**Cupressinoxylon vectense; a fossil Conifer
from the Lower Greensand of Shanklin,
in the Isle of Wight.**

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With Plates **XXIII** and **XXIV**.

INTRODUCTION.

IN the study of the anatomy of plants few subjects have received such minute attention as the structure of Coniferous wood. The simple and unique character of the elements composing such wood has rendered it peculiarly suitable for examining the growth of timber, the effect of seasonal variations and the formation of annual rings, the ascent of water, and other life-problems. But perhaps a greater inducement, at any rate among the older writers, was found in the useful and ornamental character of many of the fossil woods—coal, lignite, agate, opal, amber—which led to the formation of collections of these substances and their examination by the curious. It is hardly necessary to point out that the bulk of these woods belonged to the Coniferous type, this being due to their much wider distribution

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in former periods than at present, and the comparatively late appearance of the Dicotyledons in geological time.

Unfortunately the conditions required for the preservation of the minute anatomy of pieces of stems and roots of fossil plants differ widely from those under which the leaf- and bark- impressions have been handed down to us, and the two are therefore hardly ever found together¹. This is not entirely due to the phenomenon of leaf-fall. The imprinting of the delicate venation of decaying leaves is largely a mechanical process, and pictures to the mind still lagoons and slowly-flowing streams; whereas the fragments of wood frequently bear the marks of much tossing to and fro before they were subjected to the chemical replacement of their cell-walls by silica, lime, or iron pyrites.

It is comparatively rare that the bark or cortex is left in fossils, and it thus happens that the sole guide to their systematic position is to be found in the minute structure of the wood. The uniformity of the elements in Coniferous wood has already been noted, and the problem here presented is seen to be of no common difficulty. Some of the best workers on the anatomy of plants have devoted their energies to its elucidation. Unger, Schleiden, Schacht, Mohl, Göppert, T. Hartig, Mercklin, Cramer, Kraus, Stenzel, Schenk, Conwentz, Felix, and many others, have produced a mass of monographs and treatises, almost all of them originating in an attempt to describe fossil woods, the necessity soon arising of extending their researches to an exhaustive study of recent Conifers.

In spite of these laborious investigations, the results have frequently been anything but satisfactory. Much labour was wasted by the earlier writers in attempting to unite each fossil wood with leaf or fruit remains occurring in strata of the same age. It was however soon demonstrated that classifications founded upon the structure of the wood could not be made to agree with those recognizing the natural

¹ Schenk, in Zittel, *Palaeophytologie*, p. 873, mentions *Sequoia Couttsiae* among Coniferae. See also *Elate austriaca* in Unger, *Chloris Protogaea*, 1847.

affinity of plants. The independence of these systems was first insisted upon by Göppert, and to him therefore we owe our first real advance in the subject¹.

Göppert instituted certain classes or types of wood which he termed 'genera,' but which, so far from being synonymous with the genera of systematists, frequently united members of the most widely separated groups.

Göppert's genera, emended by Kraus², form the basis of all recent classifications of existing and fossil Coniferous woods. These may be arranged according to the following types:—

1. **Araucaria** Type. *Araucarioxylon*. Bordered pits small, touching, usually mutually compressed, several rows in each tracheide, the pits in adjacent rows placed alternately.

2. **Cupressus** and **Abies** Type. *Cupressinoxylon* and *Cedroxylon*. Bordered pits separate, in one row, or, if in more than one, the pits of different rows opposite one another, resin-canals absent, but strands of wood-parenchyma containing resin. In *Cupressinoxylon* the resin-parenchyma is abundant, in *Cedroxylon* scarce or absent.

3. **Pinus** Type. *Pityoxylon*. Bordered pits as in 2, resin-ducts with sheaths of wood-parenchyma among the tracheides and in the medullary rays, no separate wood-parenchyma strands present³.

4. **Taxus** Type. *Taxoxylon*. Bordered pits and wood-parenchyma as in 2, no resin-ducts, tracheides with well-marked spiral thickenings.

Of these four types the first two are far more frequent in the fossil condition, the Araucarian with its allies extending from the Devonian to the present time, while *Cupressinoxylon* and *Cedroxylon* are more characteristic of the Secondary and Tertiary periods.

¹ Göppert, *De Coniferarum structura anatomica*, Breslau, 1841.

² Göppert, *Monographie der fossilen Coniferen*, Leiden, 1850; Kraus, *Mikroskopische Untersuchungen über den Bau lebender und vorweltlicher Nadelhölzer*, *Würzburger Naturwissenschaftliche Zeitschrift*, v, 1864.

³ Schroeter, *Untersuchungen über fossile Hölzer aus d. arct. Zone*, *Fl. fossil. arct.*, Oswald Heer, vi, Zürich, 1880.

It is doubtful how far it is possible to separate the last two forms of wood. Strasburger states that resin-parenchyma is to be found in all Coniferous wood except that of *Taxus*¹. Beust asserts that the frequency of resin-parenchyma cannot be used in classification, the only division possible being into those with and those without it². Certainly its absence from a few sections of a fossil would not demonstrate its typical absence from the species. Thus Felix, examining a specimen described by Schenk as *Cedroxylon*, because he found no parenchyma, was compelled to alter its name to *Cupressinoxylon*³.

It becomes very difficult to draw a sharp line between the two types because of the many transitional cases. In young branches of *Cedrus Deodara* and *Cryptomeria japonica* examined by myself, the number of wood-parenchyma-cells per sq. mm. of transverse section was greater in *Cedrus* than in *Cryptomeria*, being fairly abundant in both. Yet *Cedrus* is included in the *Cedroxylon* type and *Cryptomeria* is a typical *Cupressinoxylon*.

Leaving out of consideration the collection of families included under *Araucarioxylon*, it is significant that *Cupressinoxylon* includes, among living forms, Cupressaceae, Taxodiaceae, *Podocarpus*, *Dacrydium*, *Saxogothea*, *Phyllocladus*, *Ginkgo*, *Abies Webbiana*. The 'genus' therefore comprises the Cupressaceae in general as well as members of the Abietaceae, Taxodiaceae, and Taxoideae. Among Abietaceae are to be found genera or species belonging to *Cupressinoxylon* and *Pityoxylon*, and among the Taxoideae are included *Taxoxylon* and *Cupressinoxylon*.

These facts make it sufficiently clear that the character of the wood alone is of little taxonomic value. At the same time it cannot be altogether neglected. The section *Pityoxylon* offers characters distinct enough for determining

¹ Strasburger, Ueber den Bau und die Verrichtungen der Leitungsbahnen in den Pflanzen, Histologische Beiträge, iii, 1891.

² Beust, Untersuchungen über fossile Hölzer aus Grönland, Allgem. Schweiz. Gesellschaft, neue Denkschrift, xxix, 1884.

³ Felix, Studien über fossile Hölzer, p. 29, Inaug. Diss., Leipzig, 1882.

the principal groups of *Pinus* and a certain number of species¹. Under *Cupressinoxylon*, the genera *Sequoia*, *Phyllocladus*, *Ginkgo*, *Taxodium* and *Glyptostrobus* are said by different authors to possess characters by which they may be separated from all others². A more careful study of the structure of gymnospermous wood might have placed this group between the Angiosperms and the Cryptogams instead of with the Dicotyledons as was done at first³, just as Mercklin separated *Sequoia* from the Taxaceae on account of its wood-structure at a time when it was regarded as a member of that group⁴, and as Kraus detached *Dammara* from *Cunninghamia*⁵.

In spite of the fact that the woods grouped under *Cupressinoxylon* are drawn from such widely different groups of Coniferae, there is a truly remarkable similarity in their structure. Thus Kraus mentions forty-six species of recent Conifers, belonging to various groups, with woods of this type which he states are indistinguishable. This is the more to be regretted because the bulk of fossil Coniferous woods from the Jurassic to the Tertiary periods, and especially the enormous numbers found in the Brown Coal, belong to *Cupressinoxylon*.

The earlier workers do not appear to have appreciated these facts, and their diagnoses were lamentably meagre. They do not, moreover, appear to have had any adequate knowledge of the process of petrification, nor were they aware of the differences existing as regards wood-structure between different parts of the same plant. Branches, roots, stems, portions altered by chemical action or undergoing decay, were accordingly described as separate species, so that Kraus, in his analysis of work previous to 1864, ventured the extraordinary assertion that all *Cupressinoxyla* described

¹ Schimper, *Traité de Paléontologie végétale*.

² Schmalhausen, *Beitr. zur Tert. Fl. Südwest-Russlands*, Pal. Abh., Dames und Kayser, i, 1884. See also Kraus, Schroeter, Schenk in Zittel, and Göppert, l. c.

³ Knowlton, *Fossil Woods and Lignite of the Potomac Formation*, Bull. No. 56, U. S. Geological Survey, 1889.

⁴ Mercklin, *Palaeodendrologikon Rossicum*, St. Petersburg, 1855.

⁵ Kraus, l. c.

up to that date might, from their diagnoses, very well belong to different parts of one and the same tree¹.

Many of the characters formerly used in descriptions, such as the width of the annual rings, numbers and heights of medullary rays, sizes of tracheides, thickness of walls, &c., have now been demonstrated to differ as much in the same species as in different genera. To illustrate this fact, Kraus carefully examined a fossil stem with branch attached. He showed that these two parts differed so widely in the characters just enumerated that, following the lines of the old-time diagnoses, they would have to be put into well-separated 'species.' The detailed study which has led to these results has indeed characterized the period inaugurated by Kraus (1864). Sanio, Schroeter, Schmalhausen, Russow, Kny, Schulze, Wille and others, have supplemented their general comparative study of many forms by a minute, intensive examination of individual species. In the process the earlier descriptions have been thrown into confusion, but the path has been marked out along which any work of value in this field must be followed.

It is true that these writers have shaken, one by one, the pillars upon which the classification of Coniferous woods has been erected; their work has, in this sense, been mainly destructive. The characters of absolute importance have, however, been rigidly defined, new characters have been raised from relative to absolute value; and, what is perhaps of equal importance, the conditions have been determined under which the characters of relative value may be used in diagnoses. These conditions include a knowledge of the age and morphological character of the part as well as the mode of petrification. It is nevertheless only too apparent that the work of reconstruction has only commenced, and any description of fossil wood which is to be of use in the future must include an exhaustive analysis of all the characters, both absolute and relative, which have not been proved to be purely fanciful.

¹ Kraus, l. c.

In view of this formidable and discouraging literature—an abyss in which such a vast amount of useless labour has been sunk—the description of a new ‘species’ of *Cupressinoxylon* is not an enviable task. But, as will be seen, it is possible to determine fairly accurately the age and morphological character of the specimens selected for description in the present paper; and it becomes in this way permissible to submit them to the same exhaustive analysis as would be made in the study of a recent wood.

The pieces of fossil wood dealt with are taken from a series of silicified, rolled, and water-worn fragments, much perforated by teredo-like burrows, collected from the Lower Greensand of Shanklin in the Isle of Wight¹.

Some of these specimens are in a beautiful state of preservation, showing not only the bordered pits on the radial walls with great distinctness, but even their sections in tangential view with what appears to be the suspended torus. Since a pith is to be found in all of them, it is easy to determine their approximate age; and, while it cannot be definitely stated which are stems and which are branches, certain of them show in a marked manner the arrangement of cells in the annual rings which are characteristic of roots. It has, further, been possible to obtain in each specimen several sections in the transverse, tangential, and radial directions (thirty-two sections in all), and by this means some of the minor peculiarities of individual parts have, it is hoped, been ruled out.

¹ I am indebted to Mr. A. C. Seward, F.R.S., for the first and most beautifully preserved specimen, and to Dr. D. H. Scott, F.R.S., for the others. In both cases the specimens were accompanied by sections to which I have added a considerable number.

The slides dealt with in the present paper have been numbered A. C. S. 4, 5, 6; D. H. S. 338, 344–349; C. A. B. 1, 2, 3, 7, 8, 9, 11, 12, 13, 17, 18, 23, 24, 29, 30, 35, 37–42. These sections have been cut by Mr. F. Chapman.

As regards the expense of section-cutting, this has been defrayed out of a small Government grant from the Royal Society. By this means I have been enabled to obtain a far more complete series of sections than would have been the case otherwise.

DESCRIPTION OF SPECIMENS.

Specimens 1–2 inches in diameter, with distinct, central, or excentric pith. Rings of growth well marked, averaging 1–2 mm. wide, composite, each with 2–6 bands of narrow dark summer elements. From the arrangement of the cells in the rings the specimens are considered to be young branches and roots. Pith well preserved, diameter in branches .9 mm., in roots .3 mm. to .4 mm., cells increasing in size towards the centre, 10μ to 50μ in diameter, copiously pitted, with large triangular intercellular spaces $5\text{--}15\mu$ across. Medullary sheath: in the roots the rows of tracheides pass directly into the cells of the pith, in the branches they terminate in small groups of cells irregularly arranged. Spring tracheides not differing much in branch and root, tangential width $12\text{--}25\mu$, radial $17\text{--}22\mu$; summer tracheides, in the branches, radial diameter $10\text{--}11\mu$, averaging 4–6 rows, in the roots radial diameter 12μ , averaging 2–4 rows. Bordered pits in a single row (rarely double in roots), free and rounded in branches, often touching and compressed in roots, outer diameter $7\text{--}14\mu$, inner $3\text{--}5\mu$. Tangential pits frequent, occurring in 2–7 rows of summer cells, outer diameter $5\text{--}7\mu$, inner $2\text{--}3\mu$. Medullary rays simple, usually one, occasionally two cells broad, 1–16 cells high, the average being 2–3. Cells of ray $15\text{--}20\mu$ high, $12\text{--}16\mu$ broad, radial length various, covering 2–6 tracheides. Proportion of medullary-ray-tissue to the rest of the wood about 1:30. Resin-tissue, consisting of isolated rows of parenchymatous cells, abundant, equally distributed. Length of cells various, tangential width $19\text{--}28\mu$, radial $11\text{--}20\mu$.

It has not been found possible to place this wood under any species of *Cupressinoxylon* already described. The peculiarity of the rings of growth is probably in itself sufficient to establish a new species. Besides this, however, the youth of the specimens and the detailed examination to which they have been subjected, leave few points of comparison with known fossils. It will be better to defer

these comparisons until older specimens presenting the same peculiarities have been examined.

From the frequent occurrence of this type of wood in the Lower Greensand of the Isle of Wight, I have decided to call it *Cupressinoxylon vectense*.

ANNUAL RINGS.

The rings of growth are so peculiar as to deserve an extended description. They are compound in all the specimens (Fig. 1). They are readily visible to the naked eye, and each is seen to consist of a broad, inner, clear, and a narrow, outer, denser portion. The former, under a low magnifying power, is seen to consist of wide and more or less thin walled 'spring' elements. The latter is, however, not homogeneous, but is composed of a varying number of dark lines in a lighter matrix. The dark lines are narrow bands of thick-walled, flattened cells, and the lighter parts between them consist of wider cells with thinner walls resembling the cells of the inner portion of the ring but not so large (Fig. 2).

Under the microscope the dark bands of each series strongly resemble the 'autumn,' 'late,' or better 'summer' wood of living trees; but they are seen to vary much in extent and thickness, frequently anastomosing with one another or fusing together at short distances along the circumference of the section. What is one thin band at one place breaks up to from two to five in another or increases greatly in thickness. Besides these regularly grouped bands of flattened cells, other less definite ones may be traced at various points in the wide zone of spring tracheides. A close examination of this part of the ring shows that there are frequent changes in the radial width of the elements and the thickness of their walls, sometimes constant for some distance or indeed all round the section, at other times limited to a few cells only.

In the majority of cases the narrow dark bands would be classed as 'false' or 'partial' rings. They show a gradual

transition from wide cells within to narrow thick-walled ones, the latter passing again gradually into wide thin-walled elements outside (Fig. 2). The outermost band in each series usually presents the character of a 'true,' 'normal' or 'sudden' ring, that is a sudden change from flattened summer-cells to wide succeeding spring-tracheides. This sudden change in the character of the elements is usually regarded as correlated with a profound change in the vegetative activity of the plant; and for this and other reasons the broad rings of growth described above have been treated in the present paper as rings in the ordinary sense of the term.

It is not to be supposed that these rings of necessity represent annual periods of growth, for there are sometimes deviations from the above arrangement which would render such an interpretation full of difficulty. Thus it occasionally happens that the outermost dark band of a series is gradual, and more frequently one or more of the inner bands have the character of sudden rings. The same band at different parts of the section will change from sudden to gradual several times over. Lastly, in a few instances, a sudden ring appears in the midst of the wide spring-elements, can be traced for a short distance, and then completely disappears (Fig. 4). Taking into consideration this extraordinary variability, it will be seen that we have no proper data regarding the rate of growth of the plant to which the specimens belonged, especially as transverse sections taken at short distances from one another show great differences in the arrangement and composition of the rings of growth. The adoption of the term 'annual rings' in the present paper is to be regarded as a matter of convenience in describing the other characters of the wood.

This is not the place to review the voluminous literature dealing with the effect of climate on the structure of wood¹.

¹ For references to the principal papers dealing with this subject see especially Büsgen, *Bau und Leben unserer Waldbäume*, Kap. vii, Jena, 1897; Nördlinger, *Deutsche Forstbotanik*, i, 1874; and Seward, *Fossil Plants as Tests of Climate*, C. v, London, 1892.

It is important rather to determine how frequently irregularities of the nature described occur in recent and fossil species. There appear to be no analogous cases among fossil woods already investigated. Conwentz mentions that in the amber-producing *Pinus succinifera* the rings are distinctly visible to the naked eye, but under a lens they are found each to consist of a series of narrow rings, and he states further that he remembers having seen cases of a similar nature in other fossils¹. Fliche figures an anastomosis between two rings of *Cupressinoxylon infracretaceum*², and Seward notes the presence of partial rings in his recently described *Pinites Ruffordi*³. But besides such isolated examples there appears to be nothing resembling our specimens among described fossils.

It is well known that in Dicotyledons of warmer regions the ring-formation, so regular with us, is deficient or absent. *Michelia* and *Avicennia* may be selected among many as resembling our fossil in the sharp character of the stem-rings, which nevertheless anastomose with one another, and thereby render the counting exceedingly difficult.

When however we turn to recent Conifers, we meet with much less irregularity. It has been considered worth while, in books devoted to forest-botany, to record cases of partial or indistinct ring-formation in this group. The anomaly is seen to be widely extended. Of more immediate interest to us are such plants or parts of plants in which this peculiarity occurs, if not habitually, at any rate more frequently than elsewhere.

We are told that branches are more subject to irregularities in wood-formation than stems⁴. In roots again, according to Nördlinger, it is frequently impossible to count the rings

¹ Conwentz, Monogr. d. baltischen Bernsteinbäume, 1890, p. 32.

² Fliche, Note sur les Nodules et bois minéralisés trouvés à Saint-Parres-les-Vaudes (Aube) dans les grès verts infracrétaqués, Mém. de la Soc. Acad. de l'Aube, lx, 1896.

³ Seward, *Pinites Ruffordi* from the English Wealden Formation, Journal Linnean Society, Bot. xxxii, 417.

⁴ Felix, Beitr. zur Kenntniss foss. conif. Hölzer, Engler, Botan. Jahrb. iii, 1880, p. 265.

of growth even in those plants which have rigidly-defined rings in their stems and branches¹. As will be seen directly, our specimens probably include both branches and roots.

I have observed gradual rings in branches of *Abies Pinsapo*, *Cryptomeria japonica*, *Juniperus virginiana*, and especially *Juniperus communis*, although the rings are well separable and easy to follow. The sections of *Cupressus sempervirens* in Nördlinger's famous series, on the other hand, show a confused arrangement of gradual and normal rings frequently anastomosing with one another, and rendering the counting a matter of considerable difficulty. The resemblance between these sections and our fossil is very striking. In the other cases just mentioned the gradual rings may be regarded as exceptionable disturbances in the wood-formation; in *Cupressus sempervirens* the irregularity appears to be the usual state of affairs. Thus Hartig describes two branches of this Cypress, one fifteen to twenty years old, showing only three rings of growth, and one twenty-five years old with nine rings². Through the kindness of Mr. Thomas Hanbury I have been able to examine the branches and roots of two trees of this species from his garden at La Mortola. A study of these specimens confirms the previous observations. There are the gradual and the sudden rings, the anastomosis of the narrow dark bands, and even a tendency to the formation of bundles of small rings, usually two together, alternating with clear zones, which forms so marked a character of our fossil specimens. Such irregularity as this cannot be referred to external conditions, and, as we have seen, the rings of this *Cupressus* do not of necessity correspond to definite periods of time. I have accordingly felt justified in including the irregularity in the formation of the annual rings among the distinguishing characters of the fossil under discussion.

We are sometimes able, from a study of the arrangement of the tracheides in a transverse section, to tell whether it

¹ Nördlinger, l. c.

² Hartig, Vollst. Naturgesch. d. forstl. Kulturpflanzen Deutschlands, p. 86.

is taken from root, stem or branch. In the rings of a Coniferous stem, according to Mohl¹, there is a gradual decrease in the radial diameter of the cells from the first tracheides of the ring to the last, accompanied by an increase in the thickness of the walls. In a root-ring, on the other hand, a number of layers of wide spring-elements are succeeded suddenly by a band of flattened thick-walled summer-cells which terminate the ring. This difference is explained in the following way. In a wide ring, whether in stem, branch or root, there are three distinct zones which differ as regards the form and size of their cells—an inner layer of wide square cells, a middle zone of polygonal, usually hexagonal cells, and an outer zone of typical summer-cells which are again more or less rectangular. Stems generally have wider rings than branches or roots, and all three layers are met with in them. In branches the inner layer is variable, and in thin rings is frequently absent. In roots on the contrary it is the middle layer which varies, and in thin rings it is usually wanting.

The thin rings which characterize smaller roots and branches are thus seen to be very different in appearance. In branches a set of hexagonal cells passes gradually into the thick, flat summer-cells; in roots wide, square tracheides are followed without transition by the flatter layer, which, in this case, is often reduced to only two or three rows of cells.

On applying these facts to our fossil sections we note that they can with little difficulty be divided into two sets (Figs. 2 and 3). In one of these, which I have called branch (1) and branch (2), the cells of the inner layer are polygonal and pass gradually outwards to from 2-12-20 summer cells. In the other specimens, while in places there are gradual transitions, many parts show a sudden passage from wide, frequently squared cells, to from 1-2-4-6 flat dark tracheides. These I have called root (1) and root (2). It seems therefore probable

¹ Mohl, Einige anat. und physiol. Bemerkungen über das Holz der Baumwurzel, Bot. Zeit. 1862.

that the specimens are smaller branches and roots, an assumption which is supported by a number of other characters, although a few difficulties are met with.

It should be pointed out in passing that this distinction between root- and stem-structure must be used with a certain amount of caution. If, as Mohl holds, it has its explanation in fundamental differences in the function of the two organs, it will be capable of wide application¹. There are, however, instances of stems exhibiting the typical root-arrangement. Thus Strasburger, in describing the last-formed layers of an old moribund Larch, states that the stem-rings are small and consist of very wide spring-tracheides followed suddenly by narrow thick-walled summer-cells. The same arrangement was found in the wide rings of a perfectly healthy Larch forty-eight years old. It is indeed stated by Nördlinger to be a common feature of Larch-wood². Lastly, Mohl expressly remarks on the small difference between the outer stem- and root-rings of the Larch. It cannot then be considered altogether safe to use this character alone in determining the root- or stem-nature of fossil woods. To give an example, *Cupressinoxylon distichum*, described by Mercklin³, is now regarded as a root, and yet the rings (which are stated to be the outer rings of a very thick trunk) correspond exactly with those of Strasburger's old dying Larch stem⁴.

In one of the specimens the rings are wavy, i.e. thrown into a series of irregular arches around the section (Fig. 1). This has been noted as an occasional occurrence in many recent Coniferae; and among fossils in *Cupressinoxylon nodosum* (root) by Göppert⁵ and *C. erraticum Terebinum* and *C. Fritscheanum* by Mercklin³. The arches render the measurement of the elements difficult, since the cells are much smaller where two arches meet, as if these regions were subject to pressure. Possibly this is due to the nearness

¹ Mohl, l. c.

² Strasburger, l. c., p. 24.

³ Mercklin, l. c.

⁴ See also Kobbe, Ueber die fossilen Hölzer der Mecklenburger Braunkohle, Inaug. Diss., Rostock, 1887.

⁵ Göppert, Monograph.

of small branches, as in the case of Göppert's *C. nodosum*. See also his figure of a Larch-stem with many small lateral branches and wavy rings¹.

The width of the rings of growth as defined above is somewhat variable. This character is not now regarded as of diagnostic value, since the rings will vary in width according to climate, age, soil, and the part of the plant.

As the same ring differs considerably in different parts of its course, the measurements have been taken in all directions where the structure has been undisturbed.

Branch (1). Average width of first ten rings 1.7 mm., varying from .6 mm. to 2.8 mm.

Branch (2). Average width of first ten rings 1.45 mm., varying from .7 mm. to 2.3 mm.

Root (1). Average width of first twelve rings 1.07 mm., varying from .4 mm. to 2.1 mm.

Root (2). The rings near the pith are quite indistinct. Then follow five rings with an average width of 1.7 mm., varying from 1 mm. to 3.4 mm. After this five narrow, dark bands occur at distances of from .2 mm. to .8 mm.

PITH AND MEDULLARY SHEATH.

The pith has received careful examination whenever the sections have admitted. It is obvious that from its study great assistance might be expected in determining the root- or shoot-nature of organs. This expectation was only partially realized. In the first place the usual absence of pith from pieces of fossil wood has caused it to receive small attention in the literature of the subject, and secondly the state of preservation of the cell-wall did not allow the markings to be clearly seen at the critical points. The diameter of the pith in branch (1) and branch (2) was .9 mm.; in root (1) it was .4 mm., and in root (2) .3 mm. This is in agreement with Nördlinger's statement that, while in

¹ Göppert, l. c., Tab. i, Fig. 10.

branches and in primary roots the pith is distinct, that of lateral roots is point-like if present at all¹.

An examination of the 'medullary sheath or crown' points in the same direction. While branch (1) and branch (2) have well-marked groups of primary xylem where the tracheides lose the radial arrangement (Figs. 5 and 6), roots (1) and (2) show rows of tracheides passing directly to the borders of the pith (Fig. 7). A search for the primary xylems in longitudinal and oblique sections of these specimens has not been very successful; but in the tranverse section of root (1) there is a distinct appearance of tracheides with spiral thickenings in the pith opposite several of the primary medullary rays.

In the radial sections the appearances are not so convincing. In branch (1) the tracheides with bordered pits are easily seen to be in contact with the spiral ones, these latter adjoining the pith-cells. This is what one would expect in a section of a shoot. But there is every appearance that the same is the case in root (1). The state of preservation in root (2) and branch (2) prevents their sections from throwing any light on the question.

The number of primary medullary rays varies in the sections. It is not possible to determine them accurately, but they seem to be between 2 and 7.

The cells of the pith in transverse sections are largest in the centre, from whence they decrease outwards to the 'crown' of tracheides (Fig. 7). The diameter of the former may be taken as about 45μ , while the outer medullary cells measure $10-20\mu$. In longitudinal sections the inner cells are seen to be flattened transversely, so as to extend across the pith, while the cells near the tracheides are elongated in the same direction as the latter.

All the pith-cells are richly pitted. Where undisturbed they are circular in transverse section, and have well-marked triangular intercellular spaces $5-10-15\mu$ across.

¹ Nördlinger, Forstbotanik.

THE TRACHEIDES.

The general arrangement of tracheides, as seen in transverse section, is fairly regular and similar to that in most woods of this class. Radial rows of broad cells alternate with narrow ones wedged in between them. The former represent the tracheides cut across at their broadest place, the latter the chisel-shaped ends with richly pitted walls. While the cells of each radial row are nearly constant in tangential width, neighbouring cell-rows differ very much.

In order to measure the *tangential width* of the tracheides it is obviously impossible to isolate the cells and measure them individually at their broadest part, as has been done by Schulze for recent woods¹. All that can be done is to obtain a general average of the tangential width by counting the number of cells in a measured distance². This number will depend partly on the length of the tracheides; the shorter these are, the more frequent will be the rows of narrow ends.

It has been already pointed out that the cells vary in their size in wavy rings, being apparently much compressed where the arches join. It has therefore been found necessary to multiply observations in order to obtain a true average. The results appear to be in accordance with the general laws laid down by Mohl, Sanio, Schulze, Kraus, and Conwentz. The following figures give the measurements of from 100 to 250 tracheides in each ring in eight different sections, the number of observations depending upon the state of preservation. They have involved the counting of over 17,000 cells.

¹ Schulze, Ueber die Grössenverhältnisse der Holzzellen bei Laub- u. Nadelhölzern, Inaug. Diss., Halle, 1882.

² Sanio, Ueber die Grösse der Holzzellen bei d. gemein. Kiefer, Pringsh. Jahrb. viii, 1892, p. 403.

Tangential width of spring-tracheides in μ :—

Rings	1	2	3	4	5	6	7	8	9	10	11
Branch (1)	12.5	18.8	20.7	22.7	23.7	24.3	24.5	24	24.7		
Branch (2)	14	17.5	20	21	23.5	24	25.5				
Root (1)	12.7	16	20	23	23.7	25	24	25.2	24.5	25	24.5

In root (2), the inner rings not being well defined, the tracheides were measured at about equal distances from the pith, and in successive rings where these were apparent.

Root (2) | 10 | 16.5 | 21 | 24 | 26 | 26 | 22 | 24 | 22 μ .

We thus see that the tracheides in the first ring are very small; from the second to the sixth a rapid rise takes place, and from the sixth to the eleventh the tangential width is fairly constant.

The *radial width* of the tracheides has been calculated by measuring the first ten tracheides in each ring in ten as widely separated regions of the section as possible. The resulting average of 100 spring-tracheides is assumed to be a fair guide. The measurement is, however, rendered difficult by the indefinite limits of certain of the rings, and the consequent necessity of selecting suitable rows for observation. No figures could be obtained for the first few rings, and in root (2) it was found necessary to adopt another method.

Radial width of spring-tracheides in μ :—

Rings	1	2	3	4	5	6	7	8	9	10	11	12
Branch (1)			17.2	18.7	19.1	20.6	21.5	22.3				
Branch (2)				20.4	21	23.3	22.2					
Root (1)				19.2	19.6	20.9	20.3	21.6	22.5	22.1	20.5	20.2

In root (2) well-defined rings are absent near the pith. Besides this, where the rings are visible, it is found that the largest cells are in the middle of the ring, those at the commencement being considerably smaller. I have, accordingly, measured the ten tracheides at regular intervals from the centre or in the middle of each ring.

Root (2) | 10.5 | 14 | 20 | 25 | 26 | 32 | 29 | 26 | 33 | 26 | 26 | 26 | 28 μ .

The branches show the increase in radial diameter which was to be expected. The roots show first an increase in width, followed by a decrease in succeeding rings. Without laying much stress upon this latter peculiarity, because of the fewness of observations, it may be pointed out that the arrangement is in accordance with the results obtained by Sanio. He showed that while in branches the increase in size of the tracheides is maintained until a constant is reached, in roots these elements increase in radial diameter during the first few years, then decrease, later on again increasing until a constant is reached¹.

It is important to note that, according to Mohl and other observers, the elements of roots are larger than those of stems and branches. This does not hold good in the present case, a fact which throws some doubt upon the division of our specimens into roots and branches².

An examination of the summer-tracheides, on the other hand, tends to support this division. The summer-elements of roots are stated by Mohl to be fewer in number and less flattened than those of branches and stems³, and this appears to be the case in our section. I have collected for comparison the most flattened elements of each ring, and have in each case tried to get as many in a radial group as possible (cf. Figs. 2 and 3).

¹ Sanio, l. c.

² Nördlinger, Forstbotanik, mentions cases where there is not much difference between the size of cells in stems and roots (Aspen, &c.).

³ Mohl, l. c.

Measurements of summer-tracheides.

	No. of groups measured.	Average number of tracheides in a group.	Average radial diameter of tracheides.
Branch (1)	20	4.3	11.1 μ
Branch (2)	13	5.4	9.8 μ
Root (1)	31	3	12 μ
Root (2)	25	3	12.2 μ

The walls of the tracheides are frequently seen to be striated in longitudinal sections. This is especially the case where, from the appearance of the bordered pits and the presence of fungus hyphae, it is evident that decomposition had commenced before petrification. The striation in these cases is probably due to this cause. In tangential sections, however, the summer-wood is seen to be striated even in well-preserved parts where the spring-wood is not—a phenomenon not due to decay, but often met with in the wood of recent Conifers.

The thickness of the walls of the tracheides, a character which was once considered to be absolute, varies a good deal with the state of preservation of the part. An average of 80 measurements gives 7.2 μ , ranging from 4 μ to 14 μ .

BORDERED PITS.

The bordered pits have received the utmost attention from students of wood structure. By means of these, Coniferous wood is easily separated from that of Angiosperms, and of the former the Araucarian type is cut off from the rest. There are also subordinate differences in the sizes of the bordered pits and the numbers of rows per cell in stems, branches and roots. Since in Coniferae they occur exclusively upon the radial walls, the study of radial sections has acquired great importance in diagnosis.

The bordered pits in our sections are arranged in one row—probably in great part due to the youth of the specimens. A comparison of the radial diameter of the tracheides and

that of the pits shows that there is barely room for two rows of pits in one cell. We should not therefore meet with a double row of pits unless two tracheides were placed exactly opposite one another. This arrangement of cells, as already mentioned, is more frequently met with in the root-specimens, and we accordingly find one or two instances in the root-sections of two bordered pits occurring side by side at the same level on the wall of one tracheide (Fig. 10).

In branch (1) and branch (2) the pits are usually quite free from one another, very rarely touching or slightly compressed. They are however much more abundant at the ends of the tracheides. In root (1) the pits, while generally free, are often in close contact, especially at the cell endings, the result being that their shape is oval with flattened upper and lower sides. The pits are sometimes flattened in root (2), but the structure is not well enough preserved to institute comparisons.

Bordered pits in Coniferae usually show two concentric circles in surface view, the outer and inner borders. It has been customary to determine the width of these circles most accurately in the hope of thus obtaining data for the separation of different plants. From the extended researches of Kraus¹, Wille² and others, it does not seem that there has been much progress made in this direction.

In the present specimens much difficulty has been experienced because of the varying state of preservation. At first this caused a good deal of unnecessary labour. It was found that in parts of some sections the pits showed more than two concentric circles (Fig. 15); in other cases the two circles could hardly represent the outer and inner borders of the pit, because of the large and varying size of the inner one. The appearances referred to evidently point to different stages of decomposition, some of them closely resembling for instance those figured by Hartig in his description of

¹ Kraus, Beiträge zur Kenntniss. fossil. Hölzer, II, Zur Diagnostik des Coniferenholzes, Abhandl. d. naturf. Ges. zu Halle, xvi, 1886.

² Wille, Zur Diagn. d. Coniferenhölzer, Halle, 1887.

the decomposition of spruce-timber by *Polyporus borealis*¹; and the far from rare occurrence of hyphae in the specimens shows that some fungus had been at work before petrification. The case referred to is exactly analogous to the decaying bordered pits of a piece of rotten *Sorbus Aucuparia* described by Kraus, where the inner circle increased in diameter according to the stage of decay until it fused with the outer². What at first sight was regarded as a remarkable variability in the bordered pits was thus found to be due to the state of preservation of the specimen, and all measurements made in such parts were subsequently disregarded.

The inner pore, which is circular, is not usually well preserved in the specimens. The average of a number of measurements in the best places was $3\text{--}5\mu$, these limits being rarely passed.

More detailed results were obtainable with the outer border. Many hundreds of measurements were taken with a view to determine whether, as in recent woods, any clearly marked increase could be noted in the size of the pits from the pith outwards. The small pits in the summer wood were left out of consideration.

The results are as follows:—

Greatest diameter of Bordered pits.

Branch (1), 3rd ring, 7.0μ ; 5th, 9.5μ ; 6th, 11.3μ ; 7th, 14.0μ .

Branch (2), 3rd ring, 8.4μ ; 4th, 10.5μ ; 5th, 12.8μ ; 8th, 14.0μ .

Ditto in another section, at intervals, 9.7 , 10.3 , 11.1 , 12.0 , 12.2 , 13.7μ .

Root (2), successive rings, 10.5 , 13 , 13 , 13.3 , 13.2 , 12.5 , 12.7 , 14 , 13.5μ .

Root (2), successive regions, 10.4 , 12.2 , 12.3 , 13.6 , 13μ .

These figures show how incompletely a single number would suffice to express the size of the pits. From our knowledge of their varying size in different organs, and in the same organ at different ages, we should expect to

¹ Hartig, The Diseases of Trees, English Edition, Fig. 124.

² Kraus, Mikrosk. Unters.

find a series of measurements in every recently described fossil, where the size of the specimen and the state of preservation allowed of this. Yet I have only met with one instance in which such a series of observations has been made¹.

The average diameter of the bordered pits in young roots and branches cannot be definitely stated. In the oldest parts of our sections it may be given as $13-14\mu^2$.

Bordered pits on the tangential walls are present in all the sections, both radial and tangential (excepting in root (2), where the structure is not well preserved). According to Strasburger, tangential pits are found in the summer-elements of all Coniferous woods which do not possess 'tracheidal elements' in the medullary rays³. The function of the latter is to supply a radial passage for the water, and the tangential pits accomplish this from one ring to another, there being no room in the last summer-elements for the radial pits. In support of this view Strasburger shows that tangential pits occur in other parts of the ring where the normal passage of water from one tracheide to another is interrupted, e.g. when a new medullary ray is formed, or opposite a resin-duct. A good example of this is seen among fossil woods in *Pinites Ruffordi*, where a solitary tangential pit is figured—opposite a resin-duct⁴.

In *Cupressinoxylon*, with its purely parenchymatous medullary rays, one would look for tangential pits in all the 'species.' But they have only been recorded in six of the sixty species summarized by Beust⁵. A certain amount of perseverance is necessary to find the pits in some of our sections, although they are very well seen in the others. They are much smaller than the radial pits.

¹ Conwentz, l. c., p. 40.

² Kraus, Zur Diagn., gives $15\mu +$ as the usual size in Abietinae and Cupressinae, the elements of young parts being smaller. Schenk, in Zittel, states that the full size is generally reached during the first ten years.

³ Strasburger, l. c., p. 9.

⁴ Seward, l. c., Fig. 6.

⁵ Beust, l. c.

Measurements of Tangential Pits.

Branch (1). Average of 36, outer diameter $5\ \mu$, inner $2.35\ \mu$.

Branch (2). Presence easily noted, but not sufficiently clearly for accurate measurements.

Root (1). Average of 26, outer diam. $7.3\ \mu$, inner $2.3\ \mu$.

Root (2). Structure of wall not well preserved: tangential pits not met with.

The numbers of rows of summer tracheides in each ring bearing tangential pits have been carefully determined for recent Conifers, and the different groups are seen to vary considerably in this respect. Kraus recommends observations in transverse sections, but it is only possible in our sections to use the radial ones. In the latter the tangential pits are sometimes very clear. The section of the pit has the form of a sharply cut lens-shaped space, and not infrequently the torus is found stretched across it as a short black line. In other cases this space is without the torus. In a third set of examples the lumen of the pit is filled up by infiltration, but the torus is well seen as a short black line in the thickness of the wall (cf. Figs. 11-13). These three conditions are often found close together, all manner of transitions being seen. It becomes quite possible then, after careful study, to make out the tangential pits in comparatively thick sections with the help of a substage condenser. This has been of the greatest service in counting the number of rows of summer-tracheides with these pits, because this part of the wood is generally very dense.

The observations have been most successful in branch (2). Here the tangential pits are sometimes found in the last seven rows of tracheides. This abundance of tangential pits is in agreement with the other characters of our fossil wood, showing us that in the Cretaceous period, where *Cupressinoxyla* are first met with¹, the type of wood found in *Cupressus*, *Sequoia* and *Abies* was developed in its minutest details. In Abietinae with composite medullary rays these

¹ Schenk in Zittel, l. c.

pits are much less abundant, and are rare or absent in the *Pinus* group.

The torus, so well seen in certain tangential pits, is still more clearly defined in the larger pits on the radial walls (Figs. 11 and 12). These, examined in tangential sections, frequently show the torus as a dark line suspended in the lens-shaped cavity of the pit or closely applied to one side¹—positions which might lead to interesting speculations as to the condition of the wood at the time of petrification².

MEDULLARY RAYS.

The medullary rays figure conspicuously in every published description of fossil Coniferous wood. While in Dicotyledons they are composed of similar elements but differ widely in form, in Conifers they are very uniform in shape but differ greatly in their component parts. This has led to a minute study of them in the latter class of woods. In the first place there is their difference of composition. Some of them have tracheidal as well as parenchymatous elements, and this difference is regarded as an excellent diagnostic character. Those woods further which possess vertical resin-ducts usually also have radial ones in certain of the medullary rays. The latter are then compound and are more than one cell broad. In living Conifers which have no resin-ducts, the medullary rays are simple and consist of a single vertical layer of cells. The two-rowed medullary rays, although occasionally met with, are rare³; but they are much more frequently found in *fossil* woods without resin-ducts, and this constitutes one of the differences between recent and fossil species⁴.

¹ The torus is well seen also in *Sequoia canadensis*, Schrtr., and *Pinus succinifera*, Conwentz.

² Strasburger, l. c., p. 32; also Russow, Zur Kenntniss des Holzes, insbesondere des Coniferenholzes, Bot. Centralblatt xiii, 1883, p. 37.

³ Beust, l. c.

⁴ Kraus, Mikr. Unters., mentions *Cupressinoxylon fissum*. Araucarian woods with two-rowed medullary rays are called *Pissadendron*. Among woods with resin-ducts, Strasburger mentions *Larix* as not infrequently having double medullary rays without resin ducts.

In the fossils under examination the medullary rays are uniform in structure, consisting of parenchyma alone; they are also generally one cell thick (excepting in root (2), which should perhaps be separated because of this and other differences in the medullary rays).

The characters mentioned thus far are of great importance in descriptions; as regards the constancy of those to follow we are a good deal in the dark. The earlier writers, in describing the medullary rays, were content with mentioning whether they were simple or compound, and indicating the height they might reach in cells vertically above one another, e.g. 1-18, 1-6, 2-36, &c. But the uselessness of these numbers will be at once apparent to any one who has examined a number of tangential sections of Coniferous wood, the maximum height of the medullary rays depending largely on the time taken in their examination. It has moreover been demonstrated that in this respect medullary rays vary according to their distance from the pith and height up the stem; and stems, branches and roots of the same plant may have medullary rays of different heights¹. Nevertheless we do meet with cases where the height of the medullary rays is more or less characteristic of the wood. They are usually low in *Thuja*, higher in *Cupressus* than in *Juniperus*, in Abietinae they have half the number of cells they have in Cupressinae (except *Thuja*), &c. It is therefore necessary to include the height of the medullary rays in all diagnoses, especially in those cases where we have a knowledge of the age of the part and its morphological value.

A similar series of remarks is applicable to almost every one of the characters of medullary rays which different writers have from time to time attempted to introduce. Their frequency in the wood, the height and width and radial length of the individual cells, the thickness and pitting of the walls and the general shape in cross-section—all these have been demonstrated to be valueless for the

¹ Essner, Ueber den diagn. Werth der Anzahl u. Höhe der Markstrahlen bei den Coniferen. Abh. d. natur. Gesell. zu Halle, xvi, 1886.

general separation of species, and yet there are certain genera which show marked and apparently constant peculiarities in one or other of these respects. A careful analysis is therefore necessary of the medullary rays and their cells. Such has been attempted in our sections, following as far as possible the lines laid down by Kraus, Essner, and Beust in their investigation of living forms.

At the instigation of Kraus, Essner has shown that the numbers of medullary rays per sq. mm. of tangential section in any species is greatest in the first year, and that it decreases gradually outwards, while on the other hand the medullary rays are lowest near the pith and increase in height towards the cortex. This has led him to the idea that the number of medullary cells per sq. mm. may be constant for the same species in different years. In his attempts to obtain characteristic numbers for different species, he found, however, that individuals of the same species varied more than did those of different species. This character cannot therefore be considered absolute.

Beust, arguing from the intrinsic importance of the medullary-ray-tissue in the life of the wood, regards it as probable that some relation exists between the relative bulk of this tissue and that of the tracheides. To obtain this proportion he has combined the several factors determined by Essner. It is however not certain at present how far the proportion will hold good for the different types of wood.

I have attempted to apply these observations to the fossil sections. It is not easy to determine accurately the age of the part in a tangential section of a fossil. In my specimens they have been cut as a rule between the sixth and the tenth rings of growth. The following figures represent a great deal of labour. Their worth will not be fully apparent until it is possible to compare them with those of other specimens. As their value greatly depends upon the number of medullary rays observed, I have where possible noted this.

The first (p. 357) table gives the number of medullary rays per sq. mm., as well as their heights in cells. All the slides here examined were tangential. The method adopted was to count the number of medullary rays in the field of the microscope, the area of the field having first been accurately determined. In the case of medullary rays partly included those only were reckoned which were more than half in the field.

The second table (p. 358) gives the number of medullary-ray-cells per sq. mm., as well as the average area of each cell. These combined give the proportion of medullary-ray-tissue to the whole wood. The observations on the radial sections are given as control measurements. The areas are calculated from the tangential measurements alone. Each medullary-ray-cell is practically an ellipse. In measuring its width it was impossible to decide how much of the cell wall belonged to the cell of the ray and how much to the adjoining tracheides. The whole thickness of the wall on one side was therefore added to the lumen.

Pits were observed only on the radial walls of the medullary-ray-cells. In both radial and tangential sections these were seen to be simple. In shape they were oval and obliquely placed, usually two or one per cell, occasionally three, or more rarely four. The higher numbers were, as usual, on the outer cells, the middle cells having frequently one pit each. This is in accordance with the *Sequoia* type of wood.

The longest diameter of the medullary-ray-pits could only be accurately determined in two sections. In branch (1) it varied from 3 to 10 μ , the average of fourteen pits being 6.5 μ . In root (2) the diameter varied from 6 to 12 μ , the average of thirteen pits being 8 μ .

Intercellular spaces were very clearly seen in the medullary rays, their distribution being as in recent woods.

RESINOUS PARENCHYMA.

There are no resin-ducts. Wood-parenchyma is however to be found among the tracheides, and this, from analogy

TABLE I.

	No. of medullary rays per sq. mm.	Height of medullary rays in cells, showing the number of medullary rays of each height in every hundred examined †.											Highest and lowest medullary rays observed.	Average number of cells per medullary ray.	No. of double medullary rays.	Total number of medullary rays examined.
		1	2	3	4	5	6	7	8	9	10	11				
Br. (1) { Section (1) Section (2)	62	13	38	22	13	8	3	3	...	...	...	...	1-7	2.96	...	124
	57	9	43	23	12	6	3	3	...	1	...	...	1-9	2.90	...	113
Br. (2) { Section (1) Section (2)*	94	23	33	13	14	5	5	5	...	1	1	...	1-15	2.93	1%	256
	94	20	53	16	7	2	2	0	...	...	...	...	1-6	2.24	...	195
Rt. (1) { Section (1) Section (2)	58	38	43	14	4	1	...	...	...	...	...	...	1-5†	1.87	...	131
	53	30	47	12	8	3	...	...	...	...	...	...	1-5	2.04	...	307
Rt. (2) { Section (1) Section (2)	84	17	34	17	12	9	6	3	1	...	1	...	1-11‡	3.06	3%	837
	75	7	37	16	14	11	5	3	2.5	2.5	1	1	1-16	3.54	4.5%¶	586

* In this section only a small portion was accurately tangential, therefore all the medullary rays were obtained from one part of the section.

† Very instructive curves may be prepared embodying these figures, the numbers of medullary rays of different sizes being represented by the height of the curve above the base-line. In parts near the pith the curves are steepest, becoming rapidly flattened as we proceed outwards.

‡ Felix gives low medullary rays as characteristic of roots¹. This agrees well with root (1), but not with root (2), making it possible that the latter may have to be separated.

¶ In one part of this section twenty-eight double medullary rays were counted in fourteen fields, i. e. 9% one being three cells broad. They may be frequently seen in transverse sections of this specimen.

¹ Felix, Inaug. Diss. 1882, &c.

with recent woods may be regarded as resiniferous¹. The resiniferous parenchyma may be described as abundant, and our wood is therefore to be placed under *Cupressinoxylon*.

In a transverse section of recent Coniferous wood the parenchyma may frequently be determined by its contents or the thinness of its walls, and its relative abundance thus

TABLE II.

		No. of medullary ray cells per sq. mm.	Size of individual cells † in μ (about fifty measurements in each case).			Average area of cells in μ^2 .	Amount of medullary ray tissue per sq. mm.	Proportion of medullary ray tissue in wood.
			Height (radial sections).	Height (tangential sections).	Width.			
Br. (1)	Section (1)	183	(17, 18)	16	14	176	·032 mm ²	1 : 30
	Section (2)	165		19	14	209	·034	1 : 28
Br. (2)	Section (1)	281	(16·8, 15·6)	15	12·7	151	·042	1 : 23
	Section (2)*	211		15·7	14	173	·037	1 : 26
Rt. (1)	Section (1)	108	(18·5, 21)	19·6	16	246	·027	1 : 36
	Section (2)	111		20·5	16	257	·029	1 : 33
Rt. (2)	Section (1)	270	(18·8)	19	14·2	212	·057 ‡	1 : 17
	Section (2)	271		19	14·2	212	·057	1 : 17

* See note to Table I.

† The radial length varied from 23 to 159 μ and covered from 2 to 6 tracheides.

‡ See note to Table I.

noted. This is not possible in our specimens, where the walls of adjoining cells are not separable, and it is difficult to distinguish the resin-cells from tracheides with dark contents. In longitudinal sections, however, the contents of the parenchyma are seen to be peculiar, and differ from the small rounded granules found in the tracheides. Spherical

¹ Strasburger, l. c.

masses of dark substance give the parenchymatous cells a vacuolated appearance¹. This peculiarity has been of great service in the search for parenchyma in each section (cf. Figs. 8 and 9). Transverse walls are always found in the immediate neighbourhood of such masses, as if the contents had accumulated here during the disintegration of the wood; and these transverse walls alone determine the parenchyma. There is thus some reason for the frequent description among the older writers of 'fossil resin' and 'fossil starch.'

The strands of wood-parenchyma occur as isolated rows of cells separated by transverse walls. In tangential sections the terminal cells of each row have pointed free ends, whereas in radial sections the end cells appear to terminate abruptly at a medullary ray just as many of the tracheides do. This suggests that each strand has an origin similar to that of a tracheide—from a single cambial cell. Occasionally several strands appear close together, and they are more abundant in certain sections or parts of sections. But generally speaking, the resiniferous tissue may be described as uniformly distributed.

The cells differ in appearance in radial and tangential sections. In the latter the transverse walls cut the cells across at sharp angles, sometimes slightly obliquely, and the whole strand is of equal width excepting at the ends (Fig. 9). In the radial view, on the other hand, the transverse walls are never oblique, the cell-lumen is rounded at each end, and there is usually a distinct constriction in the width of the cell at each division (Fig. 8). These facts are of considerable importance. In the first place, the shape of the wood-parenchyma-cells has been regarded as of great value by some writers²; and secondly, various species have been characterized as having rows of cells constricted at intervals. Andrae, in an all-too-short description of *Calloxylon Hartigii*—a *Cupressinoxylon*

¹ This vacuolated appearance has been noted by Kraus, Mikr. Unters., and drop-like masses of a similar nature have been described by Andrae.

² Hartig, according to Kraus, Mikr. Unters.

not unlike our own in several respects—founded on the examination of over a hundred sections, noted the same characters in the radial and tangential aspects of the wood-parenchyma¹.

There is a marked difference in the width of the cells in radial and tangential directions. The radial widths in the different specimens were 19μ , 11μ , 20μ , and 19μ , respectively, whereas the tangential were 28μ , 19μ , 26μ , and 26μ . The length of the cells varied from $\cdot 09$ mm. to $\cdot 33$ mm. in branch (1), with an average of $\cdot 19$ mm. in twenty-five measurements; in root (1) from $\cdot 04$ mm. to $\cdot 21$ mm., with an average of $\cdot 12$ mm. in twenty measurements; in root (2) from $\cdot 11$ mm. to $\cdot 27$ mm., with an average of $\cdot 19$ mm. in twenty measurements.

The terminal cells of each row of parenchyma are, as already stated, pointed in tangential sections, and are here indistinguishable from the neighbouring tracheides. These end-cells are free of contents and appear to have normal bordered pits. The latter are however difficult to make out. It is quite possible that the appearances are deceptive, because Strasburger states that in recent Coniferous woods the pits between tracheides and parenchyma are always one-sided bordered pits². See, however, Fig. 14.

In one case a strand of resin-parenchyma was traced through $2\cdot 5$ mm. when the edge of the section was reached, nine transverse walls having been passed. The average length of ten closed series of parenchymatous cells from end to end was $1\cdot 55$ mm.

It was not possible to make out any pittings on the transverse or tangential walls of the parenchyma. This is one of those subsidiary characters which should always be noted, for it is stated by Beust that the wood of *Taxodium*

¹ Andrae, *Calloxydon Hartigii*, Bot. Zeit. 1848, p. 633. See also Kobbe, l. c., Taf. ii, figs. 1 and 3 of *Cupressinoxylon uniradiatum*.

² Strasburger, l. c. See also Kobbe, l. c., where double-bordered pits are figured in the parenchyma of *Cupressinoxylon uniradiatum* (Taf. ii, fig. 1) and of *Cupressinoxylon pachyderma* (Taf. ii, fig. 10).

distichum and *Thuja gigantea* may be distinguished from all others by the thick pitted transverse walls of these cells. The reticulated pitting on the tangential walls of *Thuja gigantea* and *Fitzroya patagonica* is also considered a good character.

EXPLANATION OF FIGURES IN PLATES XXIII AND XXIV.

Illustrating Mr. Barber's paper on *Cupressinoxylon*.

Fig. 1. Transverse section of branch (1) of *Cupressinoxylon vectense*, showing composite rings. $\times 3\frac{1}{2}$.

Fig. 2. Transverse section across composite ring of a branch—the same specimen as in Fig. 1—showing gradual and sudden transitions between the large and small elements. $\times 60$.

Fig. 3. Transverse section across part of a root. $\times 30$.

Fig. 4. A partial ring which disappears completely to the right. $\times 30$.

Fig. 5. Part of the medullary sheath of branch (1). The rows of tracheides terminate towards the pith in small-celled groups. This is better seen in the portion more highly magnified in the next figure. $\times 45$.

Fig. 6. Part of the medullary sheath shown in Fig. 5, more highly magnified. $\times 100$.

Fig. 7. Pith of root (2). The rows of tracheides pass uninterruptedly into the pith. There is no appearance of the groups of small cells representing the protoxylem. $\times 100$.

Fig. 8. Resiniferous parenchyma in radial section with drop-like masses of fossil resin. $\times 350$.

Fig. 9. Resiniferous parenchyma in tangential section. $\times 350$.

Fig. 10. Tracheide showing the occasional doubling of the row of bordered pits. $\times 500$.

Figs. 11 and 12. Walls of tracheides in tangential section showing the cavity of the pits with suspended torus. $\times 500$.

Fig. 13. Radial section through part of the summer-wood of a composite ring with the torus preserved as sharp dark lines. All stages are met with, frequently near together, between the appearances in Figures 11, 12, and 13. $\times 500$.

Fig. 14. Resiniferous parenchyma in tangential section. The dark oval bodies in the walls appear to be small double-bordered pits. $\times 800$.

Fig. 15. Various appearances presented by bordered pits in surface view, probably depending upon the state of preservation. $\times 750$.

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