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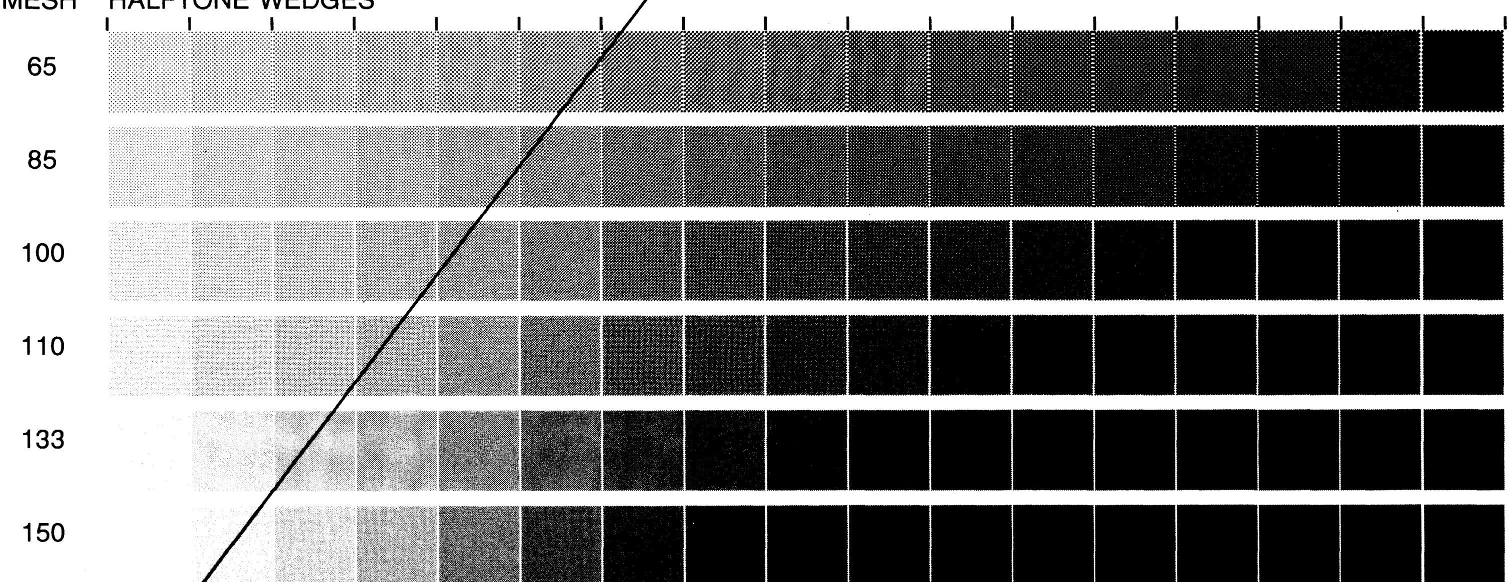

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CONTRIBUTIONS FROM THE MUSEUM OF PALEONTOLOGY

(Continuation of Contributions from the Museum of Geology)

UNIVERSITY OF MICHIGAN

VOL. III, No. 12, pp. 207–232 (7 pls., 9 text figs.) DECEMBER 18, 1931

ON *CALLIXYLON NEWBERRYI* (DAWSON) ELKINS ET WIELAND

BY

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UNIVERSITY OF MICHIGAN PRESS

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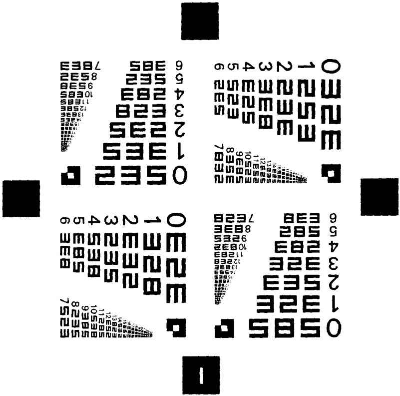
ROCHESTER INSTITUTE OF TECHNOLOGY, ONE LOMB MEMORIAL DRIVE, ROCHESTER, NEW YORK 14623



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CONTRIBUTIONS FROM THE MUSEUM OF PALEONTOLOGY

(*Continuation of Contributions from the Museum of Geology*)

UNIVERSITY OF MICHIGAN

Editor: EUGENE S. MCCARTNEY

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ON *CALLIXYLON NEWBERRYI* (DAWSON) ELKINS ET WIELAND

By CHESTER A. ARNOLD

IN THE literature on the geology of the states of Indiana, Kentucky, Ohio and Michigan mention is frequently made of the occurrence of petrified wood in the black shales which are commonly assigned to the Upper Devonian period. Although this wood has been known for many years, comparatively few attempts have been made to study it anatomically or to determine whether more than one form is present.

HISTORICAL

Probably the earliest account of wood in the black shales is a paper read before the fourth New Haven meeting of the American Association for the Advancement of Science in 1850. George C. Schaeffer (1850), professor of natural philosophy and chemistry at Centre College, Danville, Kentucky, described fossilized logs that rested upon the black shale between Lebanon and the "Knobs." His account is interesting not only because it is one of the oldest records of fossil wood in this country, but also because the description is sufficiently clear for the material to be recognized as Callixylon.[1] Part of his account is as follows:

> The medullary rays are numerous and distinct, and the whole appearance of the wood not unlike that of a beech or a sugar maple. No rings of annual growth can be found. The diameter of some of the trunks must have been at least two or three feet.
>
> This tree is distinguished from Araucaria by having three, four, or more

[1] Callixylon is characterized by the presence of mesarch primary wood bundles at the margin of the pith and close to or in actual contact with the secondary wood in which the pits on the radial walls of the tracheids are arranged in radially aligned clusters; the spaces on the walls between the groups are unpitted (Zalessky, 1911).

> dots side by side on each fiber, and by having the dots in patches, not uniformly distributed.
>
> The dots themselves seem to be peculiar; under a low power, they seem to consist of a covering dehiscent from the center. But by careful management and higher powers, they seem to consist of cells not unlike those forming the stomates of plants, only more in number, — about four to each dot, and different in shape.

He says, further, that it may be a species allied to Voltzia.

A few years later Newberry secured from the septarian concretions in the black shale of Ohio some silicified wood fragments which he submitted to Sir William Dawson. Dawson (1871) described this material as *Dadoxylon Newberryi.* Later Newberry (1889) described the material and stated that he had found it at Delaware, in Huron County, and in southern Ohio, but he was not explicit in stating just where the material came from which was submitted to Dawson. It is probable that Dawson's description was based upon material from more than one locality, although sections designated as types were recently found among the collections of the Peter Redpath Museum at McGill University. Rominger (1873–76) mentions similar material in the black shales of northern Michigan, which he considered as being of Genesee age, and Knowlton (1889) and Penhallow (1900) include this species in systematic accounts of the fossil woods of America. However, their contributions to our knowledge of this wood are comparatively slight.

In 1914 Elkins and Wieland (1914) described a specimen from the black shales as *Callixylon Oweni.* Since this account states that the material was found by Dr. Wieland in the Yale collection, its Indiana source is probable, but it might have come from any one of several localities. They also refer Dawson's *Dadoxylon Newberryi* (*Cordaites Newberryi* of Knowlton, 1889) to Callixylon, although the resemblance was pointed out previously by Zalessky (1911) when he instituted the genus, and later by White (Prosser, 1912, p. 520). Aside from mere references to one or both of these two species in subsequent literature, no further contributions to our knowledge of the petrified wood in the black shale have since been made.

AGE OF THE BLACK SHALE

It is outside the scope of this account to deal at length with the age of the black shales, which has been a matter of considerable controversy. The generally accepted Upper Devonian age for these shales has been challenged by several competent authorities within recent years. Swartz (1929) has shown that the upper part of the Chattanooga shale in northeastern Tennessee and adjacent Virginia is of lower Mississippian age, whereas the thin basal portion is Devonian. Ulrich (1926) places the Antrim shale similarly, with its basal member as Upper Devonian and the upper portion, which includes the fossil plant remains, in the Mississippian. He also includes the New Albany shale in the Mississippian (1911), although no one has ever attempted to show that this formation is divisible into the two parts.

Though the plant remains of the black shales might be indicative of Upper Devonian age, the evidence derived from them is not conclusive, since the vertical range of Callixylon is not known. However, the occurrence of this one species, both the petrified wood and the branch impressions, over so wide a territory affords strong evidence that the shales known as the Antrim, Huron, Ohio, New Albany and Chattanooga are one and the same formation and are identical in age.

LOCALITIES AND OCCURRENCE

During the recent investigation the black shales were examined in southern Indiana; in the vicinity of Lebanon, Kentucky; in southern Ohio; and in the vicinity of Columbus and Delaware of the same state. No additional material was found in Ohio or Kentucky, although about a year previous to the inauguration of the search an excellently preserved piece of wood was secured from the Chattanooga shale at the mouth of Forbush Creek near Mill Springs, Kentucky. The best localities were found in Scott and Clark counties, Indiana, and material is abundant, though widely scattered, throughout the New Albany shale horizon in this part of the state.

Since the New Albany shale is quite uniform throughout its entire depth in Indiana, it is impossible to associate the petrified wood with any particular level. It is quite probable that it extends to the top of the horizon, because at the locality at Henryville (shortly to be mentioned) the rocks overlying the New Albany shale outcrop only a short distance above the shale where numerous specimens occur. The field work consisted of an examination of the exposures of this shale wherever they could be found. Specimens are most frequently found as loose débris, but occasionally they occur *in situ.* In most quarries the petrified logs are removed as impediments as soon as they are discovered.

The Indiana specimens are quite variable in size. The largest specimen encountered during the course of the present study is nine feet long, three feet broad at the base, and tapers to about eighteen inches at the top. The expanded basal portion shows the attachment of two and possibly three large roots. This specimen, therefore, is the lower portion of a large tree (Plate I). It was found lying prostrate and half buried in the shale in a quarry two and one-half miles east of Vienna in Scott County. Segments of other logs, two and three feet in diameter, were observed in the same quarry.

Numerous specimens were also discovered in a small valley about five miles northeast of Henryville, Clark County. Though none of them were found *in situ,* the shale is extensively exposed in that locality and the tributaries of the small creek coming down the steep sides of the valley had been instrumental in dislodging many specimens, which had rolled down into the creek below.

To judge from the size of the trunks and the rarity of other fossil plant material (except Sporangites) in the New Albany shale, it appears that these logs were driftwood which had floated to its present location. On none of the logs are branches visible, but buried branch bases are revealed if the logs are broken open. Specimens found *in situ* are covered with a thin layer of coal, which apparently was derived from the carbonization of the bark layer. In no specimen is any of the bark petrified.

A series of ridges which extend both lengthwise and crosswise give to the exterior of these logs a striking appearance. These ridges are of varying length; some of them may be but a few inches long, but others may extend for half the circumference. The distance between them is also variable, but most of them are from two to six inches apart. The elevation of the ridges varies, which gives the surface a knotty aspect. The cross ridges give to the edge of a specimen a scalloped appearance, which is somewhat exaggerated if the specimen is slightly flattened. The exterior weathers to a light brown, whereas the interior is a lignitic black.

These ridges appear to be associated with quartz-filled cracks which seem to have their origin at the places of attachment of the branches. Quartz-filled cracks are abundant in the vicinity of the buried branch bases and it seems that the crystallization of the quartz in these areas caused a cracking and subsequent bulging along the lines of the ridges.

IMPRESSIONS OF THE STEM

Throughout the black shales in the region under consideration long, jointed impressions are frequently encountered, to which Dawson (1871) applied the name *Calamites inornatus.* He gives the following diagnosis:

> Ribs continuous, as in C. transitionis, but flat and broad, the breadth of each being one quarter of an inch in a stem four inches in diameter. Nodes distant, prominent in the flattened stems, owing to their greater density compared with the internodes.

He gives the distribution of this form as Cayuga Lake, New York; Kettle Point, Ontario; and Gaspé, Quebec. In 1911 Kindle found a specimen in the Huron shale near Milan, Ohio (Prosser, 1912, p. 522). White (quoted by Prosser, *ibid.*) compares this specimen to Nathorst's genus *Pseudobornia.*

During the course of the present investigation specimens of this form were found in practically every locality in which the shale was examined and they are very abundant in the Antrim shale at Alpena, Michigan. These specimens have a width varying from three fourths of an inch to six inches and are straight or very slightly curved. The distance between the so-called nodes varies slightly, but it is usually about two inches. The nodal lines, instead of extending entirely around the stems, as in Calamites, consist, especially in the larger stems, of segments which extend only part way. A segment adjacent to another, then, will not lie on the same circumference, but slightly above it, and with its end projecting back beyond the end of the segment just below (Plate II, Fig. 3). The ribs mentioned by Dawson do not show on all specimens, but where they do (Plate II, Fig. 1) they are clearly not ribs of the Calamites type as Dawson interpreted them, but are probably due to a longitudinal buckling of the surface when the stem was compressed.

Some of the specimens from the Antrim shale bear short branches which depart from the main stem at an angle of about 45 degrees (Plate II, Fig. 2). All of them are covered with a thin layer of coal, which in one specimen yielded some small fragments of silicified wood, thus showing that silicification had commenced before coalification was complete.[2] These small fragments were sufficient, however, to reveal the Callixylon type of pitting and rays of the *C. Newberryi* type. This, then, shows that these calamite-like structures are the impressions of the smaller branches of Callixylon, and without doubt the same as the large trunks from Indiana and Kentucky. The carbonized stem remains, which are common in the lower Portage of New York (Arnold, 1929, Plate II, Fig. 3) and which were interpreted as possible Callixylon remains, appear to be different.

PRESERVATION

All the Callixylon remains so far observed in the black shales are silicified and differ in this respect from the material from the Upper Devonian of New York, which, contrary to statements frequently made, is calcified. The silica is precipitated in the cell cavities and there is very little alteration of the cell walls. Small fragments of the wood can be desilicified without loss of cell structure. They can then be infiltrated with collodion, sectioned with the sliding microtome and stained with safranin in the same way as living wood. The large amount of organic matter that remains in this material renders it quite soft as compared with most silicified wood. It splits readily into thin, flat radial plates,

[2] These fragments were discovered by Professor H. H. Bartlett, to whom the author is indebted for permission to publish this information.

the surfaces of which present a woody appearance to the unaided eye. With the aid of a single lens the radial alignment of the pit clusters is distinguishable. The softness of this material and the facility with which it splits render the preparation of thin transverse sections exceedingly difficult. The best sections were prepared by Walton's cellulose peel method (Walton, 1928).[3]

ANATOMY

Pith

The pith of the main stem is large, varying from one to three centimeters in diameter. At places it is septate, but for the most

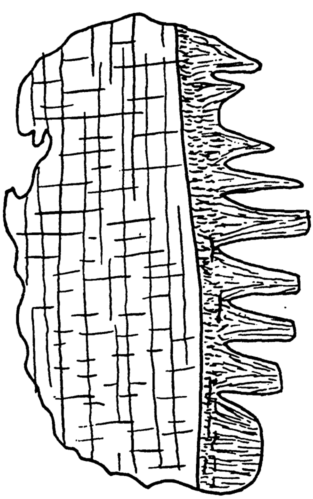

FIG. 1. Diagram of radial section, showing septation of pith. × 1

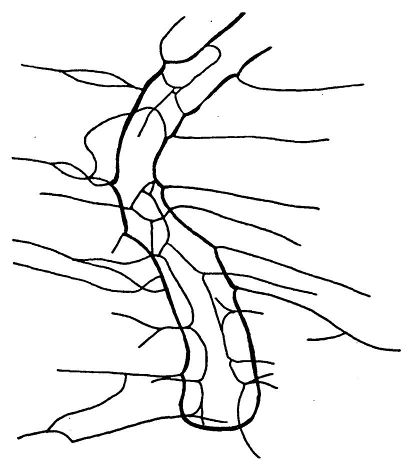

FIG. 2. Tracheid-like cell in pith, but it has failed to develop a secondary wall. × 100

part is continuous. In the septate portions the septa are regularly spaced (text Fig. 1), and the lacunae between them extend to

[3] The procedure with this material was as follows: surface ground smooth; treated for 30 seconds with full-strength commercial hydrofluoric acid; washed in water; immersed 1 minute in waste alcohol, then 1 minute in 95 per cent alcohol; rinsed with absolute alcohol; then, without being allowed to dry, etched surface covered with 5 per cent solution of pyroxylin dissolved in ether-alcohol mixture.

within three or four millimeters of the inner edge of the wood. The pith of the lateral branches is small, seldom having a diameter of more than five millimeters; at a distance of ten centimeters from the pith of the main trunk it has approximately the same diameter as at its point of origin.

The central portion of the pith appears to be loosely arranged and in most specimens it has disappeared. As the periphery of the pith is approached, it becomes slightly firmer and the cells become elongated in a radial direction. This feature is quite pronounced immediately around the primary bundles (Plate VII, Fig. 1).

Scattered throughout the pith, except in the central region, are numerous tracheids (Plate IV, Fig. 3). Except when near the outside, where there may be two or three in a group, these tracheids are isolated cells with closely wound spiral or scalariform markings. Occasional cells of the shape of tracheids have failed to develop a secondary wall (text Fig. 2).

Primary bundles

The exact number of bundles in any one section has not been determined because it has been impossible to secure a complete transverse section. To judge from the number contained in a sector, it is estimated that there are at least twenty in the main part of the stem, but they might range as high as thirty, since in many specimens they are irregularly spaced (Plate VII, Fig. 1).

Many of these bundles are separated from the secondary wood and are completely surrounded by pith tissue (Plate IV, Fig. 2). In only rare specimens is a strand separated from the secondary wood by a distance greater than its own diameter and usually the intervening pith zone is only one or two cells in extent. Other bundles may be partly separated, but still retain their connection with the secondary wood by a narrow isthmus of xylem. When these imbedded strands commence to bend outward previously to forming a trace, they do not come in contact with the secondary wood immediately, but remain surrounded by a zone of parenchymatous tissue even after they have reached the inner zone of the secondary wood.

In no other American species of Callixylon has this separation of the bundles been observed, although it is known in *C. Trifilievi* (Scott, 1912). In this species, however, only a few of the bundles are isolated and the majority of them are in contact with the secondary wood.

The continuation of the reparatory strand at the margin of the pith without the formation of a leaf gap is, so far as can be determined, identical with that of *C. Zalesskyi* and *C. erianum.* Also no connection can be observed between the isolated tracheids in the pith and the organized bundles at or near the margin.

In the lateral branches with smaller pith the primary bundles are correspondingly fewer, and most of them are in contact with the secondary wood (Plate IV, Fig. 1).

Secondary tissues

The secondary tissues show no great differences from those previously described for this or any other species of the genus. However, a few points worthy of consideration are noted.

Penhallow (1900), in diagnosing this species, says that there is no evidence of growth rings [4] (obscure or obsolete) in a radial extent of seventeen millimeters. This character is used by Elkins and Wieland (1914) as a distinguishing feature of *C. Oweni,* in which there are six growth rings in fifteen millimeters of radial extent. Examination of the type sections of these respective forms shows that the figures given above are correct for these particular specimens, but in larger specimens the spacing of the rings is so irregular that measurements taken from a small area are of no value. Growth rings were observed in practically all specimens examined, but they are usually absent from the first fifteen or twenty millimeters of secondary wood immediately surrounding the pith, and at other places they are absent for a greater distance. Generally they are spaced at intervals of three to seven millimeters, although the spacing is entirely too irregular to constitute a specific character. The radial extent of the "summer wood" is always small (Plate III), never more than two or three

[4] The term "growth ring" is used in this account in preference to the less accurate term "annual ring," which is more commonly used.

cells. Concentrically placed zones of crushed tissue may, upon casual examination, present a deceptive appearance of growth rings.

Because of the very fine preservation of the material, details of pit structure show in a striking manner. The pits are circular when not crowded and the crossed apertures are usually visible (Plate IV, Fig. 4). The more crowded pits may assume a hexagonal outline from mutual pressure. Most of the groups contain from six to fifteen pits, but variations may range from one to fifty.

The presence of "bars of Sanio" between the pit clusters was discussed in a former account (Arnold, 1929). These structures had not been previously recognized in this genus, although they are readily distinguishable in the type sections of *C. Oweni*. The authors of that species (Elkins and Wieland, 1914) mention a thickening of the tracheid walls and a "spindle shaped interspace" between the pit groups as visible in the tangential section, but farther on in the account the statement is made that the bars of Sanio are not present even in a rudimentary condition. This, of course, is a misinterpretation of these thickenings which, however, are quite different from the bars as they are commonly seen in most woods.

Considerable tangential pitting occurs in places. These tangential pits are small and range from 7.7 to 9.3 microns in diameter as compared with the radial pits, which range from 10 to 15 microns. They are round, rather distantly spaced, and are not grouped. They are common in the portions of the secondary wood adjacent to the pith and also in what appears to be the "summer wood," although this latter point is not established with finality. The radial pits in the same tracheids with the tangential pits are grouped in the usual fashion.

Rays

Penhallow (1900) describes the rays of this species as being of medium height, one- or two- or rarely three-seriate, 24 to 55 microns broad, and the oval or round cells all thin-walled. Examination of the type sections shows that his diagnosis is essentially correct, but lacking in detail because of the small amount of material upon which the species was based.

Examination of the new material shows much variation in height and seriation of the rays and in the shape and contents of the ray cells (Plate V, Figs. 1–2). Within a single specimen a considerable variation of structure exists. The majority of the rays are biseriate, at least in part. Many of them are entirely so and rays which are three- and four-seriate are not uncommon in some specimens (Plate V, Fig. 3). Rare instances were noted of rays five and six cells wide at the widest place. At first it was sus-

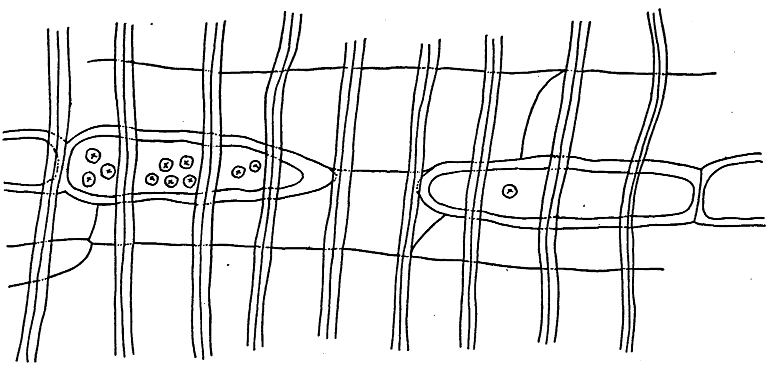

FIG. 3. Ray tracheids, showing rounding of ends of cells. × 300

pected that specimens with the very wide rays might represent distinct species, but prolonged examination showed that such features are merely variations which are likely to be found in all the material.

Many of the ray cells contain black material. In some of them the material is collected at the ends, but others are full. This mass of blackish material has usually shriveled somewhat, thus leaving a space between it and the cell wall. This gives an exaggerated aspect to the slight narrowing of the cells at the ends, and this feature was probably observed by Penhallow when he said that the ends of ray cells are "conspicuously narrower." In some of the ray cells are black globular bodies (Plate VII, Fig. 3), though others contain a foamy substance. Penhallow refers to the material in the cells as starch and resin, but its chemical nature has never been determined.

Occasional ray tracheids are encountered. They occur as thick-walled cells bearing full-bordered pits of the same type, only small, that occur in the wood tracheids. These ray tracheids are frequently isolated or several may occur in a group (Plate VI, Fig. 2; text Figs. 3–4). They are widely scattered and in many of them none will appear in a radial section of considerable size. They are more common in some specimens than in others, but because of their sporadic occurrence it is never safe to assume their

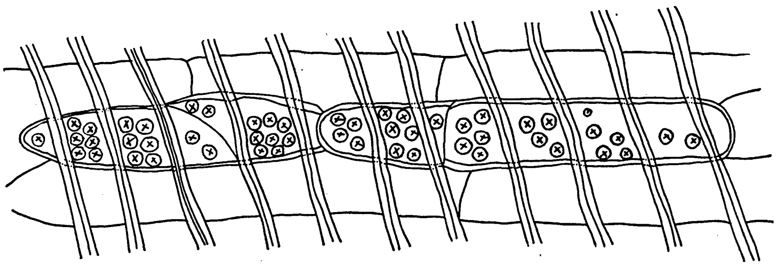

FIG. 4. Ray tracheids arranged in series and showing full-bordered pits on the side walls. × 300

absence except after a prolonged examination of considerable material. In one specimen in which they were not observed in the main trunk, they were found in abundance in a lateral branch. Many of these structures are rounded or much narrowed at the ends, so that adjacent ray tracheids may touch by only a small portion of their ends. Some of them are very short, not longer than high.

The scattered ray tracheids and the fact that they were overlooked by previous authors is responsible for the statements in connection with *Callixylon Newberryi* and *C. Oweni* that the ray cells of these species are thin-walled. No ray tracheids can be found in the type sections of the former and they cannot be recognized with certainty in the latter.

Fungous mycelium is abundant in the tracheids and ray cells of some of the material (Plate V, Fig. 4).

THE IDENTITY OF *CALLIXYLON NEWBERRYI* AND *C. OWENI*

It was only after a considerable number of specimens of wood from the black shale had been studied that it became apparent that such descriptive characters as the variations of the diameter of the tracheids and the number of pits per group, the contents of the ray cells, presence or absence of growth rings in a small section, etc., do not indicate different species. If such characters are to be used it would become necessary to establish a separate species for almost every specimen examined.

Examination of the type sections of both *Callixylon Newberryi* and *C. Oweni* [5] made it obvious that the sections of *C. Newberryi* were too small and that the material from which they had been prepared was too badly compressed for them to be satisfactory in identifying unknown material. Of the four sections representing the type specimen one is an oblique cut which is practically useless. Of the others the transverse section measures 3 × 12 millimeters, the radial 7 × 14 millimeters, and the tangential $5\frac{1}{2}$ × 13 millimeters (text Fig. 5). The longest dimension of the transverse section is in the radial direction. Small areas of them can be studied with some satisfaction, but they give no idea of the amount of variation which occurs in these woods and consequently descriptions based upon them tend to stress features which are not so applicable to the material as a whole. Penhallow's description, however, is about as accurate and as complete as the material would permit.

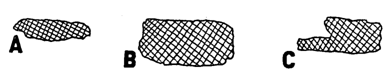

FIG. 5. Diagram showing exact size of the type sections of *C. Newberryi*. *A*, transverse; *B*, radial; *C*, tangential

The sections of *C. Oweni* are much better prepared and are from better material, so that the description is more satisfactory. The authors of that species, however, did not have access to the types of *C. Newberryi*, and hence Penhallow's meager description was their only basis for comparison. As a consequence,

[5] The type sections of *C. Newberryi* were very kindly lent to the author by Dr. T. H. Clark of the Peter Redpath Museum. Dr. Wieland has very generously donated the type sections of *C. Oweni* to the Museum of Paleontology of the University of Michigan.

the differences cited by Dr. Wieland (Elkins and Wieland, 1914, p. 75) are not so obvious when the specimens are compared, and they do not show characters justifying separation into two species.

Dr. Wieland states that the growth rings might serve as a basis for separation, but the examination of more material shows that the spacing of the growth rings is not a constant feature and it is easy to locate areas which show no rings in blocks much larger than that from which the sections of *C. Oweni* were made. Dr. Wieland suggests this possibility when he says: "It is also possible that the specimen studied by Penhallow may have been taken from an area between two such successive rings of unusual width. This is merely a conjecture. The far greater chance is that both specimens are average trunk wood and do differ by presence or absence of growth rings." The present author is inclined to the opinion that the first alternative is the correct one, and that Penhallow's section was made from one of the larger areas which contained no growth zones.

It is unfortunate that the poorer specimen must remain the type of the species when the specimen described as *C. Oweni* is more nearly representative of the material as a whole, but at the same time the association of Newberry's name with it is appropriate, since he first made it an object of study.

After it had become apparent that the material represented by the types of *C. Newberryi* and *C. Oweni* belongs to one species, the question immediately arose concerning the specific relationships of the newly discovered material. The most variable features in these woods are the width and the seriation of the rays, and at first it seemed possible that the specimens with the very broad rays might represent distinct species. Although in many of the specimens, in fact the majority of them, the rays appear narrower (Plate V, Fig. 2), there are no accompanying differences in primary wood structure or in surface features. Also, the narrower rays are invariably associated with a slight amount of flattening of the wood, which caused a slight buckling of the horizontal walls of the ray cells, but which did not affect the structures with stronger walls. This flattening gives the rays a deceptive appearance upon casual observation (Plate VII, Fig. 2).

Furthermore, since such features as presence or absence of growth rings, contents of the ray cells, and variations in size of the pit clusters are not diagnostic, the present author has concluded that the material so far studied from the black shales represents but a single species to which, according to the rule of priority, the name Callixylon Newberryi (Dawson) Elkins et Wieland must be applied, and that whatever differences do occur are within the limits of this one species.

When one is dealing with species, it is customary to emphasize differences rather than similarities. It is indeed true that with but a limited amount of material at hand for study certain differences will be noted. Also, when previous descriptions must be relied upon entirely, as was the case when *C. Oweni* was described, these differences are likely to be overemphasized. If a quantity of material is available for first-hand comparison these apparent differences will seem less conspicuous and what at first seems to be a possible specific character finally shows only as a variation which might distinguish it from another individual, but which is still well within the limits of the species.

It is only to be expected that wood with structure as complicated as that of Callixylon should vary considerably, but if the differences shown are all within the limits of one species, a momentary reflection on the pronounced similarities in all the material is sufficient to force the conclusion that a unified group is represented. Of course there still remains the possibility that we are dealing here with a group of several species which differ mostly with respect to foliar or floral characters, but in that event specific considerations must remain until such structures are discovered.

Before discussing the affinities between *C. Newberryi* and other closely related forms the revised diagnosis will be given.

Callixylon Newberryi (Dawson) Elkins et Wieland

Fossil coniferous wood, Schaeffer, Proc. Am. Assn. Adv. Sci. 1850.
Calamites inornatus, Dawson, Journ. Geol. Soc. London. 1859.
Dadoxylon Newberryi, Dawson, Canada Geol. Surv. 1871.
Cordaites Newberryi, Knowl. Proc. U. S. Nat. Mus. 1889.
Pseudobornia inornatus, White, Geol. Surv. Ohio. 1912.
Callixylon Oweni, E. & W. Am. Journ. Sci. 1914.
Callixylon Newberryi, E. & W. Am. Journ. Sci. 1914.

Arborescent; trunks straight and slender, probably reaching a height of forty feet or more; branches small and straight, caducous; outer decorticated surface ornamented with cross and longitudinal ridges of varying lengths and varying distances apart. Secondary wood gymnospermous, composed entirely of tracheids and rays; tracheids variable in size and shape and from 25 to 75 microns in diameter; wall between the lumina of two adjacent tracheids 10 to 15 microns thick; bordered pits on radial walls in groups of variable sizes, but generally numbering from 6 to 15; opposite terminals of the pit aperture at right angles; tangential pits smaller than radial pits, not grouped, not present in all tracheids; rays variable in height and width, characteristically biseriate wholly or in part, but frequently three- to many-seriate or wholly uniseriate; ray cells clear or wholly or partly filled with black or foamy material, sometimes slightly contracted at the ends; ray tracheids scattered, frequently isolated, sporadic; growth rings present, but not strongly developed; "summer wood" 2 to 4 cells in extent, rings irregularly spaced and sometimes absent over considerable radial extent. Primary wood bundles mesarch, in contact with secondary wood or separated from it by a narrow zone of pith; variable in size; 20 to 30 in the main stem. Pith of main stem 1 to 3 centimeters in diameter, but smaller in lateral branches; imperfectly septate; cells thin-walled and radially elongated when adjacent to primary wood; pith tracheids isolated and scattered.

COMPARISONS WITH OTHER FORMS

The closest relative of *C. Newberryi*, so far as our knowledge of fossil plants permits us to judge, is *Pitys antiqua* Witham. This species from the lower Carboniferous rocks of Scotland (Scott, 1902) has a large imperfectly discoid pith, which is sometimes as much as two inches in diameter. Around the periphery, and for the most part imbedded in it, are numerous mesarch primary xylem strands (text Fig. 6), sometimes forty or fifty (text Fig. 7). The secondary wood has the Dadoxylon structure, with two or more rows of hexagonal bordered pits on the radial walls of the tracheids. The rays are numerous and large, frequently being as much as 6 cells wide, but uniseriate rays are also common (text Fig. 8).

The two points of similarity between Callixylon and *P. antiqua* which are here emphasized are the broad rays and the imbedded primary xylem strands in the pith. *C. Trifilievi* differs from *P. antiqua* by having narrow rays, but the biseriate rays are char-

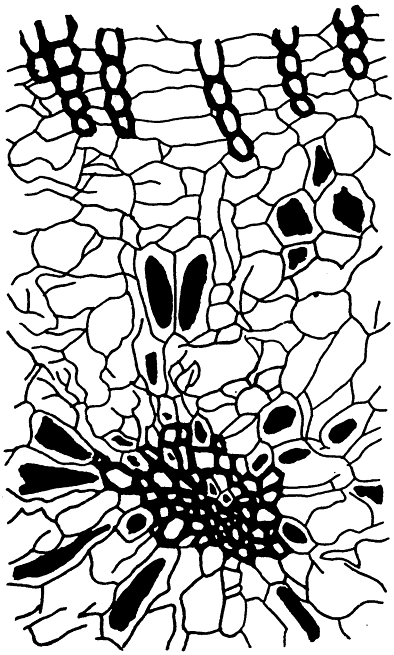

FIG. 6. Primary wood bundle of *Pitys antiqua* Witham, which is very similar to bundle shown in Plate IV, Figure 2. After Scott, 1902. × about 70

acteristic of *C. Newberryi.* Then the homology is further strengthened by the fact that many of the rays of *C. Newberryi* are 3 and 4 cells wide and, rarely, as much as 5 or 6.

In *C. Newberryi* more of the bundles (probably half of them) are in contact with the secondary wood than in *P. antiqua,* but those in the pith of both species so closely resemble each other (text Fig. 6) as to be practically indistinguishable. In this respect *C. Newberryi* resembles *P. antiqua* even more than it does the other known species of Callixylon, although this separation has been observed to exist to a limited extent in *C. Trifilievi.*

Also, in discussions of *C. Trifilievi* considerable stress has usually been placed upon the narrowing of the secondary wood segments

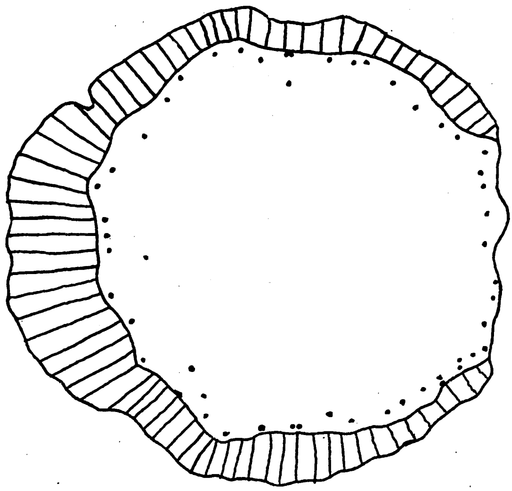

FIG. 7. Diagram of cross-section of pith of *Pitys antiqua* Witham, showing size of pith and arrangement of primary bundles. After Scott, 1902. × 1

into wedges as they approach the pith. This narrowing is not so pronounced in *C. Newberryi* and the inner edge of the secondary wood between the primary bundles presents a fairly straight line, which is intercepted by numerous rays as they join the pith.

Recent investigations of the various species of Pitys show that there are bundles scattered throughout the extent of the pith (Scott, 1923). Such structures are not present in *C. Newberryi,* although their counterparts might be recognized in the isolated pith tracheids previously mentioned.

Considering *C. Newberryi* and *P. antiqua* in all their aspects, they are certainly close relatives, the outstanding difference being the pitting on the radial walls. Were it not for this one feature it seems doubtful whether they could be regarded as belonging to separate genera, and the only other difference which might warrant serious consideration is the fact that in *C. Newberryi* more of the primary bundles are in contact with the secondary wood.

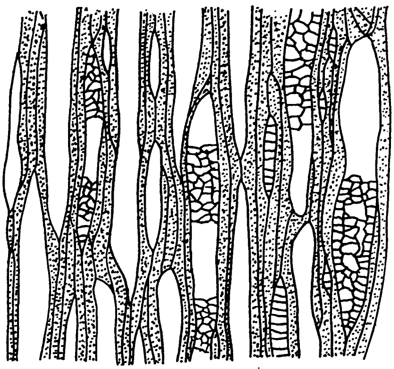

FIG. 8. Tangential section of *Pitys antiqua* Witham, showing broad rays very similar to that shown in Plate V, Figure 3. × about 20

But this feature is so inconstant and variable that it would indicate nothing more than a specific difference.

Of all the known species of Callixylon *C. Newberryi* seems to be the closest to Pitys. All the other species have narrow rays. A possible exception is *C. mentethense* (Arnold, 1929), but this form is imperfectly known and might be the same as *C. Newberryi*. Biseriation is frequent in *C. Zalesskyi* and *C. erianum* (Arnold, 1929), but it is seldom more than partial and then it rarely results in any appreciable widening of the rays in the biseriated portions.

Archeopitys Eastmanii Scott & Jeffrey is quite similar to Pitys. It was originally distinguished from Pitys by the occurrence of bundles throughout the pith, but these have been found in Pitys also and it is possible that these two forms are congeneric. A point of interest in connection with *A. Eastmanii,* however, is that it came from the base of the Waverley shale, which immediately overlies the New Albany black shale in central Kentucky. The two horizons are separated by an unconformity which, should the New Albany shale prove to be of Mississippian age, is not so great as was formerly supposed.

Though the results of the present investigation serve to link Callixylon more closely with the Pityeae, it is likewise to be distinguished more than has been previously recognized from forms representing the true Cordaiteae. The tall, slender, sparsely branched trunks of *C. Newberryi* are quite different from those of Cordaites as we have come to recognize it from the restorations by Grand'Eury (1877). True cordaitean trees, though tall and slender, show more diffuse branching. Also the wood structure, though still not closely resembling that of the Pteridospermae, is farther from Cordaites than was formerly supposed. It would seem, then, in view of the close resemblance between Pitys and Callixylon, along with the enormous development of these forms during pre-coal measure times, that the Pityeae might deserve ordinal rank.

PROBABLE HABIT

The recent identification of impressions such as have commonly been referred to *Calamites inornatus* Dawson (*Pseudobornia inornatus* White) as the branches and smaller trunks of *C. Newberryi* may be instrumental in throwing still further light on the habit of the plant. On one specimen from the Antrim shale at Alpena there are two blunt projections somewhat less than an inch in length (Plate VI, Fig. 1). It is possible that these are the leaves of *C. Newberryi* because of their similarity to the leaves of *Pitys Dayi* Gordon (Scott, 1923), which are described as short, fleshy structures without a true lamina. More material must be examined, however, before their identity can be established. They are situated at the nodes, where leaves would be expected to occur, and have left a thin carbonaceous residue.

As previously mentioned, the largest trunk discovered during the course of the present study was nine feet long. From a width of three feet at the base it narrows to one and one-half feet at the top. In the exhibition hall of the United States National Museum there is a similar trunk from the New Albany shale of Lebanon, Kentucky, which was identified as *C. Newberryi* by its surface features. It is twenty feet high and tapers from about eighteen inches at the base to about four inches at the top. It is perfectly straight, and with the exception of a slight irregularity on one side near the top, there is nothing that could be interpreted as exposed branch bases. Superimposing, now, this specimen from Kentucky upon our specimen from the same horizon in Indiana, we would have a trunk twenty-nine feet high (text Fig. 9). With this as a basis for estimation and assuming that the branch-bearing tip extended the trunk a few feet farther, it is plausible to picture the Indiana trunk as the relic of a tree which once rose to a height of forty feet. Specimens having an even greater diameter are known. A trunk in the Woodford chert of Oklahoma is said to be five feet in diameter at some distance above the base, so that calculations similar to those above would give to this Oklahoma tree a minimum height of sixty feet. The absence of preserved branches on the surface of these trunks, even on the smaller ones, indicates their caducous character. It is possible that these branches were borne near the apex of the straight slender trunks, but failing to remain attached for any length of time they never attained a diameter of more than a few centimeters. Since the branches died and

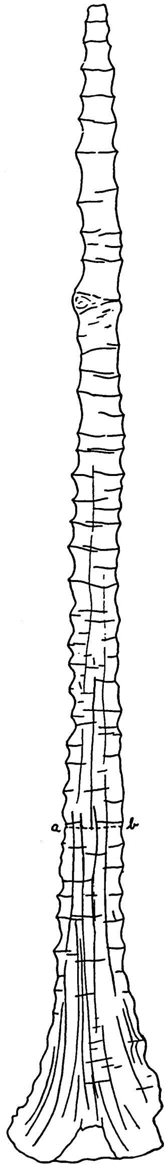

FIG. 9. Partial restoration of trunk of *C. Newberryi.* Lower portion, below dotted line *ab*, from specimen shown in Plate I; upper portion from specimen in the United States National Museum. Total height 29 feet

fell away before the trunk reached any considerable size, their bases are not exposed on the surface of the lower portion of the tree.

CONCLUSION

As stated in the opening pages of this account, the exact age of the black shales that contain the silicified remains of *C. Newberryi* still remains a question. The genus occurs in the Genesee shale, the Genundewa limestone and the lower Portage rocks of central and western New York (Arnold, 1929), in the Upper Devonian of the Donetz Basin of south Russia, and questionable remains of it are known in the Upper Devonian of Germany (Kräusel and Weyland, 1929). Hence Callixylon has so far been treated as a genus of Devonian gymnosperms which existed solely within that period. Since Callixylon has never been reported from any undisputed lower Carboniferous horizon, it can be said that *C. Newberryi*, considering it only in the light of what is already known concerning the distribution of the genus, is indicative of the Devonian age for the black shales. Should *C. mentethense* from the Genundewa limestone be conspecific with *C. Newberryi*, this interpretation would be strengthened.

Though Callixylon may be recognized for the time being as a Devonian genus, it is necessary to admit the possibility of its having extended into early Carboniferous times before it became extinct. At the same time there is considerable negative evidence that it failed to survive very far into Carboniferous times.

Interest in Devonian vegetation has been considerably increased within the past decade through several important discoveries, of which those of the Rhynie chert are probably the most outstanding (Kidston and Lang, 1917–21). Although fossils having the dimensions of trees were previously known from Devonian rocks (White, 1907), the discovery of Eospermatopteris at Gilboa, New York (Goldring, 1924, 1927), shows the size attained by some of these early pre-coal measure plants. Also of significance was the discovery of the Elberfeld flora in Germany (Kräusel and Weyland, 1929), which has been instrumental in connecting the early

Devonian flora with that of later Devonian times in such a way as to show that the two floras meet and overlap instead of being separate, as was formerly supposed (Scott, 1926).

There is a recent account of fossil trees in the Elkins and the Valleyhead sandstones (of Chemung age) in the Tygart Valley of West Virginia (Reger, 1928), to which the present author feels strongly inclined to take exception. A recent examination (which of necessity was brief) of these specimens, together with the original description of them, leaves one strongly of the opinion that there is insufficient evidence for the interpretation of these structures as trees and that they must be accounted for in some other way. Though these early times are famous for their bizarre forms of vegetation, it is at the same time unwise to postulate such structures as are present in the Elkins sandstone as trees, when so many essential diagnostic features are obscure or entirely lacking.

Should the Mississippian age of the black shales become finally established, the contained plant fossils would lose none of their evolutionary significance. The fact that these plants are congeneric with plants from Upper Devonian horizons in other localities, and their close affinity with Pitys and Archeopitys from the lower Carboniferous of both this and other countries, shows a continuity of the family which commences low down in the Upper Devonian and extends well up into the Carboniferous period.

These recent studies of Callixylon have served to emphasize two points which, it is believed, are significant. The first is the wide distribution of the genus. As it is at present known in the United States, it extends from 35 degrees north latitude in Oklahoma to about 46 degrees at Alpena, Michigan. In Europe, it extends to approximately 50 degrees in Russia. Whether these are its extreme north and south limits is doubtful. The second point is the great abundance of Callixylon remains and the relative scarcity of other forms of vegetation in the Callixylon-bearing horizons. The almost complete dominance of this genus in the New Albany, the Ohio and the Antrim shales is a remarkable fact and the same thing is true of the Genesee and Portage formations of New York. These facts, then, indicate the past occurrence of great and widespread forests of Callixylon during pre-coal measure times which, though probably lacking in such diversity of forms as constituted the coal measure forests, were fully as large and as widespread.

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PLATE I

Callixylon Newberryi (Daws.) E. & W. Trunk on exhibition in the University Museums, University of Michigan. From New Albany shale, Scott County, Indiana. Height 9 feet

PLATE II

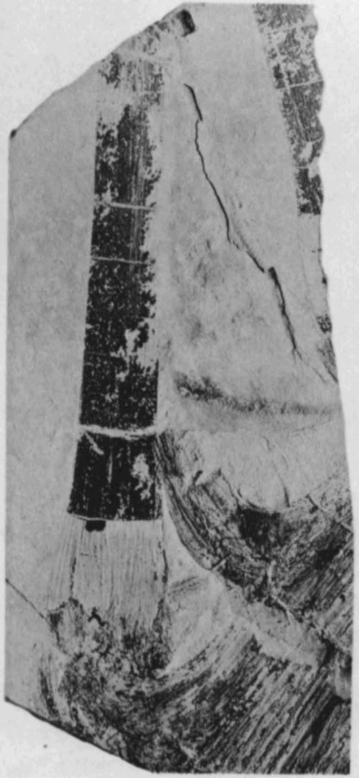


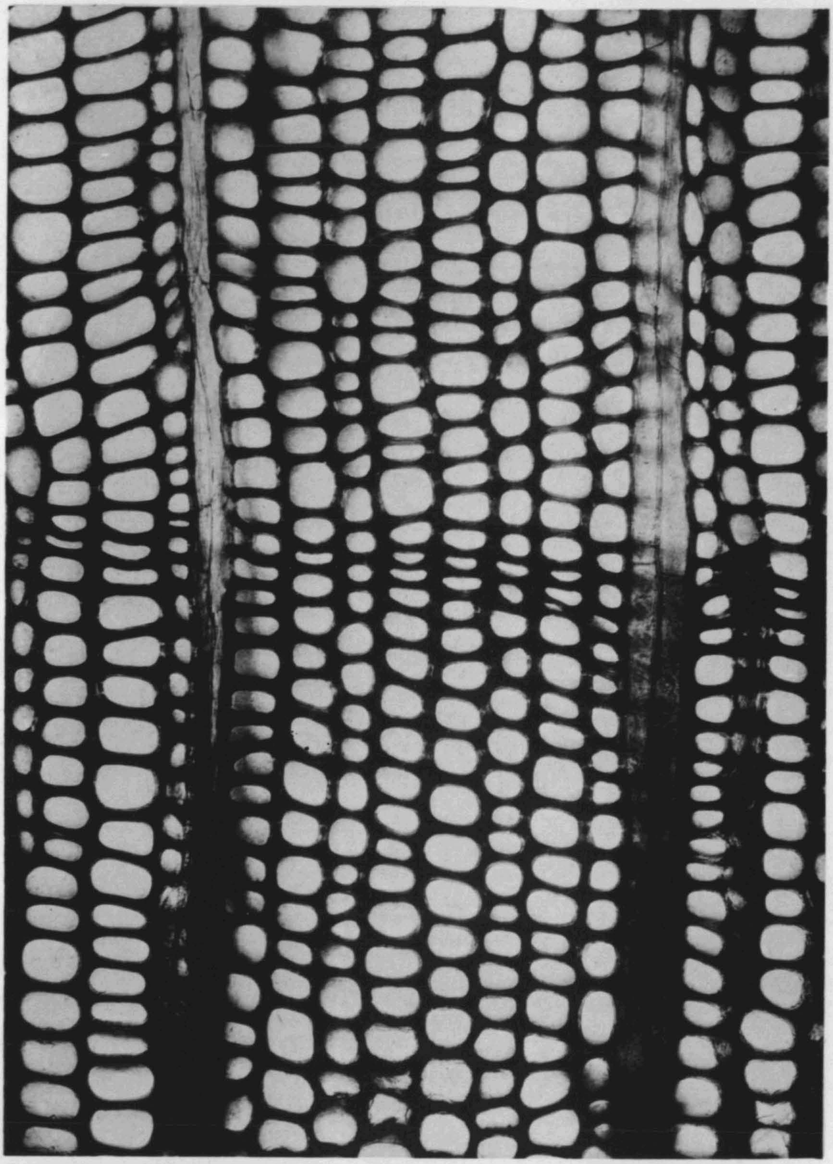
FIG. 1. Impression of branch. × $\frac{1}{3}$

FIG. 2. Impression of branch or small trunk bearing smaller lateral branches. × $\frac{1}{2}$

FIG. 3. Impression of branch or small trunk showing nodal lines and imprint of branch. × $\frac{1}{2}$

Callixylon Newberryi (Daws.) E. & W. Antrim shale, Alpena, Michigan

PLATE III



Callixylon Newberryi (Daws.) E. & W. Transverse section through portion of trunk shown in Plate I. It shows the narrow "summer wood" zone and the very fine state of preservation. × 165

PLATE IV

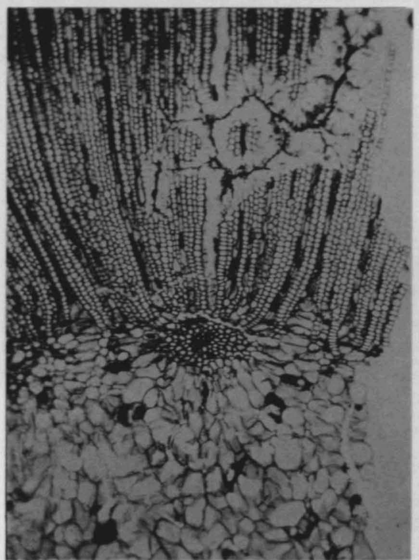


FIG. 1. *Callixylon Newberryi* (Daws.) E. & W. Primary wood bundle of small branch in contact with the secondary wood. New Albany shale, Clark County, Indiana. × 26

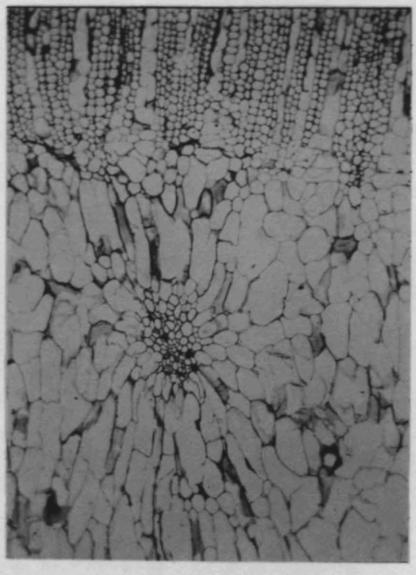


FIG. 2 *C. Newberryi* (Daws.) E. & W. Primary wood bundle of main trunk completely surrounded by pith tissue. From same specimen as Figure 1. × 26

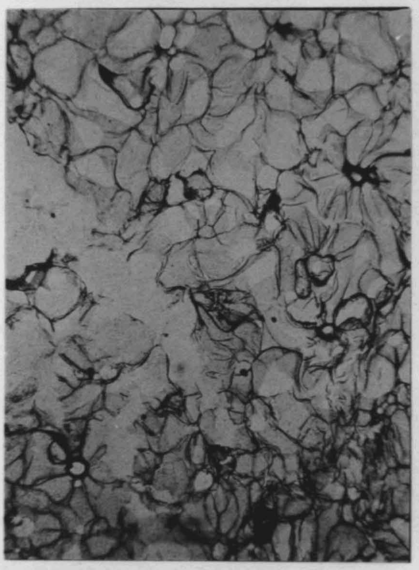


FIG. 3. *C. Newberryi* (Daws.) E. & W. Portion of lateral branch showing pith tracheids. From same specimen as Figure 1. × 37

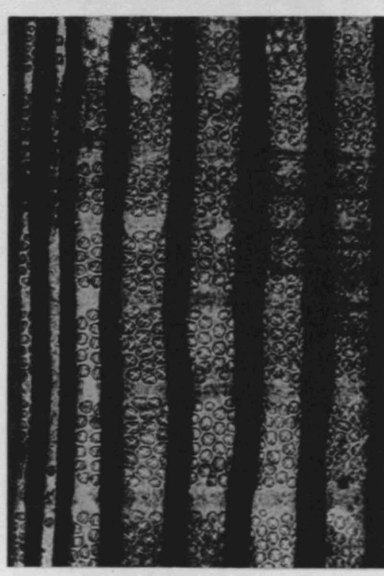


FIG. 4. *C. Newberryi* (Daws.) E. & W. Radial section, showing alignment of pit groups and crossed pit apertures. Chattanooga shale, Mill Springs, Kentucky. × 185

PLATE V

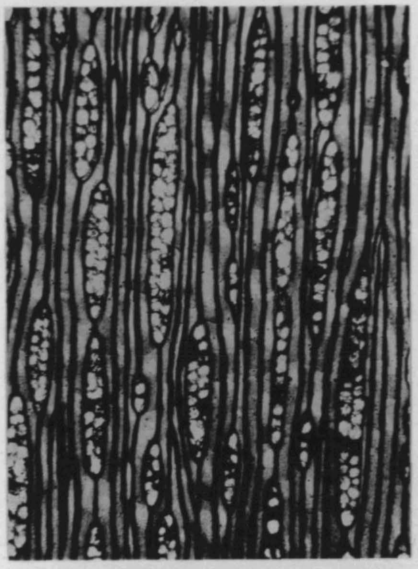


FIG. 1. *Callixylon Newberryi* (Daws.) E. & W. Tangential section showing biseriation of rays. New Albany shale, Scott County, Indiana. × 48

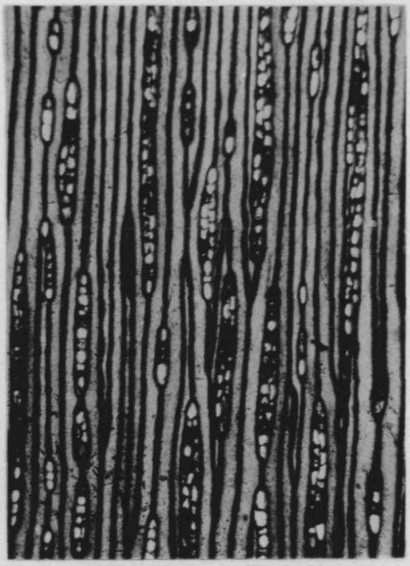


FIG. 2. *C. Newberryi* (Daws.) E. & W. Tangential section showing slight narrowing of rays due to flattening of trunk during fossilization. New Albany shale, Indiana. × 48

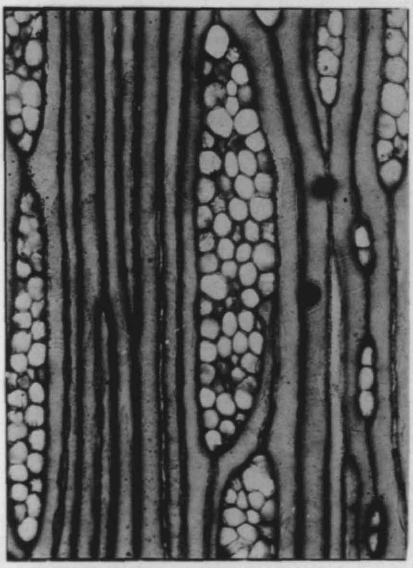


FIG. 3. *C. Newberryi* (Daws.) E. & W. Tangential section showing broad ray similar to those of *Pitys antiqua*. From same specimen as Figure 1. × 67

FIG. 4. *C. Newberryi* (Daws.) E. & W. Fungous hyphae in tracheids. New Albany shale, Clark County, Indiana. × 170

PLATE VI

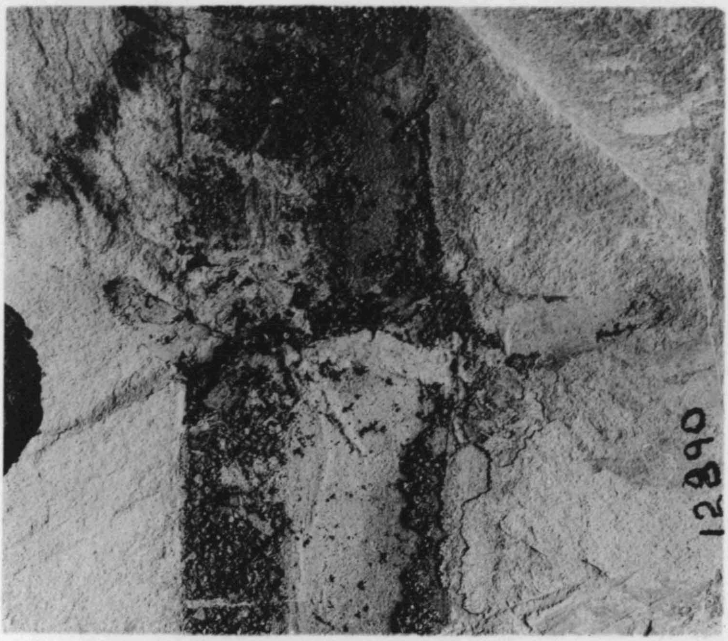


FIG. 1. *Callixylon Newberryi* (Daws.) E. & W. Impression of branch bearing two structures, probably leaves. Antrim shale, Alpena, Michigan. × 1

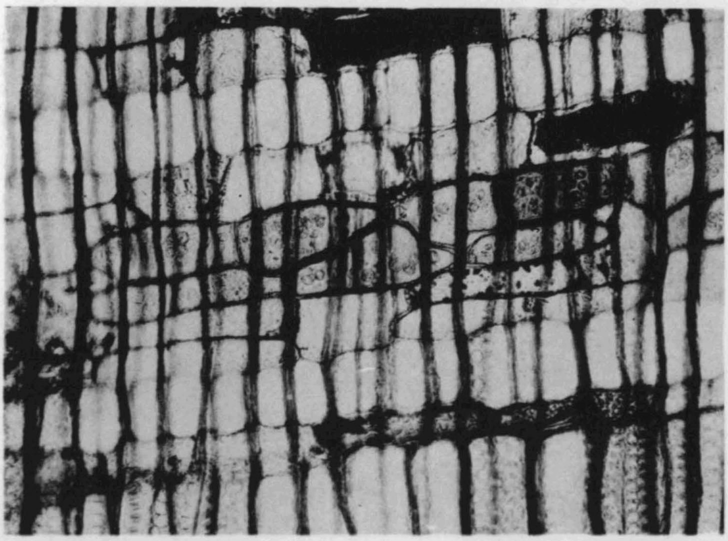


FIG. 2. *C. Newberryi* (Daws.) E. & W. Radial section showing ray tracheids with bordered pits. New Albany shale, Clark County, Indiana. × 150

PLATE VII

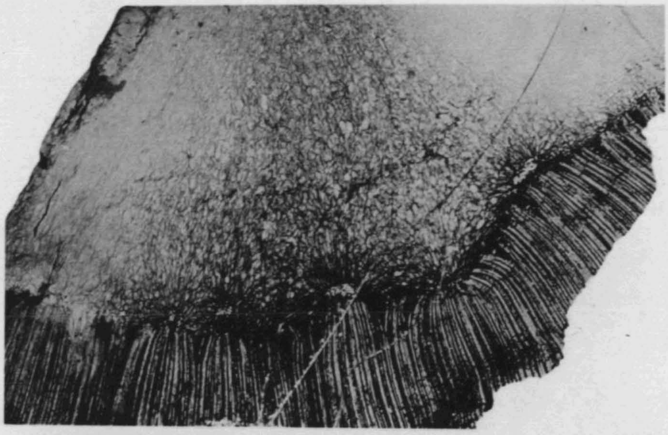


Fig. 1. *Callixylon Newberryi* (Daws.) E. & W. Sector of central portion of main trunk showing large pith, disposition of primary bundles, and inner portion of secondary wood. New Albany shale, Clark County, Indiana. × 4

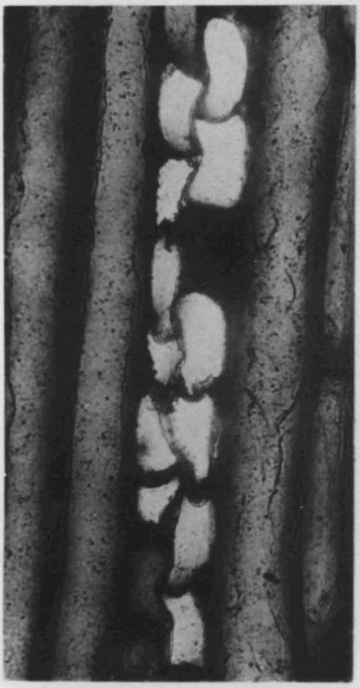


Fig. 2. *C. Newberryi* (Daws.) E. & W. Tangential section showing buckling of ray-cell walls due to compression of wood during fossilization. New Albany shale, Scott County, Indiana. × 360

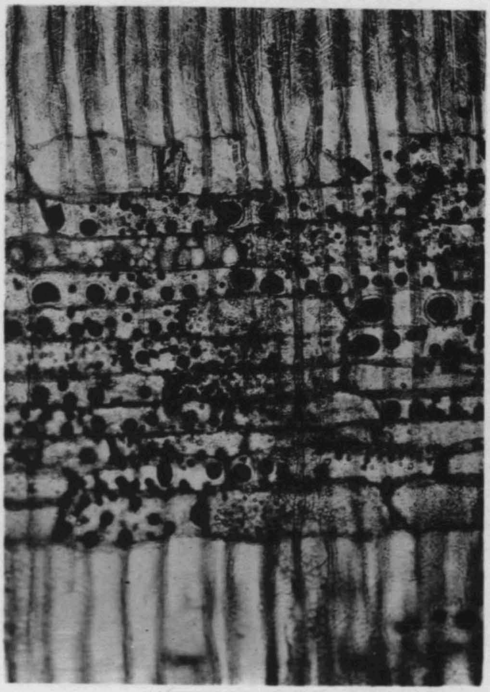


Fig. 3. *C. Newberryi* (Daws.) E. & W. Radial section showing globular objects in ray cells. New Albany shale, Clark County, Indiana. × 105

(Continued from inside of front cover)