How do we identify the North American Mesozoic-Cenozoic petrified woods?

By: Donald Kasper, May-2021

Introduction

It has been something like 160 years since regular papers on petrified wood identification have been published in the United States. Early papers of the late 1800's to early 1900's were supported by the Smithsonian and U.S. Geological Survey. Harvard and Yale have large botanical collections of specimens and papers of living and fossil woods with these early collecting expeditions. In all that time, a number of documents from the U.S. Forest Service (USFS) and U.S. Department of Agriculture (USDA) have been released on identifying certain types of commercially harvested lumber based on their cell structure, smell, density, firmness, and feel. For fossil woods most of that is not helpful as all of our quartz or opal or carbonate fossil plants are the same in terms of physical properties.

So, where are the petrified wood books to identify, say, North American woods? In 160 years, the tally appears to be zero. That is a tally of zero for Europe as well. Yes, we have lots of photographic books, but no, not one is an identification book. There is no published master classification key for these fossil woods. We have prominent paleobotanists like William Tidwell and Marc Philippe, but no classification books from them, particularly with minimal technical jargon and something that for collectors we can use without a lot of microscopy equipment. Is this even possible? What are the hurdles for writing such a book?

Overall, the author finds that perhaps the key reasons for the total lack of books to help us is based on a couple of fundamental problems. First, paleobotany is based on current wood botany, and botany is based on the reproductive structures of trees, not the wood structure. This was done because the flowers and seeds and cones have the most structural variability in plants. The second classification basis is the leaves or needles. Now, we have a pyroclastic flow, it comes down off a volcano at 400 mph and 1250 C and hits a forest and knocks it down and buries it. All that fine detail of delicate structures is incinerated. Only the large logs with enough water can survive the heat, the one exception being the brush along lake and river and sea shores getting dumped into the water, have a chance at survival. The water quenches the heat, the silica as submicron size is extremely reactive with 800 times the surface area of quartz sand, and in the alkaline conditions of the flow the silica moves quickly into solution. When it encounters the wood with some decay bacteria that are producing acid, the acidity of the solution system changes, the silica is no longer soluble in neutral to acid conditions, and precipitates out of solution. All we have left to study is the wood cell structure and some opportunistic wood features such as the bark and pith (center) if they are found.

The second problem is that botany is in chaos. The naming wars goes on forever based on what an author thinks are the important features to classify plants or a subgroup of them. In fossil woods the naming goes on incessantly to claim new genus and species. Can we identify species in fossil woods? Well, we cannot in modern woods according to the lumber industry, USFS and USDA publications, so we can take that as a no. So why are constant new species names proposed? Authors appear to be saying, "I found some small wood cell detail differences, and so will mark that with a new species name" meaning that they are claiming new woods, but cannot tell what they are, other than kind of like this genus and kind of like that, but not really matching either precisely. The author claims that if Darwin had written "The Origin of Genera" instead of "The Origin of Species" based on claims of the fossil record, he would have been much better grounded in fact over speculation. Yet, that type of Darwinian thinking set the tone of modern paleobotany even though the author does not consider wood species identification real.

What does this leave a writer to say in assessing the paleobotany and botany literature? It means the writer cannot just sum up the literature and hack out a book. The writer has to make decisions and they come hard and take study of the world literature, all bound up behind $50 per article paywalls (even works no longer covered by copyright that are over 75 years old). This results in 160 years, and no books on fossil wood identification. A few papers on classification keys of some small plant groups, and that is it. If you want to classify your wood, you have to get lucky, or a literature search of these articles may take you years and thousands in paywall access costs.

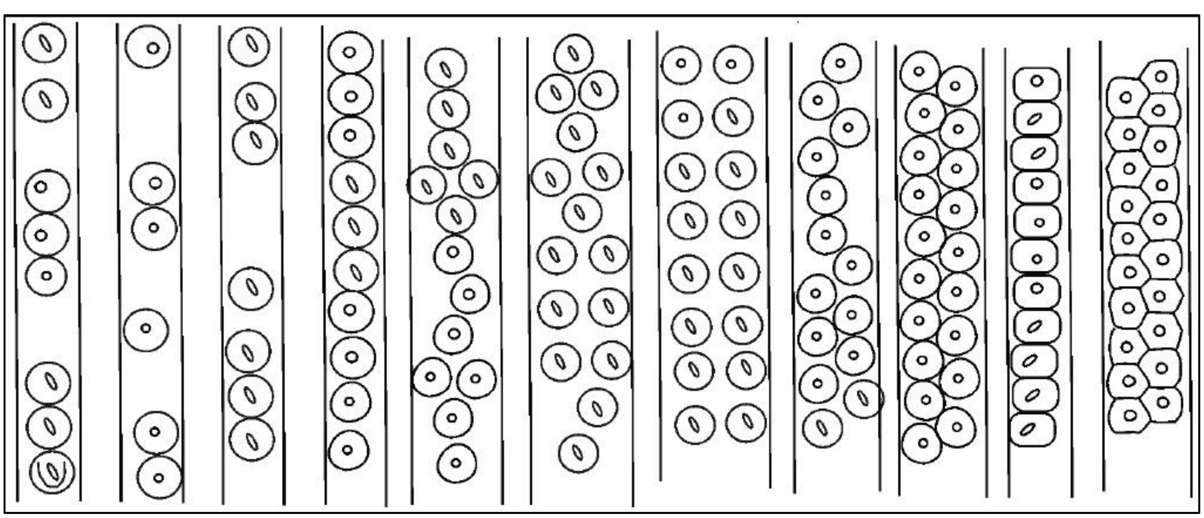
Discussion

The author in 2020 began to assemble a book with the goal of identifying the top 50 North American common woods found in petrified wood locales, documented by scientists. The goal was to use just the cross-cuts (transverse cuts), and up to 40x magnification. Dropping out is the use of the trunk vertical (longitudinal) cuts because most of the time we buy rounds, not long or plank cuts of woods. Yet, was this a reasonable presumption and could this be done? Would it lead to a poor identification, one with a lot of mistakes? Keep in mind, the reference standard for all of paleobotany since the early 1900's when longitudinal cuts were first proposed by Gothan, is all that is published. It would not just be a book of identification; it would be in opposition to a lot of published science.

What has 110 years since Gothan given us modern wood cell paleobotany study? With that, the literature is in seemingly endless identification wars, therefore, longitudinal cuts did not solve the problem of species identification or even genus identification.

This is not unexpected. A paper of Argentina Planoxylon shows all the longitudinal cell pit structure types that the author Silvia Gnaedinger found at a large fossil forest site. Pits are the structures that allow fluids and nutrients to move between cells are a big thing in paleobotany wood identification. How many pit types are there for her Planoxylon? That wood has the type identifier cells of 5 main genera of woods. In fact, it takes a while to study what type of cell pit structure it doesn't have (Figure 1). The original diagram set also has an attached breakout diagram (not shown here) that has yet a sixth wood genera shown.

Figure 1. These are all the identified Argentina Planoxylon longitudinal tracheid pit structures that Gnaedinger links to being Araucarioxylon type. The vertical bars are the wood fiber (tracheid) outlines. The round or polygonal pits in them have central pores that are membranes that allow fluid and nutrients to move between cells. The actual type for Araucaroid pits is on the right. The author in his book on fossil wood classification places Planoxylon as a synonym for Araucarioxylon, a Mesozoic conifer, as is often done in the literature as well. From: Silvia Gnaedinger (2007) Planoxylon Stopes, Protelicoxylon Philippe y Herbstiloxylon nov. gen. (Coniferales) de la Formación La Matilde (Jurásico Medio), provincia de Santa Cruz, Argentina, AMEGHINIANA (Rev. Asoc. Paleontol. Argent.) Vol. 44, No. 2, Pp. 321-335. In Spanish, English figure subtitles.



If the annual earlywood cells in conifers are subject to crushing/compaction during growth, the pit structures can change. The wider the cells are, the more pits can be found. If the cells twist, the pit count and alignment changes up the fiber cells. If there is vertical compression the cells are flattened. The smaller the structures, one can presume the more prone to compression and growth distortion they are, and over time, botanical search for ever smaller details to find the key to wood species identification does so with no strong evidence they are related to genus or species identification. The same trees, often have many pit types.

Since botany family, genus, and species hierarchical identification was based on reproductive and leaf/needle structures, there actually isn't a direct and consistent mapping from wood cells structure classification to a botanical classification. If we have a tree family that is small (a few species), the classification is easier, but when we get into families of tens of thousands of species of plants, the classification becomes entangled. Then we start to get talk of clades and tribes and other taxa groupings of plants that are similar, and our original 1800's classification is eroded. These other grouping are created to create cross-species and cross-genus plant grouping as the hierarchical relationship that originally said everything in a genus has the same features, breaks down.

Case Study 1, The Dawn of Mesozoic Conifers

An interesting observation when you step back at a field of study and take in their conclusions, is that models operate at a certain level of scale, or perhaps call it level of detail. As you change scale, it does not mean the model can still be applied. This works across all sciences. The author approaches solving these complex issues by studying the nature of the arguments involved. Let us step up to a lower-level scale at 40x from 400x longitudinal cell study and just look at the body plan of an often-collected fossil wood, Agathis.

Agathis is a super latex/pitch/resin producer today. The organic composition varies, let us call it just a resin producer here. This plant today in Malaysia is a key resin producer used in varnishes, for example. When they pour copal on ants to claim they are retailing fossil amber, they are using Agathis resin. A tropical plant with a lot of pests and constant warm weather may be a resin producer to thwart these pests. The northern latitude conifers have freezing winters that kills back these pests, so that group of trees only uses resin canals to thwart the bugs, and seal injuries to the tree.

Resin is a viscous substance. You cannot pump it through sinuous rays around plant water vessels because high viscosity substances aren't going to flow. How does Agathis adapt to this problem of physics? It has vertical resin wood fibers that are attached strongly to the horizonal rays. They have thick and strong pore connections between them, to move the resin up and then out. The rays are dead straight.

We have a body plan for Agathis. Is this found in the fossil record? As the author documents in his book, yes, this body plan is found in modern and fossil Agathis plants found around the world (Figure 2).

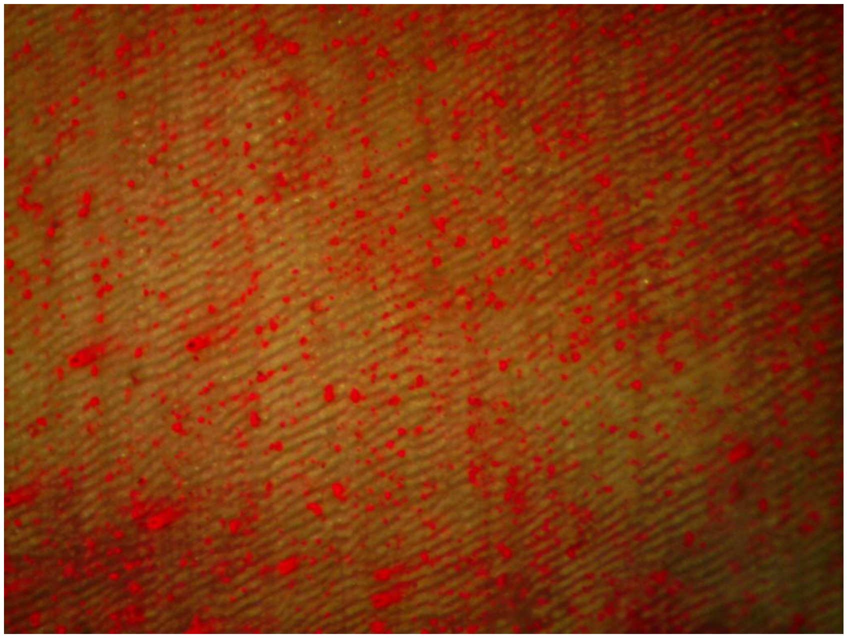
Figure 2. South African fossil <u>Mesembrioxylon</u> transverse cut. This is a synonym for Agathis and shows it has Agathis resin body plan. A Triassic conifer. The alternating tracheids adjacent to rays are filled with resin so they are dark. Rays are uniseriate (one cell wide) also filled with resin. Scale bar is 140 μm. From: D. L. Roberts, M. Bamford, B. Millsteed (1997) <u>Permo-Triassic macro-plant fossils in the Fort Grey Silcrete, East London</u>, South African Journal of Geology, Vol. 100, No. 2, Pp. 157-168. Note East London is a town in South Africa, not referring to London, England.

As we get back to the literature, many claim the Arizona picture wood is not Araucarioxylon, it does not exist, its type specimen is invalid, and it is just a bunch of Agathis. No problem, let's look at its body plan for a resin structure. The vertical tracheids and rays will all be dark even as fossils from all that included resin. What do we see? None of them. For our purposes, this resolves the debate of Araucarioxylon and Agathis. Agathis cannot be the parent genus over Araucarioxylon, or the two being the same thing, as the latter has no resin body plan, not even conifer (pine) type of resin canals periodically in the wood annual rings. So far, zero papers of the world the author has reviewed show this body plan in their Araucarioxylon identified samples.

That is not the last of the Araucarioxylon paleobotany wars. It is just a bunch of Dadoxylon comes up often as well. Let us start by stepping back and take a look at the superstructure of Araucarioxylon. It has the propensity in specimens around the world and Arizona rainbow wood to stack its wood cells (tracheids) clearly at 45 degrees to all the rays, a pattern of stacking that crosses the rays (inter-ray). It is not just a local feature between a set of say 5 tracheids between two local rays. We have a fascinating body plan (Figure 3). Like the resin body plan, is this described in our literature? No, they are looking at longitudinal cuts at 400x where only 8 tracheids are across the field of view at that magnification, so the pattern is not apparent until you are trained to look for it.

Is tracheid stacking of retailed Arizona and literature Araucarioxylon wood always present? It appears yes, unless the wood rotted or was compressed. Does any other wood have this? How about documented Dadoxylon? No, it doesn't, reviewing many papers from around the world. Dadoxylon has radially concentric tracheids, and so no, the author does not consider Araucarioxylon a synonym for Dadoxylon (Figure 4). Their body plans are different.

Figure 3. Arizona picture wood, Araucarioxylon, transverse cut, at 40x. Can you see the bottom-left to upper-right diagonal wood fiber (tracheid) stacking? The rays are vertical. These early conifers have faint annual rings that come and go, are not identifiable in all parts of the wood cut. Photo by the author.



From this, the author pens into his book these observations and keeps Araucarioxylon, Dadoxylon, and Agathoxylon distinct, the conifers that define the first modern types of conifers. We have wood body plans, we have an approach, and no one can prove that their features are more important than ours unless they can resolve all these botanical arguments with a clear model. So far, they cannot. We have just wrapped up a century of arguments about several major early Mesozoic conifers. There are yet other genera around in the Araucarioxylon-related group of this period all covered in the author's book, but without these three, our study of Mesozoic woods identification will stall.

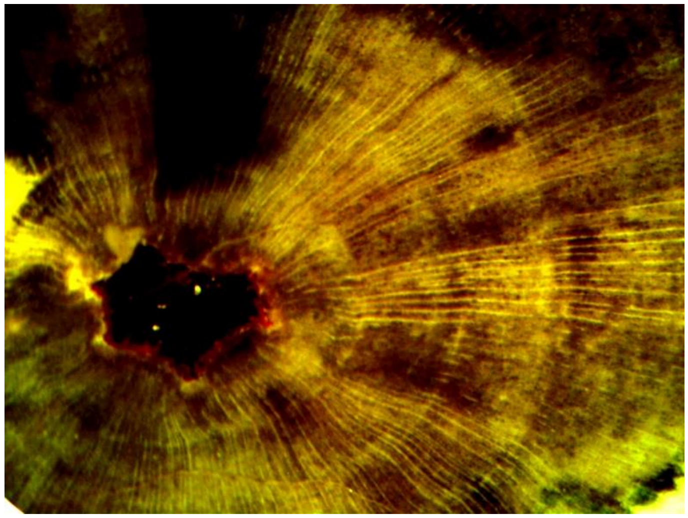
Figure 4. The author's Arizona petrified wood consistent with Dadoxylon in terms of its narrow annual rings and tracheid stacking parallel to growth rings, transverse cut. Notice the inter-tracheid spacing or thick-walled cells and oval tracheids. The tracheids are commonly shown flattened and rectangular at the annual growth rings, the transition from winter to spring tree growth. This has prominent growth rings, 4 shown here, that is not a feature of Araucarioxylon. Fossil wood specimens from around the world identified as Dadoxylon have the same tracheid body plan. Photo at 40x. Photo by the author.

Case Study 2, Wood Piths and Coloration

Yes, we can classify fossil woods and correlate them to the literature using transverse wood cuts, as well as quite a number of opportunistic features of wood families and genera that occur on occasion. We don't need a binary classification of all features and solution of yes or no regarding their presence for every one for our woods. As occasional structures also occur, we can use those, and as the author notes they have limited use and may identify just a few genera or one genus, then it can be argued—that is the whole point!

As one example, a question the author had was—are the fossil wood colors just junk from solution staining from weathering, or can we identify woods using those as the original tree wood coloration as well? Here is an example (Figure 5) of a 6-star pith, colored blood red, that identifies any modern box elder maple. This comes from Bruneau, ID. No, in our literature this is not considered as even possible. As to why, well, botany has its favorite mantras, and longitudinal sectioning covers most of them, so pretty much everything else just drops out and the science stays there for a very long time until those mantras are challenged for their viability and accuracy.

Figure 5. With blood red pith (grading to black in this CCD photo) but red to the naked eye; faint, very tiny, black, diffuse-porous vessels; virtually invisible parenchyma annual rings only seen at low resolution (at high resolution there isn't enough contrast to identify them); 6-ray pith (distorted here, a bit compressed); identifies this as box elder maple. From Bruneau, Idaho. These woods are francolite fossils, a calcite-apatite mix with calcite caged in phosphate group locations. That is not speculation; with infrared spectroscopy, the author can identify these compositional structures. Photo at 10x. Photo by the author.

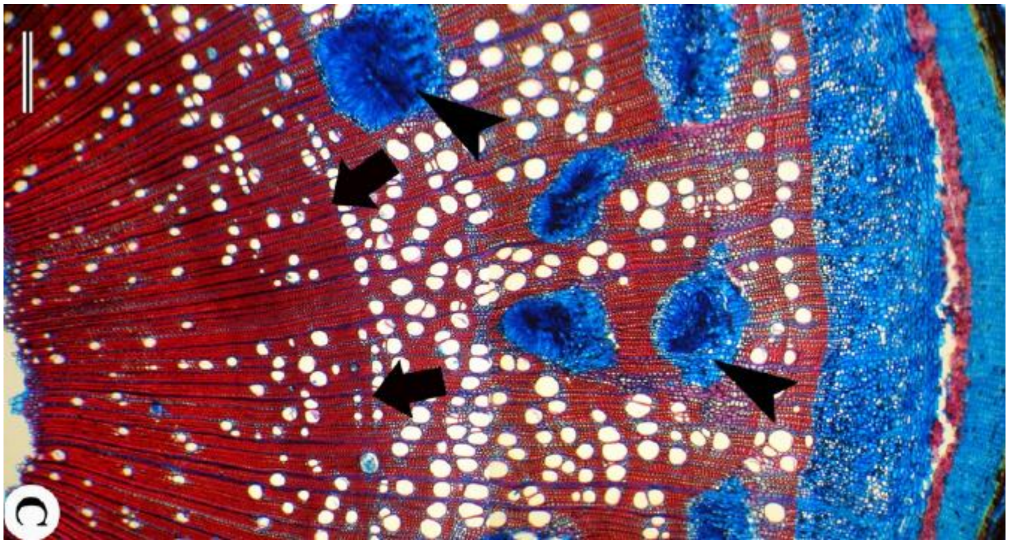


Case Study 3, Lianas, the Woody Vines

Arguments in science fascinate the author because they usually mean that the science is not advanced enough, or there is not enough data, and there is the opportunity to move the science forward. The author never gets to write solely literature summary books because these kinds of issues always come up, so just repeating the literature does not help the reader answer basic questions. By addressing them based on logical constructs to find the reasons the past attempts failed, can lead to fascinating insight and discovery. This means that the end game is for the author to construct a strong model, one that describes the issues, shows all the data, and reaches a consistent conclusion to explain them. It also predicts things that remain to be found. We are used to much of our science feeding us weak models where authors pick and choose some data complaint to their model view, and ignore the rest.

Sometimes the answers are in our literature search, such as the paper proposing that cell bundles are a body plan for woody tree climbing vines. Those in Texas would recognize Snakewood as the result of that body plan. The authors in this case even show modern woody vines before they started climbing don't have the bundle structures, then they show up at the climbing stage of the plant (Figure 6). We can propose from that, the Texas and Louisiana snakewoods are actually woody vines, so they are going to be quite small most of the time. There isn't going to be a one-foot round to find.

Figure 6. In wood the red stain chemicals used detect cellulose, and the blue stain chemicals detect lignin. Rays and phloem are blue. Left side: Non-climbing stage. Right side: Climbing stage. Both modern Loganiaceae, a vine. Arrows demarcate non-climbing to climbing transition, and triangle pointers show two of the fiber structures called "phloem islands" in botany. These fiber bundles allow for the vine to twist to envelope its host for support. This is a liana, a tree climbing, woody vine. Pith or core is on the left; cambium bark is on the right. White cells are water conduit vessels. Phloem island pattern depends on the species. If you look at Texas Snakewood retailed on EBay, you see two types of this liana wood. From: Roger Moya, Amit Dhanjinbhai Gondaliyan & Kishore Shankarsinh Rajput (2017) Stem anatomy and development of interxylary phloem in Strychnos bredemeyeri (Loganiaceae), Anales de Biología, Vol. 39, Pp. 75-87.



Conclusions

Collectors don't get perfect wood. They don't get the equivalent of lumber yard A-grade wood. They get the wood of the real world with many things going on. So, the author wrote a book that covers most of the things you will find in fossil woods, then added to that a classification of the family and genus groups (genera) of the top 80 fossil woods of North America. Based on this study, some classification criteria were added that are not used in published botany. An example is the refusal in the literature to consider why some trees have straight rays and some are sinuous around vessel structures (for the hardwoods). Each idea starts as a proposition which is the start of an investigation to consider its value in fossil wood identification. If the proposition consistently works, keep it.

The author's goal is Mesozoic to recent, the age of modern woods study. The original plan of the top 50 was extended to add the earlier Mesozoic conifers we all collect and buy, and some of the tropical wood candidates found as a result of North America being attached to North Africa until the Mesozoic-Cenozoic transition.

It can be argued, we have Western and Southwestern U.S. fossil woods from Pacific Ocean storms grown in a wet climate that tracked far inland until North America ran up over the West Coast ocean spreading center to form the Rockies, Sierras, and Pacific Coast Range, and Southern California San Gabriel Mountains, cutting off the storm flow eastward, and killing those fossil forests. Part of that spreading center in California then converted into the San Andreas fault and the uplift stopped. It can be argued that the Gulf, Southwest and West was not likely tropical, it was once wet with sequoia far inland 1000 miles, now all desert as those mountains cut off the Pacific moisture flow.

Related to all this, the fossil woods of Europe turn out to be the same set as the North American woods of this period. They had fossil sequoia as well, for example. This is not unexpected, given the original connection of North America to Europe and Northwest Africa.

Citation

Yes, a classification book to identify fossil wood family and genus can be written, and here is the first:

A Student's Guide to Identifying Mesozoic to Recent North America Petrified Wood Family, Genus, by Donald Kasper, ISBN# 978-1-9488672-6-9 Plastic Comb Bound, 327 pages, full color. Available on Amazon and at donaldkasper.com through PayPal. This is the author's 27th book on geology, and second on paleobotany. It makes use of the author's own fossil wood collection, and learning from collecting geologic trips, as well as extensive use of the literature with almost 300 literature citations.