The undersigned hereby certify that they have read, and recommend to the Committee on Graduate Studies for their acceptance, a thesis on "The Anatomical Structure of Mesozoic Plants from the Bituminous Sands of the McMurray Formation", submitted by Anita G. Gordon, B.Sc., in fulfillment of the requirement for the Degree of M.Sc.

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The Anatomical Structure of Mesozoic Plants
from the Bituminous Sands of the McMurray Formation.

by

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Since the earliest days of modern science the records of fossil plants and animals have excited the greatest interest amongst biological and geological workers. Thomson and Geddes (1) state that "in successive periods of the earth's history higher and higher animals appear. Fishes make their appearance in the Silurian, Amphibians in the Carboniferous, Reptiles in the Permian, and Birds in the Jurassic. The records as regards plants is perhaps more striking in some of its details than in its broad outlines, but every one will allow that there were Cryptogams before there were Phanerogams, and Cycads and Conifers before there were any ordinary Flowering Plants". As indicated by Darwin, the fossil record must not be looked upon as a well stocked and arranged museum, but rather as a chance collection made at hazard and at long intervals of time.

Some fossils are more or less complete and immediately give an idea of the age and appearance of the plant to which they belong. Others are but fragmentary samples of their type and can only be studied with difficulty, and often even then, no mental picture of the structure or morphology of the plant is possible.

There are several ways described by Seward (2) in which plant material may be preserved. Some specimens may reproduce with the greatest beauty an external or internal surface, but tell nothing of the original structure. These are "casts". They appear to have been formed by fine sand or mud silting around a submerged fragment, and eventually enclosing it completely. The soft tissue and cellular structure decays and the subsequent hollow fills with more fine silt. Gradually the mud hardens to rock. Thus the stone mould around the outside of the plant material encloses a stone casting. The best casts will be found in limestone beds, its harder and finer structure acting as a good preservative.

There are many varieties of casts among fossil plants. Sometimes a rock may be split, so as to show the perfect form of the surface of the stem, while the reverse is left on the stone. In other cases the cast may simply represent the internal hollows of the plant. Fine mud or silt may have completely filled the plant cavities, and whether the rest of the plant is preserved or not, the shape of the inside of the stem is represented by solid stone. Still another form of cast which is common in some rocks, are those which show the external characteristics of hard seeds. "Trigonocarpon" seeds are of this type. Casts are of great service to the palaeobotanists because they so often give clear indications of the appearance of the part they represent, particularily of stems, leaf-scars and large seeds.

Then there is a type of fossil known as an "impression". These often show more detail, and they usually retain something of the actual tissues of the plant. Much evidence has shown that the rocks which contain the best impressions were originally deposited in water under tranquil conditions. From them are drawn many important facts about the nature and appearance of plants of which the internal anatomy is known from other specimens. These are also of prime interest in the correlation of various fragments.

Sometimes impressions are very large and show highly branched and complex leaves like those of the tree-ferns. They are particularily common in the fine shales above coal seams and are often so large they cannot be brought out of the mines complete. Such impressions are black, due to the films of carbon which represent the partially decomposed tissues of the plant.

Again, isolated impressions are found in clay balls or nodules. Here the plants may be preserved without compression and something of the minute details of organization may be retained.

Another manner of preservation is typified in the fossil "Chara", in which the whole plant is completely preserved, the surface being incrusted with mineral matter. In this specimen calcium is the preservator.

Among the most important fossils are those technically known as "petrifications". In such specimens, every cell of the plant tissue can be perfectly preserved, distended as when living. The whole of the organized substance may be completely saturated by mineral matter in solution, which may subsequently be precipitated in solid from. Petrifacts are so hard that thin sections can be prepared for microscopic study.

The two most important petrifying agents are silicic acid -H_2SiO_4 - and calcium carbonate - $CaCO_3$. Sometimes small isolated fragments of wood have been completely permeated by silica which replaces the cell walls and preserves the tissue. A particularily notable example of such petrifaction is the Tertiary forest of Yellowstone Park in the Central Rockies. Here the petrified tree trunks are weathered out and stand much as they must have when alive, but, of course, bereft of their foliar branches. Calcium carbonate has the same preservative power. In calcified specimens the structural details are shown rather better, but such fossils are not common.

It is impossible in most cases, to connect such fragments with the impressions of leaves or fruits, so that plants they represent are known only by their anatomical structures.

Of still greater importance however, are those masses of stone which lie embedded in the coal seams, commonly called "coal-balls". In good coal-balls the mineral material may completely replace and petrify each individual cell of the plants in them. The plant tissues are preserved so that the most delicate structures are perfect. The particular value of these petrifactions lie in the fact that they contain plant debris. They may include a whole mass of vegetation consisting of fragments of stems, roots, leaves or seeds. They render possible the connection of various parts of many plants, since they may contain such fossils as twigs with attached leaves, or fragments of stem with their fruits.

So far, Palaeozoic specimens have provided the most valuable information about ancient plants, partly because the coal-balls found in the strata are the commonest and the most perfect examples of structural petrifactions.

In some cases a certain amount of the structure of the plants is found, after proper treatment, in the coal itself. Stopes (3) describes many of them, however, more usually, in the process of decay the tissues have become entirely decomposed, leaving only their carbonized elements. But on the upper and lower shales there are often many plant impressions.

As far as preservation is concerned, a fortunate occurrence is such as took place during the Carboniferous and Permian periods in some regions of Western Europe. It was the scene of widespread volcanic activity, and broken plant fragments became sealed in a volcanic matrix, remaining in such an excellent state of preservation as to allow of a minute investigation of the internal structures.

After describing some of the commoner methods of fossilization, we might briefly consider how plants are now supplying material for fossils of the future age. The strata richest in fossil plants, are often those which have been laid down on the floor of an inland lake, or those spread out as river-borne sediment under the waters of an estuary, as explained by Seward (2). The condition of sedimentation and of the varied circumstances attending the transport and accumulation of vegetation of today, throws a light on the possible deposition of the fossil bearing strata.

Quite different from the methods of preservation hitherto described, is that of the specimens with which this paper is concerned. They are fresh water fossils of the late Jurassic or Early Cretaceous periods. Most probably the sand with the embedded fragments of wood was laid down in the large delta of a river. The present location of the McMurray bituminous sands was in the neighborhood of the shore-line of an Early Cretaceous sea of Arctic waters, and it may have been that these fragments of wood were deposited in the sands of a river flowing down to that body of water. The splendid preservation of the fossil material is due to the infiltration of heavy bitumen, shortly after the deposition of the sand, and the consequent exclusion of oxygen, protecting the wood from further decomposition.

As Noe (4) states, the flora of today contains not only the highest and latest types of plant development, but many primitive and poorly developed types. By comparison of their anatomical and morphological structures, palaeobotanists may gain a fair conception of plant evolution. However, the real chronological evidence of plant life lies in the records of fossil plants. It is by the comparative study of the living and fossil structures that we can understand the realities of evolution.

The morphology and anatomy of fossil plants lies at the foundation of the classification of modern vegetation; as Scott (5) believes most of the direct evidence in evolution is learned from the structural features of ancient plants. It is sometimes possible to follow the progress of a group from its first appearance through the time of its maximum development, to its decline or complete extinction.

Vegetable remains are by no means evenly distributed through the series of the earth's strata. They are practically absent from some beds, while in others they are abundant.

Knowlton (6) has concluded that life must have existed at the time the oldest rocks were being formed, that is during the Pre-Cambrian, but its records are few and uncertain. Scientists are reasonably sure that plants were present and fairly widespread in Huronian or Lower Pre-Cambrian time, and that such life included algae, bacteria and probably bacilli. These algae forms were slender, often branching or worm-like. They seem to have been surrounded by a mucilaginous sheath. Associated with the algae were iron bacteria.

In the Keweenawan rocks there are found the remains of algae that had developed the power of extracting limestone from the water in which they live, and building up peculiar layers or forms around their various parts. No less than a dozen forms of this supposed lime-secreting algae have been described by Dr. Walcott. This limestone selecting habit has come down through the ages very little changed, and it has undoubtedly been of great importance in the building up of the vast beds of limestone.

By the time plant remains were freely preserved in the rocks of the earth, they show such marked differences as to suggest that they must have been undergoing considerable modification in structure during that long twilight period.

Coming to the Palaeozoic era, the Cambrian rocks have trustworthy records of organic life, but mostly that of animal life. Our knowledge of the plants of the Cambrian, Ordovician and Silurian periods is very limited, due to the fact that the great thicknesses of beds were deposited in salt water, and therefore would be unlikely to contain land plants - if indeed, a terrestial vegetation had developed by that time. However, as many as a hundred kinds of sea-weeds or algae have been described from the beds of these periods.

These are the only ones known with certainty to have lived in the earliest periods of the Palaeozoic. From the evidence afforded by the algae of these periods, they had developed so far as to establish some of the great groups of living sea-weeds, and some of these ancient types were of gigantic size.

It is now an accepted assertion that the sea is "the cradle of life", and that the land plants that later clothed the surface of the earth, developed from aquatic forms. This is fairly well proved since many terrestial plants still retain characteristics, especially in methods of reproduction, which show a direct connection with these remote ancestors.

According to the fossil records the land plants of the Devonian age seem to spring suddenly into existence. However there is such a variety of types and such complexity of structures, there must be a great deal of fossil evidence missing. It seems most probable that some of these aquatic forms had become adapted to a terrestrial existence before Devonian times, but so far very little satisfactory evidence of such adaptation is known. When the algae by continuous exposure to the air, became fully adjusted to land life, their progress must have been very rapid. In a short time many very different groups were established, some of which have come down to the present day.

One of the most interesting of these Devonian plants is known as Psilophyton. It had naked, leafless stems about two feet in height. They show the presence of stomata. These stems were provided with spines or prickles, which were not foliar organs but merely protrubances of the stem. The stems were forked and the tips display circinate vernation, as in the growing tips of modern Ferns. They grew erect from a tangled mat of creeping rhizomes with tiny rhizoids, which were obviously for the absorption of water. The fruiting organs were naked, oval spore-cases, borne on slender pedicels, and usually in pairs. The plant seems to have been homosporous.

The most ancient land plant of which the structure is at all fully known was discovered about 1914, in Aberdeenshire, Scotland, and was described by Kidston and Lang (7). It is known as Rhynia. There are two species, Rhynia Gwynne-Vaughani, and the other, three times its size, Rhynia major. The whole deposit, evidently an ancient peat bed, has been silicified. Rhynia had neither roots nor leaves, the upright stems growing from branched underground rhizomes similar in structure to those of Psilophyton. Scattered stomata are present here also. The anatomy of the vertical stems is beautifully preserved. There is a solid central cylinder, made up of tracheids, whose inner walls are marked by thick rings. Around this is a layer of thin walled cells, followed by an outer bark or cortex of thick walled cells. The spore-cases are borne in a similar fashion to those of Psilophyton, but usually singly. The spores are free, or united in fours and are typically fern-like in appearance. It is fairly clear that Rhynia and Psilophyton belong to the Vascular Cryptogams or Pteridophyta, but as yet they cannot be placed in any class of this group.

It is a feature of great interest, that a number of forms of Fungi have been discovered in these Chert Beds. They are about the first Fungi to be discovered in rocks of such an old formation. They are met with in the decayed remains of the vascular plants, also in the peaty matrix. The fungal remains are so generally distributed that they can be regarded as forming an integral part of the peat. In most cases they had evidently lived as saprophytes. These are discussed to some extent by Kidston and Lang (8).

In the uppermost beds which contained Rhynia there are the remains of a curious little plant named

Asteroxylon. Its stem is completely covered with small narrow leaves, which have a striking resemblance to the living Club Mosses. It is supposed to be related to Lycopodium and to the Ferns. There are many other Devonian plants which are more or less closely related to these just described(6).

In Lower and Middle Devonian rocks of Canada, are some very strange, large silicified trunks, first discovered by Sir William Dawson. These were studied by Carruthers along with a number of similar, uniform, European types. He concluded that they were gigantic fossil sea-weeds. The foliage or organs of reproduction are not known with certainty, so no definite relationship can be ascertained, but it seems most probable that this sea-weed, which is called Nematophycus, is nearest to the brown algae or Phaeophyceae. Eight species have so far been recognized. The plant ranges from two to three feet in diameter and is doubtlessly hundreds of feet in length. These trunks are made up of somewhat loosely compacted, longitudional tubes. In some forms the tubes appear to be arranged in the manner of growth rings.

In another type of plant, Psilophytales, are manifested certain fundamental developments. Some of the features are not altogether new, but are new in their adaptation to terrestrial conditions. They developed a vascular system for the conduction of water, and so that the stems might maintain an upright position, and they laid the foundation of a root system for the absorption of water and nourishment. Stomata were developed to allow for communication between the internal and external atmospheres. They attempted to produce leaves, and the tips of their stems were modified to serve as spore-cases.

A great number of fossil tree trunks have been found in the Upper Devonian rocks of New York State. The State Museum procured about forty stumps and have constructed a group, which is perhaps the oldest fossil forest in the world.

There is no doubt as to the gymnospermous character of some trees from Upper Devonian rocks. One of the most striking examples is Callixylon. The cells walls of the secondary wood are pitted. There are bordered pits arranged in groups of a dozen or more, with a distinct space between the groups. Other trees were characterized by six-sided pits on the wood cells. These are Dadoxylon and Araucarioxylon. Several different species are found in various parts of the world.

Again, in these rocks there was certainly a fore-shadowing of the rich and varied flora of the Carboniferous period. One fossil tree taken from near New York, combines characters of Sigillaria and Lepidodendron, two great and distinct groups of Carboniferous times.

Many of the later Devonian plants undoubtedly continued with little change into the early Carboniferous. This period is often called the "Age of Ferns", because plants, at least supposedly of this group, were far more numerous than their associates. They fall more or less into two groups, the Primofilices or ancient Ferns, and the tree-ferns. The former are again divided into Botryopteris and Zygopteris. There are three or four genera included in Botryopteris. The division is based on stem anatomy, there being ladder-like or reticulate thickenings on the inner walls of the tracheids. Little is known concerning the Zygopterids, except the structure of the petioles, and the two or four rowed arrangement of the leaves on the stems - an arrangement not known in recent ferns.

On the other hand, the tree-ferns are quite well known. They were sixty or seventy feet in height, and two or more feet in diameter. Their trunks were crowned with large, spreading, compound fronds. The stem structure of these is known as Psaronius, the foliage as Pecopteris. The character of the fructification of these Palaeozoic tree-ferns with their synangium, or fused row of massive sporangia, show a close kinship with living Marattiaceae, or elephant-ferns.

Another important group of the Carboniferous period was Sphenophyllaceae. It had its origin in late Devonian time, reached its greatest development in Carboniferous time, and became extinct before the end of the Permian. The plants of this group apparently did not leave any direct descendants, but it seems that they did evolve from the same ancient stock as the Lycopods and Equisitaceae.

Some twenty years ago it was discovered that many of the fossils with fern-like foliage were not true Ferns, but had developed the seed-bearing habit. They are now called Pteridosperms. The best known of these is Lyginopteris. The anatomy of this plant shows its direct connection with both the Ferns and the Cycads.

While the living Lycopods are quite insignificant, they were represented in the Carboniferous rocks by a large number of forms to which the generic name of

Lepidodendron has been given. They were among the largest and most splendid trees of the Carboniferous period. The nature of the large underground parts of these trees, known as Stigmaria, is still undecided; seemingly they are neither typical stems nor roots. Associated with the Lepidodendrons were trees known as Sigillaria. The large stigmarian underground parts of Lepidodendron may have been produced by these Sigillaria. It is practically impossible to tell.

An important and well known fossil group is the Cordaitales. They were exceedingly abundant and widespread in Carboniferous time, but became extinct by the end of the Triassic. They were tall, slender trees, with poorly developed root systems. Spirally thickened cells bordered the pith and were in turn surrounded by a series of cells having ladder-like thickenings. Outside that, the wood of the trunk was composed of tracheids with two or three rows of Araucarian pitting on their walls.

By this time the Mesozoic Conifers were firmly established and widely diversified. The general inference is, that they had their beginning in Carboniferous days. The most distinctive of the supposed Conifers of the Palaeozoic, is Walchia. It was abundant during

Upper Carboniferous and Permian times. Probably a dozen other genera have been described from these rocks, but none permit a satisfactory interpretation to indicate likely descendants. However, by late Palaeozoic time several distinct types of Conifers had developed.

In the Upper Carboniferous several of the older plants weremissing, and in the early Permian the decline became still more apparent. The luxuriant forests had lost some of their old established trees. Many of the old genera still maintained their ground though in diminished numbers. As Seward (9) observes, "some new types which were better adapted to the altered circumstances, replaced the old and furnished evidence of continuity with the very new and different vegetation of the future".

There are only meagre records for study from the comparatively barren rocks of the late Permian and early Triassic. Before the end of the Permain the Lepidodendrons had disappeared. No Sigillarias have been found in strata higher than lower Permian. The true Calamites and the Sphenophyllums became extinct by the end of the Permain. Some of the Palaeozoic Pteridosperms passed the boundary between the Palaeozoic and the Mesozoic eras, but many vigorous members of the class failed to survive.

With the Permian period came the complete glaciation of Gondwana Land and the subsequent development of the Glossopteris Flora over that area. Since we are more concerned with the evolution of the group of Gymnosperms, and since they played no important role in this flora, we may proceed to the Mesozoic era.

As has been mentioned, very few plants remain as evidences of the vegetation of the early Triassic. This change from the luxuriant forests of the Carboniferous to the depauperated vegetation of the Triassic deserts illustrates the disasterous consequences of the vast climatic changes taking place at this time. Scarcity of fossils is interpreted as evidence of an impoverished vegetation due to a changed physical environment.

Connecting links between the Permian and Triassic vegetation are afforded by a few Conifers. Seward (9) states,"it is this line of evolution and the line followed by the Ginkgoales which can be traced more clearly than some of the others from the Permian to the early part of the Mesozoic era. Before the end of the Permian there existed Conifers which show evidence of relationship to the Abietineae, and there is good evidence of the occurence of the Araucarian family before the end of the Palaeozoic era. Fossil evidence suggests the possibility that the line of evolution represented by the Corditales stretched unbroken into later ages. The probability is that Cycadophyta appeared before the end of the Carboniferous period, but it was not until the latter part of the Triassic that they definitely began their rapid progress toward a position of dominance."

By the time of the upper Triassic there was a striking change in the flora that covered the earth. The Lepidodendrons, Sigillarias, Equisetales, Cordiates, and the group of seed-ferns had disappeared, some utterly, and some others are now only represented by the more primitive members of the group. The Triassic Ferns afford a great contrast to those of the Palaeozoic.

The forerunners of the Cycads were living during Triassic time. These plants, now dwindled to comparative unimportance, were then developing into one of the most important groups of Jurassic and Cretaceous epochs. They probably had their actual beginning in late Palaeozois time, for by the Triassic they were firmly established and split into numerous, distinct species.

In Jurassic rocks we find Ferns, Cycads and Conifers predominant, with Cycads more abundant(6). The Conifers, or those plants more safely termed Coniferophytes, were evidentally abundant and considerably diversified, but it is doubtful if they grew to any great size. The order of Araucariaceae was pretty firmly established. These Jurassic forms may represent a step between the ancient Cordiates and the modern representatives of the Araucariaceae. Specimens which may be Sequoia have been identified in these rocks. There are others of unknown relationship, though some belong with, or have close connection with, Gingko or the maiden-hair trees. These trees were most abundant in the Jurassic. Another one of the Coniferophytes, evidently with as wide a distribution as Ginkgo is known as Baiera.

In summing up the probable appearance of the vegetation of Jurassic time, Dr. E.W.Berry says,"a picture of the flora at any time during the Jurassic would show nothing like the forests of the Palaeozoic or of Tertiary and modern times. The Jurassic floras whether of swamp or upland, as known, consist primarily of Ferns, Cycads and Conifers. The Ferns were all forms of moderate size. None of the Cycad-like forms so characteristic of this age of earth history were lofty, and the Jurassic Cycads are more comparable in appearance to what is commonly denoted by the term "scrub". Rising above the general low level of this scrub were various Coniferophytes, which may have predominated in more or less pure strands at certain localities, and among which the Jurassic representatives of the maiden-hair tree, Ginkgo, stand prominently".

In the succession of the Cretaceous flora, the vegetation of the world was transformed. The contrast between the earlier and later Cretaceous plants may be described as a contrast between the ancient and the modern. The change appears to have been very sudden, and the plant world of the latter Cretaceous was not greatly different from that of to-day.

Knowlton (6) says of the Cretaceous, "as might be expected from the widespread extension of the seas over the land, the beds deposited were mainly laid down in marine or brackish waters, and hence were poorly fitted to preserve the remains of land plants. Fortunately, however, there were quite thick fresh water deposits laid down in many places on the land, and from these a considerable representation of the plant life of the time has been recovered, though doubtless, it is only a fraction of the numbers that were then living. The plants of early Cretaceous time were mainly Ferns, Cycads and Conifers, the types of which had lived on from Jurassic time, but were fated to die out by, or before the beginning of the Upper Cretaceous". During the earlier stages of the Cretaceous period flowering plants became conspicuous members of the flora, in association with these Ferns, Conifers and other Gymnosperms.

The Cycadophyta were striking members of the Early Cretaceous flora. Equisetales and Lycopodiales of that time seem to agree very closely with modern species. Ferns continued to flourish with Gleicheniaceae and Weichselia among the more characteristic plants of this epoch. It is significant that the great majority of Early Cretaceous Ferns belong to families now only represented by a few species north of the equator, or restricted to the southern hemisphere. The Ginkgoales having reached their culmination during the Jurassic, became fewer in number and more restricted in geological range in the Cretaceous period.

The Cycads, in many respects reach their greatest development in the Early Cretaceous. Associated with these plants was a well known group, the structure, flowering and fruiting characteristics of which, are so different than anything living or fossil, that a new family was created for them - the Bennettitaceae. There is a single genus, the Cycadeoidea, but more than forty nominal species have been described.

The Conifers were undoubtedly very conspicuous in the Early Cretaceous. Five supposedly distinct species of Sequoia are known. There was a small cypress (Taxodium) which was probably the forerunner of the bald cypress. The group of trees which includes the oriental cypress (Cupressus) was represented by several trees, the wood of which is known as Cupressinoxylon. Araucaria or the monkey-puzzle pine was known by two or three species. The Yew family was well represented. Of quite different appearance was Brachyophyllum, which belongs to a group now wholly extinct. The maiden-hair tree or Gingko is found in these beds as well as its close relative Baiera.

Considering the Cretaceous Conifers as a whole, some facts of particular interest are most outstanding. For instance, there was a much greater variety in genera and species in the Cretaceous period than in the northern forests of to-day. The wide distribution of the Cretaceous Conifers in north temperate and Arctic regions is a feature which did not continue into Tertiary times.

The following table of some of the more predominant Cretaceous types of gymnospermous foliage from Seward (10) illustrates their development in that period and their rapid decline in subsequent times.

Coniferales

	Jurassic	Lower Cretaceous	Upper Cretaceous	Tertiary
Araucarites) Araucarioxylon)	x	x	x	x
Dammarites		x	x	
Sequoiites	x	x	x	x
Moriconia			x	
Widdringtonites		½x	x	
Athrotaxites	½x	x	½x	
Pinites	x	x	x	x
Podozamites	?x	x	x	

We may now consider the time in the latter part of the Lower Cretaceous, which marks one of the most important steps taken by plants in their whole developmental history, namely, the coming in of unquestionable Angiosperms. By the close of the Lower Cretaceous the Angiosperms had become so prominent, that in comparison, the Ferns, Cycads and Conifers became rather insignificant types in the vegetation.

Many of the trees which were so important during the latter part of the Lower Cretaceous, either did not survive after its close, or were greatly reduced in numbers. Some were modified, and others migrated to different parts of the world.

In the Upper Cretaceous there was evidently the same mixed forests of Conifers and hardwoods, the proportion of Conifers seems to have been larger, but possibly this is because they are more easily recognized.

It is with the gymnospermous wood of this Cretaceous period that this paper is most concerned, and with those fragmentary samples of wood discovered at Fort McMurray, Alberta, Canada. They were found embedded in the bituminous sands for which that district is well known.

Fort McMurray is a small town at the junction of the Clearwater and Athabasca rivers (11). The deposit here is the largest known body of bituminous sand in the world. The country in which the bituminous sand occurs is well wooded with poplar, spruce and jack-pine. Back from the river valley the drainage is poor, and a large portion of the country is muskeg.

The dark imposing outcrops of sand rise to a height of as much as 225 feet along the bank of the Athabasca river, and they are found for a distance of one hundred miles along the river. The surfaces of the exposures are dark brown to black in color. The minimum area which the actual exposures indicate as certainly underlain by bituminous sand, is from 750 to 1000 square miles. The formation, in all probability, has a much greater extent than this, but it is only in this area, where rivers have cut valleys through overlying material and down into, or through the bituminous sand, that the formation can be seen. Above this the sides of the valley rise more gradually for several hundred feet to the level of the surrounding country. Further down the river, the valley broadens and flattens out, the bituminous sand exposures become less high and finally disappear. A number of tributary steams enter the Athabasca river within the bituminous sand area, and exposures are found in their valleys also.

The formation rests on Devonian limestone. The first geologists to examine it, held the view that the bitumen was derived from these underlying rocks. However, no evidence that these rocks contained petroleum has come to light, and there is not sufficient data upon which to construct an alternative theory. Therefore, at the present time, opinions regarding the original source of the bitumen are most uncertain.

Along the Athabasca, upstream from McMurray, Cretaceous sandstones and shales cover the sand. Below

McMurray such consolidated beds do not appear. Presumably they have been eroded away, and the bituminous sand is covered by fifty to several hundred feet of loose drift.

The sands in question, consist of a thickness of from one to two hundred feet of sandy and clayey material, more or less impregnated with bitumen. In well impregnated beds of sand, the formation is very compact. Close inspection shows that it is composed of an aggregation of fine sand particles, each of which is enveloped by a film of soft, sticky bitumen. The sand is composed essentially of quartz with relatively small quantities of mica and other minerals. In horizontal extent the clay ledges are quite local and very irregular, but they are continuous and are not distorted to any great extent. They are thin and delicate ledges, measuring two to three inches in thickness.

In this bituminous formation one would naturally expect to find an abundance of fossiliferous material, well preserved by the incrusting bitumen. Numerous fragments of plant remains have been unearthed. They are often in association with the clay ledges common throughout the formation. However, the fossiliferous material found in the clay ledges is quite different to that in the sand. The coarse nature of the sand with its large capillaries allowed the impregnation of the bitumen, but the close colloidal structure of the clay prevented it. Therefore, fossil fragments found in direct association with the clay are quite dry and flakey. The fossil material found in the sand is crushed but it is not rotted. The bitumen must have penetrated the sand, very soon, geologically speaking, after its deposition. The action could not have been violent, but more probably one of seepage, since the clay ledges are not much disturbed.

The anatomical features of a few of these plant remains are described in this paper. Although the cellular elements of the specimens are sometimes badly crushed the wood as a whole is well preserved and especially so, considering the fact that it is in an unpetrified condition. Some samples are carbonized considerably more than others, but most of them are easily chipped and crumbled in the hands. Any decomposition which has taken place is most probably due to the unoxidized destruction of the wood due to some chemical reaction.

Once the bitumen is dissolved and washed from the surfaces of the fragmentary specimens by carbon disulphide, they are easily sectioned for microscopical examination, in an ordinary microtome. The results of such examination and study are given in detail in the following description of four axes of wood from the bituminous sands.

Before dealing with the different axes individually, there are some physical and chemical properties which might be considered, as they are more or less common to all the axes described. The wood has taken on a brown coloration which in all probability is due to changes which have taken place in the chemical composition of the cell structures. Thin sections have a decided yellow tinge except in the pith and periderm regions, where reddish brown colors are predominant. Often tracheid contents are black or reddish. No clue as to the present chemical constituents can be gained by microchemical tests for lignin, cellulose, fats, oils, tannins or pectin.

To test for lignin thin sections were soaked in an alcoholic solution of phloroglucin for about one minute. They were then mounted in a small quantity of hydrochloric acid. Lignified walls would turn a bright red, however, no reaction was given by this material.

Chlorozinc iodide was first used to test for cellulose. It seemed to cause a swelling of the cell walls, but this was not accompanied by any blue coloration. Again, after treatment with iodine, the addition of sulphuric acid caused some swelling of the cell walls, but there was no color reaction for cellulose.

The test for fats and oils with Sudan III gave no satisfaction. The middle lamellae and some cell walls and cell contents were stained reddish, but the reaction for fats and oils was negative.

To test the material for pectic bodies, sections were soaked for fourty-five hours in a twenty-five per cent solution of hydrochloric acid in alcohol. They were then washed in water, and treated with methylene blue. The middle lamellae, usually consisting of compounds of pectic acid, stained more deeply than the rest. The outer part of the cell walls appeared almost white or transparent, within that, the contents were greenish-blue. However, the sections appear to have absorbed the stain rather than having any definite reaction to the test for pectin. Another test was carried out with Ruthenium Red. The whole section took on rather a claret coloration, especially along the section edge, where it was thinnest, but there was no chemical reaction.

Sections of the various fragments of wood were treated with different stains. They seemed to absorb the reagents through the whole cellular structure, so that the staining was of no value as a test for possible cell constituents. Staining with aniline blue was very effective, in that the structural details were rendered remarkably clear. The cell walls became a dull light green, while the middle lamellae and some contents occupying a central position in the tracheids and the medullary ray cells, remained a clear light brown color. Eosin was not effective. The cell contents may have been a brighter, more reddish brown, but the clarification was more probably due to the clove oil mounting. A watery solution of safranin was slightly more effective than an alcoholic solution. The middle lamellae appeared as a dark or black line. The cell walls showed up nicely as a darker color than the cell contents, which were bright red. Methylene blue stained the middle lamellae almost black, the cell walls a decided, rather bright blue, while the other contents remained a brownish red color. The reactions of light green and Gentian violet were very similar to these others, but not as effective.

The conclusion may be drawn from these various treatments, that the material is a net-work of middle lamellae, and the meshes are filled with cellular material, the process of decomposition having been arrested at different stages in different cells. In most cases the walls are fairly well preserved, sometimes the lumen is partially filled with the decomposing cell wall, and sometimes they do not occupy much more space than in their original condition.

Tests were carried out for the determination of the best solvent for the material within the cell walls of this fossiliferous wood. Thin sections were treated over short and long periods of time with xylol, acetone, benzole, chloroform, carbon disulphide, and boiled in water. Xylol macerated the contents slightly, sometimes breaking their contact with the cell walls. While it clarified the sections, it did not seem to dissolve any of the substances. Acetone and xylol were probably most effective, but both were unsatisfactory because so many cells remained untouched by the reagents. Benzole rendered the lamellae darker. Some cell contents were drawn to the centre of the cells, but again, the reaction was irregular. While in chloroform there was a certain breaking and shattering of the contents within the cell, the reaction was very differential and not as satisfactory as some others. Carbon disulphide had only a slight effect on the cell contents, and boiling in water had no appreciable effect, even after boiling for forty minutes.

Stranger still were the reactions of concentrated hydrochloric, sulphuric and carbolic acids, on transverse and longitudional sections of this wood. There was no apparent breaking down or dissolving of the cellular structure or contents in sections soaked in concentrated hydrochloric acid. It seemed to render the walls more opaque, but where there were cells completely plugged the central contents seemed to be a brighter color and more transparent than in untreated sections. These treated sections when dehydrated with absolute alcohol, and mounted in clove oil, were rendered quite clear, the structures showing up very well.

Sections placed in concentrated sulphuric acid and subjected to heat became opaque and very dark or dull in color. When dehydrated and mounted, the results were very similar to those of the sections treated with hydrochloric acid, or maybe not as definite.

Disintegration was rapid when sections were placed in Schulze's Macerating Fluid (one gram of potassium chlorate in fifty cubic centimetres of concentrated nitric acid). When the wood was treated with the cold fluid, it almost immediately paled to a light brown color. When heated the elements were apparently dissolved. Concentrated nitric acid had much the same effect as Schulze's Fluid, but to be effective the reaction required heat, and a much longer period of time. The uniform dissolving of the material rather indicates a uniform chemical composition throughout.

While the physical and chemical composition of the wood was evidently completely changed through the period of its preservation, the structural details were very adequately preserved. We now come to the detailed consideration of this unpetrified fossiliferous wood. The fragments of stems described are called Axis 25, 26, 27 and 28. These being new species, generic and specific names have not been given to them. However, in the event of the paper being published that will be done.

Axis 25 and 26 are rather exceptional, in that, there is a lateral branch embedded within the secondary wood of both main axes. The medullas of these lateral branches are present, as well as those of the main axes. In Axis 26 there is a portion of the cortical region and two normal periderm formations in evidence.

AXIS 25.

DIAGNOSIS

The wood is characterized by alternating cylinders of crushed and uncrushed elements. The margin of the uncrushed area is very abrupt, leading us to expect that these growth rings are annual rings. The autumn wood varies greatly in width, but is usually narrower than the spring wood. The tracheids measure about 25 microns in diameter, and are very long. The bordered pits are irregularly rounded or circular, and are always of "Abietinean type". The pits are vertically isolated, and no Bars of Sanio are apparent. No wood parenchyma is present.

The medullary rays are all uniseriate, most commonly three to five tracheids distant. The ray cells are apparently uniform as regards the size and thickness of the walls, though the density and texture of the contents vary. They have smooth walls and no "Abietinean pitting". The end walls are straight in radial view, but in transverse view they are slanting at different angles, and some are curved. There is one large pit per tracheid field in the radial walls. The pit-pore is an oblique slit.

The pith of the main axis is present in the specimen, and is the shape of a small irregular five-rayed star. There is a lateral axis embedded within the secondary wood. Transverse sections of this lateral axis reveal a larger, less complicated, oval-shaped pith, much more regular in outline than that of the primary stem. There is no evidence of centripetal wood, the protoxylem lying directly adjacent to the pith. The pith seems to consist solely of parenchymatous tissue with a few stone cells interspersed in groups of three or four, or appearing singly.

HORIZON

Lower Cretaceous.

LOCALITY

McMurray Bituminous Sands at Fort McMurray, Alberta, Canada.

FINDER

Dr. F. J. Lewis, - August 1930.

DESCRIPTION

The type specimens, along with several other axes of secondary wood, were embedded in bituminous sand, attached to an irregular mass of grey clay about two feet across. They were fragments about 12 by 6 by 4 centimetres in size, entirely incrusted with bituminous sand. One contained a lateral branch embedded in the secondary wood of the main axis.

TOPOGRAPHY OF THE STEM

In the secondary wood the growth rings are sharply differentiated. The number of elements composing each growth ring vary from about ten to fifty, in radial series. The maximum thickness of the rings is about two millimetres, one millimetre being a common width. It is practically impossible to count the radial series of tracheids in an entire ring because of the crushed and distorted condition of the spring wood. The number of elements of the autumn wood are five to eight generally, although there may be up to fifty radial elements. The growth rings although usually in even concentric rings are sometimes in regular waves, sometimes irregular or again quite uneven. The elements of the crushed spring wood are often radially parallel with the elements of the autumn wood, but more often at a slant of about forty-five degrees.

In the region of the pith there is perfect regularity of the autumn wood elements, and the medullary rays become comparatively wider as the medulla is

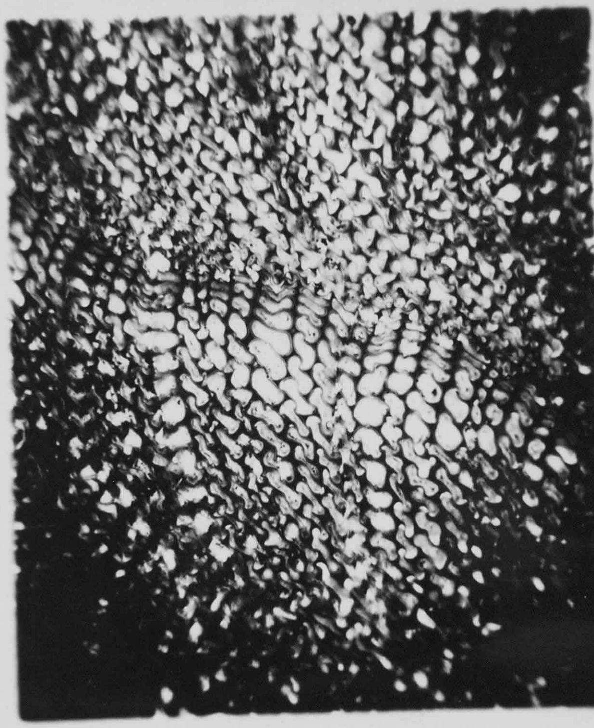

Plate 1.- Axis 25. Transverse section of the secondary wood, showing the growth rings and the absence of visible medullary rays. X 100.

approached. These rings alternate with bands of regular width of crushed tissue, through which the medullary rays are easily traced at an angle of forty-five degrees. This regularity holds only for two or three growth rings adjacent to the pith. There is evidence of faulted growth rings near the main axis, probably due to external pressure, the softer wood elements crushing easily, so that the firmer autumn tracheids overlap one another.

There is no wood parenchyma present. Normal or traumatic resin canals are absent.

Uniseriate medullary rays are numerous, principally three to five tracheids distant. There may be one to twelve wood elements between the rays. They vary in height from two to eighteen cells, rarely twenty, but most commonly four to eleven. The ray cells are very narrow, being about a quarter or less of the width of the adjacent tracheids as seen in tangential view. In length they range in number from three to twenty-six tracheid cells, in the majority of cases four to eight; however there are almost as many of the longer ones. The ray cells are rectangular in radial view; very narrow and oval-shaped in tangential view, so that their heighth is greater than their width; and are scarcely perceptable in transverse view. They must be quite plate-like in form. These ray cells are very difficult to detect in transverse view of the secondary wood, but they are much wider and more conspicuous near the pith. The thickness of the walls of the ray cells is about one quarter of the thickness of the tracheid walls. The walls are quite delicate, with no evidence of secondary thickening. The radial length of the ray cells is equal

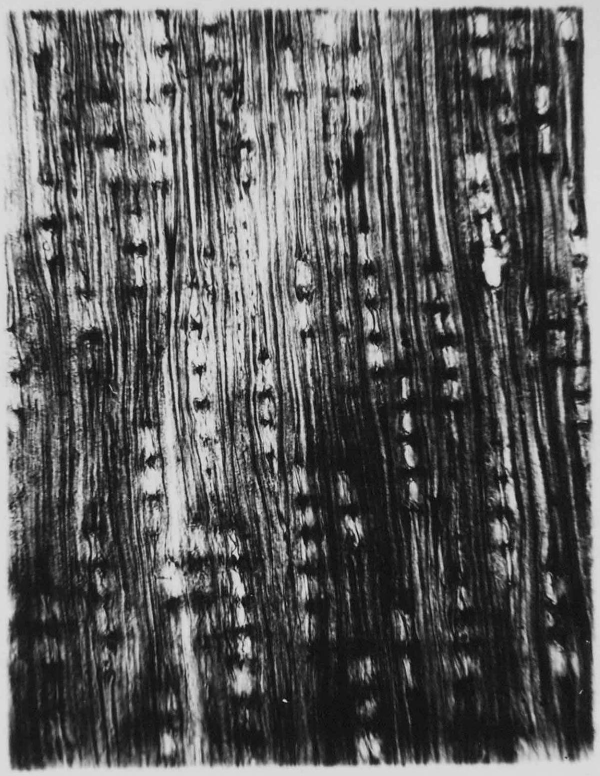

Plate 11. - Axis 25. Tangential longitudional section of the medullary rays in the region of the pith. X 200.

to the diameter of three to five tracheids.

The irregular pith of the primary axis is somewhat flattened in one direction, measuring two and one quarter millimetres in length by one millimetre in width. To one side of the pith and separated from it by one band of tracheids resembling those of the autumn wood, is a large area of pith-like tissue, of approximately the same dimensions. It would be difficult to

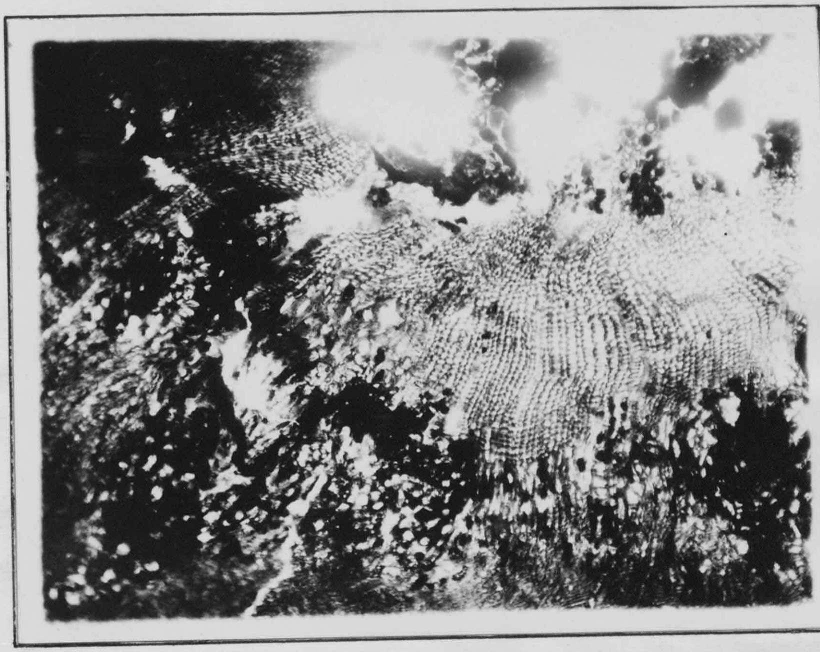

Plate 111. - Axis 25. Transverse view of the area of pith-like tissue (at the bottom) separated from the pith of the main axis (at the top) by a band of tracheids. X 61.8.

say which was the central cylinder were it not for the evidence of the converging growth rings. This condition is most probably due to some injury acquired during the growth of the axis, or a feasible suggestion is that it may be due to the fusion of two or more axes. Outside this in one region the tracheids turn from transverse to longitudional view, the elements lying now at a tangent to the central cylinder. It is probably the region of a lateral axis, but further sections to verify the supposition were impossible, owing to lack of material.

Transverse sections of the lateral axis reveal a larger, less complicated oval-shaped pith, much more regular in outline. This pith measures about two millimetres in diameter. Just outside the first or second growth ring of the main axis there are a few small patches of parenchymatous tissue and in one case even a group of stone cells. The presence of these cells in the secondary wood is most puzzling, and seems unexplainable unless due to some injury of the axis during growth. Then, in the lateral branch six and one half millimetres to one side of the pith, is an area of pith-like tissue approximately one and one half millimetres in diameter. There are stone cells present here. Sectioning inwards towards the main axis, this area is divided in a tangential direction from the lateral axis, into two areas, each of which is slightly smaller than half the original. Finally, the parenchymatous mass disappears, being replaced by the wood. The elements in this zone of wood, are much contorted and twisted in different directions. In Plate IV, the tracheids are seen transversely and longitudionally in adjacent segments. The orientation of the wood elements

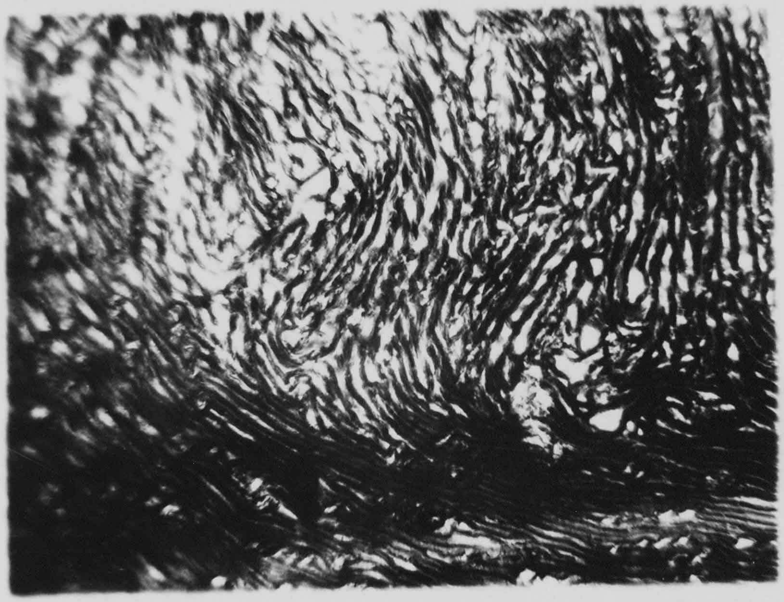

Plate IV. - Axis 25. Twisted tracheids above the "zone" of pith-like tissue in the lateral axis. X 100.

is hardly due to crushing from external pressure, it may be caused by injury during growth, or it may be that the lateral axis was very twisted in its growth causing displacement of the pith. In the latter case while sec- tioning transversely through the pith, it might be poss- ible, with the pith in a very twisted condition, to cut through another portion which is twisted up or down into the plane of the section. Further sections being un- obtainable it is impossible to verify any suggestion for the reason of this behavior.

Transverse sections show irregular streams of resiniferous substance, apparently along the much contorted paths of the medullary rays. In the vicinity of the pith of the lateral axis, there are groups of tracheids, which in longitudional view contain a great deal of resin.

Scattered throughout the wood are curious perforations, oval-shaped in longitudional view, the diameters being approximately 300 by 220 microns or smaller. They are not bounded by any wall, nor is there any special wood structure around them. These cavities are filled or partially filled with disintegrated material. They are probably due to the work of boring insects at the time of growth.

DETAIL OF THE ELEMENTS

In the majority of cases the tracheids of the autumn wood are somewhat smaller in size than those of the spring wood, but they average 20 by 15 microns. The tracheid walls of both bands of wood have approximately the same thickness. This wood has pits of "Abietinean type" which occur on the tangential and radial walls. The tracheid pitting is characterized by large flat, bordered pits occupying over three quarters of the width of the tracheids. They have uniform oblique slits, and no Rims of Sanio. There is always just one row of pits, sometimes they are very close, but never touching, and sometimes they are at a distance from each other.

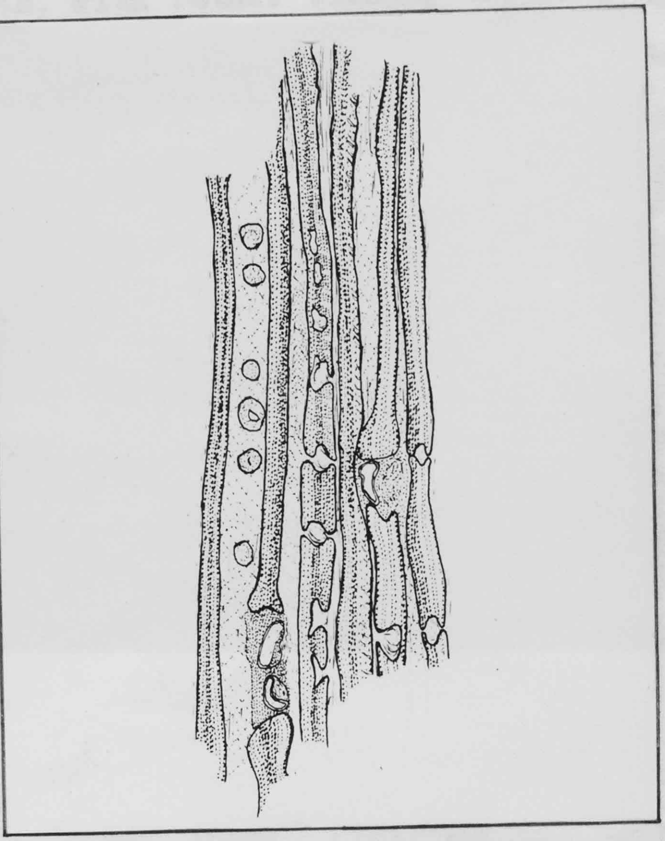

Figure 1. - Axis 25. Longitudional section, showing the bordered pits of the tracheids in surface and transverse views.

A transverse view of the bordered pits was observed in one case in the secondary wood and the torus may have been seen. However, in the region of the lateral axis the radial walls show beautiful pits in transverse view, demonstrating the complete structure with the torus.

Most of the tracheids are extraordinarily long and tubular, with very pointed ends, tapering gradually. Others, but by far the minority, are of ordinary length, with rather bluntly tapering ends. The length of the usual tracheid in this wood measures from tip to tip four or five millimetres. In the region of

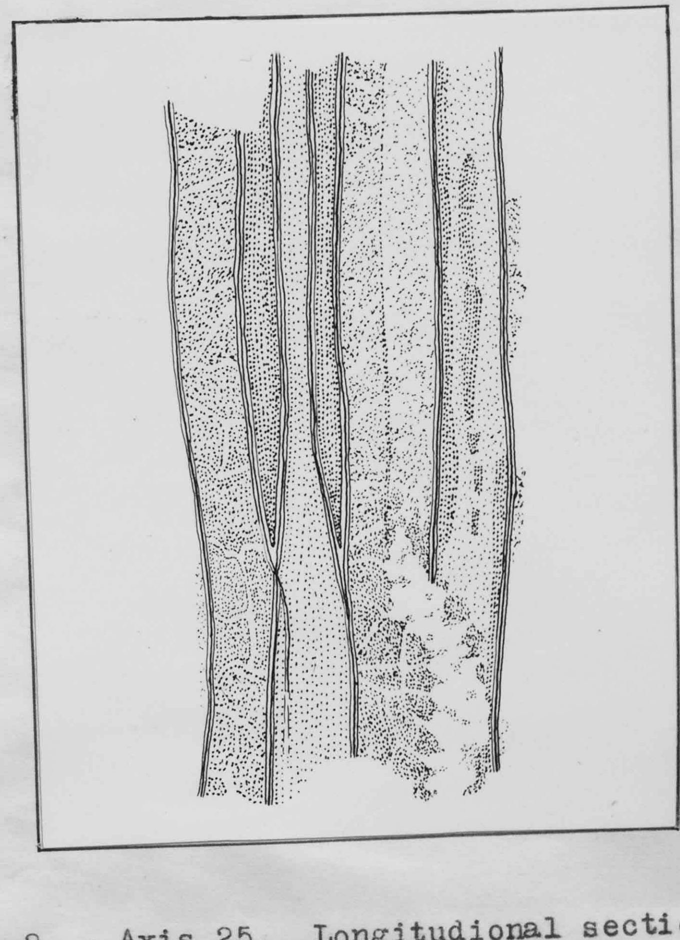

Figure 2. - Axis 25. Longitudional section showing two tracheids with comparatively blunt ends, in the region of the lateral axis.

the lateral axis the tracheids have blunt ends or bluntly tapering ends more frequently than long tapering points. In the same region the elements are so crushed and twisted that the medullary rays are seen in alternating tangential and radial views, or both simultaneously.

Longitudional views frequently show striations on the tracheid walls, which may be due to partial decomposition before complete preservation. Spirally thickened tracheid walls are not uncommon in the secondary wood. The spirals are fine and slender, and not greatly stretched apart.

Plate V. - Axis 25. Tangential longitudional section, showing the spiral thickenings of the tracheids. X 200.

In a few cases the tracheid lumen is filled with blackish contents which may have been resin, but there are no specialized resin tracheids. Resin canals are absent.

The tracheid cavity is in nearly all cases partially filled with the products of decomposition, which are lighter in color than the actual walls. Very often there are incrustations within the cell wall, which in time shrink away from the wall forming a ring within the tracheid, as seen in Figure 3.

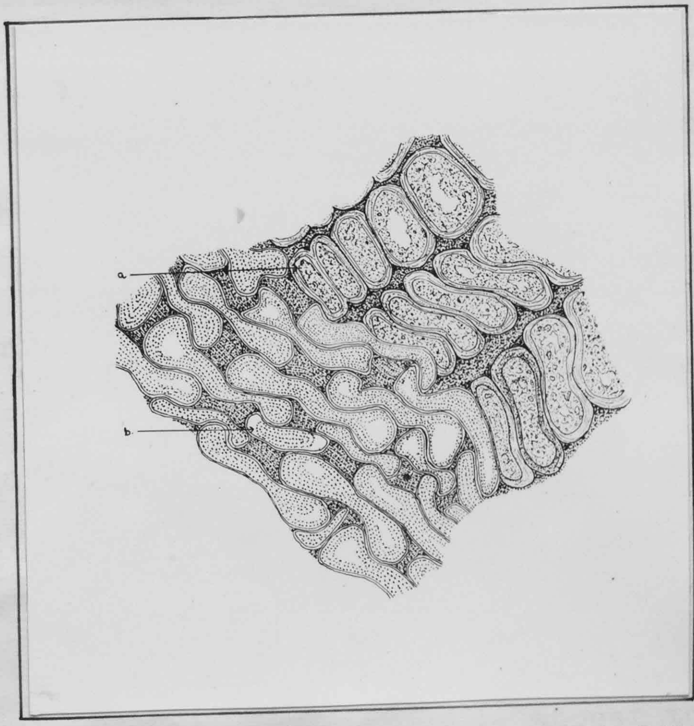

Figure 3. - Axis 25. Tracheid cavities filled with products of decomposition, and some shrunken from the cell walls as at (a) and (b).

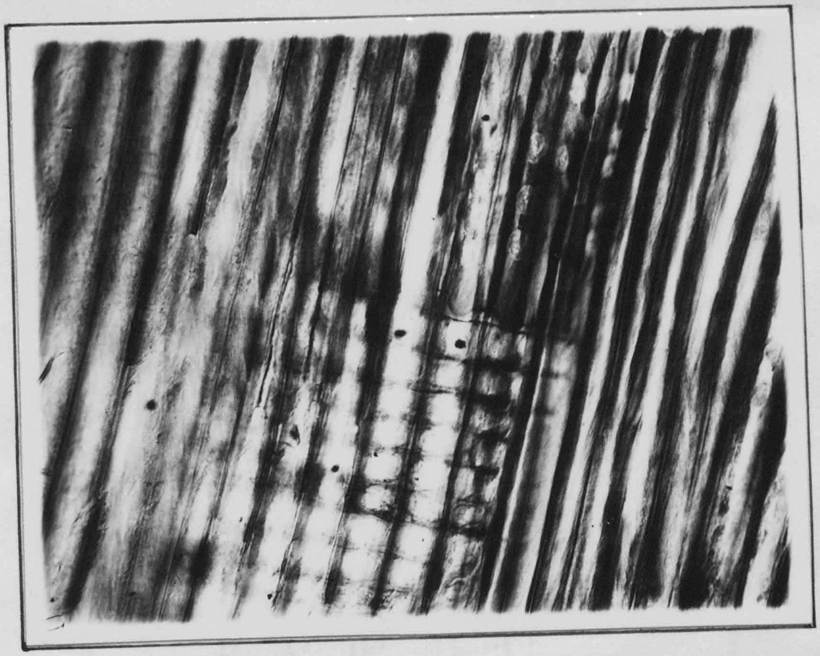

Plate VI.-Axis 25. Radial longitudional section of of the medullary rays and bordered pits of the tracheids above the ray plate. X370.

The elements comprising the medullary rays appear to be all of one kind as regards their walls and and pitting. No "Abietinean thickening can be distinguished. On the lateral walls adjacent to the tracheids, are very large, rounded pits which completely fill one tracheid field. They appear to be bordered pits, having long slit-like pores which are not quite vertical in direction. There is no lumen, but the density and texture of the contents is varying. Some ray cells appear to be blocked with a substance which may represent resin.

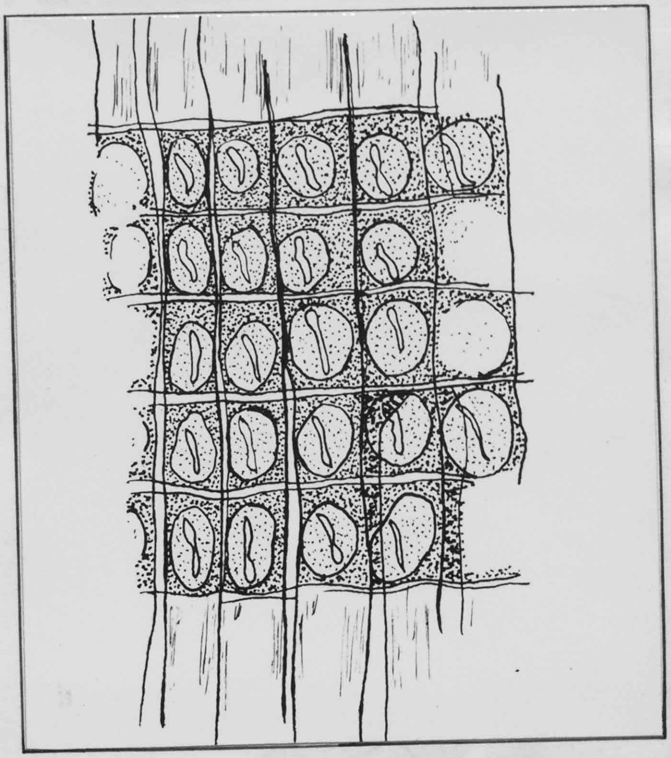

Figure 4. - Axis 25. Radial longitudional section, showing the detail of the pits in the ray tracheid fields.

In diameter the pith cells are three to six times as large as the wood cells. The walls of the pith cells are quite thick in comparison to the thinner cell walls of the secondary wood. Transverse walls of the medulla cells show no pitting. However, there appear to be groups of short, blunt tracheids interspersed with the parenchymatous cells of the pith. These tracheids are heavily pitted, the bordered pits not confining themselves to a single row, but being in pairs with no apparent arrangement. The greater number of the pith cells have contents in the form of spherical globules, which vary greatly in size and color. Idioblasts in the pith are fairly common, they are only of medium size,

Plate VII. - Axis 25. Longitudional section of the main axis pith, and the spirals of the adjacent protoxylem. X 370.

with a very small lumen or none at all, and they appear usually in groups of three or four.

AFFINITIES

Most of the details indicate a Xenoxyloid affinity as outlined by Seward (12). There seems to be none which directly contradicts similarity. The biggest disagreement is that some species of Xenoxylon characteristically have vertically flattened and transversely elongated pits, on the radial walls; this type of pit is constant in Xenoxylon latiporosum, but only occasional in Xenoxylon phyllocladoides. In Xenoxylon conchylianum, the third species known, the pits are rather less flattened than in Xenoxylon latiporosum. Sometimes in Xenoxylon there is a double row of pits, but this is seldom, and none have been seen in the type specimen.

Holden (13) says, that "in regard to the affinities of Xenoxylon phyllocladoides, Gothan states that 'it is without analogy in living or fossil gymnospermous woods'".

Ax 26 = ϕ

AXIS 26.

DIAGNOSIS

The wood has well marked growth rings with autumn wood varying greatly in width, but always wider than the spring wood. The tracheids measure up to about 22 microns in diameter, and are very long. Tracheil pits are of "Abietinean type". They are irregularly rounded and vertically isolated. There are no Bars of Sanio. Wood parenchyma is absent.

The medullary rays are all uniseriate, most commonly four to seven tracheids distant. The walls of the ray cells are apparently of the same size and thickness, with no "Abietinean pitting". The end walls in radial view are usually straight, and in transverse view are straight but slightly slanting. There is one large pit per tracheid field in the radial walls, with oblique pit-pores.

2 cm diameter

There is a lateral axis embedded within the secondary wood. The pith of this is round and slightly stellate, extending somewhat between the primary groups of xylem. Centripetal wood is absent, and the protoxylem lies next to the pith. The pith is mainly parenchymatous tissue with idioblasts interspersed in irregular groups.

Adjacent to the lateral axis apparently bordering the secondary wood of the main axis is a small area of parenchymatous cortex with intermingled groups of stone cells and sclerenchymatous fibres. The cambium cells are evident in a few sections. There are two layers of periderm formations in the cortex of this stem.

HORIZON

Lower Cretaceous.

LOCALITY

McMurray Bituminous Sands at Fort McMurray, Alberta, Canada.

FINDER

Dr. Francis J. Lewis, August 1930.

DESCRIPTION

The fragments of this wood are from the same beds as those of Axis 25 - being thoroughly embedded in the bituminous sand.

TOPOGRAPHY OF THE STEM

The growth rings are not very sharply differentiated, nevertheless they are quite distinct. In radial series the elements number from about twenty to seventy, the maximum thickness of the rings being about two millimetres. The number of elements of the autumn wood is generally ten to thirty, although they may number up to seventy. The growth rings have practically no uniformity. The radial rows of spring wood are parallel with those of the autumn, but very often pushed sideways by crushing. The tracheids of adjacent radial rows are neither alternating nor in the same tangential

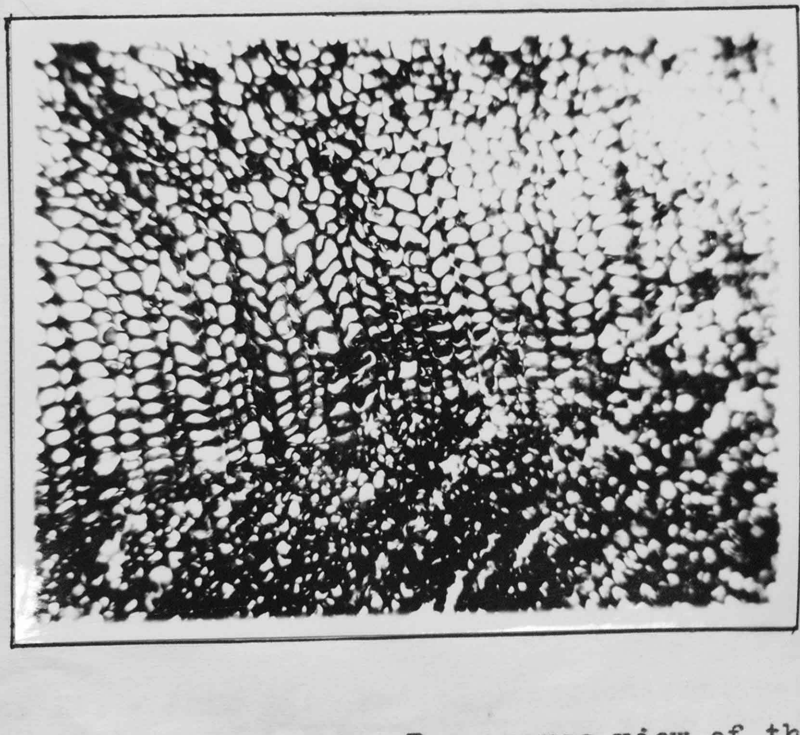

Plate VIII. - Axis 26. Transverse view of the wood of the main axis, showing the uncrushed and crushed rings. X 100.

plane, but fit into one another. The spring elements are frequently crushed into an "8" shape or flattened and collapsed.

There is no wood parenchyma, and there are no resin canals.

Uniseriate medullary rays are numerous, principally four to seven tracheids distant, but they may be one or two to twelve elements apart. The ray cells are rectangular in radial view, quite square or round in tangential view, and fairly evident in transverse view.

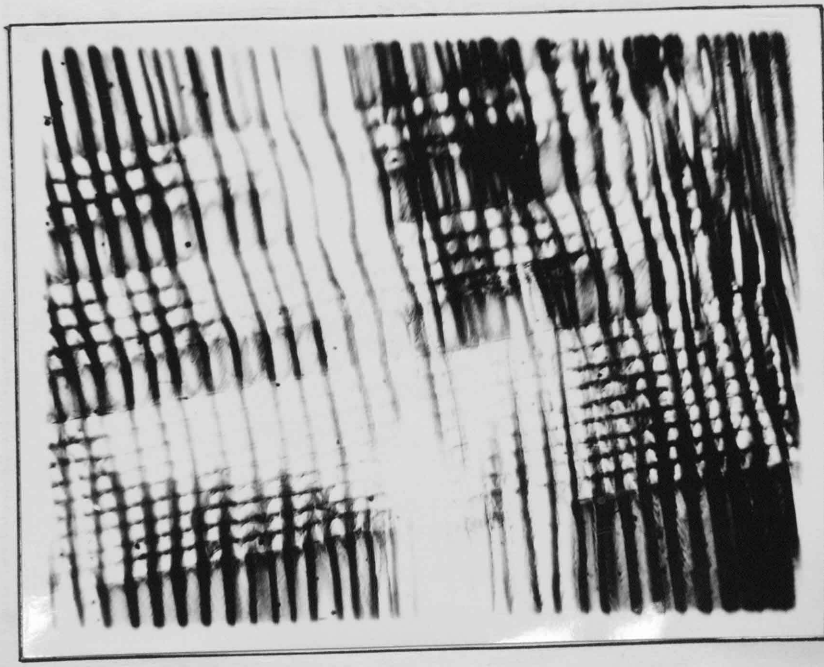

Plate IX. - Axis 26. Radial longitudional section of the medullary rays with the broad simple pits per tracheid field. X 200.

The rays vary in height from two to ten cells, most commonly from four to five. In length they range in number from twenty to thirty-five tracheil elements, some are shorter and some longer. The tangential diameter is about one third to one half that of the adjacent tracheids. The medullary rays are quite massive structures, the walls of the ray cells being about a half the thickness of those of the tracheids. Transversely the rays measure three to six tracheids in width.

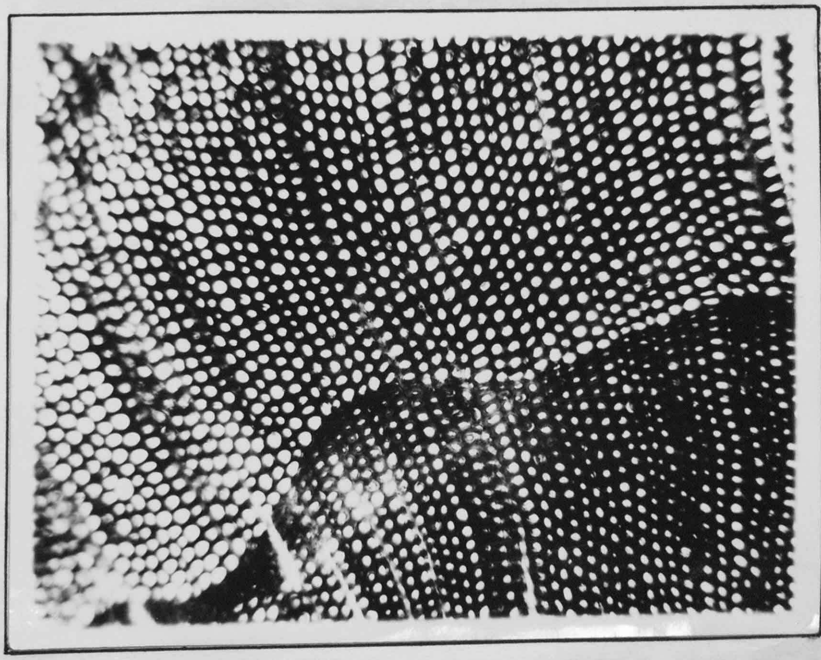

Plate X. - Axis 26. Transverse view of the wood of the lateral axis, showing the wavy structure of the growth rings. X 100.

The wood of the lateral axis is quite uncrushed and well preserved, showing perfect regularity of the wood elements, arranged in interlocking radial rows, and divided by long, very wide, uniseriate medullary rays. The first growth rings outside the pith are rather stellate in shape. Transverse sections of this embedded axis reveal a round and slightly stellate shaped pith, extending out between the groups of primary xylem.

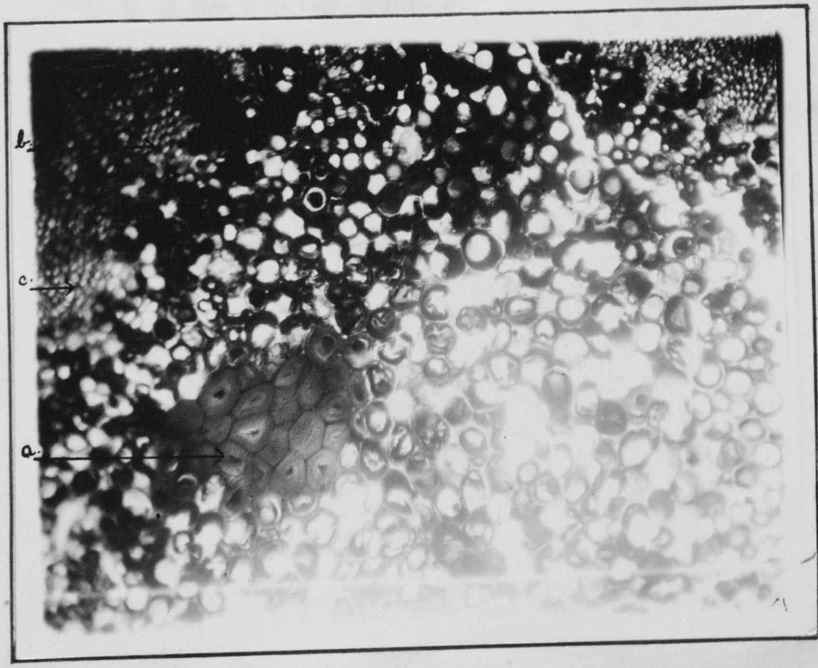

Plate XI. - Axis 26. Transverse view of the pith of the lateral axis, showing the parenchymatous cells and idioblasts at (a), also the undulations of the protoxylem into the central cylinder, as at (b) and (c). X 61.8.

There are fifteen to twenty rows of tracheids in each group of protoxylem next the pith. The pith is quite well preserved.

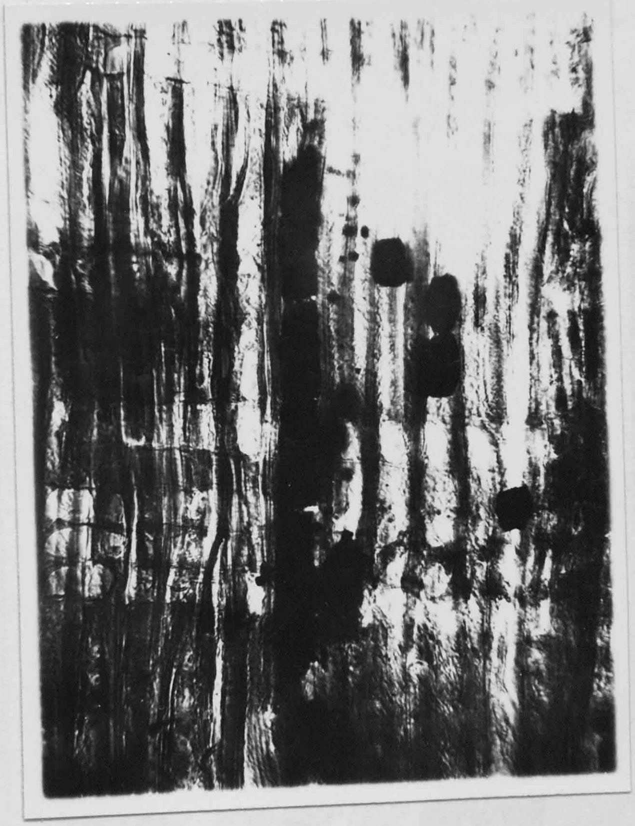

Plate XII. - Axis 26. Radial longitudional section showing resin blocked tracheids. X 200.

In longitudional sections there are several tracheids containing variable amounts of a dark, opaque, brittle substance, probably resin. A few tracheids are completely blocked by resin plugs, as seen in Plate XII.

The cortical region is crushed in most places, except for the patches of sclerenchymatous fibres and the groups of stone cells. There is the normal sequence of tissues, that is, the secondary xylem, the cambium, a region of crushed phloem and the cortex with two periderm formations.

DETAILS OF ELEMENTS

The tracheids are very thick walled, quite round in shape, and due to their arrangement, there are but

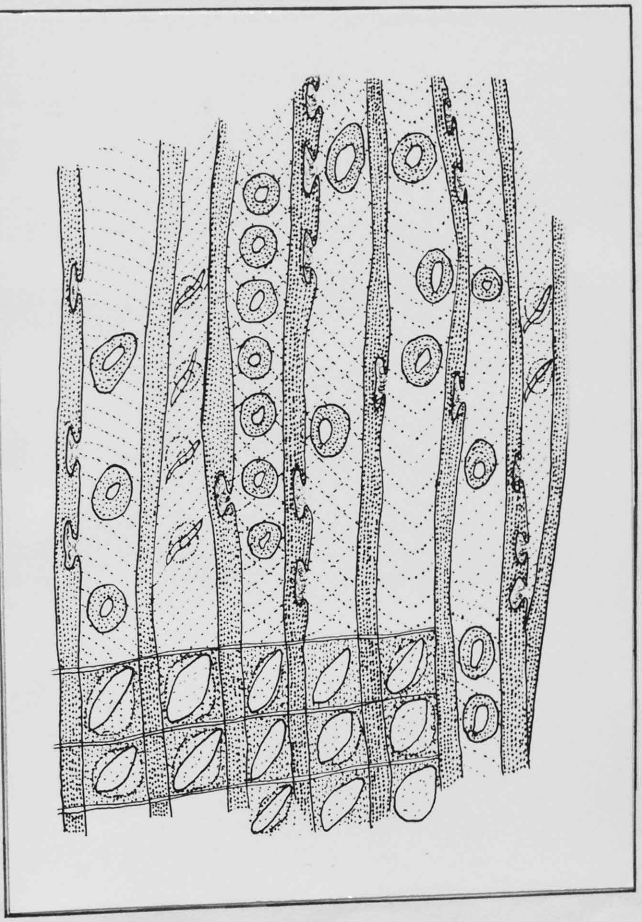

Figure 5. - Axis 26. Radial longitudional section, showing bordered pits in surface and transverse view and medullary ray pits.

small, if any, intercellular spaces. The elements of the autumn wood average about 20 by 22 microns, and are somewhat smaller in size than those of the spring wood. All the tracheid walls are very massive, having approximately the same thickness. The middle lamellae is very distinct. The tracheids have "Abietinean pitting" on their walls. The bordered pits are large and flat, occupying a half to three-quarters the width of the tracheids. The apertures are round, and there are no Rims or Bars of Sanio. Sometimes the pits are close, but never touching, and often they are in quite separate groups. On the whole they are numerous. The pits seem more profuse in the autumn wood than in the spring. In tangential sections, the complete structure of the pits in transverse view is beautifully shown. As a rule the tracheids are exceedingly long with very long pointed ends. From tip to tip they measure about four millimetres.

Spirally thickened tracheid walls are not uncommon in the secondary wood. However, due to the cracking of the tracheid walls from decomposition, nothing has been accepted as spirals unless the complete spiral on the reverse side of the tracheid is seen, or unless

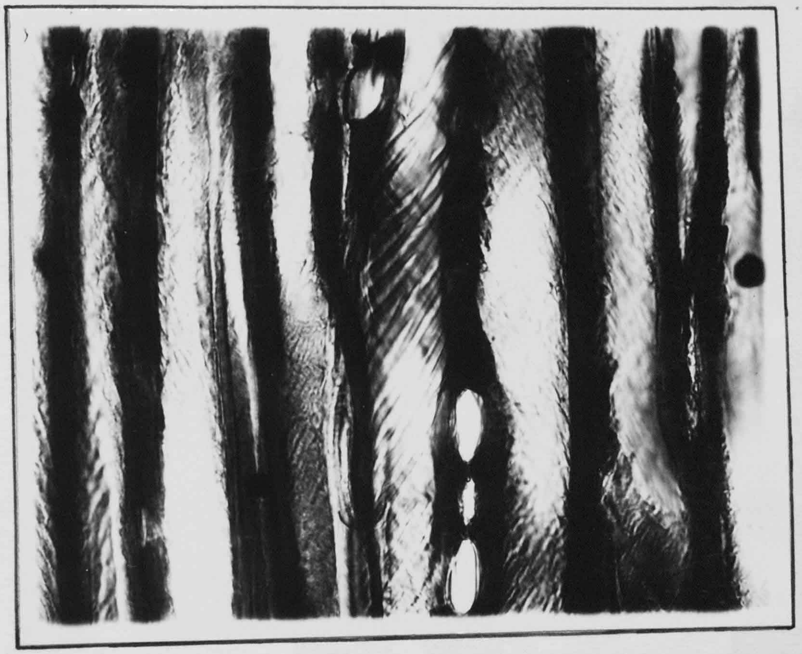

Plate XIII. - Axis 26. Tangential longitudional section showing the spiral thickenings of the tracheids. X 720.

the spirals appear pulled out of the cell at the edge of the section. Again, the attachment of the spirals to the tracheid walls is easily seen in some cases. Most of the spirals are thick and compact, not being greatly stretched apart.

Resin canals are absent.

The structure of the medullary ray cells is uniform. On the radial walls are simple, very large, rounded pits, which completely fill one tracheid field.

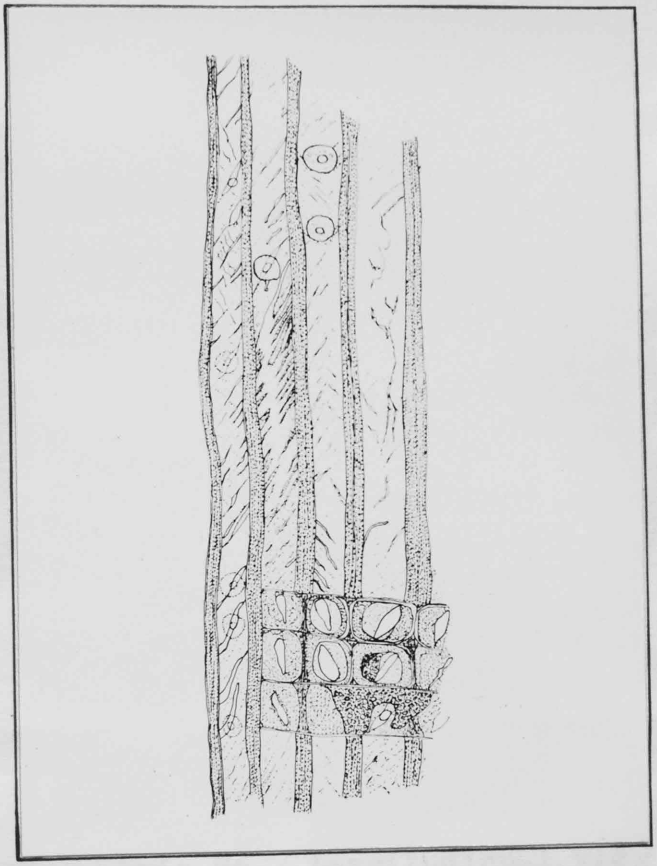

Figure 6. Axis 26. Radial longitudional section, showing medullary rays and spiral thickenings of tracheids.

The pits are not distinctly bordered, but appear to be simple with an occasional border. The pores are broadly oblique slits. There is no lumen in the ray cells.

The primary xylem of the lateral axis shows up very well and in some cases the protoxylem. In longitudional sections the protoxylem is distinguishable by the spirally thickened tracheids, directly next to the pith. The spirals in all cases seen are very thick and

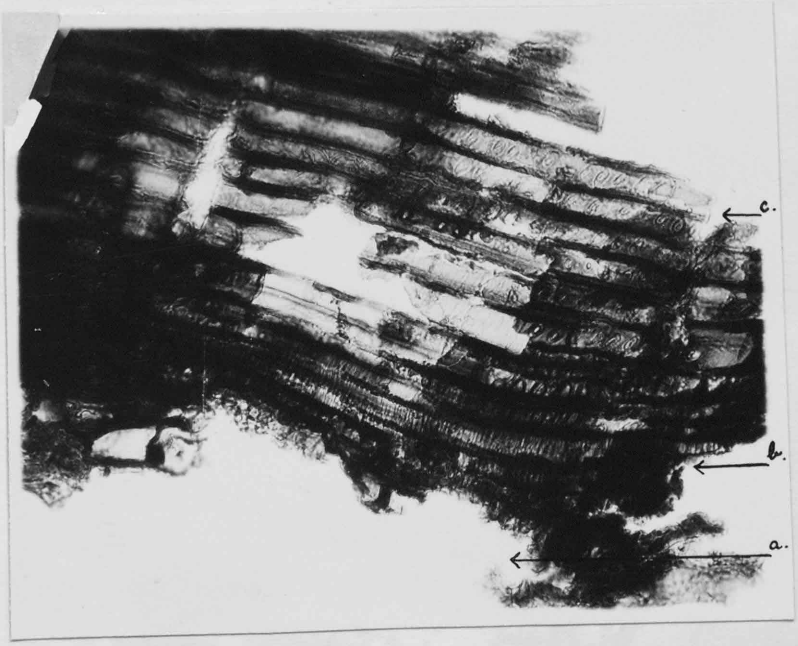

Plate XIV. - Axis 26. Longitudional view of the lateral axis showing the position of the pith at (a), the spirals of the protoxylem at (b), and the bordered pits of the metaxylem at (c). X 370.

closely coiled, being almost perpendicular to the longitudional wall of the tracheid. There are apparently only two to four rows of protoxylem. On the outside of it are the bordered-pitted tracheids of the metaxylem.

Groups of stone cells are characteristic of the lateral axis pith - they appear in compact groups, varying greatly in the number of cells to a group. They are profusely pitted and the lumen is usually filled with some darker substance. The remainder of the pith is composed of iso-diametric parenchymatous cells, generally quite round in shape, and fairly closely packed.

Plate XV. - Axis 26. Longitudional view of the pith of the lateral axis, with the wood cells to the left. X 185.

The pith cells are fairly small in diameter as compared to the larger cortical cells. The walls are comparatively thin, with small inter-cellular spaces. The parenchymatous walls are not pitted in any manner. They appear slightly smaller towards the periphery of the pith as seen in Plate XI. Many cells are filled with substances in different forms of decomposition. The majority of the pith cells are filled with globules of varying size and color, or granules, or sometimes the cells are completely plugged with opaque substances.

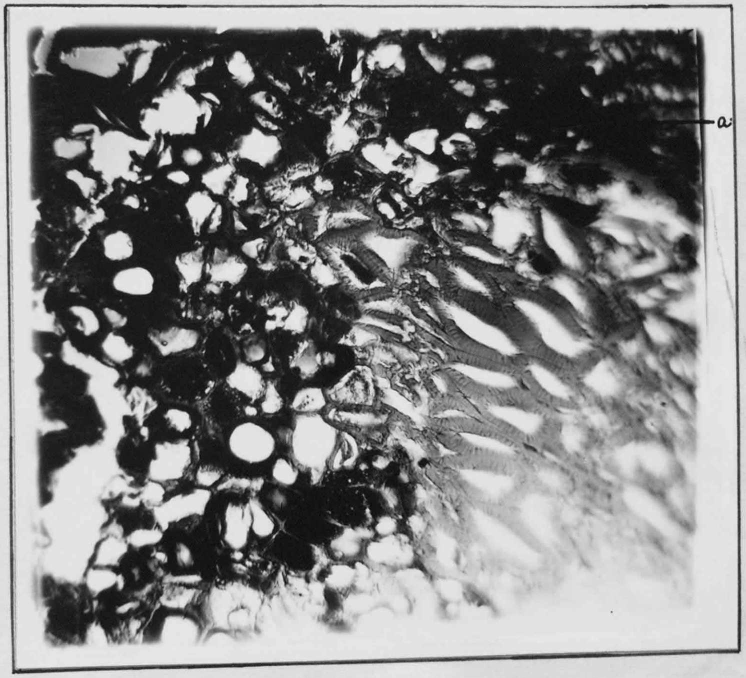

Plate XVI. - Axis 26. Cortical region, showing the parenchymatous cells, the stone cells and the periderm at (a). X 100.

In the region of the cortex and in the neighborhood of the lateral axis the tracheids go through extraordinary convolutions. Just within the cortical region the wood tracheids become horizontal in transverse section, and sometimes transverse in longitudional section. The tracheids are heavily pitted near the cortex and spiral thickenings are common. The pits are larger, with circular or oval-shaped pores. They are very close and may be touching but they do not seem to be horizontally flattened.

Plate XVII. - Axis 26. Transverse section near the cortical region, showing the thick spiral thickenings in the tracheids, and broken spirals and a few bordered pits at (a). X 400.

The parenchymatous cells of the cortex are larger and thicker walled than those of the pith. The globular contents are still present. In transverse view the walls appear to have simple pits, although in face view it is difficult to distinguish with certainty the difference between the simple round pits and the globular cell contents. In cells where the contents have shrunken from the walls there are pointed edges on the contracting substance, opposite pits in the walls. It appears that the cell contents have withdrawn from pits in the wall. The stone cells in the cortex grow to an enormous

Plate XVIII. - Axis 26. Detail of the cortex of the main axis, showing the pitted cortical cells and the stone cells. X 400.

size and are numerous, appearing usually in groups.

There is a cambium fairly well preserved. It is two or three rows in depth, of rectangular or oval-shaped cells with thin, smooth walls. The contents of the cells are opaque, and of a bright, brownish red color. In as much of the cortex as is preserved, there

Plate XIX. - Axis 26. Cambium cells at (a) on the margin of the tracheil tissue at (b) of the main axis, in the immediate neighborhood of the lateral axis. X 400.

are two distinct periderms, the innermost one is not quite as well defined as the outermost and first formed one. The periderm is three to six cells in width. It is irregular and wavy in transverse view, rather in an arc-like structure. The cells are tangentially elongated, being very long and narrow, and rather crescent-shaped to correspond with the general shape of the whole formation. They are fairly thin walled and compact, with reddish brown, opaque contents. This region of the stem is very abnormal, in that, patches of parenchymatous tissue and stone cells appear in the secondary wood within the cambium.

AFFINITIES

The two axes which have just been described are very similar. There seems, however, to be sufficient differences between them to justify a tentative separation of the types. It might be advisable to point out the distinguishing features which are of diagnostic value.

The whole structure of Axis 26. is stouter than that of Axis 25. The tracheid walls are much more delicate in Axis 25, and the general characters of the wood show a less dense structure. In this axis, the tracheids are slightly smaller, the maximum size being approximately 15 by 20 microns. In Axis 26 they commonly measure 20 by 22 microns.

In Axis 25 the tracheil pits occupy at least three quarters of the width of the tracheid. They have oblique slit-like apertures which appear on the radial and tangential walls. In Axis 26 the pits are smaller, occupying one half to three quarters of the tracheid wall, and they are apparently much more frequent on the radial walls. The pit-pores are round.

Spiral thickenings on the tracheid walls are fine and slender in Axis 25, and thick and more compact in Axis 26.

The growth rings are narrower in Axis 25, than in Axis 26, measuring ten to fifty elements and twenty to seventy, respectively. There is much less autumn wood in the former axis. There are only five to eight radial rows in Axis 25, in comparison to the ten to thirty rows in Axis 26.

The medullary rays in Axis 25 are rectangular in radial view, very narrow in tangential view and scarcely perceptable in transverse view. In Axis 26 they are radially rectangular, tangentially square or round, and fairly wide as seen in transverse sections. The walls are delicate in Axis 25, while in the other axis they are massive, being about half the thickness of the tracheid walls. The radial length of medullary ray cells in Axis 25 is about the diameter of three to five tracheids; in Axis 26 it is the diameter of three to six tracheids which makes the ray cells of the latter much longer, as the tracheids of that wood are larger.

The medullary rays of Axis 25, on the whole, are closer together and higher than those of Axis 26. In Axis 25 they are three to five tracheids distant and two to eighteen cells in heighth, but commonly four to eleven. They are very narrow in breadth, and two to twenty-six tracheid cells in length, but usually about four to eight. In Axis 26 the rays are four to seven tracheids distant; two to ten cells in heighth, but commonly four or five; about one third to one half the width of the neighboring tracheids, and twenty to thirty tracheid cells in length.

The piths of both axes are much the same size. The cells of the pith of Axis 25 are three to six times as large as those of the wood. They are quite thick-walled, parenchymatous cells, while the elements of the pith of Axis 26 are comparatively thin-walled, and fairly small in diameter. The pith cells in Axis 26 are smaller in the peri-medullary region. Short blunt tracheids are fairly common in the pith of Axis 25. The walls of the parenchymatous cells of both medullas are smooth. Idioblasts are present in both cases.

Axis 27.

DIAGNOSIS

The wood of this axis is of the most extraordinary structure. It has well marked growth rings. The tracheids are regularly arranged in radial series. The bordered pits are large and circular, with large round apertures. Sometimes they are contiguous or even touching, or, they may be oval in shape and horizontally elongated. They are generally in one row, but there may be two rows with pits opposite each other. Bars of Sanio are well marked. Wood parenchyma is in exceedingly small quantities. Resin canals are absent. Medullary rays are principally three to four tracheids distant. The majority are uniseriate, many are biseriate and a few triseriate. The rays are quite high running up to twenty-eight cells in vertical series. "Abietinean pitting" is pronounced in the medullary ray cells.

HORIZON

Lower Cretaceous.

LOCALITY

Fort McMurray Bituminous Sands, Fort McMurray, Alberta, Canada.

FINDER

Dr. Francis J. Lewis, August 1930.

DESCRIPTION

The specimen is a fragment of secondary wood rather concave in shape with a knot embedded on the inner side. The block measured 7 cms. in height, 5 in width and 2 in breadth. It is one of the many fragments found with the axes previously mentioned.

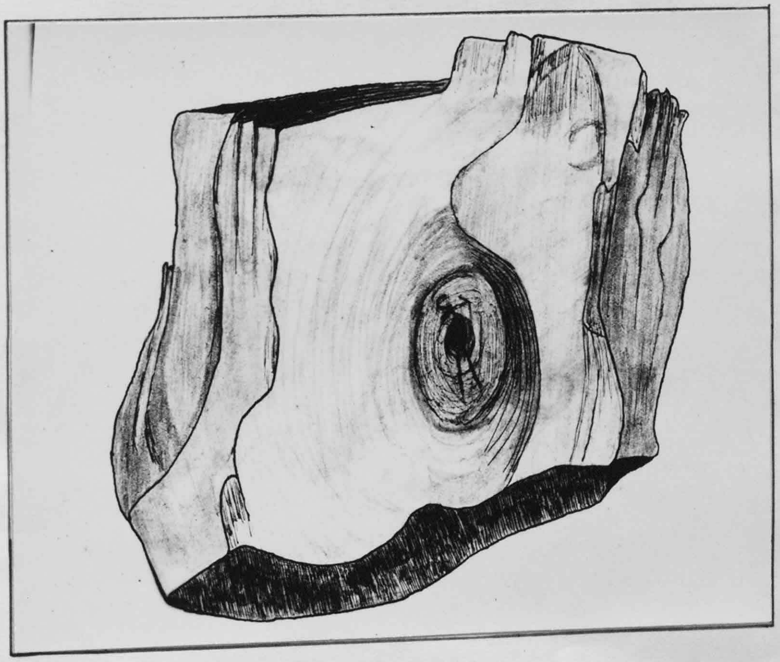

Figure 7. Axis 27. Sketch of the fragment of wood studied.

TOPOGRAPHY OF THE STEM

There are certainly concentric rings in the secondary wood, but they are of alternating badly crushed and comparatively uncrushed elements. It is impossible to make any suggestions about the structure of the wood in the former case. The width of the bands vary considerably, the number of radial elements in the uncrushed zones numbering from about six to twenty-four. The

Plate XX. - Axis 27. Transverse view of the wood, showing a growth ring. X 100.

crushed bands measure fifteen to twenty millimetres in width. On the inner side of the uncrushed area there is no sharp dividing line between it and the adjacent crushed part, one merging into the other. However, on the other side, between the two zones, there is a band not more than three cells in width of larger, probably thinner walled tracheids. The tracheids of the rest of the wood have exceedingly thick walls, the whole structure of the wood being very compact. In areas where the

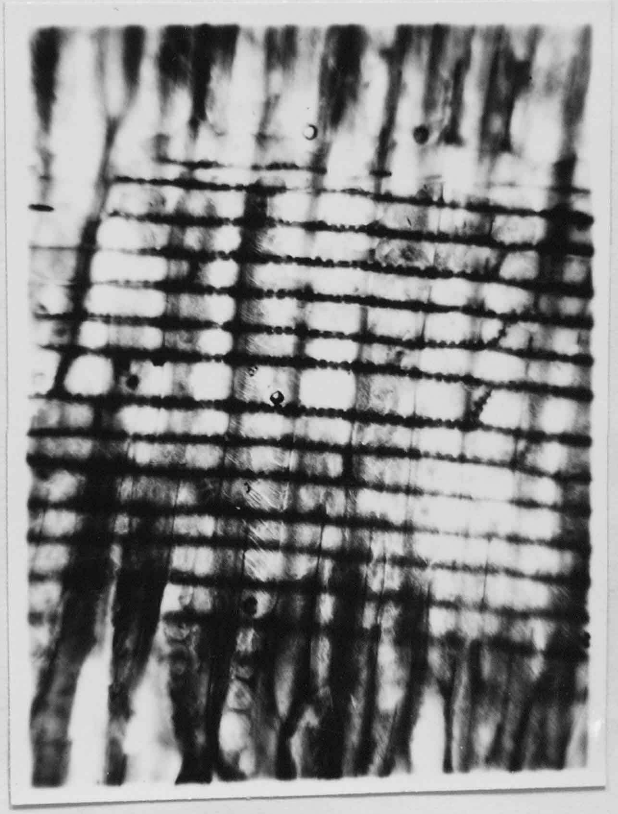

Plate XXI. - Axis 27. Radial longitudional view of the medullary rays, showing the conspicuous "Abietinean thickening" on horizontal and cross walls. X 200.

wood is not crushed, tracheids of adjacent radial rows are tangentially opposite, as can be seen in Plate XX.

There are no normal resin canals; and no taum-atic canals are present.

The medullary rays with "Abietinean pitting", are exceedingly broad and massive and numerous. They are one to seven, usually three or four tracheids distant. They are generally uniseriate, commonly biseriate, and a few are multiseriate. There is much variety in the

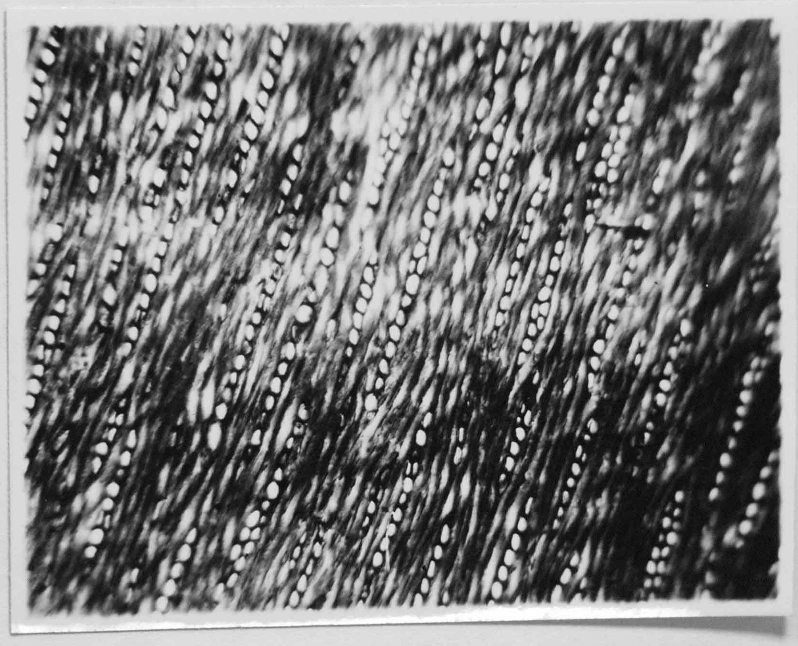

Plate XXII. - Axis 27. Tangential longitudional view of uniseriate and biseriate medullary rays. X 100.

build of the rays, some varying at different heights.

They are very high, running up to twenty-eight cells in vertical series, but being any height from one cell up to that number. In tangential view the cells are round or oval and vary greatly in size. In breadth they average about the width of the adjacent tracheids, that is when they are uniseriate. When they are biseriate the individual cells are usually alternating, although sometimes opposite. The rays are extremely long as seen in transverse section as seen in Plate XX; stretching across the wood, they pursue a zig-zag and torturous course through these large celled areas, but their continuity is unbroken. Sometimes the medullary rays run straight through the crushed area, only the elements being contorted. Then again, the whole area changes its direction quite often at an acute angle, but more often it is crushed like a folded fan.

There are small quantities of wood parenchyma present.

There are most peculiar concentric rings or patches of parenchymatous tissue neighboring on, or in the spring wood. The structure of these areas will be referred to in a later part of the description of this axis.

DETAILS OF THE ELEMENTS

The mass of wood consists of tracheids. They have exceedingly thick walls, with "Abietinean pitting" most common. The tracheids of the autumn wood vary greatly in size, those of the spring wood are enormous. The extremities of the tracheids are pointed, but they are not long tapering points as in some of the other axes described.

The tracheid pits may be large and circular, scattered, contiguous or touching. They may be large and horizontally flattened, and in double rows, usually opposite, or now and then alternating as in Plate XXIII. And again, there are small bordered pits scattered unevenly along the tracheids. In still other places there is tracheil pitting which very much resembles that of wood of Araucarian type. These pits of irregular size, are touching, and are sometimes quite angular. In tangential view of the tracheids, the pits are frequently elusive or they are not so common as on the radial walls. On the tangential walls they are round, close and about half the size of the tracheid in diameter. Sometimes the pits are almost touching, but not flattened. On the

Plate XX111. - Axis 27. Longitudional section, showing the Araucarian-like pitting of some tracheids at (a), and Abietinean pitting on the walls of other tracheids, in single rows at (b) or double rows alternating with each other as at (c). X 370.

radial walls the pits are larger; when in one row they almost fill the width of the tracheid, as seen in Plates XX111 and XXV. The apertures are round, of varying size, and a few have oblique slit-like openings. Bars of Sanio are clearly evident between individual pits or between opposite pairs.

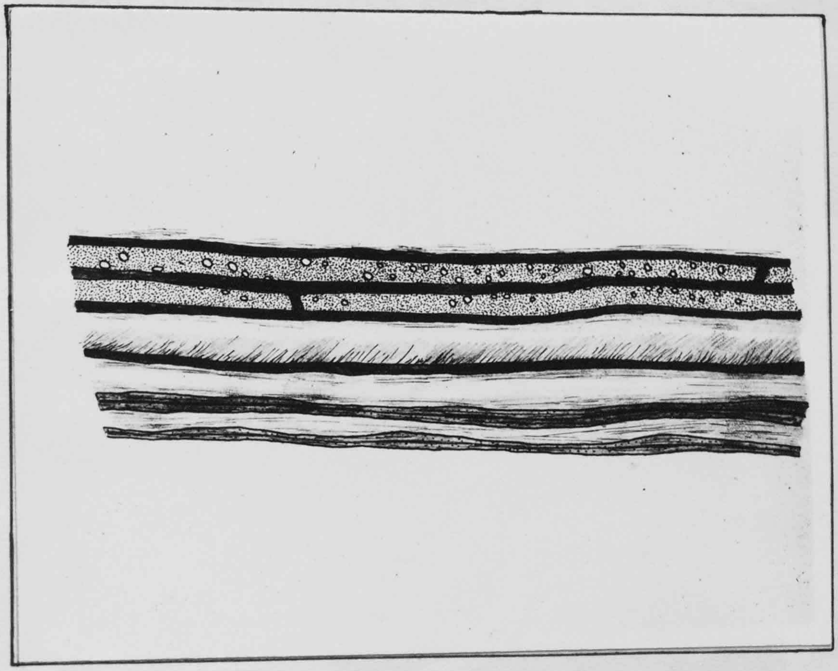

Figure 8. Axis 27. Profusely pitted wood parenchyma cells, interspersed in the tracheil tissue of the axis.

Wood parenchyma is present in the wood but in very small quantities. The cells are long and fairly narrow, with square ends. They have numerous small simple pits on the radial and tangential and end walls.

There are no resin canals present.

There is in regard both to the type of pits in the medullary ray cells and the position in which they may occur, an extraordinary variation, and from the large amount of material that has been examined it is very difficult to make any generalizations. The medullary rays as seen in transverse sections are extraordinarily wide, see Plate XX. The biseriate characteristics are easily seen. Transverse views of the pits on the radial and tangential walls are in evidence as well as the sur-

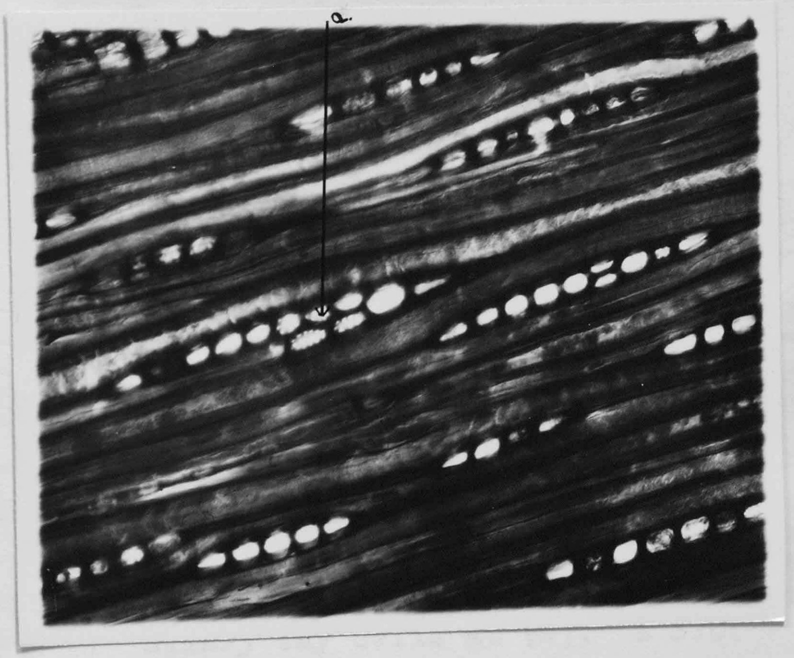

Plate XXIV. - Axis 27. Tangential longitudional section of the medullary rays, showing the pitted end walls at (a). X 370.

face view of them on the horizontal walls. These latter pits are consistently oval-shaped apertures parallel to the end walls. The other walls are covered with small, round or oval, simple pits, with apparently no arrangement. There are approximately eight to eleven small pits on the tangential walls of the medullary rays. The

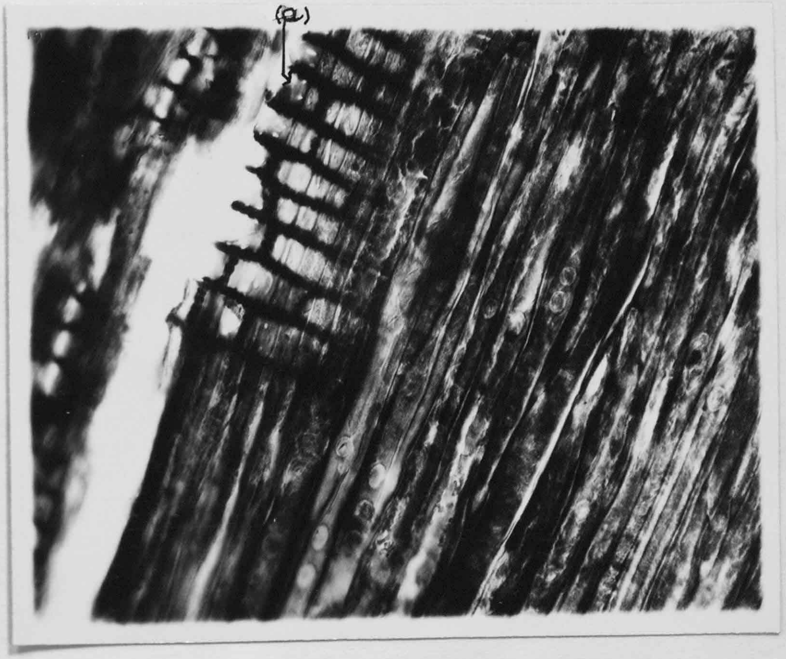

Plate XXV. - Axis 27. Longitudional section, showing the tracheil pitting and the surface view of the "Abietinean pitting" on the radial walls of the medullary ray cells at (a). X 370.

pits on the radial walls are larger, round and simple; and there are two to six of these pits per tracheid field. There is one fairly large bordered pit per tracheid field, but such pits are either very rare in occurence, or are most difficult to discover. The end walls of the medullary rays are usually straight or slanting, or sometimes curved. The radial extension of the ray cells varies from three to eight or twelve tracheids in width. The cross walls as seen in radial view are often quite pointed, tapering across the width of four tracheids.

One medullary ray, in radial view, seemed to be entirely composed of tracheids, that is, as much of the ray-plate as was seen. These cells have small bordered pits with oblique slit-like apertures. On the radial and transverse ray walls, there are a few, one to three, small bordered pits, about half the ray in diameter, and with a large round aperture. There is one of these to a tracheid field, sometimes two. The frequency of the occurrence of these ray tracheids would be difficult to estimate because of their probable decomposition during preservation. It will suffice to say they have been observed in a few cases, but again, it is impossible to figure the relative position of the tracheids in conjunction with the parenchymatous ray cells.

Fossil starch grains are quite common in medullary ray cells and are sometimes present in the tracheids, but in this case they have probably been washed in, in the process of sectioning. Often the medullary rays are blocked with dark brown or black, resiniferous substances, which however, are so opaque it is hard to determine the texture, but sometimes they are globular.

There is a large region so far unexplainable, in which the tracheids wander and twist about, branching amongst multiseriate medullary rays. Here the tracheids are much narrower, but the bordered pits are still fairly large in comparison to the width of the tracheids. They seem to arise adjacent to a medullary ray hypertrophy (which will be discussed later), but as the region is unfortunately at the very edge of the

Plate XXVI. - Axis 27. Transverse view of a patch of medullary ray hypertrophy, showing the pitting on the horizontal walls of some medullary rays, as at (a) and (b). X 370.

fragment of wood, what further connection they have would be impossible to judge, since the material is insufficient to determine this. Some of the tracheids are short with blunt ends, and have fair-sized bordered pits crowded on all their walls.

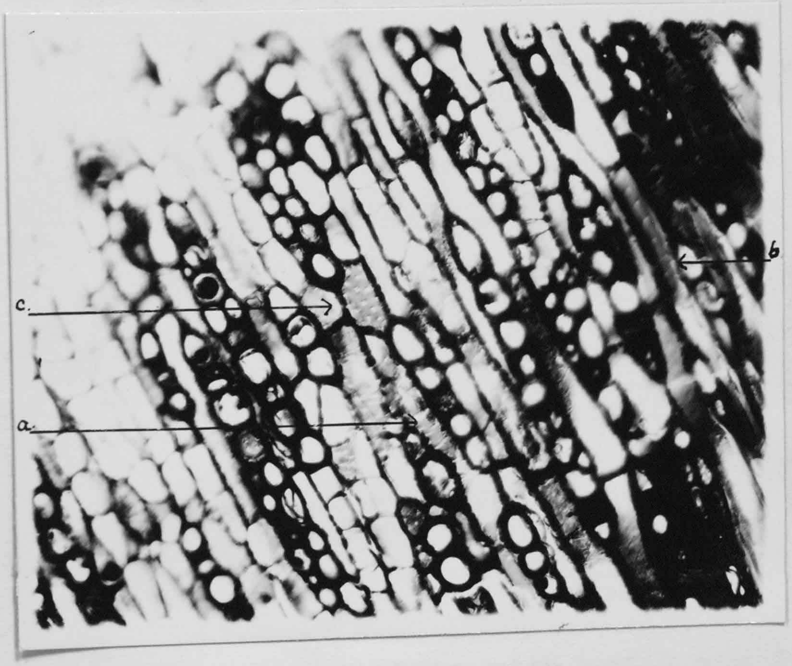

Plate XXVII. - Axis 27. Tangential longitudional view of a zone of medullary ray hypertrophy showing probable sclariform pits at (a), the round simple pits of parenchymatous cells at (b) and the profusely pitted end walls of the medullary ray cells at (c). X 370.

The previously mentioned rings or patches of parenchymatous tissue bordering on the spring wood, consist of medullary rays running irregularly or obliquely;

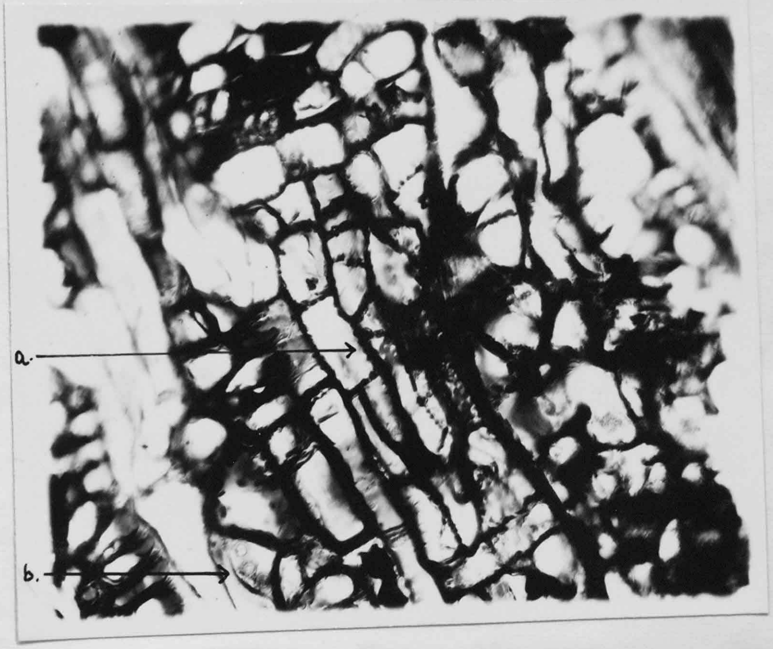

Plate XXVIII. - Axis 27. Radial longitudional view of a region of medullary ray hypertrophy, showing radial pitting of medullary ray cells at (a) and small bordered pits of the short blunt tracheids at (b). X 370.

of a fair amount of parenchyma with small simple pits, and of short wide tracheids with pits apparently only on the radial walls. All are in the utmost confusion. The medullary rays wander and curve irregularly, sometimes they widen out becoming multiseriate. The small, simple pits on the radial walls seem to be more numerous than in the medullary rays of the normal wood. The tracheids in these zones are of the most varied shapes and size; some are almost cubical. The bordered pits are large, close, and frequently arranged in rows opposite each other, and often separated by Bars of Sanio. There are frequently two tracheid pits to a medullary ray tracheid field. The shorter tracheids have smaller bordered pits or probable sclariform pits scattered unevenly along the walls, as seen in Plate XXVIII. Resin spools are common in the tracheids.

The parenchymatous cells in these regions are long, rectangular cells with horizontal cross walls. Simple pits are shown in surface and transverse views, as seen in place XXVII. The cells are sometimes filled with globular substances.

Seward (10) mentions similar tissues in connection with Antarcticoxylon, He says, they may be a traumatic phenomenon or possibly they are comparable with Nordlinger's "medullary spots", formed by local hypertrophy of the medullary tissue. DeBary (14) goes into a more detailed description of these tissues; - "in many woods, accumulations of parenchymatous cells occur, constituting as it were, local hypertrophies of the medullary rays. These were first described by T. Hartig as cellular passages, subsequently by Nordlinger as medullary spots, and by Rossmasseer as repetitions of the pith. According to investigations of these authors and of Krauss, these structures appear in cross section in the form of elongated spots, usually at the outer side, but not infrequently in the middle of an annual ring, with their greatest diameter following the periphery of the ring. In the vertical direction they often extend like passages for distances of several feet, sometimes ending blindly, sometimes branched here and there, not infrequently passing one another in their irregular course. They consist of irregularly arranged polyhedral cells, with thick pitted walls, contents including starch and tannin. They owe the names given them to the similarity of their thick walled cells to those of the pith, especially of its periphery. Medullary rays coming from the middle of the stem, enter the inner side of the spots, their cells becoming broad and assuming more and more the characters of the spots; thus the medullary rays pass over from within outwards into the passages; they further coalesce with them laterally. On the outside new medullary rays start either independent of those coming from within or they lie in the same straight line with them. Local swellings of the medullary rays due to increased breadth and number of their cells, while later they assume irregular forms, are immediately connected in structure with the small spots or passages of this kind".

On the other hand certain features suggest that this wood might belong to some type of Cycadeoidean wood. According to Wieland (15), in such wood it appears that "secondary cambial formation has intervened and resulted in the development in the cortex, exterior to the initial woody cylinder, of a dozen or more of successive exterior collateral bundle systems, simulating annual rings..........On the other hand, there is a bare possibility that there has actually been a persistence of the primary cambium with the seasonal augmentation of the secondary xylem". If this explanation can be offered, the wood is more likely to agree with the broad zones of woody tissue of Cycadeoidea Ingens and Jenneyana in contradistinction to the narrow zones common in other Cycadeoidean woods. However, the pits of this wood are distinctly of Coniferous, and not Cycadean type, and owing to the scarcity or absence of sclariform pitting this view is extremely doubtful. Wieland attaches very little philogenetic value to the manner of tracheil pitting. In this case, the wood may be Cycadeoidean and the medullary spots may be bands of phloem.

AFFINITIES

The description of this axis is only a preliminary account of part of the structural features of the wood. The examination is not sufficiently complete to allow for any ascertion of the relationship of the axis in the plant kingdom, although many of the features described, and others that have since been observed, render it likely that we are dealing with a stem very different to the ordinary coniferous type.

AXIS 28.

DIAGNOSIS

This fourth fossil to be described is a coniferous wood, composed of tracheids and xylem parenchyma. It has well marked growth rings. The secondary wood has small squarish tracheids up to about 21 by 21 microns. In the tracheid walls the pits are round, bordered, and in one row, occasionally they are in pairs along the tracheid walls. The pits are often contiguous or touching, with Bars of Sanio conspicuous. Normal resin canals are entirely absent. Resin containing xylem parenchyma is abundant and scattered throughout the wood. The great majority of the medullary rays are uniseriate but a few are partly biseriate. They are quite wide and conspicuous. The cells of the rays are alike, generally smooth walled and without "Abietinean pitting". Pits on radial walls are one to two per tracheid field; each pit is smallish and irregularly oval or round. There are numerous fungal hyphae in the medullary ray cells.

HORIZON

Lower Cretaceous.

LOCALITY

McMurray Bituminous Sands, at Fort McMurray, Alberta, Canada.

FINDER

Dr. Francis J. Lewis, August, 1930.

DESCRIPTION

The specimen consists only of a fragment of secondary wood, probably of a much larger stem. The sample is 5 cms. by 3 cms. by 2 cms. approximately. It is in an unpetrified condition, having been completely embedded in bituminous sand.

TOPOGRAPHY OF THE STEM

The secondary wood shows well marked growth rings, which average one and a half millimetres in width. The rings are quite irregular and wavy. The wood is badly crushed and twisted with the exceptions of the narrow rings of autumn wood, which are not much distorted in shape. The number of autumn elements vary from five to twelve in radial series. The largest tracheid measured was 20 by 37 microns, but they average about 20 microns in width.

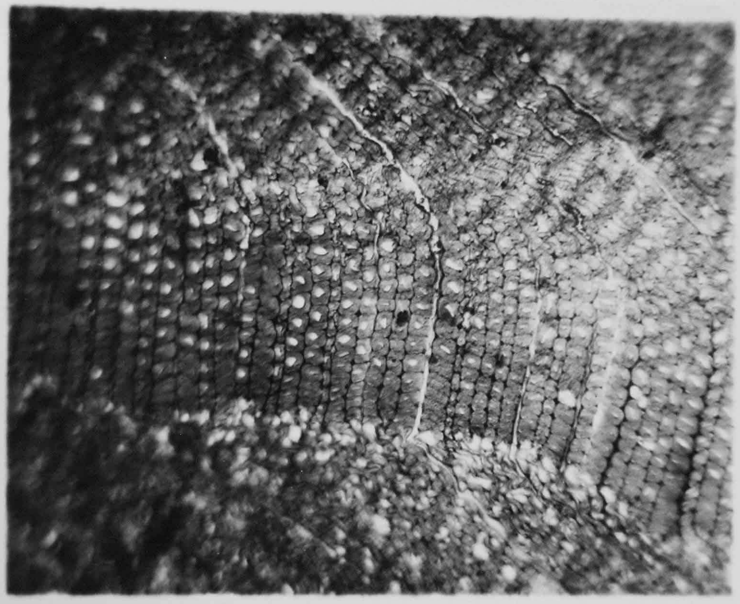

Plate XXIX. - Axis 28. Transverse view of the wood, showing a growth ring. X 100.

This wood has many resin containing parenchymatous cells scattered throughout its extent. These cells are large, square or rectangular in shape, with numerous resin spools or granules. However, normal resin canals are entirely absent.

Medullary rays in transverse section are fairly numerous and conspicuous. While uniseriate rays are the rule, here and there a ray may be biseriate. They are from one to thirteen, principally three to four tracheids distant. The rays vary from two to forty cells in height, usually fifteen to twenty-five, about half being very deep. In transverse length the ray cells are equivalent to the width of from two to six tracheids, principally about four and one half tracheids.

DETAIL OF THE ELEMENTS

The autumn wood consists of regular radial series of tracheids; the spring wood is so crushed, there is only an indication of the radial arrangement. The elements in adjacent rows are alternating. The apparently larger and more regular tracheids are fairly small sized, averaging about 20 by 20 microns. The

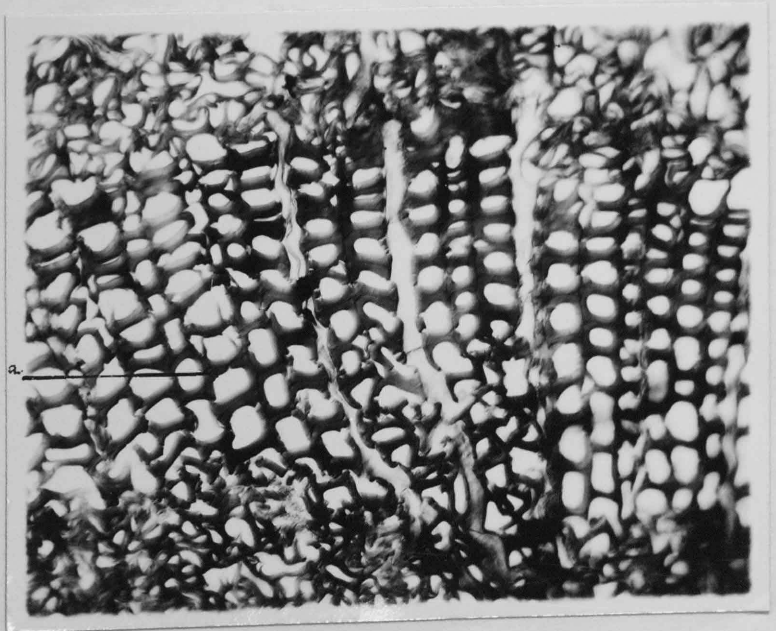

Plate XXX. - Axis 28. Transverse view of the wood showing the detail of the tracheids in a growth ring, and transverse view of a tracheil pit at (a). X 370.

tracheids are all much the same size. The spring elements seem of the same thickness as the autumn, but again, it is impossible, because of their crushed condition to determine any variation in thickness of the walls. They are quite square in shape with slightly rounded corners - unless in the crushed regions where they take on the most grotesque outlines. There are small intercellular spaces in the uncrushed autumn wood. The end walls of the tracheids are quite blunt and rounded, or elliptical.

Tracheil pits are very often visible in transverse section as in Plate XXX. In radial section they are seen to be principally in one row, however, sometimes the row is partly doubled, when they are usually opposite. The tangential walls of the autumn wood are also pitted. These border pits are very large, being in diameter about three quarters or more of the width of the tracheid. The apertures are roundish pores. Generally the pits are contiguous or touching, and slightly flattened horizontally. Bars of Sanio are very evident except where the tracheid wall is too greatly disintegrated.

Wood parenchyma is common all through the wood.

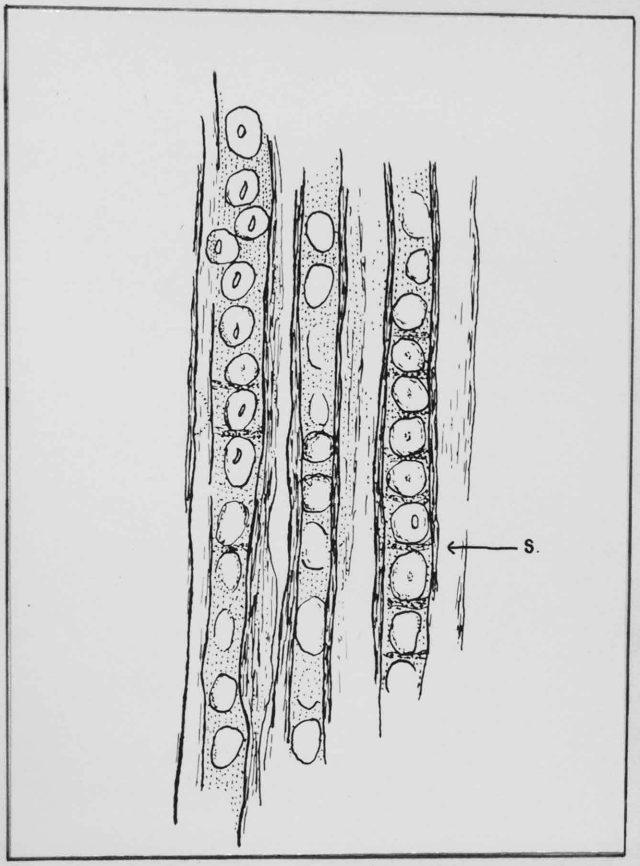

Figure 9. Axis 28. Longitudional section, showing bordered pits of tracheids with Bars Of Sanio at S.

The horizontal walls in both radial and tangential sections are rectangular. The cross walls are approximately horizontal. They are much larger than the largest tracheids of this wood. In length they are two to four times their width. They measure 28 microns or more in width and 100 to 200 microns in length. Nearly all

Plate XXXI. - Axis 28. Longitudional section, showing resiniferous wood parenchyma interspersed among the tracheids. X 200.

of these cells contain dark brown resinous remains in the form of globules, granules and spools or plugs, as in Plate XXXI.

Medullary ray cells are wide, thick-walled, stout structures, easily seen in transverse section. The ray cells are apparently uniform as regards the size and thickness of their walls, although some contain noticeably more resinous contents than others. The cross walls are straight or slightly bulged in radial view, and nearly straight in horizontal section. The

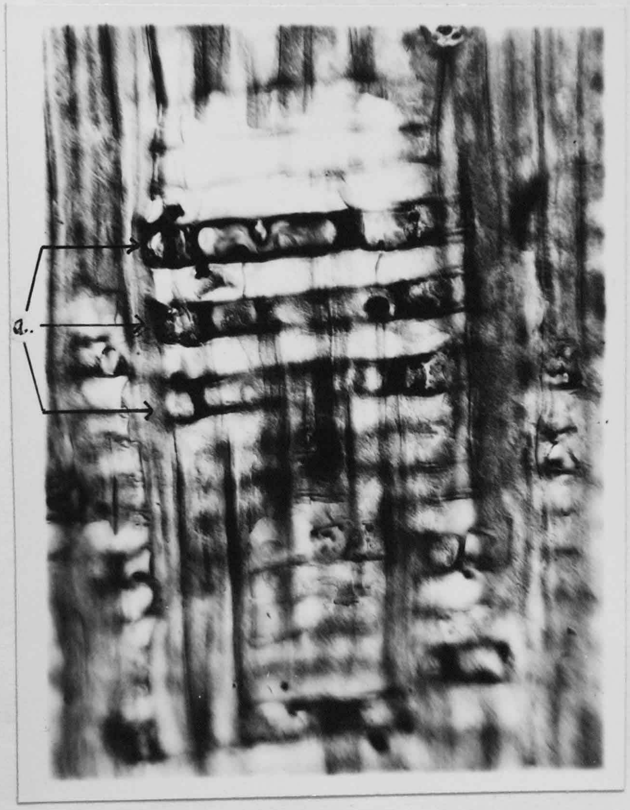

Plate XXXII. - Axis 28. Radial longitudional section showing resiniferous medullary ray cells at (a). X 200

tangential diameter of the ray cells is equal to or more than the adjacent tracheids. The radial extent of a cell is from two to six, commonly four and a half tracheids.

Plate XXXIII. - Axis 28. Tangential longitudional section, showing medullary rays and tracheids. X 370.

Although otherwise the preservation of this fossil is fairly good, the medullary ray cells do not show the pitting on their radial walls very satisfactorily. In radial section there are one or two pits per tracheid field as in Figure 10. Sometimes the pits are mere shadows. Often the tracheid walls seem to lose their identity in the medullary ray region, making it difficult to distinguish a tracheid field except by approximation. These radial pits are certainly sometimes bordered as seen in Figure 10, (a), other times they seem simple, but such negative evidence is not conclusive. They are often small, and may vary greatly in size and shape, from round to irregularly oval or almond shaped. In some instances observed there were two small

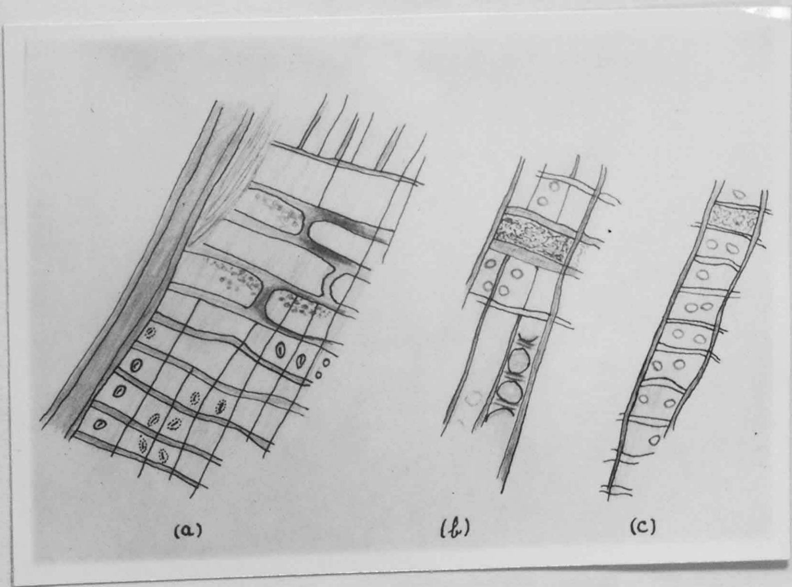

Figure 10. - Axis 28. Sketches to show different types of medullary ray pitting.

bordered pits per tracheid field - standing one vertically above the other as in Figure 10, (b). The pits seem to be on the medullary ray walls.

Usually the ray cell is vertically a little larger than the size of the tracheids it crosses. The end walls are most commonly straight. The cells appear to be all alike, and there is no sign of differentiation into tracheids. The contents of these cells vary greatly, there being an abundance of resiniferous material present, in the form of small and large globules and granules. Fungal hyphae are very common in the medullary ray cells.

AFFINITIES

In many respects this fossil closely resembles Cupressinoxylon wood, especially the species vectense, luccombense and cryptomeriodes. The main differences being that in the first two species mentioned, the annual rings are conspicuously composite, and in the latter species the growth rings are not very strongly differentiated. In Cupressinoxylon vectense the ray pits are principally one, sometimes two, or perhaps three per tracheid field, and they are definite, uniformily-sized pits. In the species lucconbense, the pits vary greatly in size and shape in the same tracheid field, and form typically groups of three or four. In Axis 28 there are one or two pits per tracheid field. A distinguishing feature of Cupressinoxylon cryptomeriodes is in the occurrence of two small simple pits per tracheid field arranged vertically; as mentioned this feature has been observed in this fossil with the exception that in Axis 28 the pits are distinctly bordered. There are several other species of Cupressinoxylon with groups of pits in the radial walls of the rays, which to some extent resemble Axis 28, but in this fossil they are generally too imperfectly preserved to make comparison profitable. The species of Cupressinoxylon with which Axis 28 has been compared are those described by Stopes (16) and Holden (17), and with two new species described by Penhallow (18).

Fragments of wood are by no means the only fossiliferous material found embedded in the bituminous sands. Specimens of leaf epidermis are frequent, being embedded in the irregular clay ledges throughout the sand. The fragments flake off readily from the sandy matrix, and after the minute sand particles and the carbonatous granules have been removed, they yield fairly good preparations.

The cell walls of the specimen of epidermis studied, are very thick and straight without any indication of folding. The lamina was probably firm and leathery as indicated by the extremely thick walled epidermal cells. These small, irregularly shaped cells are arranged to some extent, in rows. They may be iso-diametric with rounded or angular outlines, or they may be more rectangular in shape.

On the inside of the epidermis are frequent ridges, probably indicating the position of sclerenchymatous elements in the underlying hypodermis. Varying portions of the outer wall of the sclerotic cells were stripped off with the epidermis and remained adherent.

The stomata on these leaves are not numerous. They are situated in rows along the lamina. The apertures are quite frequent, but the rows are not close to each other. The stomata appear to be sunken quite deeply below the level of the epidermis. Each stoma is surrounded by a ring of thickened subsidiary cells. They number from five to seven. The cells form a canopy, slightly raised and arched over the stomatal pore, but they are now of course, somewhat crushed. The guard-cells are situated at the base of the enclosed pit. As viewed from the mesophyll side of the epidermis, they are rounded in contour and are without any special thickening.

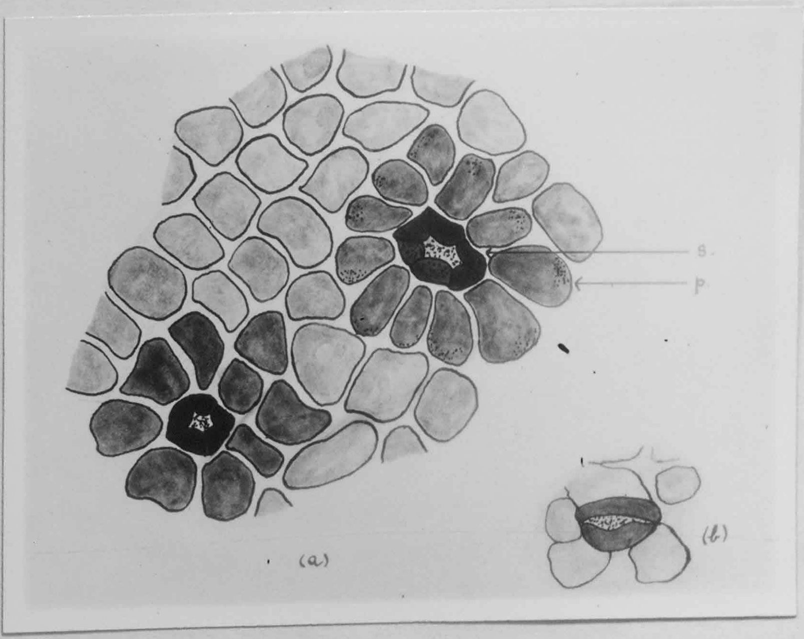

Figure 11.-Cellular structure of the fragment of leaf epidermis.(a)shows the radial arrangement of the epidermal cells at (p),surrounding the subsidiary cells at (s),of two sunken stomata. (b)shows the guard-cells, as seen from the mesophyll side of the epidermis.

The cells surrounding the stomatal apertures are much thickened. They are in a radial arrangement, around the subsidiary cells. There are seven to ten cells of this type, and they are rather more rectangular in shape than the adjacent epidermal cells.

The stomata in this specimen agree very closely with those of Nilssoniales, and more so with the genus Nilssonia, as described by Hamshaw and Bancroft (19). According to Seward (10), there are just two other genera of this family - Ctenis and Ctenopteris, but the structure of the stomata of these are quite different to those of Nilssonia.

No attempt has been made to relate these epidermal structures with any of the known species of Nilssonia, as they have been determined from large impressions giving the character of the leaf. It would be unwise to give specific rank to the fragment of stomatiferous leaf epidermis, unless the structure displayed were unique. The character of the stomata, subsidiary and canopy cells are however, sufficiently characteristic to enable us to refer this material to the little known group of Nilssonia.

Nilssonia is especially characteristic of Jurassic floras; it occurs also in Triassic beds and extends into Cretaceous floras.

Little is known of the anatomy of fossil leaves. A large number of generic names have been employed for impressions which afford no information with regard to anatomical characters, except, in some of the more favorably preserved specimens, as the one described, where a few facts as to the epidermal cells can be ascertained. It is seldom that genera or species founded on leaves can be definitely correlated with particular types of reproductive organs or stems.

Seward (10) states that "from middle and upper Cretaceous and from Tertiary beds very few Cycadean remains have been obtained and many of them are represented by fragmentary fossils that afford no definite evidence of affinity to recent genera. The antiquity of the Cycadales, that is the section represented by existing Cycads, cannot be determined; but it would seem probable that if the Cycads, apart from the Bennettitales existed in Jurassic and Lower Cretaceous floras they occupied a very subordinate position in comparison with the extinct Bennettitales...... It is a note worthy fact that the representatives of Nilssoniales, in their cuticular features, are more akin than the Bennettitales to modern Cycads. Until definite evidence is obtained as to the nature of the reproductive organs of Nilssonia, it impossible to say how closely they agree in essential characters with existing members of the Cycadales."

SUMMARY

1. Hitherto, in most of the gymnospermous woods which have been described, only the secondary structures have been preserved, all traces of the primary xylems and medullas having been lost. This, in many cases, does not afford an adequate basis for the estimation of relationships, and often it results in the wood being referred to a very different group than that to which it really belongs. Some of the material under consideration, has the great advantage of possessing large masses of secondary wood, while in some cases, all the details of the peri-medullary structures, as well the cortical tissues are preserved.

2. The state of preservation of this wood is unique. The fossil material discovered in the bituminous sands at Fort McMurray, is probably the best preserved unpetrified fossiliferous wood known. It was so thoroughly embedded in the bituminous sands, and incrusted by the bitumen, that oxygen was excluded, and thus decay

and decomposition was prevented.

3. The slight decomposition of the wood is in all probability due to the unoxidized destruction of the wood caused by some chemical reaction. However, various microchemical tests on the material yield no clue as to the present chemical composition of the cell structures. Some cell cavities are partially filled with decomposed cellular material, the process of disintegration having been arrested at different stages in different cells.

4. Axis 25 and 26 show a distinct affinity to the type of fossil wood known as Xenoxylon. While there are no primary structures or cortical tissues of Xenoxylon hitherto described, with which to compare this axes, still the secondary wood is practically identical with that of the Xenoxyloid wood described by Seward (12). That is, growth rings are clearly marked. The tracheil pitting is typically "Abietinean", without Bars of Sanio. Some of the tracheids are definitely spirally thickened. Wood parenchyma is absent. There are no resin or traumatic canals. Medullary rays show no "Abietinean" thickening", but there is one very large, rounded pit per tracheid field. The pit-pore is a broadly oblique slit.

This material cannot be correlated with any actual species of _Xenoxylon_ wood, described in any of the papers consulted.

5. An attempt to determine the generic relationship of Axis 27, to other fossiliferous wood, has not been made. The structures in the wood are so extraordinary, that even after the further study that will necessarily have to be given to this axis, it is highly improbable that it can be correlated with any fossil or modern plant.

6. Although no primary structures of Axis 28 were found, the wood is very typically _Cupressinoxyloid_ (16). Axis 28 agrees with this type of wood, in having such features as, a single row of fairly large, rounded, bordered pits on the radial and tangential walls of the tracheil elements. This row is sometimes doubled in _Cupressinoxylon_ woods and in Axis 28. Bars of Sanio are conspicuous between the tracheil pits. Spirally thickened tracheids seem absent. Large, square or rectangular, resin containing parenchymatous cells, are abundant throughout the secondary wood. There are no resin or traumatic canals. The most characteristic feature of diagnostic value in Axis 28, is the pitting

of the medullary ray walls. There is no "Abietinean thickening". However there may be only one pit per tracheid field, and they may be bordered or simple. Again, there may be two simple pits per tracheid field, arranged horizontally or vertically. The latter is typically a <u>Cupressinoxyloid</u> feature.

7. Fragments of leaf epidermis which closely resemble that of Nilssonia were found in the clay ledges in the bituminous sand formation. They were not incrusted with bitumen, but at the same time they are not petrified. The fragments have been preserved as dry material by inclusion in the clay, and the prevention of the access of oxygen by the surrounding bituminous sand.

8. All evidence points to the fact that the bitumen must have penetrated into the sand very soon, geologically speaking, after its deposition. The plant remains were evidently deposited at the same time as the sand.

9. The sand formation, and therefore the embedded fossils, whether preserved in situ or not, are of late Jurassic or early Cretaceous age.

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