant in its hiding-place exactly as we see it, until now excavated, with its contemporaneous vegetation, to form fuel for our winter fires.

[Illustration: FIG. 3.—*Rhacopteris inaequilatera.* Carboniferous limestone.]

Although many of the ferns greatly resembled existing species, yet there were others in these ancient days utterly unlike anything indigenous to England now. There were undoubted tree-ferns, similar to those which thrive now so luxuriously in the tropics, and which throw out their graceful crowns of ferns at the head of a naked stem, whilst on the bark are the marks at different levels of the points of attachment of former leaves. These have left in their places cicatrices or scars, showing the places from which they formerly grew. Amongst the tree-ferns found are *megaphyton*, *paloeopteris*, and *caulopteris*, all of which have these marks upon them, thus proving that at one time even tree-ferns had a habitat in England.

[Illustration: Fig. 4.—Frond of *Pecopteris.* Coal-shale.]

One form of tree-fern is known by the name of *Psaronius*, and this was peculiar in the possession of masses of aerial roots grouped round the stem. Some of the smaller species exhibit forms of leaves which are utterly unknown in the nomenclature of living ferns. Most have had names assigned to them in accordance with certain characteristics which they possess. This was the more possible since the fossilised impressions had been retained in so distinct a manner. Here before us is a specimen in a shale of *pecopteris*, as it is called, (*pekos*, a comb). The leaf in some species is not altogether unlike the well-known living fern *osmunda*. The position of the pinnules on both sides of the central stalk are seen in the fossil to be shaped something like a comb, or a saw, whilst up the centre of each pinnule the vein is as prominent and noticeable as if the fern were but yesterday waving gracefully in the air, and but to-day imbedded in its shaly bed.

[Illustration: FIG. 5.—*Pecopteris Serlii*. Coal-shale.]

Sphenopteris, or "wedge-fern," is the name applied to another coal-fern; *glossopteris*, or "tongue-leaf"; *cyclopteris*, or "round-leaf"; *odonlopteris,* or "tooth-leaf," and many others, show their chief characteristics in the names which they individually bear. *Alethopteris* appears to have been the common brake of the coal-period, and in some respects resembles *pecopteris*.

[Illustration: Fig. 6.—*Sphenopteris Affinis.* Coal-shale.]

In some species of ferns so exact are the representations which they have impressed on the shale which contains them, that not only are the veins and nerves distinctly visible, but even the fructification still remains in the shape of the marks left by the so-called seeds on the backs of the leaves. Something more than a passing look at the coal specimens in a good museum will well repay the time so spent.

What are known as septarian nodules, or snake-stones, are, at certain places, common in the carboniferous strata. They are composed of layers of ironstone and sandstone which have segregated around some central object, such as a fern-leaf or a shell. When the leaf of a fern has been found to be the central object, it has been noticed that the leaf can sometimes be separated from the stone in the form of a carbonaceous film.

Experiments were made many years ago by M. Goppert to illustrate the process of fossilisation of ferns. Having placed some living ferns in a mass of clay and dried them, he exposed them to a red heat, and obtained thereby striking resemblances to fossil plants. According to the degree of heat to which they were subjected, the plants were found to be either brown, a shining black, or entirely lost. In the last mentioned case, only the impression remained, but the carbonaceous matter had gone to stain the surrounding clay black, thus indicating that the dark colour of the coal-shales is due to the carbon derived from the plants which they included.

Another very prominent member of the vegetation of the coal period, was that order of plants known as the *Calamites*. The generic distinctions between fossil and living ferns were so slight in many cases as to be almost indistinguishable. This resemblance between the ancient and the modern is not found so apparent in other plants. The Calamites of the coal-measures bore indeed a very striking resemblance, and were closely related, to our modern horse-tails, as the *equiseta* are popularly called; but in some respects they differed considerably.

Most people are acquainted with the horse-tail (*equisetum fluviatile)* of our marshes and ditches. It is a somewhat graceful plant, and stands erect with a jointed stem. The foliage is arranged in whorls around the joints, and, unlike its fossil representatives, its joints are protected by striated sheaths. The stem of the largest living species rarely exceeds half-an-inch in diameter, whilst that of the calamite attained a thickness of five inches. But the great point which is noticeable in the fossil calamites and *equisetites* is that they grew to a far greater height than any similar plant now living, sometimes being as much as eight feet high. In the nature of their stems, too, they exhibited a more highly organised arrangement than their living representatives, having, according to Dr Williamson, a "fistular pith, an exogenous woody stem, and a thick smooth bark." The bark having almost al ways disappeared has left the fluted stem known to us as the calamite. The foliage consisted of whorls of long narrow leaves, which differed only from the fern *asterophyllites* in the fact that they were single-nerved. Sir William Dawson assigns the calamites to four sub-types: *calamite* proper, *calamopitus, calamodendron*, and *eucalamodendron*.

[Image: FIG. 7.—Root of *Catamites Suckowii*. Coal-shale.]

[Image: FIG 8.—*Calamocladus grandis*. Carboniferous sandstone.]

Having used the word "exogenous," it might be as well to pay a little attention, in passing, to the nomenclature and broad classification of the various kinds of plants. We shall then doubtless find it far easier thoroughly to understand the position in the scale of organisation to which the coal plants are referable.

[Illustration: FIG. 9.—*Asterophyllites foliosa*. Coal-measures.]

The plants which are lowest in organisation are known as *Cellular*. They are almost entirely composed of numerous cells built up one above the other, and possess none of the higher forms of tissue and organisation which are met with elsewhere. This division includes the lichens, sea-weeds, confervae (green aquatic scum), fungi (mushrooms, dry-rot), &c.

The division of *Vascular* plants includes the far larger proportion of vegetation, both living and fossil, and these plants are built up of vessels and tissues of various shapes and character.

All plants are divided into (1) Cryptogams, or Flowerless, such as mosses, ferns, equisetums, and (2) Phanerogams, or Flowering. Flowering plants are again divided into those with naked seeds, as the conifers and cycads (gymnosperms), and those whose seeds are enclosed in vessels, or ovaries (angiosperms).

Angiosperms are again divided into the monocotyledons, as the palms, and dicotyledons, which include most European trees.

Thus:—

- | (M.A. Brongniart). | |(Lindley). | |CELLULAR | | | | *Cryptogams* (Flowerless) |Fungi, seaweeds, |Thallogens | | | lichens | | | | | | |VASCULAR | | | | *Cryptogams* (Flowerless) |Ferns, equisetums, |Acrogens | | | mosses, lycopodiums| | | *Phanerogams* (Flowering) | | | | Gymnosperms (having |Conifers and |Gymnogens | | naked seeds) | cycads | | | Two or more Cotyledons | | | | Angiosperms (having | | | | enclosed seeds) | | | | Monocotyledons |Palms, lilies, |Endogens | | | grasses | | | Dicotyledons |Most European |Exogens | | | trees and shrubs | | ————————————————————————————————-

Adolphe Brongniart termed the coal era the "Age of Acrogens," because, as we shall see, of the great predominance in those times of vascular cryptogamic plants, known in Dr Lindley's nomenclature as "Acrogens."

[Illustration: FIG. 10.—*Spenophyllum cuneifolium.* Coal-shale.]

Two of these families have already been dealt with, viz., the ferns (*felices*), and the equisetums, (*calamites* and *equisetites*), and we now have to pass on to another family. This is that which includes the fossil representatives of the Lycopodiums, or Club-mosses, and which goes to make up in some coals as much as two-thirds of the whole mass. Everyone is more or less familiar with some of the living Lycopodiums, those delicate little fern-like mosses which are to be found in many a home. They are but lowly members of our British flora, and it may seem somewhat astounding at first sight that their remote ancestors occupied so important a position in the forests of the ancient period of which we are speaking. Some two hundred living species are known, most of them being confined to tropical climates. They are as a rule, low creeping plants, although some few stand erect. There is room for astonishment when we consider the fact that the fossil representatives of the family, known as *Lepidodendra*, attained a height of no less than fifty feet, and, there is good ground for believing, in many cases, a far greater magnitude. They consist of long straight stems, or trunks which branch considerably near the top. These stems are covered with scars or scales, which have been caused by the separation of the petioles or leaf-stalks, and this gives rise to the name which the genus bears. The scars are arranged in a spiral manner the whole of the way up the stem, and the stems often remain perfectly upright in the coal-mines, and reach into the strata which have accumulated above the coal-seam.

[Illustration: FIG. 11.—Cast of *lepidodendron* in sandstone.]

Count Sternberg remarked that we are unacquainted with any existing species of plant, which like the *Lepidodendron*, preserves at all ages, and throughout the whole extent of the trunk, the scars formed by the attachment of the petioles, or leaf-stalks, or the markings of the leaves themselves. The yucca, dracaena, and palm, entirely shed their scales when they are dried up, and there only remain circles, or rings, arranged round the trunk in different directions. The flabelliform palms preserve their scales at the inferior extremity of the trunk only, but lose them as they increase in age; and the stem is entirely bare, from the middle to the superior extremity. In the ancient *Lepidodendron*, on the other hand, the more ancient the scale of the leaf-stalk, the more apparent it still remains. Portions of stems have been discovered which contain leaf-scars far larger than those referred to above, and we deduce from these fragments the fact that those individuals which have been found whole, are not by any means the largest of those which went to form so large a proportion of the ancient coal-forests. The *lepidodendra* bore linear one-nerved leaves, and the stems always branched dichotomously and possessed a central pith. Specimens variously named *knorria, lepidophloios, halonia*, and *ulodendron* are all referable to this family.

[Illustration: FIG. 12.—*Lepidodendron longifolium.* Coal-shale.]

[Illustration: FIG. 13.—*Lepidodendron aculeatum* in sandstone.]

In some strata, as for instance that of the Shropshire coalfield, quantities of elongated cylindrical bodies known as *lepidostrobi* have been found, which, it was early conjectured, were the fruit of the giant club-mosses about which we have just been speaking. Their appearance can be called to mind by imagining the cylindrical fruit of the maize or Indian corn to be reduced to some three or four inches in length. The sporangia or cases which contained the microscopic spores or seeds were arranged around a central axis in a somewhat similar manner to that in which maize is found. These bodies have since been found actually situated at the end of branches of *lepidodendron*, thus placing their true nature beyond a doubt. The fossil seeds (spores) do not appear to have exceeded in volume those of recent club-mosses, and this although the actual trees themselves grew to a size very many times greater than the living species. This minuteness of the seed-germs goes to explain the reason why, as Sir Charles Lyell remarked, the same species of *lepidodendra* are so widely distributed in the coal measures of Europe and America, their spores being capable of an easy transportation by the wind.

[Illustration: FIG. 14.—*Lepidostrobus.* Coal-shale.]

One striking feature in connection with the fruit of the *lepidodendron* and other ancient representatives of the club-moss tribe, is that the bituminous coals in many, if not in most, instances, are made up almost entirely of their spores and spore-cases. Under a microscope, a piece of such coal is seen to be thronged with the minute rounded bodies of the spores interlacing one another and forming almost the whole mass, whilst larger than these, and often indeed enclosing them, are flattened bag-like bodies which are none other than the compressed sporangia which contained the former.

[Illustration: FIG. 15.—*Lycopodites*. Coal sandstone.]

Now, the little Scottish or Alpine club-moss which is so familiar, produces its own little cones, each with its series of outside scales or leaves; these are attached to the bags or spore-cases, which are crowded with spores. Although in miniature, yet it produces its fruit in just the same way, at the terminations of its little branches, and the spores, the actual germs of life, when examined microscopically, are scarcely distinguishable from those which are contained in certain bituminous coals. And, although ancient club-mosses have been found in a fossilised condition at least forty-nine feet high, the spores are no larger than those of our miniature club-mosses of the present day.

The spores are more or less composed of pure bitumen, and the bituminous nature of the coal depends largely on the presence or absence of these microscopic bodies in it. The spores of the living club-mosses contain so much resinous matter that they are now largely used in the making of fireworks, and upon the presence of this altered resinous matter in coal depends its capability of providing a good blazing coal.

At first sight it seems almost impossible that such a minute cause should result in the formation of huge masses of coal, such an inconceivable number of spores being necessary to make even the smallest fragment of coal. But if we look at the cloud of spores that can be shaken from a single spike of a club-moss, then imagine this to be repeated a thousand times from each branch of a fairly tall tree, and then finally picture a whole forest of such trees shedding in due season their copious showers of spores to earth, we shall perhaps be less amazed than we were at first thought, at the stupendous result wrought out by so minute an object.

Another well-known form of carboniferous vegetation is that known as the *Sigillaria*, and, connected with this form is one, which was long familiar under the name of *Stigmaria*, but which has since been satisfactorily proved to have formed the branching root of the sigillaria. The older geologists were in the habit of placing these plants among the tree-ferns, principally on account of the cicatrices which were left at the junctions of the leaf-stalks with the stem, after the former had fallen off. No foliage had, however, been met with which was actually attached to the plants, and hence, when it was discovered that some of them had long attenuated leaves not at all like those possessed by ferns, geologists were compelled to abandon this classification of them, and even now no satisfactory reference to existing orders of them has been made, owing to their anomalous structure. The stems are fluted from base to stem, although this is not so apparent near the base, whilst the raised prominences which now form the cicatrices, are arranged at regular distances within the vertical grooves.

When they have remained standing for some length of time, and the strata have been allowed quietly to accumulate around the trunks, they have escaped compression. They were evidently, to a great extent, hollow like a reed, so that in those trees which still remain vertical, the interior has become filled up by a coat of sandstone, whilst the bark has become transformed into an envelope of an inch, or half an inch of coal. But many are found lying in the strata in a horizontal plane. These have been cast down and covered up by an ever-increasing load of strata, so that the weight has, in the course of time, compressed the tree into simply the thickness of the double bark, that is, of the two opposite sides of the envelope which covered it when living.

Sigillarae grew to a very great height without branching, some specimens having measured from 60 to 70 feet long. In accordance with their outside markings, certain types are known as *syringodendron*, *favularia*, and *clathraria*. *Diploxylon* is a term applied to an interior stem referable to this family.

[Illustration: FIG. 16.—*Stigmaria ficoides*. Coal-shale.]

But the most interesting point about the *sigillariae* is the root. This was for a long time regarded as an entirely distinct individual, and the older geologists explained it in their writings as a species of succulent aquatic plant, giving it the name of *stigmaria*. They realized the fact that it was almost universally found in those beds which occur immediately beneath the coal seams, but for a long time it did not strike them that it might possibly be the root of a tree. In an old edition of Lyell's "Elements of Geology," utterly unlike existing editions in quality, quantity, or comprehensiveness, after describing it as an extinct species of water-plant, the author hazarded the conjecture that it might ultimately be found to have a connection with some other well-known plant or tree. It was noticed that above the coal, in the roof, stigmariae were absent, and that the stems of trees which occurred there, had become flattened by the weight of the overlying strata. The stigmariae on the other hand, abounded in the *underclay*, as it is called, and were not in any way compressed but retained what appeared to be their natural shape and position. Hence to explain their appearance, it was thought that they were water-plants, ramifying the mud in every direction, and finally becoming overwhelmed and covered by the mud itself. On botanical grounds, Brongniart and Lyell conjectured that they formed the roots of other trees, and this became the more apparent as it came to be acknowledged that the underclays were really ancient soils. All doubt was, however, finally dispelled by the discovery by Mr Binney, of a sigillaria and a stigmaria in actual connection with each other, in the Lancashire coal-field.

Stigmariae have since been found in the Cape Breton coal-field, attached to Lepidodendra, about which we have already spoken, and a similar discovery has since been made in the British coal-fields. This, therefore, would seem to shew the affinity of the sigillaria to the lepidodendron, and through it to the living lycopods, or club-mosses.

Some few species of stigmarian roots had been discovered, and various specific names had been given to them before their actual nature was made out. What for some time were thought to be long cylindrical leaves, have now been found to be simply rootlets, and in specimens where these have been removed, the surface of the stigmaria has been noticed to be covered with large numbers of protuberant tubercles, which have formed the bases of the rootlets. There appears to have also been some special kind of arrangement in their growth, since, unlike the roots of most living plants, the tubercles to which these rootlets were attached, were arranged spirally around the main root. Each of these tubercles was pitted in the centre, and into these the almost pointed ends of the rootlets fitted, as by a ball and socket joint.

[Illustration: FIG. 17—*Section of stigmaria*.]

"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 and fruits, 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."—(Dawson, "Structures in Coal.")

There is yet one other family of plants which must be mentioned, and which forms a very important portion of the constituent *flora* of the coal period. This is the great family of the *coniferae*, which although differing in many respects from the highly organised dicotyledons of the present day, yet resembled them in some respects, especially in the formation of an annual ring of woody growth.

The conifers are those trees which, as the name would imply, bear their fruit in the form of cones, such as the fir, larch, cedar, and others. The order is one which is familiar to all, not only on account of the cones they bear, and their sheddings, which in the autumn strew the ground with a soft carpet of long needle-like leaves, but also because of the gum-like secretion of resin which is contained in their tissues. Only a few species have been found in the coal-beds, and these, on examination under the microscope, have been discovered to be closely related to the araucarian division of pines, rather than to any of our common firs. The living species of this tree is a native of Norfolk Island, in the Pacific, and here it attains a height of 200 feet, with a girth of 30 feet. From the peculiar arrangement of the ducts in the elongated cellular tissue of the tree, as seen under the microscope, the fossil conifers, which exhibit this structure, have been placed in the same division.

The familiar fossil known to geologists as *Sternbergia* has now been shown to be the cast of the central pith of these conifers, amongst which may be mentioned *cordaites, araucarites*, and *dadoxylon.*. The central cores had become replaced with inorganic matter after the pith had shrunk and left the space empty. This shrinkage of the pith is a process which takes place in many plants even when living, and instances will at once occur, in which the stems of various species of shrubs when broken open exhibit the remains of the shrunken pith, in the shape of thin discs across the interval cavity.

We might reasonably expect that where we find the remains of fossil coniferous trees, we should also meet with the cones or fruit which they bear. And such is the case. In some coal-districts fossil fruits, named *cardiocarpum* and *trigonocarpum*, have been found in great quantities, and these have now been decided by botanists to be the fruits of certain conifers, allied, not to those which bear hard cones, but to those which bear solitary fleshy fruits. Sir Charles Lyell referred them to a Chinese genus of the yew tribe called *salisburia*. Dawson states that they are very similar to both *taxus* and *salisburia.*. They are abundant in some coal-measures, and are contained, not only in the coal itself, but also in the sandstones and shales. The under-clays appear to be devoid of them, and this is, of course, exactly what might have been expected, since the seeds would remain upon the soil until covered up by vegetable matter, but would never form part of the clay soil itself.

In connection with the varieties which have been distinguished in the families of the conifers, calamites, and sigillariae, Sir William Dawson makes the following observations: "I believe that there was a considerably wide range of organisation in *cordaitinae* as well as in *calamites* and *sigillariae*, and that it will eventually be found that there were three lines of connection between the higher cryptogams (flowerless) and the phaenogams (flowering), one leading from the lycopodes by the *sigillariae*, another leading by the *cordaites*, and the third leading from the *equisetums* by the *calamites*. Still further back the characters, afterwards separated in the club-mosses, mare's-tails, and ferns, were united in the *rhizocarps*, or, as some prefer to call them, the heterosporous *filicinae*."

In concluding this chapter dealing with the various kinds of plants which have been discovered as contributing to the formation of coal-measures, it would be as well to say a word or two concerning the climate which must have been necessary to permit of the growth of such an abundance of vegetation. It is at once admitted by all botanists that a moist, humid, and warm atmosphere was necessary to account for the existence of such an abundance of ferns. The gorgeous waving tree-ferns which were doubtless an important feature of the landscape, would have required a moist heat such as does not now exist in this country, although not necessarily a tropical heat. The magnificent giant lycopodiums cast into the shade all our living members of that class, the largest of which perhaps are those that flourish in New Zealand. In New Zealand, too, are found many species of ferns, both those which are arborescent and those which are of more humble stature. Add to these the numerous conifers which are there found, and we shall find that a forest in that country may represent to a certain extent the appearance presented by a forest of carboniferous vegetation. The ferns, lycopods, and pines, however, which appear there, it is but fair to add, are mixed with other types allied to more recent forms of vegetation.

There are many reasons for believing that the amount of carbonic acid gas then existing in the atmosphere was larger than the quantity which we now find, and Professor Tyndall has shown that the effect of this would be to prevent radiation of heat from the earth. The resulting forms of vegetation would be such as would be comparable with those which are now reared in the green-house or conservatory in these latitudes. The gas would, in fact, act as a glass roof, extending over the whole world.