Memoirs of the Boston Society of Natural History.
VOLUME 6, NUMBER 2.

THE COMPARATIVE ANATOMY AND PHYLOGENY OF THE CONIFERALES.
PART 3.—MESOZOIC AND TERTIARY CONIFEROUS WOODS.

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WITH EIGHT PLATES.

BOSTON:
PRINTED FOR THE SOCIETY WITH AID FROM
THE GURDON SALTONSTALL FUND.
APRIL, 1923.

INTRODUCTORY AND HISTORICAL.

Fossil plants have always been a source of wonder and speculation. Widely dispersed over the earth, naturally exposed in sea-cliff and stream cutting, they early formed the basis of many strange legends some of which we find embodied in the writings of such mystical philosophers as Albertus Magnus. Like all the other natural sciences, palaeobotany passed through its encyclopaedic and systematic periods. The earlier work was necessarily concerned with impressions and other superficial structures only; there was slight basis of agreement among workers; and the early literature, though voluminous, offers little but tangled synonymy to the modern student. Extensive bibliographies have been given by Göppert (1850), Ward (1885), and Knowlton (1889).

With the introduction of the microscope a new subscience of fossil plants began to develop; namely, that of structural palaeobotany. It is a very young science, for little more than a century has elapsed since Parkinson (1820) worked out the structure of a *Psaronius* stem.

English palaeobotany, however, honors Henry Witham (1831) as its real founder. In his "Observations on Fossil Vegetables" he establishes several form-genera of fossil woods based on histological features, and although later studies have shown that Witham's genera were too broad and represented complexes of woods, yet he had initiated a science whose development in the hands of English workers is one of the great achievements of modern science. True, it does not startle the layman like radium and wireless telegraphy since an appreciation of its story demands considerable training; but we are justified in saying that it probably supplies the best proof we have of the doctrine of evolution, and that it makes of plant morphology a subject of intense and living interest.

The development of continental structural palaeobotany dates from 1841, when Göppert began his studies on the conifers. He saw clearly that for a basis of comparison he must know living species intimately and so his works dealt with both living and fossil forms. His system of classification recognized the fundamental distinction between the araucarian type of wood with its "Hoftüpfel quincuncial gestellt, meist infolge gedrängter Stellung gegenseitig abgeplattet," and the pinean type with "Hoftüpfel nicht gedrängt, und wenn mehrreihig meist gleich hochstehend." His finer separation of the pinean woods was based on the presence or absence of wood parenchyma and of resin canals.

Following in Göppert's steps came Gregor Kraus, whose work appeared in 1864, and was followed later by a classification of coniferous woods contributed to Schimper's "Traité de paléontologie végétale" (1870–72). This is an important landmark and is probably the most significant classification anterior to that of Gothan's which is subsequently to be discussed. It established several well-recognized genera and its importance justifies its quotation.

The System of Kraus.

A. Cellulae prosenchymatosae aporae . . . . *Aporoxylon* (Unger).
B. Cellulae prosenchymatosae porosae.
  1. Pori uniseriales distantes vel oppositi.
    a. Cellulae prosenchymatosae sine spiralibus.
      aa. Cellulis parenchymatosis (*viz.* wood-parenchyma) resiniferis nullis.
        (*a*) Radii medullaris cellulae in sectione transversa rotundae . . . . . . *Physematopitys* Göppert.
        (*b*) Oblongae . . . . { *Cedroxylon* Kraus. *Pinites* Göppert; *Peuce* Unger.
      bb. Cellulis parenchymatosis (resiniferis) creberrimis . . . . *Cupressoxylon* Kraus. *Cupressinoxylon* Göppert. *Thujoxylon* Unger.
      cc. Crebis ductibusque resiniferis . . . . *Pityoxylon* Kraus. *Pinites* Göppert; *Peuce* Unger.
    b. Cellulae prosenchymatosae poroso-spiralis.
      aa. Radiis medullaribus porosis . . . . *Taxoxylon* Unger. *Taxites* Göppert.
      bb. Radiis medullaribus poroso-spiralibus.
        Spiropitys Göppert [probably a *Pityoxylon* and the spirals do not belong to the rays].
  2. Pori uniseriales contigui vel spiraliter dispositi pluriseriales.
    a. Pori rotundae vel contiguitate polygoni.
      aa. Radiis medullaribus simplicibus (uniserialibus) . . . . *Araucar*(*i*)*oxylon* Kraus. *Araucarites* Göppert. *Dadoxylon* Endlicher.
      bb. Radiis medullaribus compositis . . . . *Pissadendron* Endlicher. *Palaeoxylon* Brongniart (probably Cycads or Cycado-filicales).
    b. Pori compressi oblongi . . . . *Protopitys* Göppert.

The system is not faultless. Thus the genus *Aporoxylon,* which really signifies without bordered pits on the tracheids, would certainly be a startling type of wood if it really existed. The genus was founded on a specimen whose pits had been obliterated through faulty petrifaction. "Aporoxylon" is unfortunately a very common wood and always comes to rest in the waste-basket. *Physematopitys,* founded on the rounded and swollen ray-cells, has not stood the test of later studies. *Spiropitys* and *Pissadendron,* too, have proved to be unsound.

Following Kraus's system we have the classification of Schenck which is to be found in Zittel's "Handbuch der Paleontologie."

The System of Gothan.

The latest important addition to the classification and taxonomy of gymnospermous woods is the system of Gothan (1905). His particular contribution has been to point out the value of ray-cells as diagnostic of several new genera. We are inclined to think that some of Gothan's genera "auf ganz zu schwachen Unterscheidungs-Kennzeichnen beruhen," even as he remarked concerning questionable genera of other workers in the field. Every enthusiastic student tends to apply a helpful principle too widely, and doubtless the same criticism will be made of the classification contributed later.

Gothan's key with some modifications has been the basis of the anatomical studies of this paper. His article is difficult of access and his system is here quoted entire.

A. Hoftüpfel klein, alternierend, oben und unten abgeplattet, wenn mehrreihig, allseits (polygonal) abgeplattet. . . . . *Dadoxylon* Endlicher; *Araucarioxylon* Kraus; *Cordaioxylon* Felix; *Cordaixylon* Gr. 'Eury; *Araucarites* Göppert; *Cordaites* (div. auct.)

B. Hoftüpfel rundlich, grosser, nicht gedrängt; wenn mehrreihig meist gleichhochstehend.

1. Alle Tracheiden mit starker Spiralverdickung. . . . . *Taxoxylon* Unger; *Taxites* Göppert.

2. Tracheiden ohne diese (nur bei einigen Harzgänge führenden Abietineen solche, aber schwächer).

a. Abietineentüpfelung vorhanden, nur bei den grosseiporigen *Pinus*-Arten fehlend; Harzparenchym bei einigen im Spätholz, sonst fehlend.

(1) Harzgänge, horizontale und verticale, regelmässig vorhanden.

(a) Harzgängepithel dickwandig, verholzt; Markstrahltüpfel nicht eiporig; Spiralverdickung im Spätholz (selten auch im Frühholz); zahlreiche Tangentialtüpfel im Spätholz. Quertracheiden vorhanden, ohne Zacken. Abietineentüpfelung sehr deutlich.
Piceoxylon Gothan;
Pityoxylon Kraus;
Pinites Göppert.

(b) Harzgängepithel dünnwandig, nur selten etwas dickwandig; Markstrahltüpfel (Frühholz) stets eiporig. Spiralverdickung im Spätholz stets fehlend, ebenso Harzparenchym. Quertracheiden mit oder ohne Zacken. Abietineentüpfelung bei den grosseiporigen fehlend bezw. reduciert. . . . . *Pinuxylon* Gothan;
Pityoxylon Kraus;
Pinites Göppert.

(2) Harzgänge fehlend, Tangentialtüpfel im Spätholz häufig. Holzparenchym bei einigen ständig am Ende des Jahresrings, bei diesen Quertracheiden vorkommend.

b. Abietineentüpfelung fehlend, Holzparenchym ± regelmässig vorhanden.

(1) Markstrahltüpfel cupressoid (Frühholz!)

(a) *Juniperus*-Tüpfelung vorhanden. . . . . *Cupressinoxylon* Göppert.

(b) Diese fehlend.

(1a) Markstrahltüpfel glyptostroboid; gedrängt. . . . . *Glyptostroboxylon* Conwenz.

(1b) Markstrahltüpfel ein Mittelding zwischen beiden (nur in ausgewachsenem älterem Holz typisch); gedrängt in ± grosser Anzahl auf dem Felde (oft mehr als 6).

(2) Markstrahltüpfel podocarpoid bis typisch grosseiporig (Rest der Taxaceen). Meist nur 1-2 Tüpfel pro Kreuzungsfeld. Harzparenchym ± haufig.

(a) Markstrahltüpfel podocarpoid bis teilweise eiporig. . . . . *Podocarpoxylon* Gothan.

(b) Markstrahltüpfel typisch eiporig. . . . . *Phyllocladoxylon* Gothan.

In publications subsequent to the above, Gothan has set up several new genera such as *Anomaloxylon*, *Protocedroxylon*, *Protopiceoxylon* and *Thylloxylon*. Diagnoses of these are given later.

Among French contributions to coniferous xylopalaeontology should be mentioned the works of Lignier (1907). He conservatively recognizes but five types of wood: *Araucarioxylon*, *Cedroxylon*, *Pityoxylon*, *Cupressinoxylon*, and *Taxoxylon*. Lignier has, however, adopted a very questionable recommendation of Conwenz and of Felix (1882) and by use of the prefixes *Cormo*-, *Rhizo*-, and *Clado*-, attempts to differentiate between stem, root, and twig wood.

The Anomalous Development of Structural Palaeobotany.

A few words may now be said concerning the rather anomalous development of palaeobotany and the relation of the American studies to those of European workers. The development is called anomalous since, paradoxical as it may seem, we really know more about Palaeozoic plants than we do about those of the Mesozoic and early Tertiary.

From the exquisitely silicified and calcified remains of the Carboniferous vegetation we can study the histological details even to such minutiae as divisions of the apical meristems and the organization of spore tetrads in the sporocytes. But as we ascend through the rock strata into the Mesozoic all this changes. Just when a significant modernization was taking place, the remains are so scantily and so poorly preserved that they give us little more than tantalizing glimpses. The volume in which the Mesozoic history of the earth was written has fared miserably: fire and water and rough handling have destroyed the records. After all these years Darwin's "abominable mystery" of the origin of the Angiosperms remains as an irritating thorn in the botanical flesh.

One cannot resist drawing a parallel with human history. Thus, Egypt offers us a fossil record through which we enter with startling intimacy into the life of her people. The civilizations of Greece and Rome, too, are well known. But as we enter the Middle Ages—the Mesozoic and Tertiary of human history—the records become obscure and confusing. The geological and human Mesozoics were alike periods of storm and stress.

The Development of the American School of Palaeobotany.

Early Work.

In America, except in rare cases, we lack the Palaeozoic structural material so abundant in the Old World. We do, however, possess a considerable wealth of Mesozoic remains, and as a consequence American students have set themselves to the difficult task of unraveling the tangled Mesozoic record. Most of our material is in the lignitic state and progress was necessarily delayed for a long time waiting for the development of a technique to cope with such refractory stuff.

To Sir J. W. Dawson (1854) belongs the honor of first investigations on American fossil woods. The specimens which he studied were silicified trunks from Prince Edward Island, and were mostly members of the extinct gymnospermous order *Cordaitales*. For such woods we use the name *Dadoxylon*.

Dr. F. H. Knowlton (1889) continued Dawson's investigations and described many species from petrifactions. He also attempted lignitic woods but histological technique was scarcely advanced enough at the time to make the preparations particularly satisfactory.

It is to work of students at Harvard University that we owe the recent impetus to the study of fossil woods. The success attending these investigations has been intimately related to progressive perfection of the nitro-cellulose method which enables one to soften the brittle and friable lignitic specimens and to imbed them in a homogeneous matrix for sectioning. Sections so prepared are far superior to anything yielded by petrifactions. Practically the only modifications which such woods have undergone is change in color and distortion due to pressure. Histological details, such as tracheid and ray markings, are as well preserved as in living woods.

The secret of the finest sections lies in two words: charred wood. Unmodified woody lignite is often hardly worth sectioning; its tracheids are commonly collapsed or their lumina are blocked with gummy substances; the rays are crushed and their diagnostic features obliterated.

In almost every lignite bed, however, one finds flattened trunks and branches which are covered with a charcoal film. These attest the prevalence of forest fires in the ancient days and are the specimens which repay study. The charcoal itself is not the valuable part. This should be sought in the boundary zone between charred and uncharred wood, where the modified tracheidal walls, because of their slight scorching, were rendered incapable of hydrolysis and consequently have not been swollen and crushed.

A brief historical review of the work at Harvard is now in order.

In three comprehensive papers on living conifers, Jeffrey (1903, 1905, 1912) laid a foundation for his investigations upon fossil forms even as Göppert had done in 1841. But the modern student was approaching his problem in a new way. Darwin had intervened, and research was now directed to the discovery of features which might throw light upon the phylogeny of the conifers. Certain general working principles of comparative anatomy were formulated and their application led to conclusions regarding the history of the groups of conifers that were somewhat at variance with conventional views. Arising almost as a necessity from the richness of the fossil material various new form-genera were from time to time proposed by Jeffrey or by those working with him. Thus we have *Brachyoxylon* for the wood of the well-known Cretaceous conifer *Brachyphyllum*, *Araucariopitys* for a wood with a blend of araucarian and pine characters, while the prefix "*Para*" has been used by several students for araucarian woods which superficially resemble members of the Abieteae. Thus we have *Paracedroxylon* Sinnott, *Paracupressinoxylon* Holden.

Geological and Geographical Distribution of the Lignites of the United States.

In the spring of 1917, the funds available from a Sheldon Traveling Fellowship from Harvard University made possible the extension of these investigations on the lignitic woods of the United States. Up to this time nearly all the material studied had come from the easily accessible Cretaceous deposits of the Atlantic Coastal Plain. Hence a chance to compare the fossil coniferous flora of the western United States with that of the East, to search for new and annectant forms, and to gather information concerning the ancient geographical distribution of the conifers was eagerly accepted.

The lignites of the United States present a combination of geological, botanical and economic problems. With the first two aspects we now propose to deal. Reference will be made from time to time to literature which deals with the third aspect, though this does not particularly concern us.

Definition and Description of Lignite.

The term *lignite* has been well defined by Dumble (1892). He says: "Under this name are included portions of wood—trunk, stem, leaf, or root—more or less fossilized and altered into brown coal; yellow to dark brown in color and with a fracture varying according to the character of the wood from which they were derived. It is not infrequently the case that there can be found in a single piece, woody structure and particles altered into earthy, pitch or glance coal. Lignites occur in single trunks or particles scattered through the sands, and as logs imbedded in deposits of brown coal of different varieties. Much of it, as it comes from the mine, retains its form and character so completely as to be almost indistinguishable from the ordinary wood of the present time, except that it is somewhat darker in color. It is frequently the case that such a log will be partly lignite and the remainder silicified wood. Lignite is formed principally of coniferous woods, less often of endogenous woods, peat and water plants.

"The trunks of trees which are altered into lignite are seldom found standing at the locality at which they grew; and if they are, it is in a broken condition. They are more often found in horizontal positions, generally flattened, so that their breadth is to their height as 1:3 to 1:15."

Many of the flattened trunks, as before stated, show clearly the marks of fire; they are encrusted with charcoal which often manifests the cubical fissuring so characteristic of the surface of charred boards.

Another striking feature of many lignites and one quite contrary in value to the last, is the prevalent inclusion of iron-pyrites. This seems particularly characteristic of the charred specimens; it fills the tracheids with slender glistening wires; it crystallizes out in its familiar pyritohedrons in resin canals and wound cavities; its rhaphide-like crystal-aggregates spot the naturally cleaved surfaces. It destroys the edge of the microtome knife and tries the temper of the investigator, since it cannot be removed without destructive action on the tissues.

Economic and Geological History of Lignite Beds.

The lignites of the United States are largely confined to the Comanchean, Cretaceous and Eocene periods. The economic deposits lie almost wholly in the two last. This does not mean that specimens of great scientific importance will be found only between these horizons, for from the Triassic deposits of Texas I have collected interesting remains, and have studied wood from the Carboniferous which was in the lignitic state and so well preserved as to permit of easy identification. But these specimens from pre-Cretaceous strata occur in isolated fragments associated with clay or sand and can be of slight importance except to the palaeobotanist.

The earliest report of lignites in the western United States is probably that of Lewis and Clark in 1804, but outside sporadic references no detailed study was undertaken until 1869, when Dr. F. V. Hayden (1869) began his survey of the Western Territories. From 1869 to 1878, Drs. Hayden, Meek, Lesquereux, and others associated with the U. S. Geological Survey published extensively on the geology and palaeontology of this region which is almost uniformly underlain by immense beds of lignite. For many years there was a heated discussion concerning the geological age of these deposits; palaeobotanical and palaeozoölogical evidence was contradictory. The testimony of the former pointed to the Eocene age of the strata (Heer even identified certain of the plant remains as Miocene), while the latter affirmed a Cretaceous age for them. The discussion has been reconciled by a decision favorable to both parties, for modern geologists agree that these debatable strata were laid down in a time of transition from Cretaceous to Eocene. Cretaceous reptiles still held sway, but the forests through which they wandered bore a Tertiary facies.

A list of the more important papers dealing with this vexed question, now happily settled, will be found in Hayden's Sixth Annual Report; and the reports themselves should be consulted for the extensive and detailed observations on stratigraphy, mineralogy, petrology, palaeontology, etc., of the region.

The great economic importance of the minerals contained in these rocks quickly absorbed the attention of geologists to the complete exclusion of more philosophical problems, and thenceforth the publications of the Geological Survey have been primarily economic.

The value of the lignite to dwellers in a region where fuel was scarce, was soon recognized, and development started on an extensive scale. Many new areas were prospected for coal and much money was expended in attempts to work coal-beds whose thin seams make profitable mining prohibitive. The Dakota Formation is a case in point. It is very doubtful if there are any paying coal seams in this formation. The same vain attempts have also been made to find paying lignite seams in the Triassic and Cretaceous strata of the eastern United States where small quantities of lignitized remains occur. Two areas only have maintained their supremacy as productive regions: the Great Interior Region—a vast expanse running from the 26th to the 55th parallel of north latitude, and from near the 103d to the 115th meridian; and the Pacific Coastal Area with mines confined almost wholly to California.

In the following analysis the lignites of the United States will be considered according to their geographical areal distribution, their chronological correlation, and their specific characteristics. All the data on Cretaceous correlations have been drawn from White (1891) who divides the United States into seven great areas where Cretaceous strata are exposed. These areas coincide fairly well with the lignite deposits and from five of them I have collected lignites. The Pacific Border has also yielded its quota but from rocks of a later age. White's divisions of the American Cretaceous are as follows:

1. Atlantic Border Region.
2. Gulf Border Region.
3. Texan Region.
4. North Mexican Region.
5. South Interior Region. } The Great Interior Region.
6. North Interior Region. }
7. Pacific Border Region.

The Atlantic Border Region and its Woody Remains.

From this region came the lignitic remains which formed the foundational studies of the work at Harvard.

Referring to White's tables, the Cretaceous strata offer the following type-section:

TERTIARY		Eocene and later deposits.
	Marine Division	New Jersey Marl Beds New Jersey Clay Marls and their equivalents
	Non-marine Division	Raritan and Amboy Clays (hiatus in the South) Potomac Formation (hiatus)
CRETACEOUS AND COMANCHEAN		Older rocks: Triassic, Cambrian and Archean.

As the table shows, these Cretaceous (including Comanchean) deposits rest unconformably on the eroded earlier rocks. From the Potomac and Raritan beds have come the lignites. At the classic hunting-ground, Cliffwood, New Jersey, the Raritan and Amboy clays are worked for brick-making. They are also exposed in a sea-cliff not far from the town. In the spring of 1917, the Avery Brick Company struck a basal pavement of woody lignite in one of their clay-pits. It was a heterogeneous mass of crushed stems and branches, much of which showed marks of fire. From it we secured a quantity of structural material. This later proved to be mostly fragments of the wood *Brachyoxylon* Jeffrey, with some admixture of *Paracupressinoxylon* Holden and *Pityoxylon* Kraus. In the sea-cliffs other material of similar affinities was found, along with many pyritized cones of "*Sequoia*" (*Geinitzia*) *gracillima*. But there was no trace of *Sequoia* wood, and as Jeffrey has shown, these so-called sequoias are in reality araucarians with wood of the *Brachyphyllum* Brongniart type, *viz.*, *Brachyoxylon*. The woods will be considered in more detail later.

The Gulf Border Region.

In this area are included portions of the States of Georgia, Alabama, Mississippi, Louisiana, Tennessee, Kentucky and the whole of Florida. The following table not only shows the divisions of the strata, but correlates them with those of the Atlantic Coastal Plain.

	Atlantic Border Region	*Gulf Border Region*
TERTIARY	Eocene and later beds	Eocene and later beds
	(hiatus)	(hiatus)
CRETACEOUS	New Jersey Marl Beds	Ripley Formation
	Clay Marls	Rotten Limestone
	Raritan and Amboy Clays	Tombigbee Sands
	(hiatus)	(hiatus)
COMANCHEAN	Potomac Formation	Eutaw and Tuscaloosa Formations

The lignitic woods in the Gulf Formations are little known. Abnormally cold weather and snow made collecting almost impossible in the winter of 1917 when I reached this region, and what few fragments I found were from Tertiary deposits and of little interest. Comanchean and even Triassic lignites are known to occur in this area and later search should yield many specimens of interest.

The Texan Region.

This region has yielded some remarkable woods of widely diverse ages, for within the State of Texas there are structural lignites ranging in age from Triassic to Eocene.

The following table shows the sequence of deposits:

Tertiary (Eocene)	Fayette Division Yegua Division Timber Belt Division Basal Clays
Cretaceous, Upper or Black Prairie	Glauconitic Ponderosa Marls Austin Chalk Eagle Ford Shales Lower Cross Timber Sands (or Timber Creek)
Comanchean	Washita Fredericksburg Trinity or Bosque
Triassic	Dockum

The Triassic Lignite of Texas.—As has been stated, the Triassic strata of Texas contain lignitic woods. The first indication which came to hand of this fact was derived from a paper by Dr. Cummins (1890) in which he writes: "A few miles before reaching Dockum, situated in the western edge of Dickens County, [Dockum, by the way, is now non-existent except in name] I came upon a bed of conglomerate sandstone and red clay resting unconformably upon the clays and sandstones of the Upper Permian entirely unlike anything I have heretofore seen in Texas. This formation lies along the foot of the Staked Plains in a narrow belt. Because of its extensive occurrence in the vicinity of Dockum, I gave the formation the name of Dockum Beds. . . . In the conglomerate are many silicified trunks of trees."

Drake (1892) refers to these same beds again, and mentions the names of several geologists who had encountered a similar formation in equivalent stratigraphic position farther west. He then goes on to state: "A few miles west of the mouth of Blanco Cañon I found some pieces of trees that had been changed into lignite and imbedded in the sandstone of the conglomerate. The impression among people who have seen these trees was that they were probably the outliers of a bed of coal, but such is not the case. There is no probability that anything more than a few isolated pieces of lignite will be found there, and that, too, of very poor quality."

It was this almost parenthetic note which led me to the town of Spur in Dickens County, Texas, the nearest railway center to the region described by Dr. Cummins. Here I found a general vague knowledge among the residents of "coal" deposits in their neighborhood, but all assured me that it was not of any value. Our judgments of value, however, would scarcely coincide. The first definite information which came to hand was from Mr. C. B. Jones, manager of the Spur Farm Lands. The owners of these lands have made a detailed geological survey of their extensive holdings, and among other things, desirous of knowing what lay beneath, they sunk a boring to a depth of nearly one mile. This is the justly famous "deep boring at Spur" which actually traverses Tertiary, Triassic and Permian deposits and penetrates the Carboniferous strata for nearly four hundred feet. Mr. Jones placed in my hands certain unpublished data which Dr. W. O. Crosby assembled in 1916 and from them the following extract is taken.

We may note the position of the Dockum Beds in their relation to under- and overlying strata. This detail came from the deep boring.

5	Tertiary (Miocene)	200 feet
4	Triassic (Dockum)	300 "
3	Permian (Red Beds)	2000 "
2	Permian Dolomite	2850 "
1	Carboniferous (Cisco)	389 "

"The Dockum Beds," says Crosby, "consist of sandy clay and shale overlain by harder sandstone and conglomerate, the total thickness being from 200 to 300 feet.

"At many points in the coarse Triassic sandstone and conglomerate scattered masses of lignite, in the form of isolated fragments of trees, may be observed, but never anything like a regular or continuous bed of lignite and nothing at all approaching a workable deposit."

Through the kindness of Mr. Jones I was enabled to visit one of the localities mentioned by Crosby, and there obtained a quantity of structural material which as will be subsequently shown is very probably the wood of *Voltzia*. It lay in the banks of a small stream embedded in sandy clay, and associated to some extent with petrified and semi-petrified wood.

The Comanchean Lignites of Texas.—Referring once more to the Texas time-scale on page 49, it will be seen that the Triassic (with the exception of western Texas just considered) is typically overlain by Comanchean strata. The basal division of the Comanchean is the Trinity or Bosque, which in its turn consists of three beds: the Basement Sands beneath, the Glen Rose Beds overlying them, and the Paluxy Sands above. These are by no means constant but vary widely in their lithology, relative development and in their lignitic inclusions. In general it may be said that their best exposures lie in Wise, Parker, Hood, Erath and Bosque Counties; but for details of distribution, palaeontology, etc., reference should be made to the various publications of the Texas Geological Survey, especially to a paper by J. A. Taff (1892). The Trinity strata yielded structural lignites from three principal stations: (1) about one mile south of Cottondale (Glen Rose Formation) in a small cañon among the hills; also in the side of a low hill near the road which runs south from the same town; (2) near Weatherford, on Curtis Branch, and in a stream bank near the farm of Mr. Schleger about three miles from town; and (3) in the bed of Wolf Branch some three miles from the town of Bluffdale. The Cottondale deposit contained a stratum several inches thick of "leaf coal"—mere yellow cuticular flakes from crushed twigs. The Weatherford material from the second station is particularly valuable since much of it is in a charred condition.

"The whole of the Trinity formation, like the Potomac and Tuscaloosa formations, seems to have been littoral or at least not of open sea origin. This is indicated by lithological and also by palaeontological characters so far as the latter are known." This inference is strongly corroborated by the included lignite, which in its scattered distribution and admixture with sand and clays, as well as its often lenticular and local beds, points to a condition of deposition in coastal basins at the debouchment of streams. On the other hand the overlying Fredericksburg and Washita deposits are just as clearly of marine origin: no wood is found—a negative character which can carry little weight—but the great calcareous deposits and marine fauna point clearly to the origin.

The Cretaceo-Eocene Lignites of Texas.—The lower Cross Timber Sands lie above the Comanchean. This is again a marine deposit but the fossils all differ, hence one must infer an unconformity though this is not evident. These marine strata, however, need not detain us, for not until the Eocene or late Cretaceous deposits are reached do lignites again appear. Hill definitely assigns these beds to the Eocene portion of the Laramie. White writes: "There seems to be little reason for doubt that the lignitic beds of eastern Texas, as well as those of the states of Mississippi and Louisiana which are usually regarded as of early Eocene age, are really equivalent to the upper part of the Laramie."

The woods which I collected from these strata are often angiospermous, and are sharply distinct from those of the Trinity which are gymnospermous, and indeed offer a facies strikingly similar to that of the Cretaceous lignites of the Atlantic Coast; namely, those of the Potomac and Raritan Formations.

The Texan Eocene lignites are confined to the three upper divisions: the Timber Belt, the Yegua, and the Fayette. No attempt has been made to differentiate these finer divisions in the following considerations on correlations. Here lie the great workable coal beds of Texas. The literature which deals with the economic aspect is voluminous and considers chemical analyses, coking and briqueting experiments, fuel values, distillation, etc. The woods themselves have apparently never been studied though everyone who has dealt with the lignites has remarked the prevalent woody structure and the miners vaguely surmise that this is poplar wood, or sycamore, etc. The deposit is enormous. It stretches entirely across the State from Red River to the Rio Grande, and its coal beds frequently show a thickness in certain localities of from eighteen to twenty-four feet. The belt is some 650 miles long, 200 miles wide and embraces 600,000 square miles of coal area.

Dumble gives the credit of the first published description to J. J. Riddell (1839) who noted the silicified trunks overlying the Brown Coal, "some of which show a diversified metamorphosis since some are partly lignitized or are converted into limonite." He further states that in the coal itself the "ligniform structure is almost always easily discernible." My collections from these Eocene deposits were made from mines at the following stations: Rockdale, Bastrop, Wooters, Como and Alba. This is substantially the list of mines given by Phillips and Worrell (1913). In their report will be found analyses, and discussions of the economic features of these coals.

White's next geographical division of the American Cretaceous, (no. 4), is the North Mexican Region but at the time these investigations were in progress no American was entering Mexico in search of fossil woods.

The Great Interior Region.

South Interior Region.—This is a subdivision of the Great Interior Cretaceous area. It comprises Colorado and portions of Kansas, Nebraska, Wyoming, Utah, Arizona, New Mexico and northwestern Texas. It extends some 600 miles north and south and more than 800 miles east and west. Its strata practically belong to the Cretaceous period, rest unconformably on Jurassic deposits, and range in age from the Dakota to the Laramie.

North Interior Region.—This comprises nearly the whole of Montana and nearly or quite the whole of North and South Dakota, as well as parts of Nebraska, Wyoming, and Idaho; while in Canada the districts of Assiniboia, Alberta and the greater part of Saskatchewan, Athabasca and western Manitoba are included. It was said that the East Texas lignite deposit was enormous. The areal extent of the Great Interior deposit is staggering. When one considers that it has been traced (including northern Mexico) from the 26th to the 55th parallel of north latitude, a distance of nearly 2300 miles, and from the 103d to the 115th meridian, nearly 1200 miles, any theory to account for such prodigious deposits of wood becomes almost unthinkable. One can only postulate an extremely dense arboreal vegetation in a rainy climate, a land-locked sea, and vast stretches of time. This great Cretaceous deposit may be considered *en masse*. Its historical-economic aspect has already been noted above and we may now consider the classification of its strata and attempt a correlation with regions already discussed. Clark's (1891) correlation paper on the Eocene has been of great help here.

Hayden's Missouri section ran as follows, and beside it are given correlative divisions for deposits farther to the west.

Cretaceous-Eocene	Not recognized (or Fort Union)	7 Laramie
	5 Fox Hills group 4 Fort Pierre group	6 Montana
Cretaceous	3 Niobrara group 2 Fort Benton group 1 Dakota group	5 Belly River 4 Colorado 3 Dakota
Comanchean		2 Kootanie (only in the north) 1 Carboniferous or Devonian

Comanchean deposits are practically lacking in the South Interior region, but in the North Interior they are seemingly present as the Kootanie Formation. Furthermore in this same region the Belly River Formation is intercalated between the Colorado and the Montana Formations. In Alberta, Dawson states that the Kootanie rests unconformably upon Carboniferous and Devonian limestones. Some of its plants bear an Upper Jurassic facies. Newberry has recognized the lignite-bearing deposits of the Kootanie in the vicinity of the Great

Falls of the Missouri in Montana. Coal is also abundant in the Belly River Formation, while its flora and fauna are very similar to those of the Laramie.

1. *The Dakota Formation.*—The search for lignite in the Dakota Formation proved almost wholly unsuccessful. Hayden, Burchard (1904) and others have discussed the Dakotan lignites of Nebraska. In no locality, however, were there more than trifling and disappointing specimens available. At Hayden's (1869) type locality, Ponca, Nebraska, I collected a few pieces of badly pyritized wood and a few well-preserved angiosperm fragments. At Wilson, Kansas, there were formerly many mines but these are now wholly abandoned and fallen in, so that only carbon-bearing shales with rare charcoal fragments are to be seen. Old residents often assured me that they had seen lignites taken from these mines which showed the "grain of the wood," and doubtless a more thorough search would yield valuable specimens, particularly if the mines could be reopened. For unpublished data concerning these Dakotan lignites and for several specimens, I am particularly indebted to Dr. Barbour of the University of Nebraska, who also gave me several fragments of a Carboniferous lignite which is easily identified as a *Dadoxylon* species.

2. *The Laramie Formation.*—Not till we reach the Laramie do we again strike coal-bearing deposits in the Interior Basin, but here they are found in the greatest abundance. Owing to the historical confusion in which the strata were involved, the Laramie received many local names. Thus its several beds have been variously called Fort Union, Great Lignite, Judith River and Bitter Creek. An excellent discussion of the Laramie and its puzzles will be found in Clark's (1891) correlation paper on the Eocene. Lithologically the Laramie is rather uniform: its members are usually sandy or argillaceous and the whole formation contains coal and silicified wood. White considers it to represent deposits laid down in a great land-locked sea near the critical level and subject to frequent oscillation. Large islands were probably present.

The lignites of the Laramie are as evidently formed from transported woods as are those in Texas. Flattened branches are to be seen *in situ* with their extremities smoothed and rounded off by water action; some specimens of compact lignite show fragments of water-worn charcoal in almost every cleavage. Stumps of trees are not rare, but they are as often bottom-side up as in their natural position. At Cape Elizabeth, Washington, the beach is strewn with just such a tangle of stumps and woody débris, giving us some hint, perhaps, as to the conditions which prevailed in the great interior sea during Laramie times. The miners constantly speak of the lignite beds as made up of driftwood, and they are probably right in the inference. Leaf impressions are commonly found only in clays or sandstone above the coal, and their deposition marks the close of violent stream transportation and the inauguration of quieter conditions.

Beekly (1912) mentions an exposure in the bluff of the Missouri River, a few miles southeast of Culbertson, Montana. This lignite, however, is much weathered and of no botanical interest. Much of it—as is indeed a common condition in the northern area—has been burned, and the overlying clay is converted to red or pink porcelain-like clinker.

At a point farther up the stream, however, right at the place where a ferry plies over the river, there is a seam of lignite about five feet thick which was exposed in the spring of 1917 by one of the characteristic shifts of the Missouri. Here lie many large pieces of wood in the clays, both above and below the coal, while the foliated lignite itself contains charcoal.

Bauer (1914) has worked out in detail the deposit in the vicinity of Plentywood, Montana. The best specimens here are to be found at a mine about two miles north of the town. From the roof of the mine itself I obtained a large piece of wood from an upright stump and from the storage shed outside the mine many good fragments.

The Glendive Field (Hance, 1912) yielded only insignificant specimens. In the hills near the town there are lignitic clays and shales, but the chief mine of the area five miles east of Sidney, Montana, was full of water in September, 1917. At Hodges, however, in the same area there is a fine exposure of woody lignite (also rattlesnakes and scorpions!) in a "draw" just south of the town.

In North Dakota the Williston Lignite Field (Herald, 1913) gave the best specimens. At a mine three miles east of Williston one finds a very woody type of lignite with many charred and flattened branches. In the hills close at hand there is abundant silicified wood, gray to black on freshly broken surfaces, but weathering white and decomposing into asbestos-like fibrils.

At Sentinel Butte (Leonard and Smith, 1909) there is a remarkable deposit over twenty-five feet in thickness in the side of the Butte itself. It also is particularly woody.

The deposit at Medora in the same Bad Lands area is almost amorphous. This is somewhat surprising in view of the fact that Leonard and Smith (1909) give the inference that its woody structure is comparable to that at Sentinel Butte. From what one gathers from the miners, however, it would seem that these beds are subject to rather extreme horizontal variation. One continually hears statements to the effect that "last week we dug through a whole bed of logs."

The mines at Dickinson and Wilton (Smith, 1910) both yielded structural material but the Cannonball field (Lloyd, 1914) in the southern part of the State was wholly disappointing.

Colorado has long been famous for its coal deposits, but the sediments in this State have been profoundly disturbed and the attendant metamorphism has played havoc with the buried wood, in many cases converting it into a high grade of bituminous coal. It soon became evident that the only chance of finding structural material was to keep as far to the east of the mountains as possible. Hayden specifies Golden and Marshall as stations whence structural débris has been obtained. At Golden, in a clay bank close to the town, leaf impressions are to be found along with rare remains of branches, all extremely flattened and too much modified to permit of identification. Marshall again has several coal mines in operation but outside of "nigger-heads" (petrified trunks) little structural material is available. These coal beds are all near-bituminous.

It was in the banks of Monument Creek, between Colorado Springs and Breed, that the best Coloradan specimens came to light. One of Hayden's (1869) reports has the following paragraph: "About five miles east of the base of the mountains and four miles northeast of Colorado City, Mr. Gehrung has a land claim where a coal bed crops out of the bank of a creek. Above the coal is about eight or ten feet of clay. . . . This clay is filled with fragments of vegetable matter, some seeds and plants." All trace of Mr. Gehrung and his claim has disappeared with the vicissitudes of time, but I am confident that the same formation is found along Monument Creek, for here are chocolate-colored clays filled with plant fragments most of which, very unfortunately, are mere carbonaceous films. Near Breed, however, lignitized trunks begin to appear and from one fine-grained sandstone I gathered pieces of a large palm stem which itself lay in a sheath of clay in the sandy matrix. At the mines near the terminus of the car line on North Tejon Street, woody material is not uncommon.

As to the coals in southeastern Colorado, *viz.*, in the Walsenburg district (Richardson, 1910), they are too nearly bituminous to yield structural remains. From western Colorado and southern Wyoming I can only report failure to find material of botanical value. Coal is abundant but either advanced to the bituminous condition or, exposed in natural outcrops to a long succession of insufferable summer suns, it has slacked into beds of black powder. It would be of interest to examine a fresh surface in the almost continuous exposures along the railroad cut and the Gunnison River from Grand Junction to Delta. The historic Rock Springs and Point of Rocks in Wyoming yielded only impressions.

The Pacific Coast Region (*Tertiary*).

Last of all there remain for consideration the lignites of the Pacific Coast found in the States of Washington and Oregon. As has already been said, California has Cretaceous beds containing lignite, but the beds in the States just mentioned are of either Eocene or later age. The existence of lignitic woods in the Olympic Peninsula was first brought to my attention by Dr. H. S. Conard, who made a trip into the region some years since. At my request he sent me the following memorandum from his notes taken at the time:

"Notes of walk from mouth of Queets River south to Grenville at mouth of Quiniault River:

"Beach narrow, bounded by high gravelly cliff, probably 50 feet or more. From 10 to 40 feet below top of this was an old forest bed with recent gravels below again and stumps in place. The wood of these was only slightly modified; gathered some near Raft River. The specimens mentioned are in the Dept. of Geology, University of Pennsylvania." Dr. Conard was also able to put me on the track of literature concerning these deposits.

The following table of the western Washington strata is adapted from one given by Weaver (1912). In the Tejon and Miocene strata lie the lignites.

Quaternary		
Pliocene		
Miocene		Quiniault Formation
Oligocene	Blakely horizon	
	Porter horizon	
	Lincoln horizon	

Upper Eocene	Tejon Series	Arago Formation Olequa Formation Chehalis Formation
Lower Eocene	Wanting	

Basement complex of Palaeozoic and Mesozoic rocks.

Arnold and Hannibal have listed several "excellent plant localities" from the Tejon Series and it was among these that I selected a number for study. Four miles from Elma on Delazine Creek, fossil wood lies along the stream from whose bed it was derived. Some of it is almost jet-like in its hardness. Near Vader on Stillwater and Olequa Creeks, coal seams appear, containing logs and branches. This material is again very hard and splits easily with cubical cleavage. At Toledo on Salmon Creek, not far from Vader, fossil wood is abundant. The river gravels are strewn with flattened exfoliating trunks, while the clays of the banks contain charcoal and fine impressions. This wood is far less modified than that at Vader; some is even soft and yellowish inside.

The material which Dr. Conard reported from the sea-cliffs of the Quiniault Reservation lies in Miocene gravels. I collected material both from Point Grenville and from the cliffs above Taholah north of the Quiniault River.

Arnold and Hannibal have also reported "abundant plant remains" Oregon, from Cape Blanco, which are embedded in volcanic ash. My interpretation of the adjective "abundant" scarcely coincides with theirs, however, since in a two days' search I found only a small quantity of wood fragments and a few cones of a Picea. This material is again Miocene in age.

So, as the result of a half-year's search, we now have a collection of American lignitic woods which range in age from the Triassic to the Tertiary Period; most of these are from Comanchean and Cretaceous strata. To the naked eye they can be seen to include both gymnospermous and angiospermous woods. They were collected from the States of New Jersey, Mississippi, Louisiana, Texas, Colorado, Nebraska, South Dakota, North Dakota, Montana, Washington and Oregon.

HISTOLOGY AND TAXONOMY OF LIGNITIC WOODS OF THE UNITED STATES.

In the opening portion of this paper the historical aspect of the subject of palaeobotany was considered and incidentally certain principles of diagnosis and classification were there discussed. It is unfortunately the case that certain details of wood anatomy much used by the older students are now known to fluctuate greatly between members of a single species or even within different parts of the same individual. Such, for instance, are detailed measurements of tracheid diameters, of wall thickness, of pit mouths, of ray dimensions, of the number of tracheids per annual ring, or of the relative amounts of spring and summer wood. The early investigators often rely all too strongly on such characters, and it thus becomes difficult to compare their species with those of more modern workers. From the mass of anatomical details, however, we have selected a certain set which the consensus of opinion regards as most stable. These are listed in the following table, and furthermore they are placed in a certain order which our diagnosis has followed throughout. The characters believed to be most important are italicized.

Table of Diagnostic Data to be Assembled from Wood Sections.

ANNUAL RINGS: *presence or absence of;* relative abundance of spring and summer wood; nature of transition from spring to summer wood.

RESIN CANALS: *normal or traumatic; one or both directions;* size, shape, etc.; *character of secretory cells;* presence or absence of tyloses.

WOOD RAYS: *uni- or multiseriate;* height in cells; shape, length, etc., of cells; *presence or absence of marginal tracheids;* of resin. Lateral pits as to *number per tracheid field, oöpores or oculipores,* shape and inclination of the mouth; *presence or absence of pits on other walls.*

WOOD PARENCHYMA: *terminal or diffuse;* abundance, distribution, contents.

TRACHEIDS: variation in size; *radial pitting as to seriation, crowding, bars of Sanio,* and pit mouths; *presence or absence of resin-filled tracheids;* of tyloses.

MEDULLA: size; *presence or absence of sclerites;* of resinous structures.

It is not always necessary to consider all these features and the list is to be looked upon as suggestive rather than accepted as a formal system.

A few definitions of words are necessary. We have adopted the term *wood ray* as urged by Jeffrey (1917), who very truly maintains that the term "medullary ray" is a misnomer. For if it means composed of medulla, then it is morphologically inaccurate; while if it means extending radially outward from the medulla, then a protostelic stem-cylinder with secondary growth, along with most roots, has no "medullary rays." The term *wood ray* represents simplicity and accuracy and should supplant complexity and inaccuracy.

Tracheid-field (first employed by Dr. Stopes), is used for Gothan's "Kreuzungsfeld" and Lignier's "aire mitoyenne." It applies to that portion of a tracheid which is covered laterally by a juxtaposed ray cell.

The need for two simple terms to distinguish the two types of lateral ray-pits has been felt and the terms *oöpore* and *oculipore* are coined. The word oöpore is the equivalent of Gothan's "Eipore" which has been somewhat extensively used by English and American authors. An oöpore is a lateral ray-pit of oval or more or less circular opening around which no border is to be seen. For the tracheidal pit has been modified *pari passu* with the broadening of the simple ray-pit till its border is wholly lost, and a clear unbordered area reaches from tracheid lumen to ray-cell cavity. Oculipore, on the other hand, is the term used for a lateral ray-pit whose opening seen against the bordered pit of the tracheid resembles the conventional figure of an eye. The oculipore grades into the oöpore, and according to Gothan, the term "Eipore" (our oöpore) may only be used when the border is entirely lacking.

Throughout the succeeding studies one single ideal has dominated—the ideal of phylogeny—and a careful search has been instituted for characters which, in the light of past studies in wood anatomy, have been shown to be of phylogenetic significance. This has taken definite precedence of any attempt to multiply genera or species, although it unfortunately becomes necessary to make many new species, since the woods were largely from deposits never before studied as to their woody flora.

We have sought for stages in the evolution of the histological elements which are manifested in an advanced condition in modern conifers; or for reversionary characters due to traumatic stimuli; or for retentive and recapitulatory features.

In this ideal of the work, the "Principles of Comparative Anatomy" formulated by Jeffrey have been frankly applied. Derived by induction from a remarkably wide field of study, we believe their validity to be firmly established, and we have not hesitated to employ them deductively. If it be objected that these principles are not yet everywhere accepted as valid, one can but reply that the observed facts are recorded in some detail under each specimen considered, and they are thus open to independent judgment by those botanists who may not agree with our own inferences.

After three years of observation and study of the facts from which these principles were derived, and after witnessing striking confirmation of them in all the groups from pteridophytes to monocotyledons, we can affirm pragmatically: they work.

A Key to Coniferous Woods (including Cordaitales).

The following key to coniferous woods is based particularly on Gothan's system which includes the best points of the older systems and adds to them valuable diagnostic data derived from the rays. We agree with Dr. Stopes, however, in the advisability of using the generic name Podocarpoxylon in a wider sense than does Gothan. The particular change introduced has been the inclusion of the traumatic resin canal as a feature of high diagnostic value. Further details of the system are considered later. In the general form of the classification we have used the system recently proposed by Conard (1919).

Cordaitales and Ancient Woods of Uncertain Affinity.

Woods of the Palaeozoic and early Mesozoic Periods with annual rings obscure or lacking, resin canals and wood parenchyma wholly (palingenetically) absent. Rays thin-walled and laterally pitted only with oculipores or oöpores. Tracheids beset with scattered or contiguous, uniseriate or multiseriate bordered pits. Bars of Sanio absent. . . . . *Dadoxylon* Endlicher (18…
Woodworthia Jeffrey (191…
Voltzioxylon, gen. nov.
Xenoxylon Gothan (1910).
Callixylon Zallessky.

Coniferales.

Abieteae.

Annual rings usually distinct; resin canals either normal or traumatic or confined to conservative parts. Wood-ray cells usually pitted on all their walls. Wood parenchyma either wholly lacking or sparsely represented, and then commonly confined to the end of the annual ring. Tracheids of the adult wood with spaced, circular or oval bordered pits; these uniseriate, or when multiseriate, opposite one another; bars of Sanio present in the adult wood.

A. Normal resin canals well developed in both directions . . . . (PININ…

B. Secretory cells of the resin canals thin-walled. Marginal tracheids commonly present on the rays; lateral ray-pits in the form of large or small oöpores or oculipores; parenchyma only in connection with resin canals. . . . . *Pityoxylon* Kraus (1870–72).

B′. Secretory cells of the resin canals thick-walled and lignified, the canals themselves more or less *moniliform or fistular*. Marginal tracheids present; ray-cells all strongly pitted and with small oöpores or oculipores on the lateral walls. Wood parenchyma usually present at the end of the annual ring. . . . . *Piceoxylon* Gothan (1905).

A′. Resin canals only traumatic or confined to the conservative parts, usually vertical, only rarely in both directions. Rays strongly pitted on all their walls; lateral pits usually oculipores; marginal tracheids variable. Wood parenchyma if present terminal, rarely diffuse

(ABIETINAE)
Cedroxylon Kraus (1870–72).

Cupresseae, Taxodieae, and Taxaceae.

Annual rings usually distinct; resin canals neither normal nor traumatic (except in the last genus). Wood ray-cells pitted laterally with oculipores or oöpores, but commonly with few or no pits on horizontal and tangential walls. Wood parenchyma usually abundant and diffuse. Tracheidal pitting as for the Abieteae.

A. Resin canals neither normal nor traumatic.

B. Tertiary spirals absent.

C. Lateral ray-pits few to many; oculipores throughout the annual ring

Cupressinoxylon Göppert (1850).

C′. Lateral ray-pits one to few; large oöpores in the spring wood, in summer wood with or without borders. . . . . *Podocarpoxylon* Gothan (1905).[1]

B′. Tertiary spirals well developed. . . . . *Taxoxylon* Unger.

A′. Traumatic resin canals present in one or both directions; ray-pits sometimes widened to oöpores; otherwise as in *Cupressinoxylon*. . . . . *Sequoioxylon*, new genus.

Araucariaceae.

Bordered pits of the adult wood more or less contiguous and flattened (except in young wood), uni-, bi-, or multiseriate, and when in more than one row typically alternate. Bars of Sanio and opposite pitting absent from the adult wood. Either resin canals (normal or traumatic), or parenchyma, or both present throughout.

Tribe I. Araucariopityeae.

Ray-cells heavily pitted on all the walls (abietean pitting). Normal or traumatic resin canals often present. Wood parenchyma usually absent; rarely terminal or diffuse.

Protopiceoxylon Gothan.
Araucariopitys Jeffrey.
Planoxylon Stopes.
Thylloxylon Gothan.
Metacupressinoxylon, gen. nov.

[1] The use of *Mesembryoxylon* Seward (1919) as a substitute for this genus has been considered. The term itself is preferable since it implies no relationship with *Podocarpus*. As the genus is diagnosed, however, it is too broad—including as it does *Sequoioxyla* (abietean pitting and resin canals), along with *Brachyoxyla* (*cf. M. bedfordense* Stopes). We have for that reason preferred to use the genus *Podocarpoxylon* in the extended sense proposed by Dr. Stopes.

Tribe II. Brachyphylleae.

Ray-cells thin-walled and pitted only laterally; pits usually only small oculipores, sometimes oöpores; and few to many per tracheid-field. Traumatic (or normal?) resin canals present. Normal wood parenchyma absent. *Brachyoxylon* Hollick and Jeffrey (1909).
Paracedroxylon Sinnott (1909).
Telephragmoxylon, Torrey (1921).
Anomaloxylon Gothan (1910).

Tribe III. Araucarieae.

Wood rays as in Brachyphylleae. Neither normal nor traumatic resin canals present (except in *Paracupressinoxylon potomacense* Sinnott and Bartlett). Diffuse wood parenchyma always present (confined to conservative regions in the living genera).

Paracupressinoxylon Holden (1913b).
Araucarioxylon Kraus (1870–72).

Discussion of the Key.

But few points in the preceding table need any discussion. Several attempts have been made in the past to distinguish between the genera *Dadoxylon* and *Araucarioxylon*, but it is the opinion of the European authority (Gothan) whose systematic work has had the greatest influence on coniferous xylopalaeontology in recent years, that the two cannot be separated, and he has adopted the name *Dadoxylon* Endlicher for all woods with alternating contiguous pitting and the typical araucarian ray. Seward (1919) does the same.

We have essayed, however, to effect a separation on a new basis. The *Dadoxyla*, under which we include not only cordaitean woods but others of unknown or problematical affinity, are wholly without resin canals or wood parenchyma. The absence of both these elements we believe to be palingenetic. On the other hand the Araucariaceae have been set apart because of the possession of either resin canals or wood parenchyma or of the two conjoined. As is well known, the living genera *Araucaria* and *Agathis* have neither of these structures in the stem wood, which at first sight would seem to destroy the distinction between *Dadoxylon* and *Araucarioxylon*; but a little consideration shows that the living genera all have abundant parenchyma in their root and in their cone axis. In other words its absence from the cauline region is held to be *a recent loss*. Furthermore, and substantiating this inference in the most remarkable manner, we have yet to find a true *Araucarioxylon* from the Cretaceous deposits (*viz.*, with characteristic pitting, rays, wound reactions and persistence of leaf-traces), which is not well supplied with wood parenchyma in its *stem* wood. This ready diagnostic feature of the genus may yet be found to be retained in the stem wood of all the fossil forms, for we are compelled to believe that the living genera represent a recent and final stage of regression.

In referring certain woods to an araucarian rather than to a pinacean affinity it must be admitted that the question of their position is one the answer to which depends upon the relative weight given to certain character combinations. We hold that anatomical and palaeontological evidence points to the Abieteae as the ancestors of the other coniferous groups. If this is so, then there are bound to be vague intermediate regions somewhere among late Palaeozoic or early Mesozoic conifers, in which the introduction of cupressean, or araucarian characters into a pine complex, makes a sharp distinction between these groups almost impossible. Somewhere and sometime the araucarian pitting was substituted for the abietean, the bar of Sanio was lost, and resin canals passed from a state of epiphany to that of potentiality.

A notable example of such a transitional wood is *Araucariopitys* Jeffrey (1907); its rays are abietean, it possesses traumatic resin canals, but its tracheidal pitting and absence of bars of Sanio show that it is not of the nature of any true abietean wood with which we are familiar. In founding the genus *Araucariopitys* and subtribe Araucariopityoideae, Jeffrey has expressed its synthetic nature and has incidentally given us a group name to accommodate other similar woods which have since been found. We have only changed it from subtribe to tribe.

It became a question of extending the definition of the Abieteae or the Araucariaceae to embrace such annectant genera and the araucarian features were judged to be of strongest value. Thick-walled and heavily pitted rays are made by Gothan the feature upon which to base a final decision favorable to inclusion in the Abieteae, but it has been shown that the so-called abietean rays are present in conservative regions of living araucarians, and that they also occur as traumatic reversions. Hence one may well believe that their ancestors exhibited these features in their ordinary stem as well as in their root wood. It may be noted in passing that Gothan (1910) himself is impressed with the araucarian facies of the Polar woods which he described, for he says: "Es ist überhaupt gemein hinauffallend wie häufig man in der Hoftüpfel zahlreichen Hölzer der oberen Juraformation des Nordens, araucarioiden Charakteren begegnet." In regard to the positive characters upon which we base our reference to the Araucariaceae, namely the presence of contiguous flattened pits and the absence of bars of Sanio, the latter is of greatest importance. But since in petrified material, which is always inferior to good lignitic remains, this detail may be wholly undeterminable, one may be forced to depend upon the former only. The combination of the two seems, however, to be the only safe guide.

Among the *Cupressinoxyla* we have followed Gothan in our adoption of the genus *Podocarpoxylon*, but have used it in the broader sense advocated by Dr. Stopes. It must be admitted that it is not a clear-cut genus, for there is no sharp distinction between oculipores and oöpores. Furthermore, Miss Holden has described a *Dadoxylon* wood from India whose ray cells bear oöpores; which is also a feature of the taxodian genus *Sciadopitys*.

A word as to *Sequoioxylon* may be inserted. It is a clearly recognizable genus, the affinity of which with the living sequoias is close, although we do not maintain that all *Sequoioxyla* are woods of *Sequoia*. In cases of failure to find wounded areas, woods otherwise of sequoian habit must of necessity go into the genus *Cupressinoxylon*.

It is among the Araucariaceae that the greatest change has been made. The genera and species are becoming numerous and some form of classification was necessary. We have adopted Hollick and Jeffrey's (1909) three groups: Araucariopityoideae, Brachyphylloideae, and Araucarioideae raising them to the rank of tribes. No attempt has been made to formulate a generic key here. Diagnosis of several araucarian genera will be given later and references appended to permit those interested to turn to the original generic descriptions. It will be evident that the tribes are based on certain character combinations held to possess real phylogenetic significance. The Araucariopityeae, as the name suggests, include woods with a synthesis of abietean and araucarian characters: namely, abietean rays, normal or traumatic resin canals, and the usual palingenetic absence of wood parenchyma. Along with these characters, however, go araucarian pitting and total absence of bars of Sanio. Such woods are making the transition from the Abietaceae to the Araucariaceae and are the most ancient of the araucarians. A few of them seem to have evolved wood parenchyma, though the genesis of this element is best illustrated by the next tribe.

The Brachyphylleae form a very natural assemblage; they have lost the ancient abietean rays, their resin canals are only recalled under traumatic stimuli and some of them (*cf. Telephragmoxylon, infra*) manifest incipient stages in the formation of wood parenchyma, along with the pitting and lack of bars of the more typical araucarians.

The Araucarieae seem to be continued regressions from the Brachyphylleae. Their resin canals are gone even beyond traumatic recall, but wood parenchyma has come to full expression. *Paracupressinoxylon* often seems to retain a type of pitting characteristic of the juvenile wood of *Brachyoxylon*. *Paracupressinoxylon potomacense* Sinnott and Bartlett (1916) is one of those annoying exceptions where Nature refuses to be relegated to formal categories. It is a wood transitional from Brachyphylleae to Araucarieae which has attained wood parenchyma but has not yet lost its traumatic resin canals. *Paracupressinoxylon cupressoides* and *Paracupressinoxylon trinitense* on the other hand seem to be without resin canals. More precise characters distinguishing the genus *Araucarioxylon* will be given under a later generic description. Kräusel (1918, 1920) has recently suggested a new family, Protopinaceae, to include among other forms *Brachyoxylon*, *Protopiceoxylon*, and *Araucariopitys*. We cannot, of course, countenance the assumed phylogenetic position implied in this family name. Furthermore it does not seem wise to establish a new family for a group of obviously araucarian woods. Indeed it is with some doubt as to its desirability that we have raised the araucarians to family rank in accordance with Conard's classification.

Diagnoses and Descriptions of Twenty-two Lignitic Woods.

In the following diagnoses and descriptions the terms *annual rings*, *resin canals*, *wood rays*, *wood parenchyma*, *tracheids* and *medulla* are respectively abbreviated as: A.R., R.C., W.R., W.P., T., and M. From the diagnoses we have tried to keep out all reference to such facts as would characterize only the specimen in hand—such, for instance, as the possession of fungus or worm borings, or of slits in the tracheid walls, obliterated ray-markings, and other such artifacts. The order of treatment follows that of the key just discussed. A word is perhaps necessary regarding the system used in numbering these woods before they had been identified. Each specimen is referred to the geological horizon and State in which it was found, followed by two numbers. The first of these stands for a certain locality in the State, while the second is the number of the specimen itself. The first species considered, however, bears the reference number given it by its collector.

DADOXYLON Endlicher.

Pinites Witham, Observations on Fossil Vegetables, 1831.
Dadoxylon Endlicher, Synops. Conif., 1847.
Araucarioxylon Kraus, Sitzungb. Naturf. Gesellsch. zu Halle, 1882.
Cordaioxylon Felix, Untersuch. über d. inn. Bau westfal. Carbonpflanzen, 1886.
Cordaixylon Grand 'Eury.
Cordaites various authors.

Annual rings usually obscure or wholly lacking. Resin canals and wood parenchyma absent (palingenetic). Wood rays thin-walled, pitted laterally with few to very many small oculipores (very rarely oöpores). Tracheids abundantly beset with contiguous, uniseriate or multiseriate bordered pits; these, when in more than one row, alternating and hexagonal through mutual pressure. Bars of Sanio wholly absent.

Dadoxylon sp.

Carb. Neb. 15–7–12.

A.R. None.
R.C. None.
W.R. Uniseriate, few to 30 cells deep, lateral pits usually 1 or 2 oculipores per tracheid-field; other walls thin, unpitted.
W.P. None.
T. The radial walls beset with alternate or uniseriate contiguous pits with small oval mouths.

This specimen, which was given me by Dr. Barbour of the University of Nebraska, is badly pyritized but is of interest since it shows how a lignite from such a distant period as the Pennsylvanian may still be in a state of preservation sufficient to permit of diagnosis. This particular species of *Dadoxylon* is characterized by its small number of pits on the lateral walls of the rays,—nowhere have I seen more than two per tracheid-field. Moreover, they are relatively large and analogous to the oculipores of the Cupresseae. Such a small number of ray-pits, while not the rule, is not unknown among the *Dadoxyla:* thus, *Araucarites thamnensis* Göppert, *A. cupreus* Göppert, and *Dadoxylon vorgesiacum* Unger, are said to have one or two pits per tracheid-field, and also the few rows of bordered pits on the tracheids which characterize this specimen. In many characters too, it is similar to *Cordaites* (*Dadoxylon*) *edvardianum* Dawson from Prince Edward Island.

Dadoxylon sp. From Pennsylvanian Eurypterid Beds near Peru, Nebraska. Collected by Dr. E. H. Barbour.

VOLTZIOXYLON, gen. nov.

Synonomy as for *Dadoxylon*.

Annual rings indistinct or wanting. Both resin canals and wood parenchyma palingenetically absent. Wood rays usually uniseriate, thin-walled, and marked laterally with few to many small oculipores per tracheid-field. Tracheidal pits uni- or biseriate, usually spaced and circular; mouths tiny, oval or slit-like. No bars of Sanio. A characteristic Triassic wood.

Voltzioxylon dockumense, sp. nov.

Tr. Tex. 5.1.

A.R. Not visible.
R.C. None.
W.R. Uniseriate (?) few to 15 or more cells deep; cells in radial aspect resinous; lateral pits 2 to 9 oculipores per tracheid-field with slit-like openings; other walls delicate and unpitted.
W.P. None.
T. Beset with rows of spaced, circular pits with tiny slit-like to oval, crossed mouths; pits not rarely in two rows, then alternating but not flattened by pressure.

The discovery of this interesting Triassic wood has been noted above. The amount of detail exhibited by the radial sections is surprising since the specimen is badly crushed. Evidently our sections were taken from the longest diameter of a flattened branch, for in transverse and tangential sections the tracheid lumina are completely obliterated by crushing. The absence of annual rings, of wood parenchyma and of resin canals either normal or traumatic, with the possession of delicate-walled rays bearing numerous oculipores with slit-like openings, along with the abundance of alternating pitting, builds up a complex of features not found in any modern wood. Closest to it are the living araucarians, but these possess wood parenchyma in their conservative regions which leads to a conclusion, perfectly substantiated by their fossil representatives, that the lack of wood parenchyma in their stems is coenogenetic. In this Triassic wood, however, the lack of parenchyma is palingenetic, as is also the complete absence of resin canals.

In 1913, Miss Ruth Holden (1913a) described certain woods from Canada which she successfully linked up with the pith casts of *Voltzia coburgensis* Shauroth. There can be little doubt as far as histological comparison can prove identity that we are dealing with a wood of the same or an allied genus. The affinities of *Voltzia* have been much disputed. It has been placed among the Taxodieae and the Cupresseae, while Miss Holden suggests that it may be one of the earliest type intermediate between the Abieteae and the Araucariaceae. We incline, however, to the opinion that it represents rather a plant transitional to the Pinaceae and in view of its problematical nature have thought best to place it in a noncommittal position among the *Dadoxyla* and allied woods. If, as we believe, the absence of all resinous structures and of wood parenchyma are palingenetic features, then this reference is really the safest that can be made. In founding the new genus *Voltzioxylon* we are not thereby committed to the position that this Texan wood is the wood of *Voltzia*. Future studies may show that such is not the case and the way will then be open to remove it to its correct position.

An apposite word may be inserted concerning the genus *Woodworthia* Jeffrey (1910a) which was also derived from Triassic strata not far distant from those in which our own specimen was found. Its pitting is, however, more typically dadoxyloid, while the presence of persistent short shoots is a pinean feature we have not found in *Voltzioxylon*. Both this and our genus, however, lack wood parenchyma and resin canals.

Plate 8, fig. 1.—Transverse section. This figure is introduced to show the condition of much of the Triassic lignite. The tracheids are seen to be crushed flat, and their lumina blocked with resinous matter.

Fig. 2.—Radial section. In spite of the crushed condition the radial sections exhibit surprising detail. In our photograph both types of tracheidal pitting are evident, and in the cases of biseriation it should be noted that the pits retain their rounded form and are not hexagonal as in more typical *Dadoxyla*. On the left of the photograph portions of two rays are visible.

Voltzioxylon dockumense, gen. et sp. nov. Triassic Dockum Beds. Spur, Texas.

PITYOXYLON Kraus (in part).

Pinites Witham, Observations on Fossil Vegetables, 1831.
Pityoxylon Kraus, Schimper's Traité de Paléont. végétale, 1870.
Pinoxylon Gothan, Zur Anat. lebend. und fossil. gymnosp. Hölzer, Königl. Preuss. Geol. Landes. u. Bergakad., Berlin, 1905.

Resin canals normal in both directions, secretory epidermis thin-walled. Wood rays marked on the lateral tracheid-fields with oöpores, these sometimes very large; horizontal and terminal walls either pitted or smooth; marginal tracheids present on the rays and either smooth-walled (soft pines) or irregularly thickened (hard pines). True wood parenchyma wholly lacking. Tracheids beset with uni- to multiseriate bordered pits separated by bars of Sanio. When in two or more rows always opposite.

Pityoxylon sp.

Cr. Lar. N.D. 3.2.

A.R. Summer wood a thick zone some 30 cells wide.
R.C. In both directions; secretory cells thin-walled and sending tyloses into the canal cavity.
W.R. Uniseriate except when containing resin canals, one to ten cells high, resinous, marginal tracheids present. Ray cells thick-walled and strongly pitted on horizontal and terminal walls with one or two round oöpores per tracheid-field.
W.P. None.
T. With uniseriate pits, these circular with round mouths.

The specimen is not well preserved and partial decay has filled the walls with oblique cracks. It is hard to differentiate the marginal tracheids in radial section, but in tangential aspect the lateral walls of the uppermost and lowermost ray-cells possess bordered pits which are also dimly seen in radial aspect in face view. Whether the walls are smooth or dentate cannot be determined. A characteristic ray feature is the great variability in the inclusion of resin. Some cell rows are heavily filled with this brown secretion, while others are practically empty. Hence the rays in radial aspect are often zoned longitudinally with lighter and darker stripes.

A comparison with *P. columbianum* Penhallow (1907) is of some interest. That species has sparingly dentate marginal tracheids and large thin-walled resinous parenchyma cells around the resin canals. These sometimes form "large and irregular tracts upwards of 6–9 tracheids wide." Tyloses are not obvious. In the abundance of resinous parenchyma and lack of tyloses *P. columbianum* is not in accord with our species. As we have stated, it is impossible to make out whether the ray tracheids have dentate margins. Both woods, however, are derived from the great northern Laramie deposit.

Pityoxylon sp., from Cretaceous Laramie deposits at Sentinel Butte, North Dakota. Lignite mine.

Pityoxylon (Pinus) scituatensiforme (Bailey) n. comb.

Cr. Rar. N.J. 1.3.

A.R. Spring and summer wood not strongly differentiated. Limits of annual rings probably less clearly marked than in living pines.

R.C. Normal in both directions; the vertical canals surrounded by secretory cells with thick walls; tyloses abundant, and the whole secretory region inclosed in a sheath of highly resinous parenchyma which in cross-section appears in broad irregular patches. Horizontal canals in fusiform rays, smaller than the vertical.

W.R. Heavily resinous, 1 to 15 cells high, mostly uniseriate; cells usually large and laterally bulging; ray tracheids present, margins probably not dentate; lateral pits lenticular oculipores to large oöpores, about two per tracheid-field; horizontal walls thick and abundantly pitted; terminal walls thinner.

W.P. Lacking except for the patches associated with the resin canals; then thick-walled and pitted like the ray-cells.

T. Similar in size; pits large, circular, uniseriate, spaced; separated by bars of Sanio; the narrowed ends of the tracheids often moniliform due to the extreme size of the pits.

M. Cells thick-walled, heavily pitted and interspersed with nests of sclerites.

Four or five Cretaceous *Pityoxyla* with marginal tracheids are described in the literature. Two of these, *P. Sewardi* Stopes and *P. Woodwardi* Stopes, are from the Lower Greensand of England. *P. Benstedi* Stopes (1915) from the same level, is probably, as its author suggests, more closely related to *Larix* than to *Pinus*. It should at least be referred to the genus *Piceoxylon* Gothan. Another, *P(inuxylon) Paxii* Kräusel (1918) of Miocene age has recently been described.

The American Cretaceous species possessing marginal tracheids are *Pinus scituatensiforme* Bailey (1911), *Pinus protoscleropitys* Holden (1914), and *Pityoxylon Vateri* Platen (1907). Our species is undoubtedly the first and was in fact derived from the same locality. Bailey writes of the tylosed canals of his form, "surrounded by large masses of thick-walled and highly resinous parenchyma cells," its resinous rays, and its sclerotic pith; while his plates show figures which could be duplicated from our own slides, though our wood is in a better state of preservation.

In comparing the American and European species of Cretaceous *Pityoxyla*, one striking feature of similarity is to be noted, namely, the presence of masses of gummy parenchyma associated with the resin canals. For not only is this feature characteristic of the species possessing ray-tracheids, but it is seen in those in which these elements are absent, as for instance, *P. scituatense* Jeffrey and *P. foliosum* Holden. It must not be forgotten, however, that other and contemporary "pine woods" were without these curious parenchymatous tracts, so their value as a primitive characteristic must remain in doubt.

In referring this wood to *Pityoxylon* Kraus rather than to *Pinus* we do not thereby commit ourselves to the opinion that it belonged to the living genus. In *Prepinus* Jeffrey (1908) we already have another "pine" and other genera may yet be discovered.

Plate 8, fig. 3.—Transverse section. Introduced to show the curious resinous patches which surround the resin canals. Three canals are to be seen, around two of which the sheath of resinous parenchyma is particularly well developed.

Pityoxylon scituatensiforme (Bailey) n. comb. Cretaceous Raritan clays, Matteawan, New Jersey.

Pityoxylon ***cf.*** **Vateri** Platen.

Mio. Ore. 1.5.

A.R. Well marked; summer wood dense and transition from spring to summer wood rather abrupt.
R.C. In both directions; the vertical surrounded by a few rows of non-resinous parenchyma; mostly in the summer wood; horizontal canals in fusiform rays, not abundant and slightly smaller than the vertical canals.
W.R. Few to ten cells deep (twig wood), non-resinous; lateral field with one or two oöpores per tracheid-field; horizontal and terminal walls strongly pitted; marginal tracheids not visible.
W.P. None.
T. Pits uniseriate and pinean.

This specimen of pine wood is from a branch which is about twelve years old. The rate of growth, however, was very slow for the radial diameter is only about one centimeter. Hence we cannot be sure that the lack of marginal tracheids is a mature feature of the wood; and furthermore, the state of preservation does not permit us to deny their presence definitely. The non-resinous character of the rays and the resin-canal parenchyma is of some diagnostic value. A comparison with the amber-bearing *Pinus succinifera* (Göppert) Conwenz (1890) is of some interest. Both are from Tertiary strata and in that species the marginal tracheids are late in appearing. The colorless parenchyma around the resin canals is another point of similarity.

A relationship to, or perhaps identity with *P. Vateri* Platen (1907) from the Tertiary strata of California is suggested. This species has the same ray pitting as ours but dentate marginal tracheids were definitely seen.

Pityoxylon cf. *Vateri* Platen. Miocene volcanic ash deposits, Cape Blanco, Oregon.

PSEUDOTSUGA Carrière.

Pseudotsuga annulata (Platen) n. comb.

Mio. Ore. 1.6.

A.R. Very distinct; summer wood forming about one-half the yearly growth; spring wood very open and delicate. Twig wood dense with little variation in size of tracheids.
R.C. Normal in both directions; vertical canals often paired and usually confined to the summer wood; secretory cells thick-walled; horizontal canals much smaller and in elongate fusiform rays, sometimes two together.
W.R. Uniseriate (except for those which contain resin canals), two to twenty cells deep, slightly resinous; marginal tracheids present; lateral pits small, circular, two or three per tracheid-field; horizontal and terminal walls thick and strongly pitted.
W.P. Wholly terminal, not common.
T. With strong spiral thickenings in the spring tracheids, these not evident in the summer wood. Pits uniseriate with large circular mouths.

It would be pleasing to be able to identify this wood with *Pseudotsuga miocena* Penhallow (1907), but if one compares the two strictly it must be admitted that there is considerable difference. Thus *P. miocena* is said to have a thin zone of summer wood (three to ten rows) while in ours the summer wood occupies at least one-half the annual ring and is some thirty cells broad. Again, *P. miocena* has ray cells with "thin upper and lower walls devoid of pits." We are inclined to doubt this statement since such thin-walled and unpitted rays are not at all characteristic of the genus *Pseudotsuga*. The breadth of the summer zone is possibly a variable character.

From the living *P. mucronata* the wood differs in its less robust character, its far fewer resin canals and its more delicate rays which do not show the irregularity in tangential aspect of those of *P. mucronata*. From *P. macrocarpa* Mayr. it is to be separated because of the absence of resinous tracheids.

Under the name *Pityoxylon annulatum*, however, Platen (1907) has described an undoubted *Pseudotsuga* from California Tertiary deposits which seems to be identical with our own. He himself says of it: "Der Douglastanne findet sich noch heutigen Tages in Kalifornien. Das vorliegende Fossil durfte erweisen dass sie oder eine ihre nächsten Verwandten bereits in Pliocaen einen Bestandteil der Wälder dieses Landes bildete." We deplore the species name since all *Pseudotsugae* are "annulatum," but the law of priority must permit it to stand. We feel justified, however, in removing it from the genus *Pityoxylon* to *Pseudotsuga*.

Plate 8, fig. 4.—Transverse section. In the lower part of the field is to be seen a zone of summer wood in which lie two small juxtaposed resin canals, while in the upper part a sheared zone of the much more delicate spring wood is visible.

Fig. 5.—Radial section. Tertiary spirals are here clearly evidenced and on one tracheid at the left hand of the photograph a row of round bordered pits is plainly visible.

Fig. 6.—Tangential section. Photographed to exhibit a horizontal resin canal running in an elongated fusiform ray. About five tracheids from the left-hand side, a cross-diaphragm may be noted; this is the end wall of a wood-parenchyma cell. In *Pseudotsuga*, wood parenchyma is confined to the end of the annual ring.

Pseudotsuga annulata (Platen) n. comb. From Miocene volcanic-ash deposits, Cape Blanco, Oregon.

PODOCARPOXYLON Gothan.

Cupressinoxylon Göppert, Monog. der fossil. Coniferen, 1850.
Podocarpoxylon (with *Phyllocladoxylon*) Gothan, Zur Anat. lebend. und foss. gymnosp. Hölzer, Königl. Preuss. Geol. Landes u. Bergakad., Berlin, 1905.

Resin canals absent. Wood rays with horizontal and terminal walls smooth; lateral walls marked (in the spring wood at least) with one to several oöpores. Bordered pits uniseriate or multiseriate, bars of Sanio present.

Podocarpoxylon texense, sp. nov.

Cr. Lar. Tex. 6.1.

A.R. Strongly marked because of the heavily resinous summer tracheids. Wood very coarse.
R.C. None; wounded areas produce only heterogeneous parenchyma and septate tracheids.

W.R. Uniseriate two to ten cells high and usually very resinous; lateral tracheid-field bearing one or two oculipores with lenticular openings, these may pass completely to oval oöpores on the spring tracheids; horizontal walls sparingly pitted.

W.P. Present and completely filled with resin, diffuse.

T. With peculiar pitting; the pits small to large, spaced, uniseriate, opposite and flattened; or alternate and flattened; sometimes of odd shapes; when contiguous an evident ridge lies between each pit and its neighbors thus enclosing it in a rim. More normal bars of Sanio also present. Tangential pits small and circular, usually scattered in more or less irregular rows.

This wood is extremely characteristic of the great Tertiary lignite deposits of eastern Texas. We have collected it from mines at Como where it seems to be particularly abundant, and again at Rockdale. As it comes from the mines it is of an ashy-brown color and cleaves easily into blocks. Its fuel value must be considerable because of its remarkably high resin content.

In nearly all its histological details this wood is so heterogeneous that it rather upsets all our formal "genera." Even its cross-section leads one to expect peculiarities, for the great tracheids with their rounded contours are commonly separated by what seem to be double walls but which in reality are the opposing faces of two bordered pits. The wood parenchyma is so resinous as scarcely to show its walls, while the rays in like manner are blocked, as are also the tracheids at the end of the annual ring.

The wood rays are diversified in their lateral pitting, for one discovers "sequoian" and "podocarpoid" pitting in the same low-power field with all degrees of inclination of the pore from upright to horizontal.

As to the pitting of the tracheids, there is such a diversity in size, shape and mutual relations of the pits as to make it difficult to think of anything similar. Sometimes they are scattered and small; again large and mutually compressed and alternate or opposite. When alternate and hexagonal through pressure they are usually separated by thickened rims which are probably of the nature of true bars of Sanio.

A careful search was instituted for resin canals but with wholly negative results. Several areas of wounded tissue were discovered, but the reaction had been toward tracheid septation and parenchymatization, and no evidence of schizogenous canals was found. We had suspected that the real affinity lay with *Sequoioxylon* but a careful consideration does not point that way.

Since the ray-pits are linear and upright in the summer wood and usually broadened to oöpores on the spring cells, we have referred this wood to the genus *Podocarpoxylon* Gothan, though a separation from *Cupressinoxylon* is somewhat questionable.

Plate 8, fig. 7.—Transverse section. Here the highly resinous nature of the wood is well brought out, for not only the rays but many of the tracheids are filled with opaque resin. This is particularly true of the summer tracheids, a line of which passes horizontally across the middle of the field. In the radial walls of several of the tracheids large pits are seen in section, appearing as two delicate walls bounding a lenticular area whence the middle lamella has disappeared.

Fig. 8.—Tangential section. This section is taken through the summer wood and the tangential bordered pits come out sharply along with the relatively low rays whose cells are often resin-filled. In the radial walls of the tracheids appear the bordered pits.

Plate 9, fig. 9.—Radial section. This shows a detail of the ray and attests the justice of our generic reference, for the oöpores are large and unmistakable.

Figs. 10 and 11: Show details of the tracheidal pitting of whose heterogeneous nature we have already spoken. Even the most skeptical cannot doubt that bars of Sanio are really present.

Podocarpoxylon texense, sp. nov. From Tertiary deposits, Rockdale, Texas; lignite mine.

Podocarpoxylon washingtonense, sp. nov.

Ter. Wash. 3.5. and 3.3.

A.R. Well developed, narrow; contrast between spring and summer wood marked.
R.C. None.

W.R. Uniseriate, few to twenty-five cells deep; lateral tracheid-field with about two small oöpores; other walls smooth.

W.P. Abundant, diffuse and heavily resinous.
T. Pits spaced and uniseriate.

(Probably the same as *Taxodioxylon sequoianum* (Merckl.) Gothan.)

Two specimens of this wood are at hand: one (much the better preserved) from a twig and the other from a large trunk. In the trunk wood the annual rings are narrow and strongly marked by the abrupt transitions from spring to summer wood. The cross-section appears thickly sown with wood-parenchyma cells. One slightly wounded area is included among the tangential sections, and here the parenchyma is particularly abundant, though it is not of the nature of wound-cap tissue. Resin canals have not been seen.

The rays are often twenty-five cells deep in the adult wood; in the twig they do not often run over ten cells in depth. The lateral ray-pits are in the form of one or two small circular oöpores per tracheid-field and even in the summer wood this shape is maintained (Gothan's phyllocladoid pitting). The bordered pits, almost destroyed by decay in the trunk wood, are uniseriate and round-mouthed.

These specimens came from the banks of Salmon Creek near Toledo, Washington. It seems to have been a common type of wood there in the Tertiary Period. The gravels of the stream are strewn with large exfoliating trunks, most of which show the same macroscopic features. A common character is the bright yellow color of the soft, inner, unoxidized portions of the trunk. In the clay along with the wood I found many fragments of charcoal and abundant impressions of the leaves of dicotyledons. Doubtless further search would reveal impressions of the leafy twigs of the very common conifer whose wood we have just described.

Kräusel (1918) has recently described a wood derived from eighteen different stations in German Brown Coal mines of Miocene age, which he identifies with *Taxodioxylon sequoianum* (Merckl.) Gothan. His diagnosis runs as follows: Wood of *Cupressinoxylon* structure, ... without abietean pitting. Wood parenchyma more or less abundant, particularly in wounded wood, and then with thick pitted walls. Resin canals traumatic, vertical and in tangential rows. Ray-pits rather large, and many on the tracheid-field. Pore of spring wood horizontal, with almost obsolete borders, not circular but oval. The description fits our Washington wood very well except for the presence of traumatic resin canals in the German specimens. The possession of these canals was not a character of the wood on which Gothan founded the species, and many of Kräusel's specimens are without them. Fig. 13, Plate 9, of this paper, should be compared with Kräusel's Fig. 2, Taf. 31, as should also Fig. 14, Plate 9, with Fig. 2, Taf. 33.

If the woods are identical, or very closely allied, as I suspect, then we have an interesting situation. Before reading Kräusel's article I had remarked upon the great quantities of this wood in the Tertiary deposits of the Olympic Peninsula. Kräusel considers *Taxodioxylon sequoianum* the "häufigsten vertretene Holztypus" of the German Tertiary Brown Coals. But what shall be done about its name? I have already explained that I cannot differentiate Gothan's finer divisions among *Cupressinoxyla* (in a large sense). I have adopted his *Podocarpoxylon* as a form-genus for woods with oöporous ray-cells; and *Sequoioxylon* for *Cupressinoxyla* with traumatic resin canals. This means that *Taxodioxylon sequoianum* according to our system must become *Sequoioxylon sequoianum*. It is probably the same wood as our *Podocarpoxylon washingtonense*. The transference to the genus *Sequoioxylon* does no violence to a wood of which Kräusel says: "Seine vollige Übereinstimmung mit *Sequoia sempervirens* Endl. ist bereits von Gothan nachgewiesen worden."

Plate 9, fig. 12.—Transverse section. Portions of three annual rings are shown. The characteristic large, resinous, parenchyma cells scattered through the crushed wood are evident, as are also the strongly differentiated zones of spring and summer wood.

Fig. 13.—Tangential section. This figure is included to show a mass of thick-walled resinous parenchyma which is probably related to a slight traumatic disturbance. This is seen at the right of the figure, while at the left the more normal state of the parenchyma is visible.

Fig. 14.—Radial section; ray detail. Crossing the center of the field runs a ray five cells deep, and in almost every tracheid-field are seen one or two small circular to oval oöpores. Running vertically is a row of wood-parenchyma cells while on the tracheids are evidences of the bordered pits.

Podocarpoxylon washingtonense, sp. nov.? From Tertiary deposits, banks of Salmon Creek, Toledo, Washington.

Podocarpoxylon McGeei (Knowlton) Sinnott and Bartlett.

Cr. Rar. N. J. 1.6. and 1.4.

A.R. Defined by narrow zones of denser wood.
R.C. Not seen.
W.R. Slightly resinous, mostly uniseriate but not rarely with certain cells doubled. Rays rather widely varying in depth, from few to over thirty cells; narrow and straight; lateral pits one (two to three) oöpores in the summer wood, bordered, and with linear upright pores. Rarely lateral fusions are seen producing a lattice-like oöpore; other walls smooth.
W.P. Present; resinous; diffuse.
T. Narrow with uniseriate spaced or sometimes contiguous pits separated by bars of Sanio; pits rather uncommonly biseriate and opposite. Resinous diaphragms not uncommon.

The wood here described,—a well-preserved specimen,—has somewhat the "feel" of an araucarian conifer. In its tracheid pitting it is brachyoxyloid, *viz.*, the pit arrangement varies from scattered and spaced to contiguous and flattened; in a few cases I have detected alternate biseriate pits. Another araucarian feature of less importance is the not uncommon appearance of resinous diaphragms in the tracheids. Yet these araucarian characters cannot stand before the common condition of opposite pits and unmistakable bars of Sanio. The latter are exceptionally well developed on the large tracheids. All in all we seem to see in this wood an abietean type which is inclining in the araucarian direction and at the same time showing a ray character commonly held to be a podocarp feature. The reference to *P. McGeei* seems almost certain. Sinnott and Bartlett (1916) have diagnosed that wood as follows: "Annual rings poorly marked. Wood parenchyma present but not abundant. Tracheids usually very broad, their radial walls provided with large bordered pits in one or more rarely two rows, pits in the latter case opposite. So-called 'bars of Sanio' well developed. Pits from tracheid to ray generally one or two to the crossing field, large. Pore from rather small and obliquely vertical ('podocarpoid') to very large ('eiporig'). Rays thin-walled, pitless, frequently biseriate, and in many cases exceedingly tall, often attaining a height of sixty or more cells.

"Localities: Central High School and Meridian Hill Park, Washington, D. C.

"Horizon: Patuxent. (Lower Cretaceous.)"

A close comparison between the foregoing description and the diagnosis of our own specimen shows that the only differences are such as might well be due to the more robust character of the Patuxent wood. Sinnott and Bartlett, however, speak of another specimen collected near Montella, D. C., that possesses narrower tracheids, etc., and they suggest a relationship to *Cupressinoxylon Wardi* Knowlton. Its resemblance to *P. McGeei*, however, is so close that they do not separate it. Now the differences are possibly only those which separate trunk and branch wood and into the latter category our own specimen probably falls. Thus *P. McGeei* has rays as deep as sixty cells; in our specimen they never run much above thirty. In the former they are largely biseriate, in the latter rarely so. Again, the former has very broad tracheids, while in our specimen they are narrow. In other respects, however, there is practical identity in detail, and preferring rather to err on the side of conservatism, we have referred it to the same species.

The discrepancy in the geological horizons is of more importance. Ours is from the Cretaceous Raritan clays; that of Sinnott and Bartlett from the Comanchean Potomac Formation. As is well known, however, there is no "lost interval" in the eastern United States between these periods, and a single Comanchean species of *Nageiopsis* (if *Nageiopsis* it be) may have persisted into the Cretaceous; but since a form "species" of wood does not necessarily mean specific identity in the Linnaean sense, it might well be that these two specimens from different horizons represent woods of two closely allied species.

The hypothesis of a podocarpoidean intermediation between the Abieteae and the Araucariaceae, which are so characteristic of Comanchean and Cretaceous deposits, gains added weight from the araucarian features of this wood, though it must not be forgotten that the "podocarpoid ray" has little systematic significance; for just such rays characterize the genus *Sciadopitys* as well as one undoubted *Dadoxylon*, not to mention many species of *Pinus*.

Under the name *Cupressinoxylon podocarpoides*, Reiss (1907) has described a Cretaceous or Cretaceo-Eocene wood from Japan with oöpores on the lateral walls of the rays. His opinion is that "da die Gattung *Podocarpus* heute eine typisch japanische Formengruppe darstellt, so war es gar nicht auffallend, wenn auch fossile Holz, entweder ihr selbst oder eine nahe verwandten angehört hatte, und auf diese Möglichkeit soll der gewählte Species-name des Holzes hinweisen." His wood seems to be closely related to the American species.

It is becoming apparent that in the Cretaceous period there was a strong similarity between the coniferous floras of eastern America and Japan. Thus *Brachyoxylon* (*Yezonia*) (Stopes and Fujii, 1910; Jeffrey, 1910) is a common wood in each country, and there is probable identity between our *Geinitzia Reichenbachi* (Geinitz) Hollick and Jeffrey and the Japanese *Cryptomeriopsis antiqua* Stopes and Fujii; while between *Podocarpoxylon McGeei* and "*Cupressinoxylon*" *podocarpoides* the resemblance is so evident as to declare a close relationship. Reiss' specimen should now be transferred to the genus *Podocarpoxylon* Gothan.

Plate 9, fig. 15.—Tangential section. Here the uniseriate rays are shown, one of them being twenty-five cells deep; and in addition one can see evidences of tangential pitting on the tracheids proving that this is summer wood.

Fig. 16.—Radial section. About one-half of the photograph is covered by a ray in which the oöpore character of the lateral pits is evidenced. The section, however, was taken through the summer wood and hence light borders sometimes appear. The tracheidal pits show up clearly, but the bars of Sanio are practically wanting in this particular field. In *Plate 10, fig. 17*, however, taken from another point on the same slide, the most skeptical cannot doubt the presence of these bars. The evident bars along with the prevalent opposite pitting wholly justify the reference to a non-araucarian affinity.

Plate 10, fig. 18.—This is introduced to illustrate a not uncommon condition of pitting in this wood. It is seen to approximate the araucarian condition.

Podocarpoxylon McGeei (Knowlton) Sinnott and Bartlett. Specimens collected from Cretaceous Raritan Clays, Matteawan, New Jersey.

Podocarpoxylon dakotense, sp. nov.

Cr. Lar. N. D. 3.1.

A.R. Present, summer wood a narrow zone of some three to six tracheids.

R.C. None.

W.R. Uniseriate, sparsely resinous, two to twelve cells deep, lateral pits usually one large, oval, oblique oöpore per tracheid-field; in the summer wood oculipores possessed of slit-like openings.

W.P. None, but certain tracheids occluded with gum or resin.

T. Of medium diameter with thick walls and rounded lumen; summer tracheids of equivalent wall-thickness throughout, only varying in their size and tangential broadening; bordered pits uniseriate, usually spaced, but sometimes partly contiguous and flattened; mouths of pits extended as slits to their borders; no bars of Sanio seen.

The specimen is a cylindrical branch and this should not be forgotten in considering its anatomical features. It is about 2.5 cm. in diameter, charred and in a fair state of preservation. Through its combination of dense wood, lack of parenchyma, ray-cells with large oöpores and somewhat brachyoxyloid pitting it is a distinctive specimen. Whether the resinous tracheids are a normal feature or an artifact cannot be determined, but they are not obviously related to the rays as in the araucarians. The bordered pits are variable in size and distribution as well as in contiguity. They may be uniformly distributed over the whole length of a tracheid or show but three or four in the same region. In nearly all cases their mouths are extended as slits to the border of the pit, and thus it happens that when two are crossed the evident aperture of the pit appears squarish. The oöpores of the rays are correlated with these oblique mouths. The whole specimen is abundantly traversed with fungal hyphae whose tiny borings are thickly strewn over the tracheids. Bars of Sanio have probably been obliterated by decay.

There is no wounded area to prove the point, but we are inclined to believe that this twig may have belonged to one of the many "sequoias" which so characterize this epoch. The absence of wood parenchyma may be a recapitulatory feature. The fossil sequoias seem to be closer to the pines than do the modern species and the absence of parenchyma in young wood would not be surprising.

Podocarpoxylon dakotense, sp. nov. From Cretaceous Laramie strata, Sentinel Butte, North Dakota. Lignite mine.

SEQUOIOXYLON, GEN. NOV.

Cupressinoxylon Göppert (in part), Monogr. der fossil. Coniferen, 1850.

Annual rings strongly developed; contrast between spring and summer wood very marked. Resin canals wholly traumatic and in one or both directions. Wood rays with a few oculipores or oöpores on the lateral tracheid-field; other walls either smooth or sparingly pitted. Resinous wood parenchyma present, diffuse, sometimes confined to the summer wood. Tracheids with one to several rows of bordered pits separated by bars of Sanio, and when in more than one row, opposite.

Sequoioxylon montanense, sp. nov.

Cr. Lar. Mont. 1.1.

A.R. Very marked because of the abrupt transition between spring and summer wood and the extreme contrast between the two in size of cells; summer wood only two to ten cells thick.
R.C. Traumatic in both directions.
W.R. Uniseriate, delicate, few to twenty cells deep; the cells elongate vertically, and tangentially rather narrow; the lateral tracheid-field with from one to four oöpores with oval to circular openings.
W.P. Not abundant, and confined to summer wood.
T. Striking variation between tracheids of spring and summer wood, both as to size and wall-thickness. Bordered pits in from one to four rows, remarkably small; when in more than one row, strictly opposite; bars of Sanio well developed; pit mouths circular.

In considering this, the first species of an extremely interesting set of woods from the middle West, it is necessary to indicate not only the very evident sequoian features but also certain characters in which these ancient woods differed from those of more modern time. First of all it should be pointed out that they are, comparatively speaking, a modern group, for we have found no trace of such woods among strictly Cretaceous deposits. In their very coarse texture, with the surprising difference in wall-thickness between spring and summer tracheids, in the diffuse wood parenchyma, and in their traumatic resin canals, these woods show striking similarity to that of the living Sequoias. Their ray-pitting is but slightly different and only such as might characterize various closely related species of a rich "sequoian" complex. The lateral ray-pits of all the living species of the genus show a tendency to approach the oöpore condition,—for their oval oculipores with somewhat horizontally directed axes very commonly lose almost the whole border. It is in their resin canals, however, that the ancient forms show their greatest difference. This difference has much theoretical significance. For whereas in the living *Sequoia washingtoniana* (Winsl.) Sudw. and *S. sempervirens* (Lamb.) Endl., only vertical canals return as a response to traumatic stimuli, in the four Tertiary species described here the same causes induce the formation of canals in both directions. The only logical explanation of this discrepancy is to admit that the ancient forms stand closer to their abietean ancestors than do the modern ones.

Kräusel (1918) has remarked concerning the Japanese *Sequoia* described as *S. hondoensis* by Miss Yasui (1917) that: "Wenn Yasui in der von ihm [*sic!*] beobachteten Harzgangbildung eine neue Bekräftigung von Jeffrey's Ansichten über die Stammesgeschichte der Koniferen sieht, ist er in Irrtum, da sie den bereits bekannten Tatsachen nichts hinzufügt." I feel that the same criticism cannot be made of the facts which I have set forth above. Along this same line it is of interest to note that the Miocene *Taxodioxylon sequoianum* has only vertical resin canals, which of course puts it on the level with the living Sequoias. This would be expected, since it is more recent than our Cretaceo-Eocene species.

Specific details of the wood under consideration may now be briefly discussed. The specimen is heavily charred and because of this it has been difficult to get cross-sections thin enough to permit one to distinguish accurately between tracheids and wood parenchyma. But it is clear that scattered through the summer zone are certain cells with larger lumen in which evidences of granular matter are not infrequent. In tangential aspect undoubted chains of parenchyma cells are often visible which seem to be wholly normal structures. They are filled with resin drops, a feature held by Penhallow (1907) to be diagnostic of *Sequoia* woods.

The wood rays are remarkably small in the tangential aspect; not rarely they broaden out in the middle part to receive one, or sometimes two small traumatic canals. The horizontal canals are not infrequently found in transverse section also, and in one case I was able to trace a certain canal through six annual rings. That they are really traumatic in nature cannot be doubted since they have been seen to join with the vertical canals which lie in tangential zones. The latter can be studied in both cross and longitudinal aspect and show themselves to be moniliform and tylosed. The ray-pitting is almost of the type denominated "podocarpoid" by Gothan. In the pitting of the spring tracheids there is witnessed another striking feature, for their radial walls have given plenty of room for display; triseriate pitting is common and even quadriseriation is not lacking. The pits are small and circular with round mouths, and are separated by bars of Sanio.

Any attempt to compare this wood with other and similar fossils which are described in the literature is almost hopeless, since most of them have been included in the large and vague genus *Cupressinoxylon* and the most important character of all, the wound resin canal, has not commonly been observed.

Penhallow has differentiated the genus *Sequoia* and among the four species which he includes in his work on North American Gymnosperms (1907), three at least have traumatic resin canals. One of these, however, *S. Penhallowii* Jeffrey, is probably not a *Sequoia;* its reference to the genus was based on Penhallow's diagnosis. But Professor Jeffrey now inclines to the opinion that it is in all probability a primitive species of *Abies.* There remain then the two species: *S. Langsdorfii* (Brongniart) Heer, and *S. Burgessii* Penhallow. We believe that in one of our own species we have rediscovered *S. Burgessii. S. Langsdorfii,* on the other hand, must remain in some doubt, since the lateral ray-pits were not seen in it. But identity with the specimen here being considered, is ruled out on other grounds, for *S. Langsdorfii* has its "resin-cells rather numerous throughout the growth ring," which is not the case with our specimen.

Cupressinoxylon Holdenae Seward (1919) from the Eocene London Clay has shown only vertical resin canals.

Platen (1907) has described three woods from the western United States which undoubtedly fall into the genus *Sequoioxylon.* These are: (1) *Cupressinoxylon taxoidiodes* Conwentz from California Tertiary deposits, which possesses both vertical and horizontal (?) canals, very tall rays with from one to six pores per tracheid-field, and bordered pits in from one to four rows. Of this wood he says, "Die beiden recenten Sequoienspecies sind auf Grund ihrer Holzanatomie nicht zu unterscheiden." (2) *C. Pannonicum* (Unger) Felix is from Tertiary deposits of Nevada. It has vertical traumatic resin canals; two to five elliptic pores per tracheid-field, which are in one row on the inner ray-cells, and in two rows on the outer. The wood parenchyma is abundant and there are about two rows of bordered pits on the tracheids. And again he says, "Das Holz dürfte einer *Sequoia* oder *Taxodium* entstammen." (3) *C. distichum* Merkl. has not shown resin canals but it is probably a *Sequoioxylon* also; while last of all *Taxodium Credneri* Platen, from Miocene deposits has traumatic canals, very deep rays which are sometimes forked ("gegabelte"), and clearly manifested transitions from septate tracheids to wood parenchyma. Platen does not speak of the occurrence of oöpores on the rays of these species though Gothan's use of oöpores as a diagnostic detail was published two years before his thesis, hence we may infer that they were not a striking feature of the woods. We are not able to identify any of our species with these of Platen, which is not surprising, since his specimens come from later horizons.

It is of interest to see that xylopalaeontological study confirms the evidence supplied by impressions of the existence in America in the Tertiary period of a widely dispersed group of conifers which were of sequoian affinity. Such woods have now been found in California, Nevada, Montana, North Dakota, Colorado, Yellowstone Park and Saskatchewan.

Plate 10, fig. 19.—Transverse section. Here is shown the extreme contrast between spring and summer wood. The spring zone is so exiguous that it has been unable to withstand the pressure to which it was subjected and the consequent shear is very evident. The wood parenchyma is not well seen in this figure.

Fig. 20.—Tangential section. This was taken through the summer wood since it is impossible to get a strictly tangential section through the spring wood because of the distortion. The uniseriate rays are evident, and a little to the left of center is seen a dark resinous plate held in a cavity which marks the position of a row of parenchyma cells.

Fig. 21.—Transverse section. In this figure we see the traumatic resin canals. The spring wood is far more collapsed than in Fig. 19; but since the resin canals are in the summer zone they are not profoundly disturbed. A little to the right of center a horizontal canal is seen crossing the vertical row. There can be no doubt as to the traumatic nature of these canals. They are filled with yellow vesicles of resin and when cut longitudinally manifest the moniliform appearance common to such traumatic structures.

Fig. 22.—Radial section. The distortion makes it difficult to get any clear-cut radial view, but this figure brings out the heavily pitted tracheids. On the most prominent one of them, near the center, lie three rows of small pits. In the upper left-hand corner a bit of a ray is visible with the lateral tracheid-fields marked with oval oöpores.

Fig. 23.—To show the bordered pitting more sharply, this view, similar to the last, is introduced.

Sequoioxylon montanense, sp. nov. Charred wood from Cretaceous Laramie deposits, bank of the Missouri River, Culbertson, Montana.

Sequoioxylon dakotense, sp. nov.

Cr. Lar. N. D. 5.3. and 5.1.

A.R. Very marked through the contrast of spring and summer wood. The latter dense and from two to eight cells in thickness, the former thicker and made up of very large thin-walled cells, thus occupying a zone ten times as broad as that of the summer wood.

R.C. Traumatic in both directions; the vertical in tangential rows and conspicuous; the horizontal in fusiform rays, small and rare.

W.P. Present throughout the ring but not abundant.

W.R. Usually uniseriate, few to twelve or more cells deep, averaging about six or eight; narrow, resinous; lateral pits oval, of medium size, oöpores, or sometimes with slight borders; two or more per tracheid-field, the long axes horizontal or slightly oblique; other walls smooth.

T. Spring tracheids very large and with from one- to four-seriate large, round pits, when in more than one row the pits strictly opposite; bars of Sanio strongly developed.

This wood is striking in all its microscopic features. The strong contrast between spring and summer wood, the numerous vertical traumatic canals and the abundant large pits on the tracheids are all sequoian features. The chief character which separates it from the last species is the far greater size of the bordered pits. This cannot depend on the greater age of the wood for both are from the trunk wood of large trees and the tracheids do not vary much in diameter. The pits of *S. montanense*, however, have a peculiar dwarfed appearance. At one point in the sections, I have detected a zone of septate tracheids in the summer wood. It will be recalled that Platen noted the same in the fossil wood which he named *Taxodium Credneri*. It is of interest, however, as a manifestation of the general principle that traumatic stimuli lead to reversion. For we hold that this condition of tracheid septation antedated the condition of true parenchymatization, and later on we shall show the notable confirmation of this theory which has come to light. The same reasons which led us to set up *S. montanense* as a new species apply in full to this specimen also.

Plate 10, fig. 24.—Transverse section. Across the field runs a row of vertical traumatic resin canals.

Plate 11, fig. 25.—Tangential section. In this figure a vertical canal with its secretory parenchyma is shown in longitudinal section. Its moniliform appearance is eminently characteristic.

Fig. 26.—Radial section. The extreme brittleness of the carbonized tracheid walls is evidenced by the shattered appearance of this section. On the left, portions of several tracheids show well the bordered pits.

Fig. 27.—Radial detail of tracheid. This figure is introduced to show not only the typical opposite pitting but also the unmistakable bars of Sanio.

Fig. 28.—Radial detail of ray. That the lateral ray-pits are of the type held by Penhallow to be diagnostic of the genus *Sequoia* is evident. It should be noted that they closely approach the oöpore condition and that their axes are decidedly oblique. In the central row of ray-cells a tangential wall is visible; it is somewhat thinner than the horizontal ones.

Sequoioxylon dakotense, sp. nov. Charred wood from Cretaceous Laramie deposits; Wilton, North Dakota; lignite mine.

Sequoioxylon laramense, sp. nov.

Cr. Lar. Mont. 2.4.

A.R. Very strongly marked.
R.C. Traumatic in both directions.
T.R. Uniseriate, not often more than ten cells deep; cells oval to circular; lateral pits one or two (three), round oöpores.
W.P. Abundant in the summer wood, filled with resin drops.
T. Pitting uni- or biseriate, when in two rows, opposite; pit mouths round; bars of Sanio present; tangential pitting abundant at end of annual ring.

This wood is in some respects similar to *S. montanense,* for it has traumatic resin canals in both directions, wood parenchyma in the summer wood, and oöpores on the ray-cells. The rays differ, however, in the larger size of their cells and the wood parenchyma is far more abundant. This last character also differentiates it from *S. dakotense.* Again this species has not the peculiar small pits which characterize the tracheids of *S. montanense.* The traumatic resin canals are very common; scarcely a block of wood can be sectioned but shows long tangential bands of these extremely well-developed structures. They are surrounded by strongly pitted parenchyma and are often somewhat tylosed. The horizontal canals, on the contrary, are rare. They are best seen in the tangential aspect of the summer wood, for the spring wood is usually crushed and sheared. They are lenticular in outline and not abnormally large. The wood rays, as stated in the diagnosis, are of the ordinary coniferous type and bear from one to three oval to circular oöpores on the lateral field. Wood parenchyma is plentiful in the summer wood. In transverse section its cells are distinguishable among the heavy charred summer tracheids by their larger lumen and drops of resinous secretion. In tangential aspect the same features, along with their cross-walls and simple pits, show clearly. Here, then, is another Montanan *Sequoioxylon* which was found at a station about thirty miles north of the one whence came *S. montanense,* but in deposits of the same age. Its evident resemblances have been pointed out and the two species were probably closely related. Both belonged to a group not so far removed from the Abieteae as are the living Sequoias.

Plate 11, fig. 29.—Transverse section. Here are exhibited not only the great contrast between spring and summer wood, so characteristic of all these sequoian species, but also a row of vertical and tylosed resin canals running through the middle of the field and crossed at right angles by a horizontal canal which is best seen moving through the uppermost zone of summer wood where it broadens out.

Fig. 30.—Transverse section. This figure is included in order that the wood parenchyma may be shown. Scattered through the dense zone, whose uncrushed condition is evidently dependent on the very great thickness of its tracheid-walls, one can see cells with larger lumen than the majority which surround them; these are wood-parenchyma cells. In the lower right-hand part of the photograph three of these may be seen to have resinous contents.

Fig. 31.—Tangential section. This specimen is so heavily charred that it is difficult to get a section that will show details. However, in the center of the field lies a fusiform ray with a horizontal resin canal containing vesicular resin. Above and to the left of this the appearance of tangential pits on the tracheids proves that this is summer wood. To the right of the resin canal several parenchyma cells with resin drops are seen.

Sequoioxylon laramense, sp. nov. From Cretaceous Laramie deposits, Plentywood, Montana; lignite mine.

Sequoioxylon (Sequoia) Burgessii (Penhallow) n. comb.

Cr. Lar. Col. 2.5.

A.R. Well developed, zone of summer wood thin.

H.C. Horizontal canals traumatic, very large, lenticular and blocked with tyloses. Vertical traumatic canals not seen. The lenticular areas often appear to contain two canals.

W.R. Uniseriate, few to fifteen cells deep, not particularly resinous, lateral pits from one to three oval to circular oöpores per tracheid-field; other walls smooth.

W.P. Present and confined to the summer wood, slightly resinous.

T. Pits uniseriate, or opposite biseriate or triseriate and separated by bars of Sanio; mouths large and oval.

The most striking feature of this wood is the presence of the extremely large resin canals bounded by an epithelial lining one or two cells thick. Into the lumen are thrust large bladdery tyloses. These great resin canals are also often seen in cross-section and it is sometimes possible to follow them through many annual rings since their great size offsets the disjunctions which a plane section would cause in a small and sinuous canal. Vertical traumatic canals have not yet been seen, but in one section a tangential band of resinous parenchyma is visible which may well contain resin canals whose lumina have been obliterated by crushing. The possession of such extremely large resin canals is not a sporadic feature. They have been noted in several European woods. For instance, they occur in *Protopiceoxylon* Gothan (1910) which is said to have normal resin canals in addition. Gothan's text-figure of one of these traumatic canals closely resembles the canals of our own specimen even to its double nature. The great "Spindelmarkstrahlen" of *Anomaloxylon* may belong to the same category. An identity of our species with it is, however, completely excluded on all the other characters, for it is very doubtful if woods with "Hoftüpfel meist einreihig, oft gedrängt und alternierend, unter- und oberwarts abgeplattet (araucarioid)," can be relegated to the Abieteae.

Pityoxylon silesiacum Göppert from Tertiary deposits of Japan is another wood that these enormous resin canals. Neither are they unknown in living genera, for we have shown sections of an abnormal piece of *Picea mariana* (Mill.) BSP. which are spotted extraordinarily large canals of this character.

Under the name *Sequoia Burgessii,* Penhallow has described a fossil from the Eocene of Porcupine Creek and Great Valley groups which is either identical with or very closely related to our specimen. Vertical resin canals seem to be wholly wanting, but in tangential aspect there are seen large resin passages containing tyloses. In other features also the wood agrees closely with our own and we feel justified in referring the latter to the same species.

Plate 11, fig. 32.—Transverse section. Running obliquely through the sheared zone of wood is seen a large tylosed resin canal.

Plate 12, fig. 33.—Tangential section. In this photograph a canal similar to the last is seen in tangential aspect. In the large lenticular ray lie two resin cavities surrounded by a common mass of secretory parenchyma.

Fig. 34.—This is similar to the last but a little to the right of center are seen several rows of wood parenchyma.

Fig. 35.—Radial detail of ray. Even as in *Sequoioxylon dakotense* the sequoian ray-pits with their approximation to the podocarpoid condition are evidenced.

Fig. 36.—Radial detail of tracheid. The bordered pitting has a resemblance to that of *Sequoioxylon montanense.* The traumatic canals, however, fully justify a separation from that species.

Sequoioxylon Burgessii Penhallow. From Cretaceous Laramie deposits, Colorado Springs, Colorado; lignite mine.

BRACHYOXYLON Hollick and Jeffrey.

Araucarioxylon Kraus, in part.
Brachyoxylon Hollick and Jeffrey, Mem. N. Y. Bot. Garden, vol. 3, p. 54, 1909.

Annual rings usually visible; traumatic resin canals present. Wood rays thin-walled with few to many small oculipores on the lateral tracheid-field. Wood parenchyma absent. Tracheids beset with scattered or contiguous pits, when biseriate always alternate. Bars of Sanio absent. Pith large and interspersed with stone cells.

Brachyoxylon woodworthianum, sp. nov.

Cr. Rar. Mass.

A.R. Obscure.
R.C. Traumatic in the vertical direction.
W.R. In twig wood, uniseriate, from one to three cells high, resinous; in older wood uniseriate or biseriate, two to twenty cells high, somewhat resinous; traumatic rays thick-walled with abietineous pitting; lateral tracheid-field with few to many oculipores with elongate and slit-like openings.
W.P. None.
T. Pits in the twig wood scattered and uniseriate; in the older wood scattered or contiguous, uniseriate or more rarely alternate and biseriate. Bars of Sanio not present. Resin-filled tracheids confined to twig wood and usually definitely related to the rays.
M. With scattered stone cells.

This interesting wood was found on the island of Martha's Vineyard by Professor J. B.

Woodworth and was turned over to me for study. The specimen consisted of a large piece of lignitized trunk wood in which there was very fortunately embedded a small twig so well preserved that it could be studied in detail and its structure compared with that of the adult stem wood. To the naked eye there were visible on the large fragment about one hundred rings; these can also be seen, but not so well, under the microscope. The wood is somewhat crushed but the histological details are well preserved. The presence of traumatic resin canals and the absence of parenchyma show that it belongs to the subtribe Brachyphylleae.

The traumatic rays deserve some consideration, since, in addition to the significant possession of abietean pitting, their cells often contain nuclei. It is in the comparison of twig and trunk wood, however, that the greatest interest lies. The differences between these two are profound enough to relegate the portions to two different species, were their anatomical connection unknown. The twig possesses low, non-resinous rays. In cross-section these are often seen to be bordered by resin-filled tracheids, although the latter sometimes spread out in fan-shaped masses. But perhaps the most significant feature is the abietean character of the tracheidal pitting, *viz.*, abietean in the fact that the pits are scattered and rarely contiguous. They lack, however, any trace of intervening bars of Sanio. The pith contains sclerites and the primary wood is of the ordinary coniferous type. The earlier tracheids possess a much closer type of pitting than do those which soon follow, and an even more significant feature is sometimes seen, for certain of the earliest-formed tracheids are beset with true *Dadoxylon* pitting. The trunk wood has highly resinous rays, no resin-filled tracheids, and almost exclusive araucarian pitting, which even takes on alternating contiguity.

The lucky discovery of twig and trunk wood of a single *Brachyoxylon* species permits us then to realize that scattered pitting is not necessarily an abietean feature. If a Cretaceous wood lacks bars of Sanio, and if at the same time the rays are of the araucarian type, it must be referred to the Araucariaceae. This warning is needed since some doubt has been expressed concerning the correctness of former diagnoses of certain woods from the Raritan deposits. In many cases the remains were small but highly important axes, such as those of cones and leafy twigs, and the pitting was often found to be similar to that of the twig wood of the *Brachyoxylon*, sp. just described. Hence one might be easily led to assume the abietean or cupressean nature of the fragments, since he might not realize the value of ray, or pith, or traumatic characters upon which the conclusion as to the correct affinity of the specimen was founded.

Plate 12, fig. 37.—Transverse section of adult wood. The section is not highly magnified but the absence of marked annual rings is to be noted. The rays have largely lost their walls, but their course is indicated by the resinous inclusions.

Fig. 38.—The wood of this section came from the same block as the last but it has suffered far more from shear. The significant feature is the row of resin canals running across the field; they manifest the usual appearance of such traumatic reversions.

Fig. 39.—Tangential section. On one side of this figure three great traumatic rays appear while on the other side rays of the normal character are profusely scattered. The traumatic cells have the thick and pitted walls held to be characteristic of the Abieteae.

Fig. 40.—Radial section. Here is shown a feature to which attention was called above, namely, the presence of nuclei in the traumatic ray-cells. Preserved in the resinous matrix, they have retained a startlingly life-like appearance. The heavily pitted rays are seen to better advantage also and the uniseriate tracheidal pitting is in evidence.

Plate 13, fig. 41.—Radial section. Tracheidal detail, to show the more typical "araucarian pitting" of the wood.

Fig. 42.—Radial section of twig. This photograph was taken at the junction of medulla and primary wood. At the right is the dark resinous mass of the pith; on its left-hand border lie two small tracheids with spiral thickenings, then follow two tracheids with reticulate markings, and next to these the most significant element of all,—a tracheid beset with alternating, mutually flattened pits. It is a striking case of the retention of true *Dadoxylon* pitting.

Fig. 43.—That the type of pitting just shown is not the normal type of the twig tracheids is proved by this figure taken at some distance from the center, for here there is no evidence of crowding, but instead the scattering of pits commonly held to be characteristic of the Abieteae. The ray-pits are also clearly visible on the low ray, but their spindle-like form is due to the partial decay which has also produced striae and cracks in the walls of the tracheids.

Brachyoxylon woodworthianum, sp. nov. Lignite from the island of Martha's Vineyard, Massachusetts, Cretaceous, Raritan deposits.

Brachyoxylon comanchense, sp. nov.

Co. Tex. 1. 41., 1.11.

A.R. Delimited by a row of tracheids two or three cells wide; annual rings often variable in density.
R.C. Traumatic and vertical only.
W.R. Uniseriate, from one to six cells deep, cells almost circular, slightly resinous; lateral pits up to twelve per cross-field, tiny, circular to oval in outline.
W.P. None.
T. Very variable in size in different zones, radial pits usually contiguous and flattened, rarely biseriate; on large tracheids often horizontally elongate and with large oval mouths.
M. Containing sclerites.

Two specimens of this wood are at hand: one of these, no. 1.41, is from a young branch, while no. 1.11 is from trunk wood. In the first specimen two lateral twigs are making their exit, thus permitting a view of the sclerotic pith-cells. Its tracheids are also comparatively narrow and its pits small. In the other the very large tracheids are covered with great oval pits. The difference in size of the tracheids of various annual rings is often considerable and suggests rather extreme climatic variation. The traumatic resin canals lie in a tangential zone which on one side can be seen gradually to fade out into a strip of heterogeneous and partially parenchymatous tissue. Certain cells in this area are crossed with walls bearing bordered pits, and thus seem to be true septate tracheids similar in nature to those which occur as a normal feature in the genus *Telephragmoxylon* at the end of the annual ring. Such a septation of tracheids possesses little significance, however, when confined to wounded regions, since it is found in almost all genera of woods. The lumen of the traumatic canals is usually partially occluded by resinous and simply pitted parenchymatous tyloses. In radial sections their moniliform character is seen along with the modified tracheidal tissue which surrounds them. The ray-cells are quite typically araucarian, but their pit openings are far less slit-like than in many true *Araucarioxyla* or certain other *Brachyoxylon* species.

Specimen no. 4.13 is doubtfully included with the above; its bordered pits have slit-like mouths and the oculipore openings, too, are more elongate than is the case in the other two specimens.

Plate 13, fig. 44.—Here are shown the well-developed resin canals invaded by tyloses, and also the annual rings which are more strongly marked than in *Brachyoxylon woodworthianum* though even here the summer wood is very slightly differentiated.

Fig. 45.—A portion of a resin canal in radial aspect; it lies in the center of the field and is seen to be moniliform and tylosed. On various tracheids the contiguous uniseriate pits are visible.

Fig. 46.—Radial section, ray detail. Five tiers of ray-cells appear in this photograph, and on the lateral tracheid-field are seen the numerous tiny circular to oval openings of the oculipores.

Brachyoxylon comanchense, sp. nov. From Comanchean deposits, Cottondale, Texas; bank of stream.

Brachyoxylon raritanense, sp. nov.

Cr. Rar. N. J. 2.7.

A.R. Poorly marked but sometimes delimited by a slight narrowing of tracheids.

R.C. Not seen.

W.R. Few to fifteen cells deep, not highly resinous, lateral walls with from one to nine oculipores per tracheid-field, these small with slightly elongate oval mouths, not usually slit-like.

W.P. None.

T. Often resin-filled; bordered pits typically brachyoxyloid, *i.e.*, contiguous and flattened, to scattered uniseriate; mouths oval and crossed; biseriate pitting not seen; tangential pits present at end of annual ring.

This wood is a pyritized charred specimen but it is nevertheless well preserved. The rays have largely lost their horizontal and terminal walls, but their lateral area is clearly imprinted on the tracheids, thus offering all the essential markings. In tangential aspect the cavity which now occupies their previous position has often been widened out to a fusiform shape due to the expansive effect of the crystalized pyrites. The lack, or poor development of annual rings is to be noted. This is not a hard and fast *Brachyoxylon* character, for in *B. comanchense* from Texas rings are clearly defined though the summer wood is meager. This cannot be a feature due to the geographical or geological disjunction of the species, since in *Paracupressinoxylon trinitense* from the same level in Texas, rings are wholly absent. The lateral ray-pitting is clearly discernible and in the form of the pit openings this species resembles *Brachyoxylon notabile* Jeffrey. Most of the bordered pits are contiguous and flattened though spacing is not rare. I have not detected biseriation even at the ends of tracheids.

Plate 13, fig. 47.—Transverse section to show the prevalent resin-blocked tracheids.

Fig. 48.—Radial section to illustrate the distinctive pitting. On one side is a ray on whose lateral tracheid-fields the pits stand out sharply. The small, square, dark spots scattered through the tracheids are pyritohedrons of iron disulphide.

Brachyoxylon raritanense, sp. nov. Collected in Cretaceous Raritan Clays, Matteawan, New Jersey.

PARACUPRESSINOXYLON Holden.

Paracupressinoxylon Holden, Annals of Bot., vol. 27, p. 537, 1913.

Wood parenchyma present and diffuse. Ray-cells thin-walled and pitted only on the lateral walls with a few oculipores. Resin canals present or absent. Tracheidal pits usually as in *Brachyoxylon*. Bars of Sanio not present.

Paracupressinoxylon cupressoides Holden.

Cr. Rar. N. J. 2.5.

A.R. Obscure; summer wood only a few cells thick and with slightly smaller tracheids.
R.C. Not seen.
W.R. Mostly uniseriate, usually from two to twelve cells deep, slightly resinous, lateral pits one or two oculipores per tracheid-field with lenticular elongate mouths.
W.P. Abundant, resinous, diffuse. Wounded areas exhibit strongly sclerotic wood parenchyma but no resin canals either at or near the wound.
T. Pits mostly uniseriate, spaced; mouths broadly lenticular.

The wood, in the larger use of the term, is a *Cupressinoxylon*, since in addition to the abundant wood parenchyma it possesses a wounded area in which there is no trace of traumatic resin canals. In this particular specimen the rays are often destroyed by pyrites which have widened their cavities into lenticular gaps. The wood-parenchyma cells are large and filled with vesicular resin; they stand out sharply in all the sections, because of their darker color. Part of our specimens came from a large, much-pyritized stump in a clay-pit of the Avery Brick Company at Matteawan, New Jersey. The wood is traversed by numerous worm borings, and the cylindrical cavities are bordered with wound parenchyma and are often filled with amber-like resin.

We have compared this specimen with the descriptions and figures of *Paracupressinoxylon potomacense* Sinnott and Bartlett, but there are differences between them which make strict identity impossible. That species has low rays (one to three cells high) and traumatic resin canals, while traumatic stimuli in our specimens lead, so far as we have seen, to the formation of parenchyma only. Miss Holden (1914), however, has described from Cliffwood, New Jersey, fragments of lignite identified with *Paracupressinoxylon cupressoides* Holden which she discovered in the Jurassic deposits of Yorkshire (Holden, 1913b). Our wood is undoubtedly the same, for even as in that species the rays are thin-walled and no resin canals have been seen. As to Holden's *Paracupressinoxylon cedroides*, we are of the opinion that the possession of thick-walled abietean rays is a character sufficient to justify the founding of a new genus. Since the thin-walled *Paracupressinoxylon cupressoides* was published at the same time as the thick-walled *P. cedroides* the rule of priority does not interfere with the transference of the latter to a new genus for which we propose the name *Metacupressinoxylon*. The Yorkshire wood now becomes *Metacupressinoxylon cedroides* (Holden) n. comb. The generic diagnosis follows.

METACUPRESSINOXYLON, GEN. NOV.

Wood parenchyma present and diffuse; traumatic resin canals present. Wood rays thick-walled and heavily pitted with small lateral oculipores. Tracheids beset with uniseriate spaced, or biseriate alternating, bordered pits. Medulla homogeneously parenchymatous.

Since making the above change we have been gratified to find that Professor Seward writes, "The species *P. cedroides* should not, in my opinion be included with *P. cupressoides* in one genus."

Plate 14, fig. 49.—*Paracupressinoxylon cupressoides* Holden. This figure shows the presence of wood parenchyma in the unmodified wood below, while the wounded area is introduced to prove that a traumatic stimulus does not induce the formation of a schizogenous resin canal, for only sclerotic parenchyma intermixed with abundant thin-walled resinous cells is visible.

Fig. 50 is from a radial section through one of the borings of which we have spoken. Bordering the wound there can be seen a dark band of resinous parenchyma, while farther out the highly disturbed tracheids of the wood are visible.

Paracupressinoxylon cupressoides Holden. Specimens collected in Cretaceous Raritan clays, Matteawan, New Jersey.

Paracupressinoxylon trinitense, sp. nov.

Co. Tex. 2. 123.

A.R. Seemingly quite absent. (To the naked eye faint bands are visible.)

R.C. Not seen.

W.R. Average from two to twelve cells deep, not highly resinous; terminal and horizontal walls unpitted; lateral tracheid-field with one or two oculipores with lenticular openings, these sometimes widening to oöpores.

W.P. Present but not abundant.

T. Pits mostly scattered and round with large oval mouths; bars of Sanio absent.

In cross-section this wood is very brachyoxyloid, for its tracheids are much of the same size throughout, and annual rings are not evident under the microscope. The wood parenchyma is uncommon but its presence suffices to indicate that the wood is not one of the *Brachyoxyla*. The lateral ray-pits not infrequently widen out to true oöpores. This might suggest a reference of the wood to *Paraphyllocladoxylon* Holden, but it is such a fluctuating character that we prefer to retain such specimens in a single genus.

This wood is different from most of those which characterize the Comanchean deposits of Texas. The preservation is excellent, but we have searched in vain for any evidence of the presence of bars of Sanio, and are forced to believe that they were not present. We have been very cautious about employing this piece of negative evidence alone to distinguish between abietean and araucarian woods. Here, however, there is a positive character which militates against a reference to the genus *Cupressinoxylon*, in which an abietean wood of this character would be placed. The annual rings are scarcely discernible; this is an araucarian character. That the absence of rings is not due wholly to climatic conditions is proved by the fact that other woods from the same deposits have them well developed. Taken in conjunction with the absence of bars there can be little doubt that we are dealing with an araucarian wood,—a member of the tribe Araucarieae.

Comparison with *Paracupressinoxylon potomacense* Sinnott and Bartlett (1916) is of interest since that wood is derived from the Potomac strata which are generally supposed to be of the same age as the Trinity deposits of Texas. The resemblances are extremely close and, in fact, are only such as might separate allied species. *P. potomacense* has poorly developed annual rings, uniseriate bordered pits, one or two ray-pits per lateral tracheid-field and low rays. The differences lie in the deeper rays of our specimen (up to twelve cells) with a tendency to form oöpores; and in the traumatic resin canals of the eastern species. As a parallel to *P. potomacense* we may well name our wood *P. trinitense.*

Plate 14, fig. 51.—Transverse section to show the homogeneity of the wood with the absence of annual rings and the sparsely distributed wood parenchyma.

Paracupressinoxylon trinitense, sp. nov. From Comanchean Trinity deposits, Weatherford, Texas.

TELEPHRAGMOXYLON[1] TORREY.

Synonomy as for *Araucarioxylon.*
Telephragmoxylon Torrey, Annals of Bot., vol. 35, p. 73, 1921.

Annual rings evident; resin canals traumatic in the vertical direction. Wood rays uniseriate, or partly biseriate; lateral pits from few to many small oculipores per tracheid-field, other walls thin and unpitted. Wood parenchyma none. Tracheids of two kinds: normal and septate, the latter confined to the end of the annual ring and divided into short segments by cross-walls which bear bordered pits. Radial pitting of the tracheids uni- or biseriate, contiguous and flattened; when in more than one row, alternating. Tangential pitting abundant. Medulla interspersed with masses of sclerites.

Telephragmoxylon brachyphylloides, sp. nov.

Co. Tex. 1.5. and 1.11.

A.R. Evident but not striking.
R.C. Traumatic in the vertical direction.
W.R. Uniseriate or biseriate in old wood; from two to sixteen cells deep, slightly resinous, lateral tracheid-field with few to ten small oculipores, with oval to circular openings.
W.P. None.
T. Pitting in young wood uniseriate, contiguous and flattened, in older wood often biseriate, alternate, contiguous; or sometimes in two rows, but the rows slightly separated. Pit mouths elongate, oval and crossed. Terminal tracheids of an annual ring (best seen in tangential or transverse section) septate.
M. With nests of stone-cells.

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[1] Dr. Kräusel (Paläobotanische Notizen, Senckenbergiana, vol. 3, part 5, p. 138–139, Dec. 1921) has taken exception to the genus *Telephragmoxylon* on the ground that the septate tracheids are due to traumatism. Before instituting the genus this possibility was fully considered but no evidence in its favor could be found. Surely it would be a strange thing if a tree suffered annual wounding which invoked the formation of septate tracheids at the end of each annual ring and around the whole periphery.

In an article (Torrey, 1921) published some months ago we called attention to this new wood. It is one of the most interesting we have discovered and offers a striking confirmation of a theory whose best discussion is to be found in Jeffrey's Anatomy of Woody Plants. It is there contended that wood parenchyma was derived historically from tracheids which first of all underwent segmentation and later, through loss or non-development of the secondary thickening layer, were converted into wood parenchyma. Not only does parenchyma, then, have its genesis in tracheidal tissue but its first appearance is held to have been among the summer tracheids at the ends of the annual rings, where it is in some way correlated with the resumption of active growth at the beginning of the next season. This view was derived from comparative anatomical investigation among the Abieteae, where root wood of the genus *Picea* in particular exhibits at the end of its annual ring all stages of transition from septation of ordinary thick-walled tracheids through conditions of interspersed thick- and thin-walled moieties of a single tracheid, to complete parenchymatization.

In the wood now under consideration,—a Comanchean fossil araucarian,—a stage in the septation process never before observed is strikingly manifest: at the end of the ring nearly every tracheid is crossed by diaphragms in which bordered pits are as evident as they are on the radial or tangential walls. As to the physiological significance of this phenomenon Professor Jeffrey has suggested that it might be a mechanism for retarding the rapid upward movement of water in the spring and thus facilitating its radial distribution to the developing cambium. There is no evidence whatsoever of protoplasm or other matter in these short tracheids, hence it is evident that the storage function had not yet been attained.

Wood parenchyma has originated independently in at least two coniferous lines: the pine-abietean and the araucarian. In the former the incipient stages still persist in the older genera; while among the araucarians it has originated several times. Thus it occurs fully formed in the Jurassic *Metacupressinoxylon cedroides*, its inception is witnessed in the Comanchean *Telephragmoxylon*, while it may have had a separate origin in *Paracupressinoxylon*.

If Gothan is right in assigning *Dadoxylon* (*Araucarioxylon*) *spitzbergense* Gothan to the Triassic period, we must believe that wood parenchyma is of far more ancient origin than we had supposed, but we are aware that the age of the strata in which this wood was found has been called in question. In all likelihood it is not older than the Jurassic or Cretaceous and then it takes its place in the genus *Araucarioxylon* (in the restricted sense). Gothan himself is a bit puzzled by his specimen for he says: "Diese Vorkommen [wood parenchyma] bildet für Hölzer von rein araucarioider Struktur etwas Besonderes, denn bei lebenden Araucarieen wie bei fossilen ist es nur höchst selten und nur vereinzelt zu finden, so dass es praktisch als fehlend zu bezeichnen ist." It should be remembered that among "fossilen Araucarieen" Gothan includes the *Dadoxyla*. It seems hardly probable that among the many known woods from the Triassic period which are so conspicuously characterized by the complete absence of parenchyma, one specimen only should be found with parenchyma in a diffuse condition.

As to Caspary's *Araucariopsis macractis*, which was separated from *Dadoxylon* because of its possession of wood parenchyma, the age is unknown and Gothan merely suspects that it Palaeozoic or early Mesozoic on the evidence of the "Jahresringesverhältnisse." The presen or apparent absence of annual rings, however, is a very insecure single criterion on which base the age of a wood. It is probably a true *Araucarioxylon.*

In the literature we know of only one instance in which the normal septation of the trachei at the end of the annual ring has been noted. Among the Jurassic Coniferae from Yorkshi studied by Miss Holden was a species of *Brachyoxylon* in which the same feature was seen, b the significance of the discovery was not recognized at the time. This wood should now included in the genus *Telephragmoxylon.*

The reference of our interesting genus to the Brachyphylleae is based on its wound reactio its sclerotic pith, the pitting of its younger wood, and the lateral ray-pitting which is ve similar to that of the contemporary *Brachyoxylon texense.*

Plate 14, fig. 52.—Transverse section; detail of septate tracheids. In this highly magnified view t remarkable phenomenon which sets the genus apart is seen. Stretching obliquely across the field i darker band of tracheids. The dark color is due to the fact that a lucky section has cut at least fi tracheids in succession at such a point that their cross-walls are visible. On one of these septa a pair bordered pits is clearly seen, and evidences of the same are visible on three more.

Fig. 53.—Tangential section. This section is cut slightly out of the tangential plane and incline just enough toward the transverse to exhibit the tracheids at the end of the annual ring. These run i an oblique band across the field. It can be seen that practically every tracheid is septated by doub parallel lines which represent the faces of two bordered pits from between which the middle lamella ha disappeared. Even under the low magnification it is plain that just as was evidenced by Fig. 5 (Plate there are sometimes two pits per septum.

Fig. 54.—Here under higher magnification the double pits of the septa are strikingly evident and th presence of tangential pits with which these "fragmented tracheids" are always liberally provided, i also to be noted.

Fig. 55.—Is introduced to show the araucarian nature of the tracheidal pitting of this new wood.

Telephragmoxylon brachyphylloides, sp. nov. Specimens from Comanchean deposits Weatherford, Texas.

Telephragmoxylon comanchense, sp. nov.

Co. Tex. 2. 121.

A.R. Limits of annual ring marked by a zone of summer wood three or four cells wide. Spring wood coarse.

R.C. Traumatic, vertical.

W.R. Uni- or biseriate; few to twenty cells high (average eight to ten cells), very resinous, variable in shape and size; often large and bulging in part. Lateral pits few to many per tracheid-field, oculi- pores with oblique slit-like openings.

W.P. None.

T. Large, interspersed with resin-filled tracheids related to the rays. Septate tracheids few at the end of the annual rings. Bordered pits somewhat variable in size and arrangement uniseriate, or biseriate alternate, usually contiguous, sometimes irregularly opposite; mouths oval, oblique and crossed.

The heavily resinous rays are correlated with the resin-filled tracheids which often border them. Similar resinous tracheids are characteristic of the living araucarians. The rays themselves are very striking in tangential aspect, not only because of their dark-colored contents, but because they vary in depth and tend to assume odd forms due to their swollen cells and the mixture of uni- and bi- and even triseriation in the same ray. Their lateral oculipores differ in their slit-like openings from those of *T. brachyphylloides* where they are oval to round.

The septate tracheids at the end of the annual rings are far less numerous than in the last species. Their paucity made it questionable whether it might not be best to retain the wood in the genus *Brachyoxylon*, but since other characters are also similar to those of *Telephragmoxylon*, a reference to the latter is probably more desirable. In this species is seen a transition from an antecedent *Brachyoxylon* condition to the condition found in *T. brachyphylloides*. Of course it is possible to interpret these two *Telephragmoxyla* in the reverse order and to look upon the one as the degraded condition of the other, but it seems more probable that the series is a progressive one.

Plate 14, fig. 56.—This figure of the traumatic resin canals is introduced to show the brachyoxyloid nature of the wood.

Plate 15, fig. 57.—Transverse section of normal wood. The evident annual rings and highly resinous rays are to be noted.

Fig. 58.—Tangential section. Again in this section appear the rays composed of swollen resinous cells. Certain tracheids are traversed by fungal hyphae which may be seen piercing their walls.

Fig. 59.—Here is shown the significant diagnostic feature: two tracheids exhibit septation. In addition tangential pits are visible and also the bulky resinous rays.

Fig. 60.—Radial section. The bordered pits in this figure are less modified by pressure than is the case in *T. brachyphylloides* though this is not a constant feature as is proved by the next figure. On one of the ray-cells a dark, oval marking represents an uncommon coronal arrangement of the oculipores.

Telephragmoxylon comanchense, sp. nov. From Comanchean sands, Weatherford, Texas.

ARAUCARIOXYLON Kraus.

Dadoxylon Endlicher, Synops. Conif., 1847.
Araucarioxylon Kraus, Sitzungsb. d. Naturf. Gesellsch. Halle, 1882.
Cordaioxylon Felix, Untersuch. über d. inn. Bau. westfal. Carbonpflanzen, 1886.
Cordaioxylon, various authors.

Annual rings usually obscure. Resin canals neither normal nor traumatic. Wood rays usually uniseriate; thin-walled, with a few to many small oculipores on the lateral tracheid-fields. Resinous wood parenchyma diffuse (in the living genera confined to conservative regions). Tracheids marked with uni- to multiseriate contiguous bordered pits; when in more than one row, typically alternating; bars of Sanio wholly wanting. Leaf-traces persistent.

Araucarioxylon texense, sp. nov.

Co. Tex. 1. 10.

A.R. Obscure.
R.C. None.
W.R. Two to ten cells deep (about six common), resinous, uniseriate, with several to many oculipores per tracheid-field.
W.P. Abundant, diffuse and heavily resinous.

T. With oval to rounded lumina; bordered pits usually contiguous, uniseriate and flattened. More rarely biseriate and alternate.
Leaf-traces persistent.

The obscurity or lack of annual rings in this wood is a feature which has long been held to be of diagnostic value for the genus *Araucarioxylon*. There is no evidence of their presence in this specimen.

The preservation leaves much to be desired, for the structural changes which it has undergone have given an appearance similar to that of *Araucarioxylon noveboracense* Jeffrey (1912) from the Cretaceous deposits of Staten Island. Thus in both, the tracheid walls are swollen and the lumina are filled with granular or vesicular matter; both manifest the same characteristic deep-brown resinous parenchyma, although in our specimen from Texas this is more abundant than in the Staten Island species, and is so well preserved as to show its cross-walls very clearly in radial sections.

The tracheidal pitting is possibly another character on which the species are to be separated, since it is more commonly biseriate in *A. noveboracense* than in *A. texense*. On the whole, however, the wood of the former is more robust and this may account in some degree for the prevalent biseriate pitting. The persistence of the leaf-traces in our specimen is another feature which insures the correctness of our reference to the genus *Araucarioxylon*, and proves that the specimen is from stem wood.

There are certain features of this Comanchean *Araucarioxylon* which may be correlated with its greater age. We hold that the Araucariaceae represent a degrading series whose origin is to be sought among the Abieteae and whose gradual path of evolution is rather clearly marked in the successive subtribes, Araucariopityeae, Brachyphylleae and Araucarieae. As a primitive member of the last subtribe we should expect this wood to show features now confined more particularly to the conservative organs of living genera of araucarians. And this is exactly the state of affairs, for not only is its pitting simpler and more brachyoxyloid, but it possesses abundant diffuse parenchyma in its stem wood. Thus it manifests characters which in living genera are confined almost wholly to root or first annual ring or to reproductive axes. The modern araucarians, then, have lost the parenchyma which was present in the cauline region of their ancestors, and their bordered pits have become multiseriate. They exhibit, so to speak, the second childhood of their remote ancestors, the *Dadoxyla*.

Plate 15, fig. 61.—Transverse section. This shows the unmistakable wood parenchyma scattered among the tracheids. In many cases the transverse sections of bordered pits are visible.
Fig. 62.—Tangential section. In the center of the field lies one of the persisting leaf-traces. With a hand-lens the tiny tracheids of the trace itself are visible.
Fig. 63.—Radial section. This is photographed to show the wood parenchyma in detail. It is evident that here are two heavily resinous parenchyma cells separated by a delicate transverse septum.
Fig. 64.—Radial section; detail of pitting. The wood is not charred and so its preservation leaves much to be desired, but on the tracheid to the left of center the alternating and distinctive araucarian pitting is clearly shown.

Araucarioxylon texense, sp. nov. From Comanchean deposits, Cottondale, Texas.

Summary of Species.

In the systematic part of this paper just finished, twenty-two species of fossil coniferous woods are described. Of these, sixteen are new or at least have not been identified with other known species. The list of species and their distribution by States is as follows:

Colorado:	*Sequoioxylon Burgessii* (Penhallow) comb. nov.
Massachusetts:	*Brachyoxylon woodworthianum*, sp. nov.
Montana:	*Sequoioxylon montanense*, sp. nov.
Nebraska:	*Dadoxylon*, sp.
New Jersey:	*Pityoxylon scituatensiforme* (Bailey) comb. nov.
	Podocarpoxylon McGeei (Knowlton) Sinnott and Bartlett
	Brachyoxylon raritanense, sp. nov.
	Paracupressinoxylon cupressoides Holden
North Dakota:	*Pityoxylon*, sp.
	Podocarpoxylon dakotense, sp. nov.
	Sequoioxylon dakotense, sp. nov.
	Sequoioxylon laramense, sp. nov.
Oregon:	*Pityoxylon* cf. *Vateri* Platen.
	Pseudotsuga annulatum (Platen) comb. nov.
Texas:	*Voltzioxylon dockumense*, gen. et sp. nov.
	Podocarpoxylon texense, sp. nov.
	Brachyoxylon comanchense, sp. nov.
	Paracupressinoxylon trinitense, sp. nov.
	Telephragmoxylon brachyphylloides, sp. nov.
	Telephragmoxylon comanchense, sp. nov.
	Araucarioxylon texense, sp. nov.
Washington:	*Podocarpoxylon washingtonense*, sp. nov.

GENERAL SUMMARY AND CONCLUSIONS.

Having finished the descriptions of the species of fossil woods, there remains only one task: to summarize the work and to draw conclusions. This can best be done through an attempt to trace the phylogeny of the main lines of the Coniferales, in so far as they are becoming evident through our improved understanding of the remains. The correlative and highly important evidence presented by impressions can be but slightly touched upon. The value of such evidence is recognized but it is a science with which we are not competent to deal, and furthermore, very little has been done in the way of correlating the structural remains and the impressions of Mesozoic plants.

The Derivation of the Coniferales.

That the conifers rose from the Cordaitales is no longer to be doubted. Among the Cordaitales is found the main theme, so to speak, on which the later coniferous variation was based. It will therefore be of value to begin with a consideration of the distinctive features of this ancient order of gymnosperms.

The Cordaitales had departed rather widely from their fern-like ancestors in their general habit as well as in their anatomy. They had developed the shaft-like stem and the simple elongate leaf. These features were to be carried on by their descendants. In them were witnessed, too, the last stages and final disappearance of stelar centripetal xylem. The ancient heavily pitted tracheid was retained, but there had been a great reduction of ray-tissue, so that instead of the spongy stele of the cycad allies, there was now a strong woody cylinder such as is familiar to us in modern conifers and in *Ginkgo*. In leaf anatomy their bundles, surrounded by sheaths of transfusion tissue, retained the mesarchy of their ancestors. Last of all the fructifications showed a significant modernization, since the seeds were borne on secondary axes of the strobilus even as in *Pinus*. Renault's figures of the female strobilus of *Cordaites* have long been familiar. An even more striking exhibition of the short-shoot character has recently been figured by Berry (1920, p. 354) who shows a *Cordaianthus* bearing ovules on brachyblasts which are beset with pine-like needles. The figure should be compared with that of *Prepinus* Jeffrey (1908), or of *Pityites Solmsii* Seward (1919). We must thank Professor Berry for a new piece of evidence for the "ingenious hypothesis" that the pines came directly from the Cordaitales. Very unfortunately the immediate descendants of the Cordaitales are scarcely known. During the Triassic and Jurassic periods, just when a significant modernization was taking place, the conditions for the preservation of structural material were so unfavorable that few fragments have come down to us to tell of the road along which the gymnosperms were moving. But the fragments, few though they be, when taken in conjunction with our "living cordaite," *Ginkgo*, offer a body of evidence which like a guide-post points the way to the Abieteae.

Perhaps the most cordaitean of the fragments is *Woodworthia* Jeffrey (1910a), a wood which had the tracheidal markings and the ray structure of its ancestors, but possessed in addition persisting brachyblasts whose elongation followed their progressive sealing-in by the radial growth of the trunk, and which must have borne their leaves in a spiral phyllotaxy, since in their radial passage through the trunk wood they are beset with numerous departing leaf-traces. Thus they manifest the brachyblastic condition in its ancient form. At the highest state of its development this has become the abbreviated shoot with sheathed needles so characteristic of the pines.

Woodworthia retained the ancient histological features of its parents, but in *Voltzia*, another Triassic fossil, variously considered by palaeobotanists as a cupressean, a taxodian and an araucarian, the cone anatomy lies far from the Cordaitales as we know them, and rather recalls that of the Abieteae. On the other hand, the wood structure is still cordaitean in the broad sense of that term, since, although the pits have broken the formalistic line-up of *Dadoxylon*, they are still individually of the same type, with tiny oblique cross-mouths and without trace of bars of Sanio. Moreover, the rays are cordaitean. Woods of the *Voltzioxylon* type have been found in Nova Scotia, Texas, Sweden and Russia, while the impressions of the genus *Voltzia* are spread over the earth.

In the last section of this paper we shall point out that *Ginkgo*, an admitted cordaitean derivative, bears many significant anatomical resemblances to *Pinus*.

The Phylogeny of the Abieteae.

The evidence, then, which may be assembled from the all too few Jura-Trias fossils and from Ginkgo, points sharply to the Abieteae as the group foreshadowed, and in the Cretaceous period this prophecy passed into full revelation. This seeming sudden efflorescence of conifers is not so in fact, for it must not be forgotten that in the closed volumes of Triassic and Jurassic history there are many pages upon which the story of early abietean evolution was written. During those long ages the ancient cordaitean stock was slowly moulded into the abietean. That the changes conduced to a perfected mechanism well adapted to the conditions of the environment is well assured by the continued persistence of the pines and their representation in no negligible degree among the living conifers. But never after the Cretaceous period did they possess such a complicated anatomical organization.

Among the Cretaceous pines the remarkable genus *Prepinus* Jeffrey demands special consideration. The plant is known from its sturdy brachyblasts which are thickly beset with scales below and with many needles above. In the structure of the needles the retained cordaitean features are strikingly manifest: for not only is there seen the double sheath of transfusion tissue around the vascular strand, but the xylem of the trace itself is partly centripetal.

Professor Seward has recently questioned the statements concerning the resemblance of the *Prepinus* needle to the leaf of *Cordaites principalis*. But surely equivalent sequence and histological identity of tissues in homologous organs must be accepted as valid criteria of affinity between allied plants if there is no evidence of parallelism or other disturbing factors to militate against it.

Two lines of evolution rose from the ancient pinean stock: one to deploy into the modern Abieteae, Taxodieae, Cupresseae and probably Taxaceae; and the other to produce the rich araucarian complex. Jeffrey's studies have shown that the living Abieteae fall naturally into two subtribes,—the Pininae, most highly specialized and yet most primitive, which includes *Pinus*, *Picea*, *Pseudotsuga* and *Larix;* and the derived and regressive Abietinae which embraces *Abies*, *Cedrus*, *Pseudolarix* and *Tsuga*.

Cupresseae and Taxaceae.

From the Abieteae arose the further simplified Cupresseae. Their elaboration requires but the progressive development of parenchyma which had already begun to diffuse in certain Abietinae, along with the continued degradation and final disappearance of resin canals. The podocarps and taxads may also have had an abietean origin. Their wood anatomy is on a level with that of the Cupresseae, while their female strobili show evidences of reduction.

Unfortunately Gothan's genus *Podocarpoxylon* can be held to have little systematic significance. We know little concerning the actual history of the group. Sinnott following Jeffrey and Chrysler has argued for a podocarpinean intermediation between the Abieteae and the Araucariaceae.

The Taxodieae or Sequoieae.

From the pines still another line of evolution led to the sequoias. Two species of the genus *Sequoia* survive: *Sequoia washingtoniana* (Winsl.) Sudworth, and *Sequoia sempervirens* (Lamb.) Endlicher. Both produce traumatic resin canals, and the former has normal canals in conservative regions. These retentive and reversionary characters point directly back to an ancestor in which they were normal features of the wood.

We have realized for some time that horizontal resin canals are the first to show the degenerative effect in a regressive stock, and that they may pass into a condition of latency while the vertical canals are still fully functional. This is witnessed in the genus *Protopiceoxylon* Gothan. Later they may be lost altogether, as is the condition of all the abietean woods except that of *Cedrus*, which standing closer to its parent stock than its relatives, exhibits well-formed traumatic canals in both directions.

In a considerable number of species of sequoia wood from the Laramie deposits, we have been so fortunate as to find wounded material, and in them wound resin canals are present in *both* directions. The implications of this fact should be evident, namely, that the *Sequoioxyla* were derived from the pines in which normal resin canals run in both directions. As recently as in Cretaceo-Eocene time, the *Sequoioxyla* stood near enough to their ancestors to produce traumatic resin canals in both directions. Significantly enough the Upper Miocene *Taxodioxylon* (*Sequoioxylon*) *sequoianum* (Merck.) Gothan and the two living species of *Sequoia* have passed a step farther. One of the latter not only shows vertical wound canals but testifies to its origin in retaining normal resin canals in "peduncle, axis, and scales of the female cone" as well as in the first annual ring of vigorous branches. *Sequoia sempervirens*, on the other hand, has lost all trace of normal resin canals.

One point of some economic importance demands consideration. It begins to appear that the great Tertiary economic lignite or brown-coal deposits of the world are formed largely of sequoia wood. Yasui (1917) has reported such a wood from the Tertiary coal-fields of Japan. Kräusel (1918) finds several probable sequoia woods,—*Taxodioxylon taxodii* Gothan, and *Cupressinoxylon wellingtonoides* (Prill) Kräusel,—abundant in the German mines. Our American Laramie lignites offer a strong *Sequoia* facies while the wood called *Podocarpoxylon texense*, which forms the basis of the Texan lignites, seems to be of sequoian affinity. How many sequoias are lost in the literature under the name *Cupressinoxylon*, no one can say.

The Araucariaceae.

We now approach the great battle-ground of coniferous phylogeny. We may state the problem briefly: Did the araucarians come from the Cordaitales or did they come from the pines? In other words which is the most ancient group of conifers?

On the face of the matter there seems to be but one answer. The woods of the araucarians cannot be distinguished from those of the Cordaitales. Such is Gothan's opinion and so he places both types of wood in the form-genus *Araucarioxylon*. Pitting is identical on rays and tracheids; both (seemingly) lack resin canals and wood parenchyma. Surely one must have striking evidence to the contrary to oppose such obvious facts and to argue that the araucarians came, not from the Cordaitales but from the pines.

Progressive and Regressive Series.—Many years ago, in a work on fossil cephalopods, Alpheus Hyatt pointed out that these organisms in their phylogeny seemed to progress from a state of simplicity to complexity only to fall back through regressive stages to a simple condition again. Briefly, he came to see that the Cambrian straight-shelled, ancestral genus *Orthoceratites* rose through many genetic series of *Cyrtoceros, Gyroceros,* and nautiloid forms till a highly coiled shell came into being. Alongside the coiling process were progressive changes in septal suturing and opening of the shell-mouth. Arrived at extreme complexity the regressive process set in until in the Cretaceous period the genus *Baculites* appears with a simple straight shell so like that of its Cambrian ancestor that some geologists had actually classified the two in the same genus. Hyatt further pointed out that the Biogenetic Law was perfectly illustrated in the extreme genera, whose successive ontogenetic stages were fixed as the shells increased in size. An analysis of Hyatt's work will be found in Cope's Origin of Genera. The principle just discussed has been called orthogenesis.

In recent years biologists have been averse to trusting to the inductive method in deriving such broad generalizations. Perhaps biology has suffered thereby,—certainly its appeal to the imagination has lessened. No one who has worked much in plant morphology from the newer evolutionary point of view, particularly if he has taken the fossil evidence into consideration, can have failed to note what appears to be the sweep of the same orthogenetic law.

Hypothetical Precarboniferous herbs passed into tree forms, only to sink back to herbs in recent time. Ferns have "concentric closed bundles,"—so do monocots,—and yet what sane botanist today thinks of any close affinity between them? Modern Magnoliaceae have scalariform pits on their tracheids and yet Bliss has recently established beyond a doubt that these have resulted from fusions of bordered pits in rows and are totally unrelated genetically to the condition found in cycads. Such pitting can no longer be used as a point in favor of the bennettitalian affinity of the Ranales (Bliss, 1921). The regressive part of the same process seems to be running today among the conifers. *Woodworthia, Prepinus, Pityites Solmsii,* and a recently discovered and as yet undescribed three-needle pine from the Cretaceous lead finally in modern times to the reduced *Pinus monophylla.*

From a parallel course of reasoning I believe that the araucarians represent the extreme regression of the pine series, and that their supposed cordaitean features are senile and coenogenetic characters.

Palaeontological Evidence of Phylogeny.—The pines run back at least to the Triassic period, certainly as far as the araucarians. There is no palaeontological evidence that they are a modern group which arose from the latter. The earliest-known woods of araucarian affinity were discovered by Gothan in Jurassic deposits of Spitzbergen. They are so abietean, that is, so little modified from their ancestral state, that, basing his reference on the heavily pitted ray-cells, he classifies them with the Abieteae in spite of the fact that they bear araucarian tracheidal pitting. The most primitive of these woods is *Protopiceoxylon* (an example of most unhappy taxonomy). It is a wood in which the degenerative process is just beginning. While we are perfectly willing to let Gothan classify this wood with the Abieteae, we insist that it be considered a protoaraucarian since we believe that it is an abietean conifer not far enough removed from the pines to have fully lost its resin canals and abietean rays. Its pits, however, have taken on the araucarian arrangement, or if one prefers, they have reverted to the *Dadoxylon* condition.

The character of the pitting of tracheids is by no means a stable one. Fluctuations between the two types are not uncommon in fossil woods. An instance of this may be seen in *Cupressinoxylon Walkomi* Sahni (1920) and in the wood we describe as *Podocarpoxylon dakotense.* The transition from araucarian to abietean pitting is easily effected in the ontogeny of *Ginkgo* or of *Brachyoxylon,* while the reverse is seen in the cone axis of *Araucaria.* In the latter the early-formed tracheids bear a definite biseriate opposition of bordered pits. Miss Holden observed the same phenomenon in the young wood of fossil araucarians. We must protest most vigorously against the name Protopinaceae which Kräusel (1918a, 1920) suggests for these transitional woods. Certainly if they are to be elevated to the rank of a family they should be given a name which commits us to no phylogenetic theory.

Araucariopitys Jeffrey may be said to stand next in line with *Protopiceoxylon,* for its horizontal resin canals are lost even beyond traumatic recall, while the vertical canals have slipped into a state of latency and only reappear under the stimulus of wounding. Like *Protopiceoxylon,* however, it still retains the heavily pitted rays of its ancestors.

We differ from Penhallow and Gothan in our interpretation of the significance of wound resin canals. For whereas they see in such structures "Anpassungsmerkmale," prophetic of future conditions, we interpret them as reversionary phenomena. If Penhallow and Gothan are right then, to take a striking case, the *Sequoiae* of the Eocene period were false prophets. They were obviously "predicting" that their descendants were to have resin canals in both directions like a pine. Yet *Sequoia washingtoniana* and *Sequoia sempervirens* have resin canals developing only *vertically* when wounded. The only way out of the dilemma is to say that the living *Sequoiae* are more primitive than the fossils. If anyone should be inclined to argue this theory seriously let us ask if the normal resin canals of cone axis and cone scales and first annual ring of the root and vigorous branches are also "predictions." It should be obvious from this digression on *Sequoia* that the interpretation of traumatic resin canals as reversionary phenomena is logical and satisfactory, and that any other interpretation leads to curious inconsistencies.

With the Brachyphylleae came the next regression: some of the members of the tribe are strangely analogous in outward aspect to certain Taxodieae and yet their internal anatomy is unmistakably araucarian. We have described several new species of the genus *Brachyoxylon* and have pointed out in some detail the very significant features which were exhibited by a young twig of *Brachyoxylon woodworthianum*. For next the medulla lie tracheids beset with *Dadoxylon*-pitting; farther out the pits exhibit an arrangement commonly considered to be abietinean, while in the trunk wood itself the tracheids are often marked with alternating, flattened, bordered pits. The wood may be said to retain the stages of its own progressive ontogeny and to illustrate clearly the biogenetic law.

The *Brachyoxyla* all retain the power to form traumatic resin canals, and along with this reaction the rays, too, near wounded regions, usually show a significant thickening and heavy "abietean pitting." But the most interesting feature which any member of the Brachyphylloideae has yet evidenced, is the septation of tracheids which is seen in the new wood, *Telephragmoxylon*. We have discussed this phenomenon in some detail under the first species of *Telephragmoxylon* described. There we pointed out how perfectly it substantiates the theory of the origin of wood parenchyma, and how closely it parallels a series of similar stages in the abietean-cupressean stock.

From the *Brachyoxyla* the advance to the true fossil *Araucarioxyla* is easy. Wood parenchyma is distributed throughout the stem (diffuse), and all evidences of resin canals have been "pushed out" of the wood. But still another step was taken: the wood parenchyma invaded root and reproductive axis but disappeared from the cauline region. As the Cretaceous and Tertiary periods advanced the araucarians retreated from the northern lands before the glacial cold, and later before a host of angiosperms, coming we know not whence. Slowly they were decimated in numbers, while the process of anatomical regression went on. Today they survive as two genera only, which possess a *cauline* woody organization so analogous to that of the ancient *Dadoxyla* that a separation from them is impossible.

The Living Araucarians.—Having discussed the palaeontological evidence leading to the belief that the araucarians are derivatives of the pines, a summary may be inserted concerning the testimony of the living araucarians themselves as to their origin.

(*a*) It is well known that the wood of the root and cone axis of these plants is well supplied with wood parenchyma. Let us again emphasize the fact that the extinct species possess abundant *cauline* wood parenchyma.

(*b*) The conservative wood of the cone axis often possesses abietean rays. It should be recalled that the tribe Araucariopityeae is founded on fossil woods of this character.

(*c*) Traumatic abietean rays are easily recalled in the root wood of araucarians while *Brachyoxylon* shows the same reversionary character in its wounded stem wood.

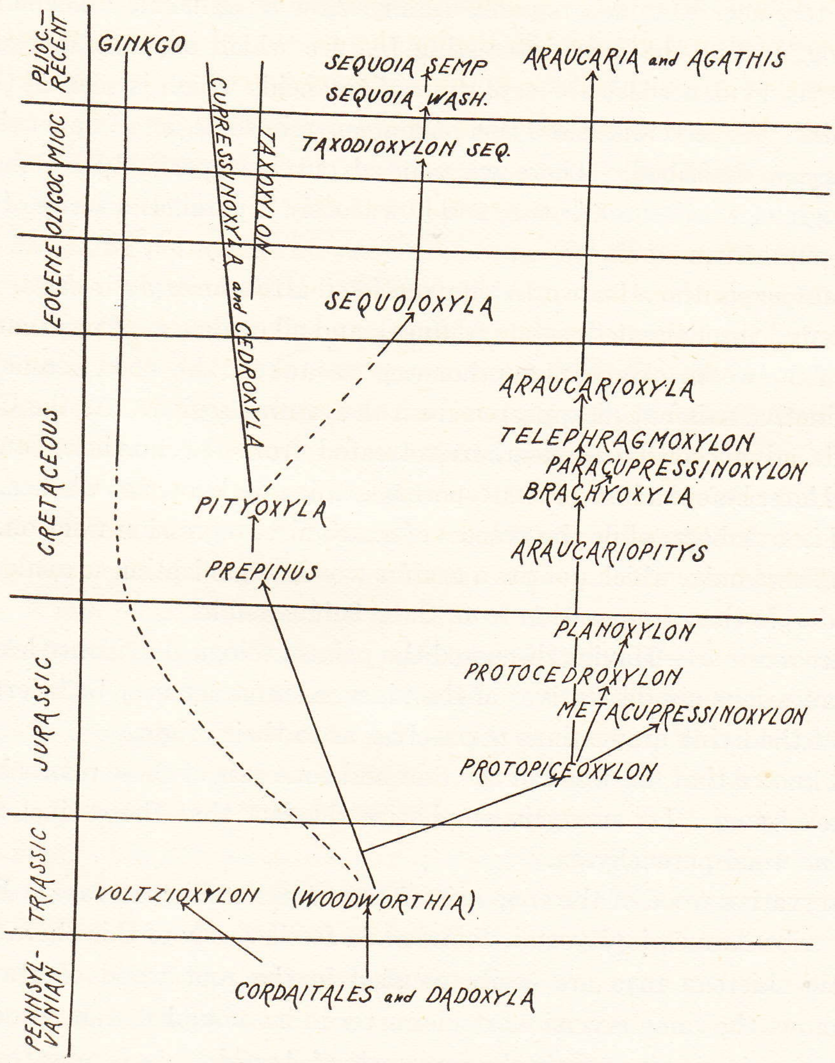
(*d*) Undoubted resin canals occur in the cone scale of *Agathis*. As is repeatedly emphasized above, resin canals were an ancient araucarian possession.

(*e*) Abietean pitting and bars of Sanio occur in the cone axis of certain living araucarians. These are pinacean features.

(*f*) Young plants of *Araucaria* do not have persistent leaf-traces, hence their persistence in the adult wood is probably not a palingenetic feature.

From the above evidence we believe we are justified in saying that the araucarians represent a series originating among the Abieteae and that they have been undergoing simplification since Cretaceous time.

Ginkgo as a Cordaitean Derivative allied to Pinus.—We have reserved till the end one piece of evidence regarding the antiquity of the pines. For some reason morphologists who argue for the derivation of Abieteae from Araucarieae are curiously averse to considering the anatomy of our "living cordaite," *Ginkgo*. We all agree that it runs back and is lost in the cordaitalian



TEXT-FIG. 1.—Phylogeny of the coniferales.

plexus. *Ginkgo* has many resemblances to *Pinus*. Its short shoots are on the primitive level of those of *Prepinus* and of *Pityites Solmsii* Seward; its male strobilus is obviously pine-like, as are also its winged microspores, its two male prothallial cells, and its endokinetic mechanism of anther dehiscence. Its tracheidal pitting is identical with that of *Pinus* even to the possession of the bar of Sanio. If *Ginkgo* came directly from the Cordaitales so did *Pinus*.

Lest anyone try to derive *Ginkgo*, too, from the araucarians we hasten to assure him that its seeds, leaves and wood-ray features are cordaitean and that the pitting of the first-formed tracheids of its root wood offers one of the most perfect and beautiful testimonials we possess as to the truth of the biogenetic law. So obvious is the recapitulation that we use slides of *Ginkgo* wood to teach this law to elementary students.

It would appear, then, that both *Ginkgo* and *Pinus* had a direct cordaitean ancestry and that all the other tribes of conifers were derived from the Abieteae.

In the appended figure an attempt is made to embody the main points of the preceding discussion in the form of a phylogenetic tree linking the major types of fossil woods together. It should be realized that any such scheme as this is only tentative; it presents the writer's views, however, and may also serve as a mnemonic system.

Acknowledgments.

In conclusion the writer wishes to express his sense of obligation to the many who have contributed to the success of this work. To a Sheldon Traveling Fellowship from Harvard University he is indebted for the necessary funds; to the courtesy of Dr. Smith of the University of Alabama in offering the use of a private library he owes part of the historical and geological material. To Dr. E. H. Barbour of the University of Nebraska he expresses his thanks for assistance and for specimens. To Mr. James Austin of the Harvard Laboratories is attributed much of the success which attended the technique of the work. But above all others is he indebted to Professor E. C. Jeffrey, whose advice, large patience, and ever-ready help with the difficult histological and photographic technique made the investigation possible.

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EXPLANATION OF PLATES.

All the figures are from photomicrographs. Detailed descriptions of each will be found in the body of the text.

PLATE 8.

Fig. 1. Transverse section of *Voltzioxylon dockumense*, gen. et sp. nov.
Fig. 2. Radial section of the same.
Fig. 3. Transverse section of *Pityoxylon scituatensiforme* (Bailey) n. comb.
Fig. 4. Transverse section of *Pseudotsuga annulata* (Platen) n. comb.
Fig. 5. Radial section of the same.
Fig. 6. Tangential section of the same.
Fig. 7. Transverse section of *Podocarpoxylon texense*, sp. nov.
Fig. 8. Tangential section of the same.

PLATE 9.

Fig. 9. Radial section with detail of ray of *Podocarpoxylon texense*, sp. nov.
Fig. 10. Radial section with detail of tracheidal pitting of the same.
Fig. 11. Same as Fig. 10.
Fig. 12. Transverse section of *Podocarpoxylon washingtonense*, sp. nov.
Fig. 13. Tangential section of wounded wood of the same.
Fig. 14. Radial section with detail of ray of the same.
Fig. 15. Tangential section of *Podocarpoxylon McGeei* (Knowlton) Sinnott and Bartlett.
Fig. 16. Radial section of the same.

PLATE 10.

Fig. 17. Radial section with tracheidal detail of the same.
Fig. 18. Same as Fig. 17.
Fig. 19. Transverse section of *Sequoioxylon montanense*, gen. et sp. nov.
Fig. 20. Tangential section of the same.
Fig. 21. Transverse section through wounded wood of the same.
Fig. 22. Radial section of the same.
Fig. 23. Same as Fig. 22.
Fig. 24. Transverse section of *Sequoioxylon dakotense*, sp. nov., through wounded wood.

PLATE 11.

Fig. 25. Tangential section of *Sequoioxylon dakotense*, sp. nov., through a traumatic resin canal.
Fig. 26. Radial section of wood of the same.
Fig. 27. Radial detail of tracheid of the same.
Fig. 28. Radial detail of ray of the same.
Fig. 29. Transverse section of *Sequoioxylon laramense*, sp. nov., through wounded region.
Fig. 30. Transverse section through summer wood of the same.
Fig. 31. Tangential section of the same showing resin canal.
Fig. 32. Transverse section of *Sequoioxylon Burgessii* (Penhallow) n. comb.

PLATE 12.

Fig. 33. Tangential section of the traumatic canal of *Sequoioxylon Burgessii*.
Fig. 34. Same as Fig. 33.

Fig. 35. Radial detail of ray of the same.
Fig. 36. Radial detail of tracheid of the same.
Fig. 37. Transverse section of *Brachyoxylon woodworthianum*, sp. nov.
Fig. 38. Transverse section of wounded portion of the same.
Fig. 39. Tangential section of same showing traumatic rays.
Fig. 40. Radial section of traumatic ray with nuclei.

PLATE 13.

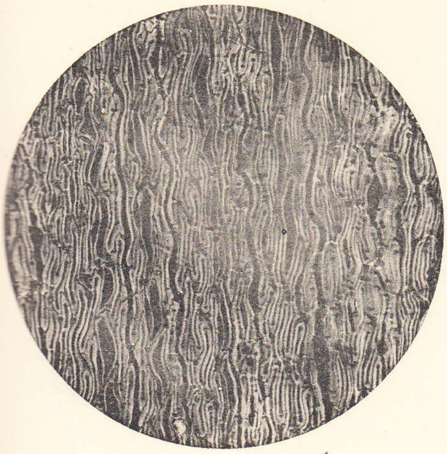
Fig. 41. Radial section of *Brachyoxylon woodworthianum*, sp. nov., with tracheid detail.
Fig. 42. Radial section through the primary xylem of a twig of the same.
Fig. 43. Radial section of later twig wood of the same.
Fig. 44. Transverse section through wounded area of *Brachyoxylon comanchense*, sp. nov.
Fig. 45. Radial aspect of traumatic resin canal of the same.
Fig. 46. Radial section to show ray detail.
Fig. 47. Transverse section of *Brachyoxylon raritanense*, sp. nov.
Fig. 48. Radial section of same to show tracheid and ray detail.

PLATE 14.

Fig. 49. Transverse section of *Paracupressinoxylon cupressoides* Holden through a wounded area.
Fig. 50. Radial section of the same through a worm-boring.
Fig. 51. Transverse section of *Paracupressinoxylon trinitense*, sp. nov.
Fig. 52. Transverse section of *Telephragmoxylon brachyphylloides*, sp. nov., showing characteristic tracheidal plates.
Fig. 53. Tangential section of the same.
Fig. 54. Tangential section of the same more highly magnified.
Fig. 55. Radial section of the same with tracheid detail.
Fig. 56. Transverse section of *Telephragmoxylon comanchense*, sp. nov., through a wounded area.

PLATE 15.

Fig. 57. Transverse section of normal wood of *Telephragmoxylon comanchense*, sp. nov.
Fig. 58. Tangential section of the same.
Fig. 59. Tangential section of the same with septate tracheids.
Fig. 60. Radial section of the same for tracheid and ray detail.
Fig. 61. Transverse section of *Araucarioxylon texense*, sp. nov.
Fig. 62. Tangential section of the same with leaf-trace.
Fig. 63. Radial section of the same with wood parenchyma.
Fig. 64. Radial section of the same for tracheid detail.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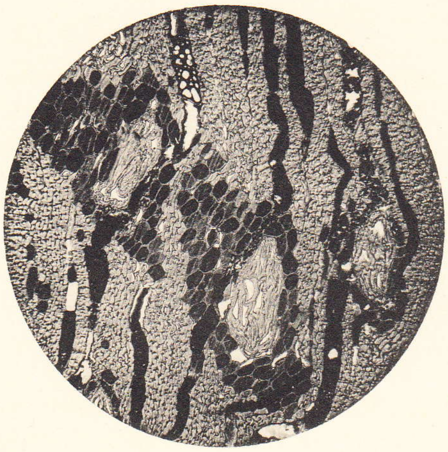
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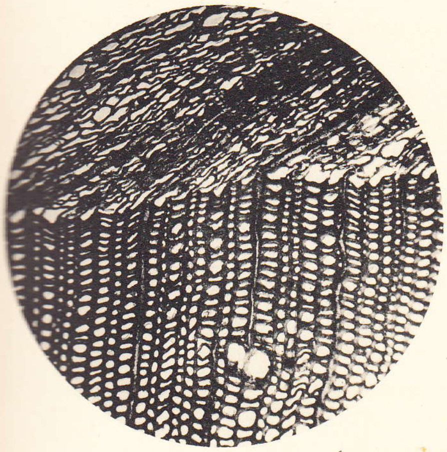
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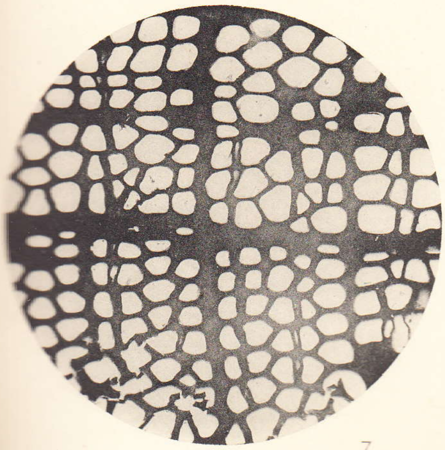
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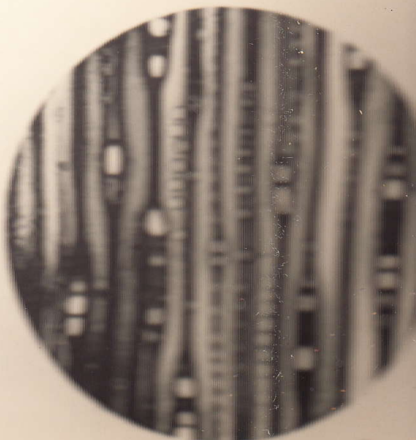
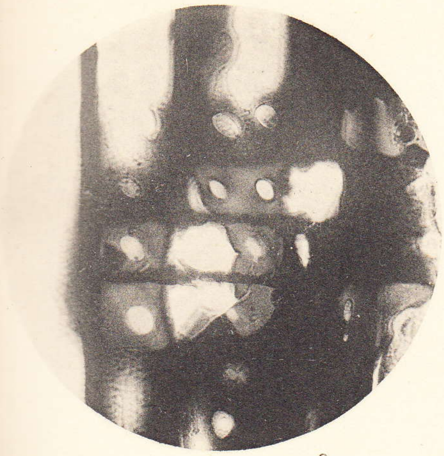


TORREY ON FOSSIL CONIFERS.

HELIOTYPE CO. BOSTON



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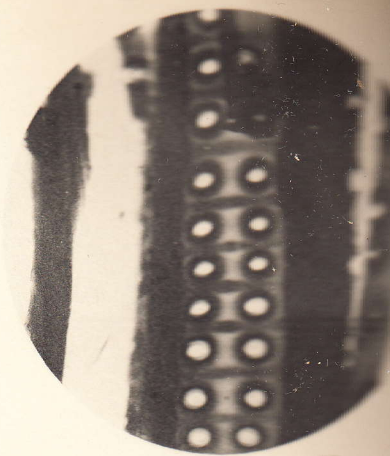

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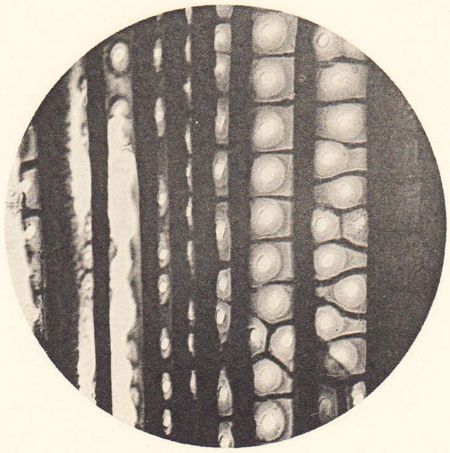

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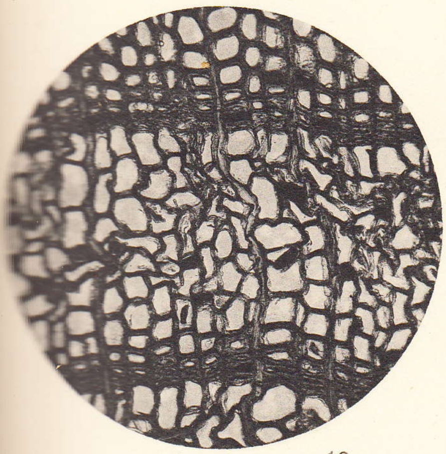

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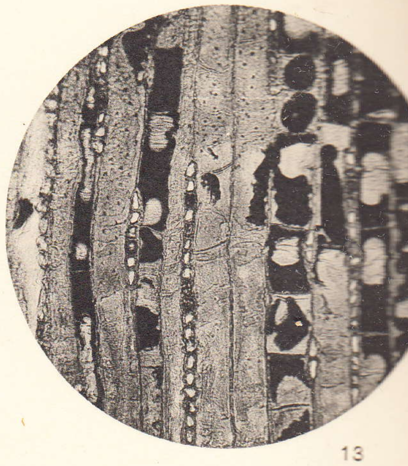

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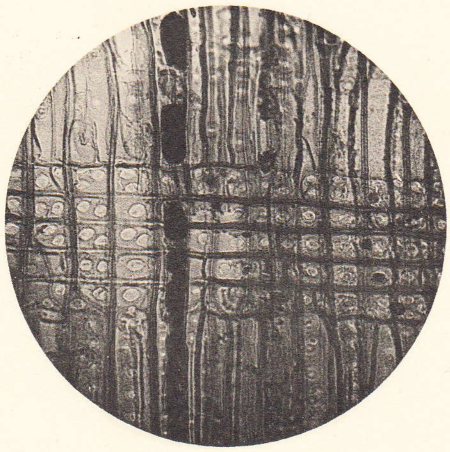

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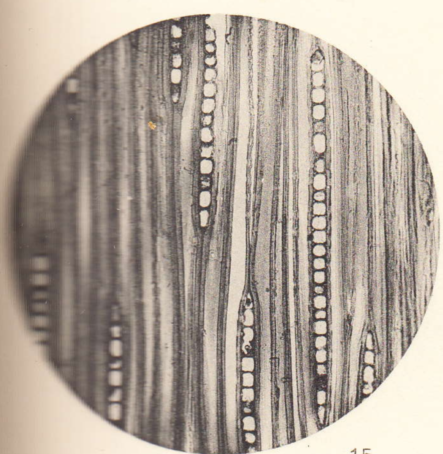

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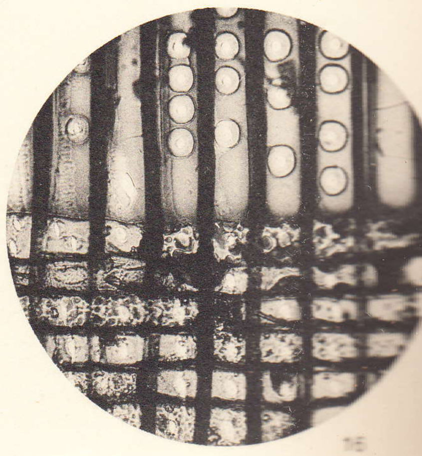

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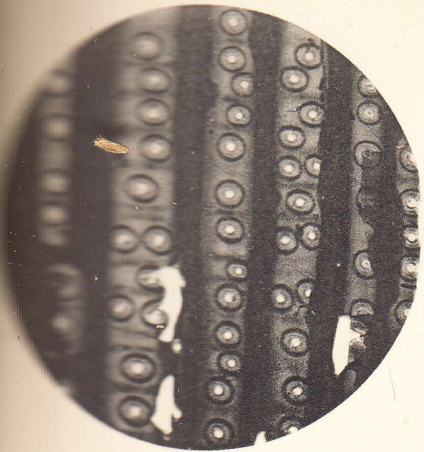
Torrey on Fossil Conifers.



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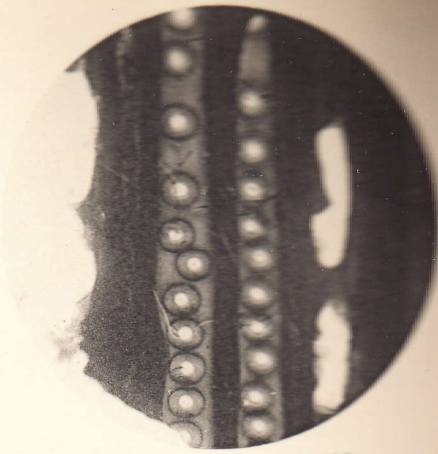

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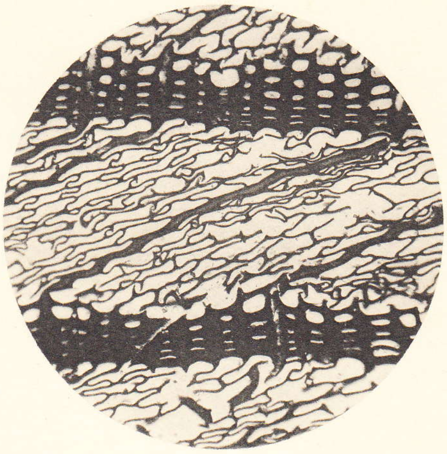

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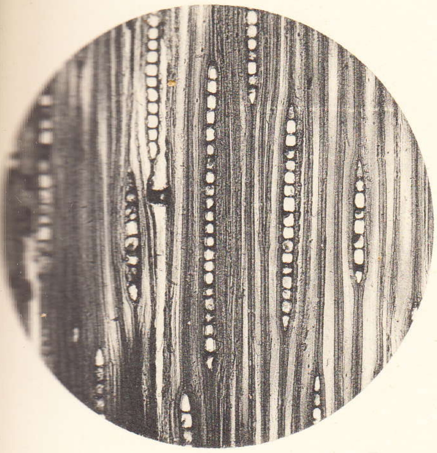

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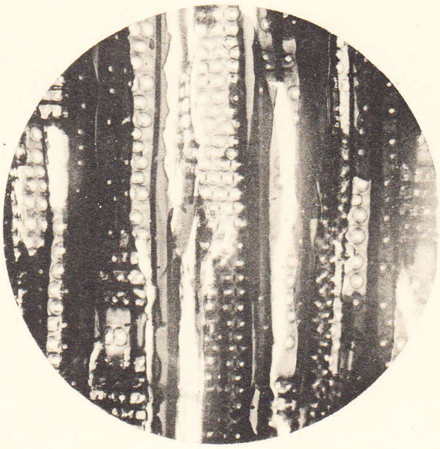

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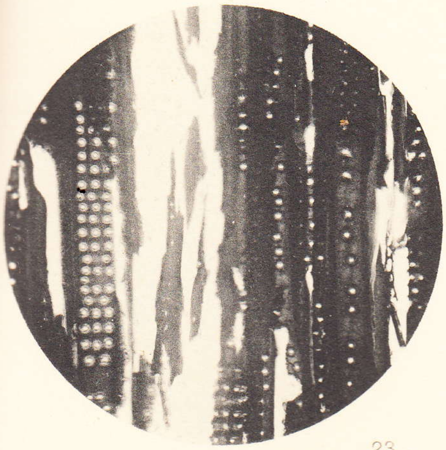

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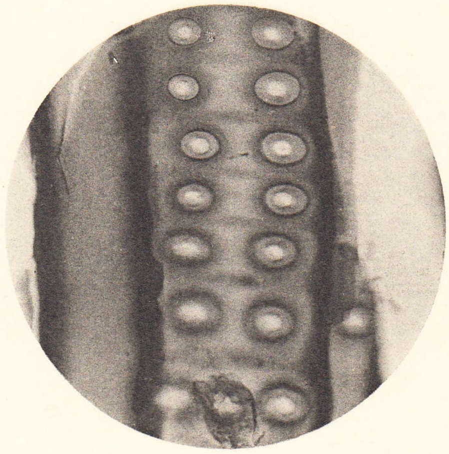

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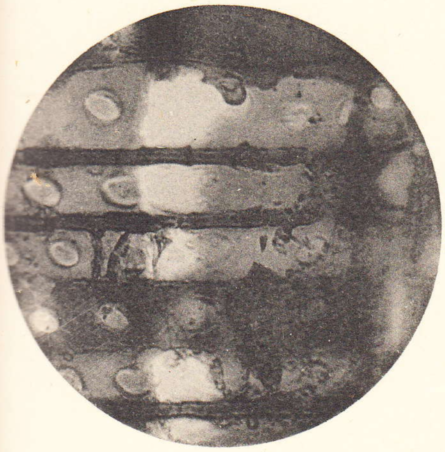

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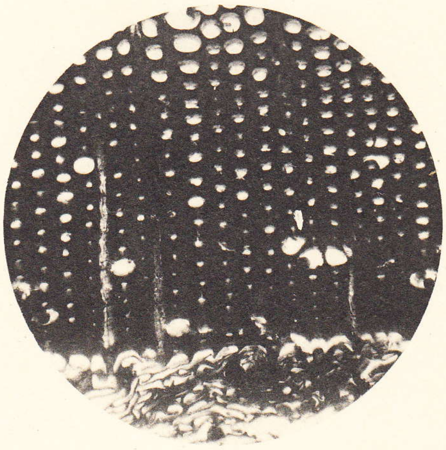

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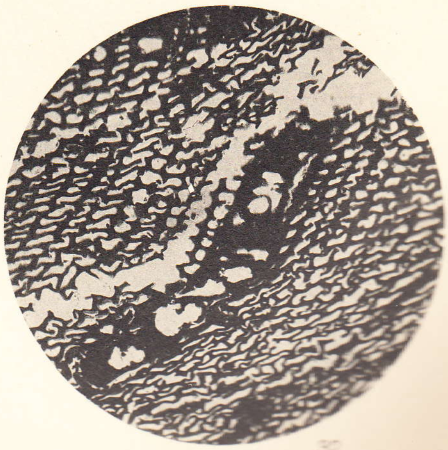

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TORREY ON FOSSIL CONIFERS.


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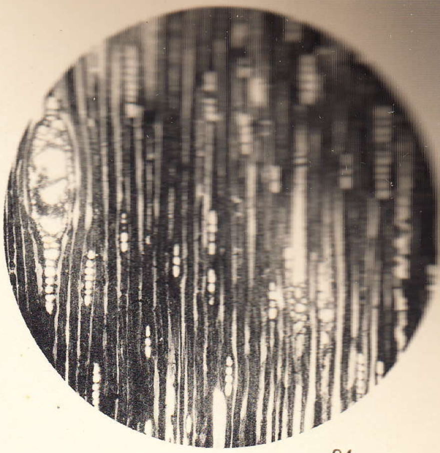
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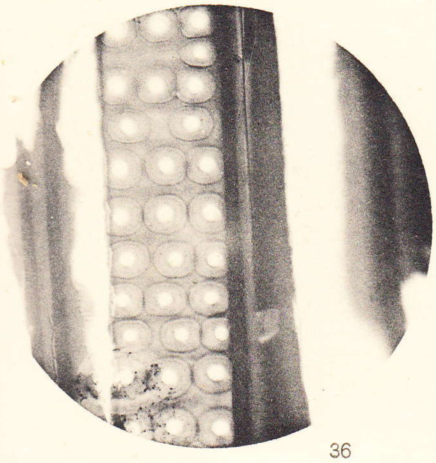
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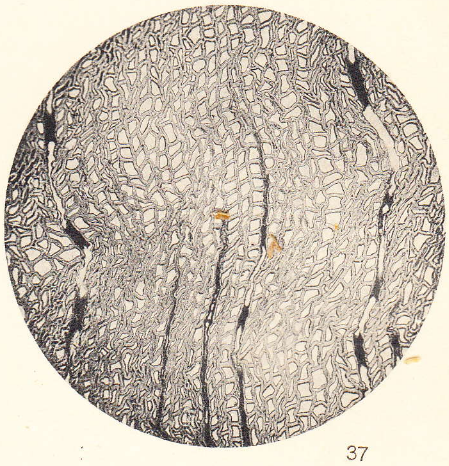
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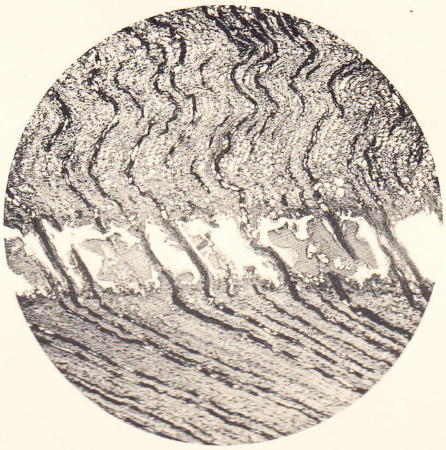
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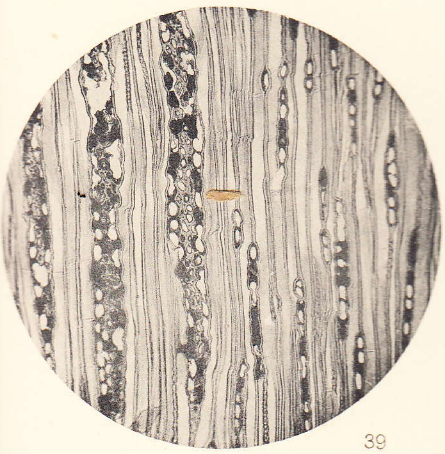
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TORREY ON FOSSIL CONIFERS.

HELIOTYPE CO. BOSTON


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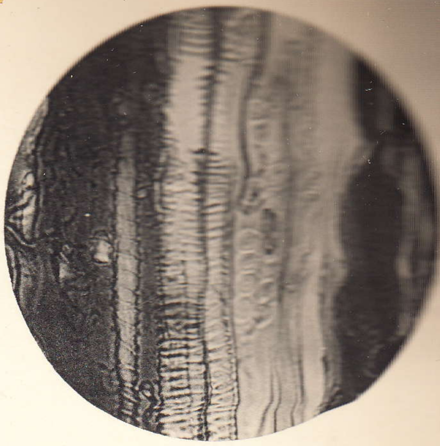
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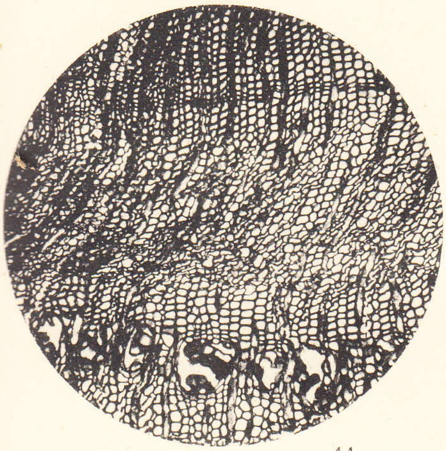
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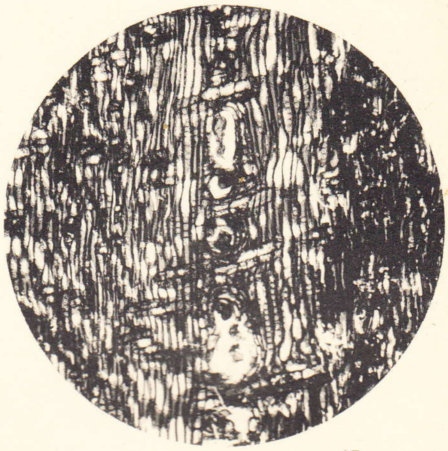
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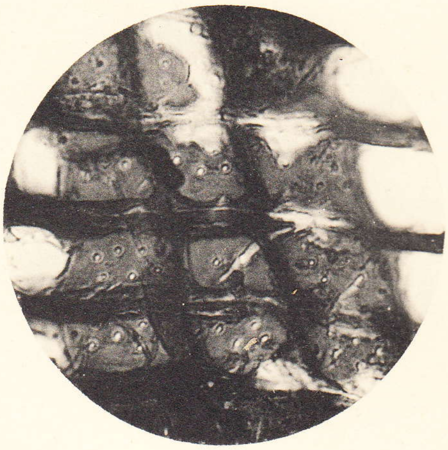
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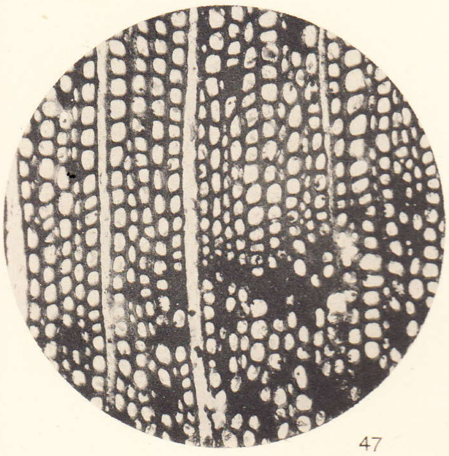
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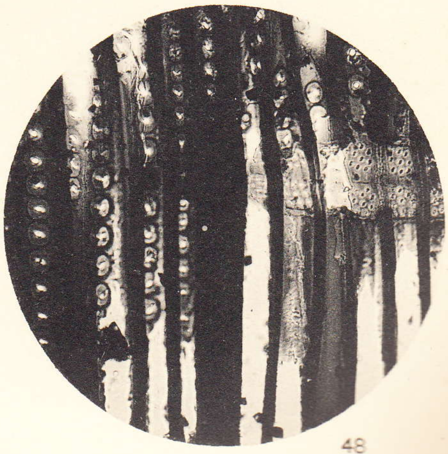
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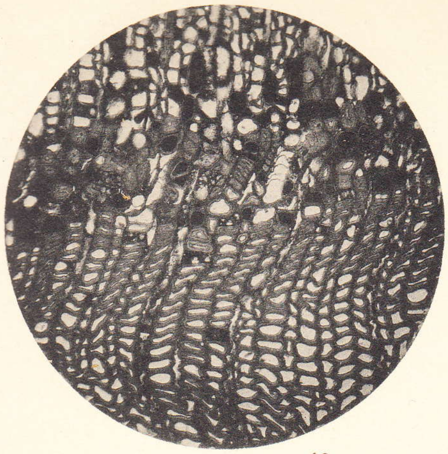
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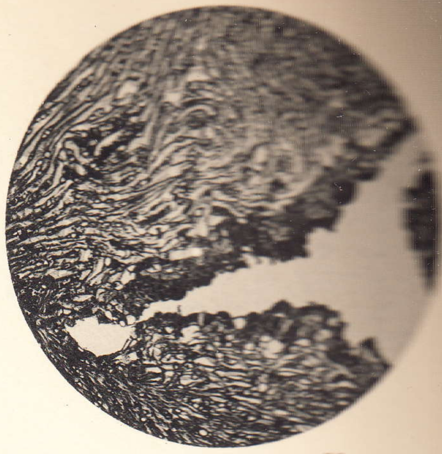
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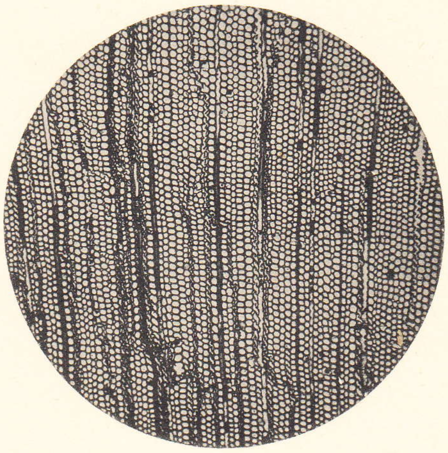
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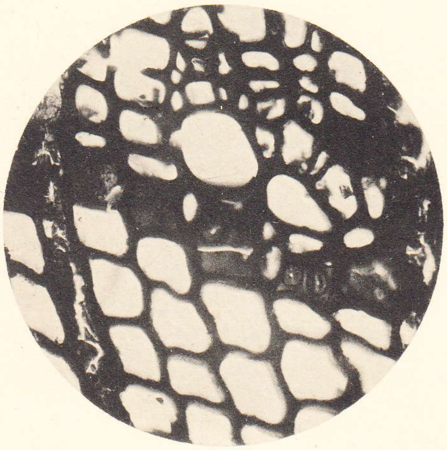
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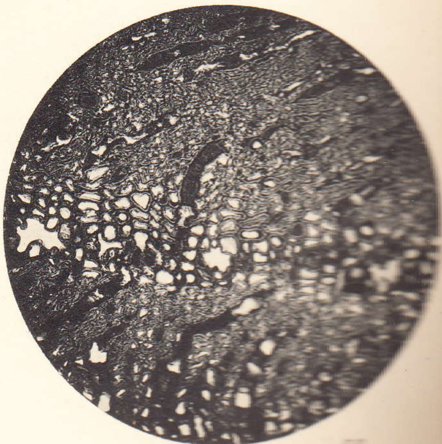
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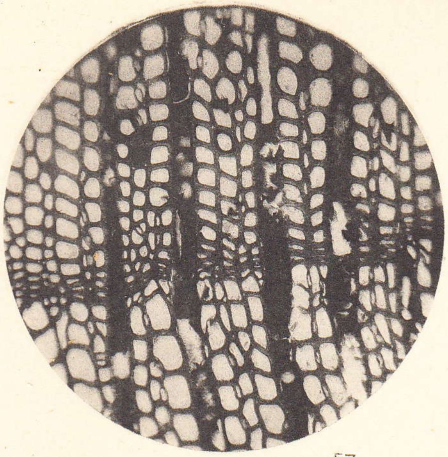
Torrey on Fossil Conifers.

Heliotype Co. Boston



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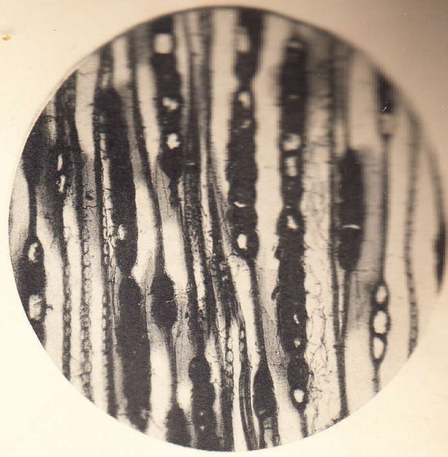

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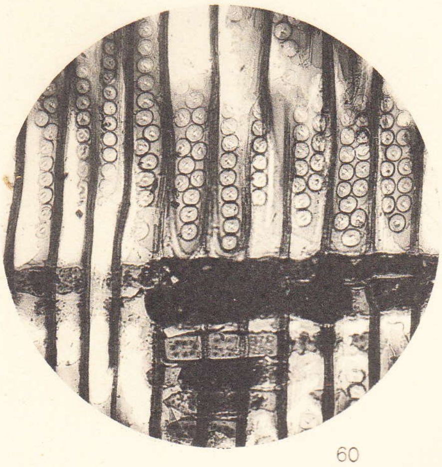

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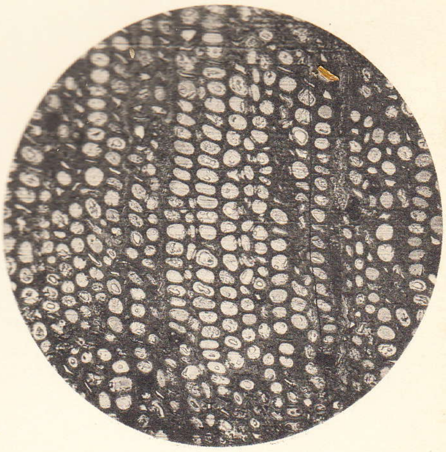

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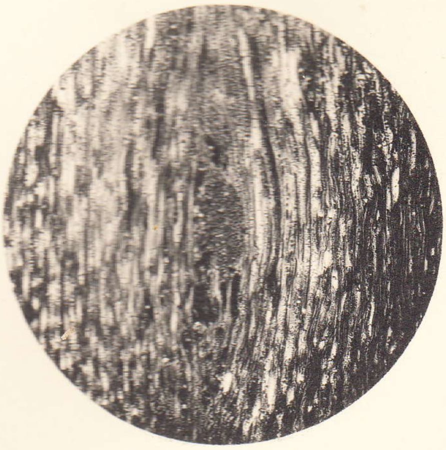

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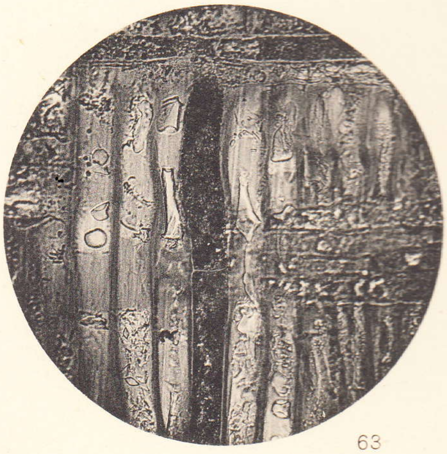

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TORREY ON FOSSIL CONIFERS.