PETRIFIED WOOD IN OKLAHOMA

By
Neil H. Suneson

Reprinted from The Shale Shaker, vol. 60, No. 6, May/June 2010

OKLAHOMA GEOLOGICAL SURVEY
INFORMATION SERIES 14
2010

OKLAHOMA GEOLOGICAL SURVEY
100 E. Boyd, Rm. N-131
Norman, Oklahoma 73019-0628
ph: 405-325-3031; 800-330-3996
fax: 405-325-7069
ogs@ou.edu
www.ogs.ou.edu

OKLAHOMA PETROLEUM INFORMATION CENTER
OGS PUBLICATION SALES OFFICE
2020 Industrial Blvd.
Norman, Oklahoma 73069-8512
ph: 405-325-1299
fax: 405-366-2882
ogssales@ou.edu

Oklahoma Geological Survey
Mewbourne College of Earth and Energy
The University of Oklahoma
Norman, Oklahoma
2010

Cover description:
Upper photograph: Petrified wood (genus unknown) collected from Nowata Shale (Desmoinesian, Pennsylvanian), Jenks, Oklahoma. Top of specimen is 13 inches across. Donated to Oklahoma Geological Survey by Shawn Story, Will Rogers Junior High School, Claremore, Oklahoma.

Lower photograph: Petrified wood (possibly *Dadoxylon adaense*) collected from Wewoka Formation (Desmoinesian, Pennsylvanian) near Kerr Lab, Ada, Oklahoma. Specimen is 20 inches long.

This publication is issued by the Oklahoma Geological Survey as authorized by Title 70, Oklahoma Statutes 1981, Section 3310, and Title 74, Oklahoma Statutes 1981, Sections 231-238. It is available on-line and as color photocopies. Copies have been deposited with the Publications Clearinghouse of the Oklahoma Department of Libraries. September, 2010.

OKLAHOMA GEOLOGICAL SURVEY
G. Randy Keller, *Director*

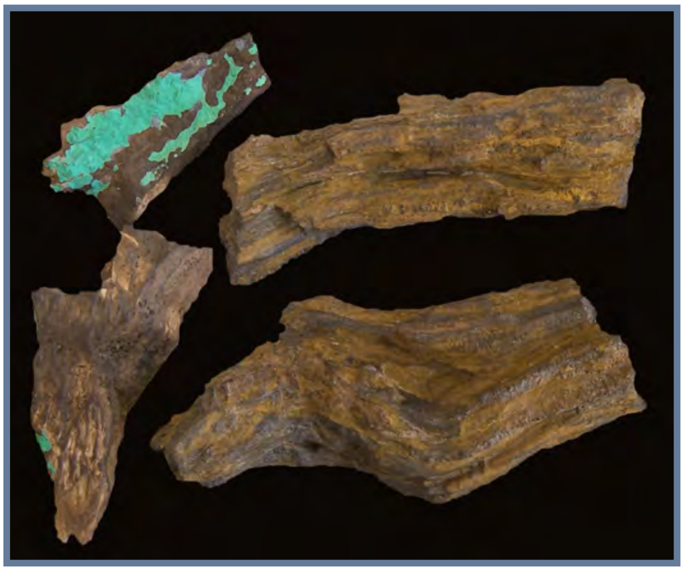
INFORMATION SERIES 14
ISSN 0160-8746

PETRIFIED WOOD IN OKLAHOMA

Neil H. Suneson
Oklahoma Geological Survey
Mewbourne College of Earth and Energy
University of Oklahoma

Reprinted from The Shale Shaker,
vol. 60, No. 6, May/June 2010

Oklahoma Geological Survey
Mewbourne College of Earth and Energy
The University of Oklahoma
Norman, Oklahoma
2010



Description of Photographs:

Upper left: Petrified wood log in the Post Oak Conglomerate (Permian) from near Lake Frederick, Tillman County, Oklahoma. Much of the wood is replaced by calcite.

Upper right: Petrified wood logjam at the Goddard Youth Camp near Dougherty, Oklahoma. The dam was built by Wayne Edgar, director of the camp, from wood he collected from Cretaceous formations in southwestern Arkansas. The Antlers Sandstone (Lower Cretaceous) of southeastern Oklahoma contains petrified wood. (Photograph courtesy of Rick Andrews)

Lower left: Petrified wood collected from the top of the Garber Formation (Leonardian, Permian), southeastern Grant County, Oklahoma. Most of the wood is replaced by iron oxide minerals and is associated with copper mineralization. Upper right specimen is about 7 inches long. (Photograph courtesy of Mark Brickman)

Lower right: Petrified wood stump in front of the Midgley Museum in Enid, Oklahoma. The stump was purportedly found near Woodward; if so, the wood probably is from the Ogallala Formation (Miocene).

Shale Shaker

THE JOURNAL OF THE OKLAHOMA CITY GEOLOGICAL SOCIETY

Petrified Wood In Oklahoma

Neil H. Suneson, Geologist IV, Oklahoma Geological Survey
Adjunct Professor, ConocoPhillips School of Geology and Geophysics, University of Oklahoma
nsuneson@ou.edu / 405.325.7315

Introduction

In the fossil world, petrified wood may be second only to dinosaurs in its fascination to humans, and "wood turned to stone" probably has the longer history of the two. In fact, a fossil cycad was placed in the tomb of the Marzabotto necropolis over 4000 years ago by the ancient Etruscans. It was accompanied by other funerary objects and thus must have had some special significance. Furthermore, it appears that the trunk of a fossil cycad may have been used by Neolithic people as a sharpening stone (Wieland, 1916) and thus may have "the longest known history of any fossil" (from www.plantapalm.com/vce/intro/historicalperspective.htm, acc. 2/27/10). Around 1000 A.D. the Persian astronomer, chemist, mathematician, physicist, scientist, theologian, and philosopher Avicenna suggested "that organic materials might be 'turned into stone by a certain mineralizing, petrifying power … and this transmutation of the bodies of animals and plants is just as short a step as the transmutation of waters. Yet it is impossible that any organism should be changed into a single element; rather, the elements are changed into each other successively and so pass into the dominant element'." (Scurfield, 1979, p. 377). One of the greatest German theologians and philosophers of the Middle Ages, Albertus Magnus, clearly understood the origin of petrified wood: "Even more rapidly it (water) converts earthy things such as wood, plants, and the bodies of animals, etc. For these, if immersed in Water, are attacked by such a mineralizing power and changed into something of an earthy nature, suitable material for stones, which is [then] dried out and solidified and developed into the specific form of stone by the mineralizing power dissolved as vapour in the Water" (Wyckoff, 1967, p. 32).

Leonard Da Vinci used fossils to develop his theories on the origin of the Earth and more recently was connected directly to petrified wood and the CIA by Dan Brown, author of "The Da Vinci Code." An encrypted sculpture, Kryptos, currently resides in the courtyard of the CIA's headquarters in Langley, Virginia (Figure 1). It consists of an S-shaped copper scroll that appears to come out of an upright petrified tree, a water-filled basin, stones marked with Morse code, and a compass. The Guardian calls it "one of the world's most baffling puzzles, the bane of professional cryptologists and amateur sleuths who have spent 15 years trying to solve it" (www.guardian.co.uk/world/2005/jun/11/danbrown.books, acc. 2/27/10). Kryptos is referred to twice on the dust jacket of the U.S. version of Dan Brown's novel "The Da Vinci Code" (http://en.wikipedia.org/wiki/kryptos, acc. 2/27/10).

Figure 1. Kryptos sculpture in front of CIA Headquarters. A great deal of attention has been focused on decoding the cryptograph conceived and designed by artist Jim Sanborn. But little attention has been paid to why the scroll appears to come out of a large, upright petrified tree (left side of photograph). Image from http://www.austininc.com/SciRealm/kryptos.jpg

Petrified wood continues to be of interest both to scientists and the layperson. Petrified wood plays a significant role in three U.S. national parks and monuments (Petrified Forest in Arizona, Florissant in Colorado, Yellowstone in Wyoming, Montana, and Idaho). In addition, there are numerous state parks, private parks, and protected natural areas in the U.S. that feature petrified wood. Protected petrified "forests" also are present elsewhere throughout the world (Dernbach, 1996). Because much petrified wood is silicified and therefore hard and because the wood grain may be preserved, rockhounds collect, cut, and polish petrified wood for use in jewelry. Geologists value petrified wood because it gives them clues to the depositional environment of the formations in which it occurs and, in some case, petrified wood is associated with ore deposits, particularly uranium and copper. If the kind of wood and the age of the formation can be determined, petrified wood (and other plant fossils) can be used to determine the paleoclimate of an area. And paleobotanists value petrified wood because it provides information on plant evolution.

Petrified wood occurs in two principal modes in Oklahoma. The most common occurrence of petrified wood is as pebbles and cobbles in some modern and ancient river gravels (Figure 2). Modern gravel deposits occur along many of Oklahoma's major rivers. Some Oklahoma rock and mineral clubs secure permission from sand and gravel companies that are quarrying these deposits to search through their gravel piles; in addition to petrified wood, fossil bones (including dinosaur bones) and teeth are not uncommon in the gravel. Some ancient gravel deposits in Oklahoma also contain pebbles and cobbles of petrified wood; three relatively widespread formations that contain such gravels are the Gerty Sand (Pleistocene), Ogallala Formation (Miocene – Pliocene), and Antlers Sandstone (Cretaceous). The Gerty Sand marks the former course of the Canadian River and occurs near the towns of Allen, Gerty, Ashland, Savanna, and Bache. The Ogallala Formation covers much of the Panhandle and northwestern Oklahoma (especially Ellis County) and the Antlers Sandstone extends from Broken Bow to Antlers to Dickson and south of Wilson in southeastern Oklahoma. The petrified wood that occurs as rounded pebbles and cobbles in these gravel deposits was "petrified" (discussed below) elsewhere in an older formation and was later (probably much later) exhumed by erosion, incorporated into the sediment of an ancient river, transported some distance, deposited, re-exhumed by erosion or quarrying operations, and discovered.

Figure 2. Petrified wood gravel from General Materials quarry along the Canadian River, Oklahoma City. Petrified wood is common in gravels associated with the major modern rivers in Oklahoma, in terrace deposits associated with the rivers, and in ancient fluvial deposits. This material was collected by Granville Morgan, long-time Oklahoma City rockhound, and donated to the Oklahoma Geological Survey's education collection.

Other occurrences of petrified wood in Oklahoma represent wood that was petrified at the site and in the formation where it is currently found (*in situ*) (Figure 3). The age of the formation is the same as the age of the original tree. In most of these occurrences the wood had fallen and was moved some distance (but not far) before being buried and petrified. However, its current location is where it was petrified. (The petrified tree trunks at Petrified Forest National Park in Arizona are examples of petrifaction of moved wood; in this case, the wood was transported in an ancient river system.) Rarely, trees are petrified in growth position – the site of petrifaction is where the tree was growing. Not only is the age of the formation in which the petrified wood occurs the same as the original tree, but the site where it is found is the same as where it was growing *and* where it was petrified. (The petrified forests of Yellowstone National Park and the petrified sequoias at Florissant Fossil Beds National Monument in Colorado are examples of petrifaction of wood in growth position.) To date, none of the petrified wood in Oklahoma has been shown to have been petrified in growth position, although some of the rare occurrences associated with the Pennsylvanian coal beds in northeastern Oklahoma may come very close.

This brief overview of petrified wood in Oklahoma describes only that petrified wood that was petrified *in situ* (Figure 3). These occurrences are more interesting to geologists than the pebbles and cobbles in gravel deposits because the wood tells us something about ancient vegetation and climate. The wood is useful for paleobotanical research – What kinds of plants were growing in Oklahoma at any particular time, and what was the relation of the different plants to the entire ecological community? In addition, geologists are interested in the depositional environment of the formation that contains the wood – Was the wood deposited in an ancient riverbed, swamp, or perhaps as waterlogged debris in an ocean? The minerals that form the petrified wood and how they were precipitated may be determined by studying *in situ* specimens. And finally, because many people will never see specimens in the field, architectural and monumental uses or displays of petrified wood in Oklahoma are described.

Petrifaction and Other Types of Preservation

For the purposes of this report, petrified wood (as distinct from the more general terms "fossilized" or "fossil" wood) is wood that has undergone petrifaction. Petrifaction is "a process of fossilization whereby organic matter is converted into a stony substance by the infiltration of water containing dissolved inorganic matter (e.g., calcium carbonate, silica) which replaces the original organic materials, sometimes retaining the structure" (AGI Glossary, 2005). "Petrification" is a synonym. In some cases the term "permineralization" is used to describe the infilling of pore spaces in organic matter by minerals, however, the AGI

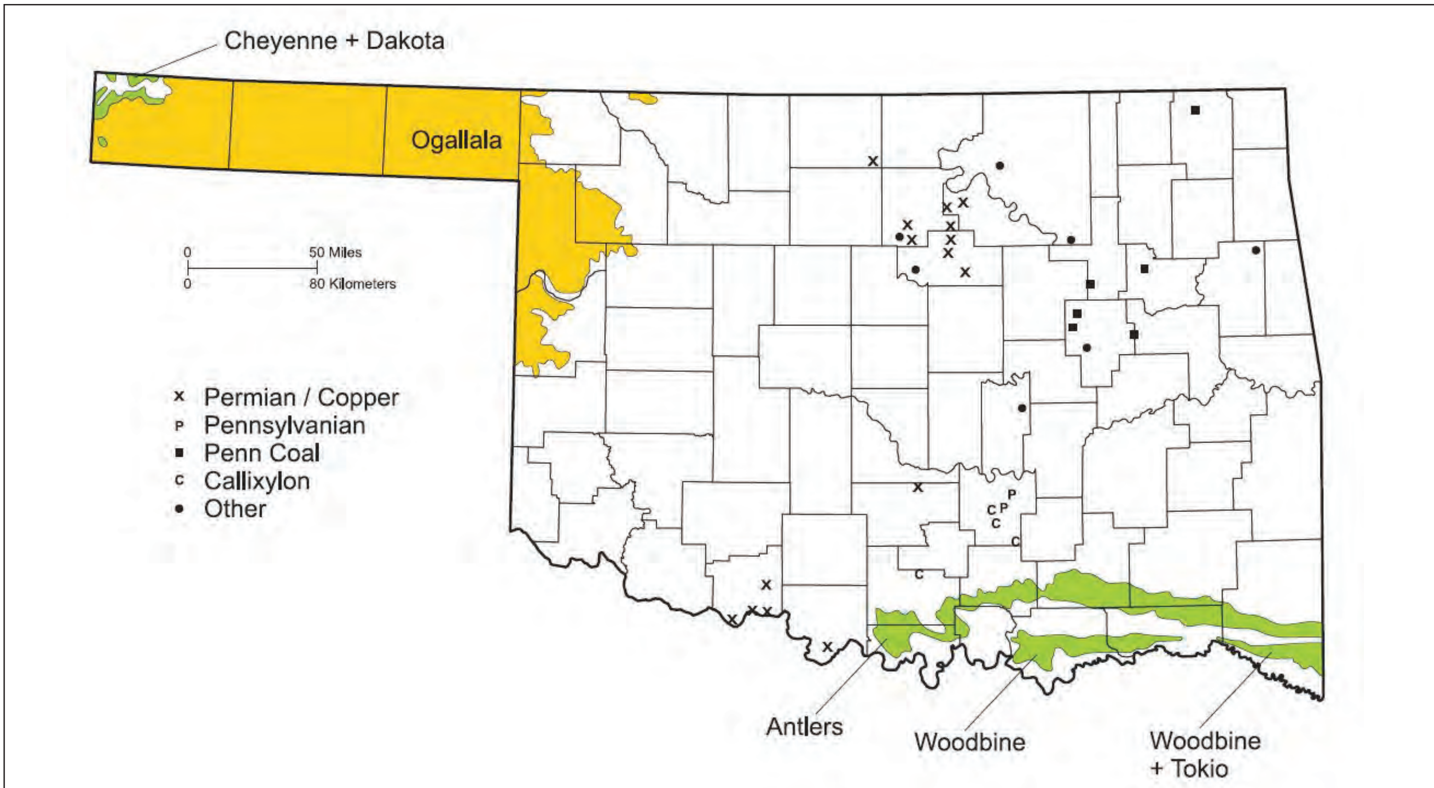


Figure 3. Map showing petrified wood localities in Oklahoma. Individual localities are shown with symbols; the Ogallala Formation, Cheyenne Sandstone, Dakota Group, Antlers Sandstone, Woodbine Formation, and Tokio Formation contain petrified wood, probably at many localities.

Glossary restricts permineralization to animal hard parts such as bones.

The most common mineral that replaces wood is quartz (SiO_2) and several other varieties of silica minerals, including opaline silica and chalcedony (Table A). Thus, much petrified wood is also referred to as "silicified wood." Technically speaking, opal is not a mineral, rather, it is a non-crystalline (or amorphous) form of hydrated silica ($SiO_2.nH_2O$) that contains as much as 20% water, but more typically 3 – 9%. Chalcedony is a cryptocrystalline variety of quartz in which individual crystals can only be seen with an electron microscope. Quartz is crystalline silica composed of silicon – oxygen tetrahedra in which the oxygens are all connected in a three-dimensional network. This chemical "bonding" makes quartz hard; well-silicified wood is also hard and therefore is popular among lapidaries for jewelry. The hardness also makes silicified wood resistant to erosion which explains why it can occur as pebbles and cobbles in river gravels a long distance from its source.

Many other minerals can replace wood; the most common are calcite, aragonite, pyrite, and marcasite. Calcite and aragonite have the same chemical composition (calcium carbonate – $CaCO_3$) but different crystal forms and other physical properties (e.g., specific gravity and hardness). Similarly, pyrite and marcasite have the same composition (iron sulfide – FeS_2) but different properties. Other much less common minerals that have replaced wood in Oklahoma are barite ($BaSO_4$), hematite (Fe_2O_3), chalcocite (Cu_2S), malachite ($Cu_2CO_3(OH)_2$), and azurite ($Cu_3(CO_3)_2(OH)_2$).

Wood also can be "fossilized" (as distinct from petrified or silicified) by other processes. Leaves and less commonly limbs and stems of trees can be preserved as compressions and impressions (Figure 4A). These form when, for example, a tree limb falls into water and is buried by sediment. As sediment accumulates and the limb becomes more deeply buried, the air and water in the limb are forced out and what once may have been a round limb becomes elliptical and

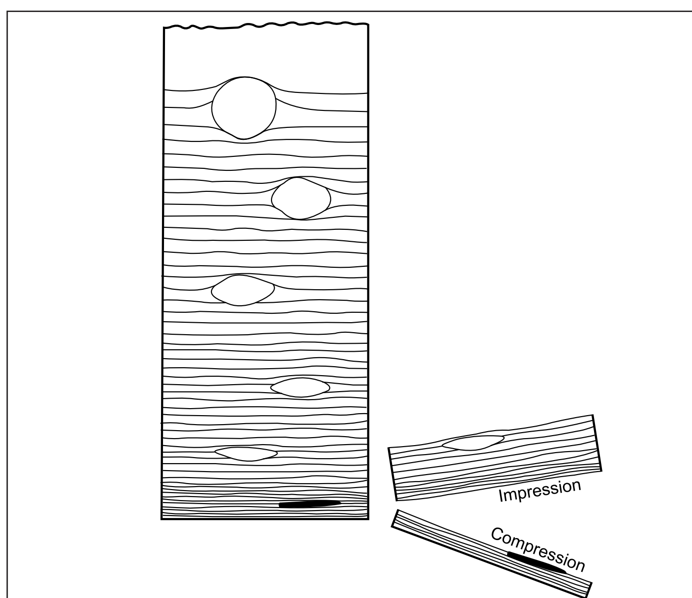


Figure 4. A. Origin of wood impressions and compressions showing the flattening of a limb under the weight of overlying sediments (modified from Arnold, 1947, fig. 12).

eventually almost flat. Over time only a relatively thin film of carbon may remain, but the details of the outside of the limb are preserved. A compression is what remains of the limb; an impression are the marks left in the surrounding sediment.

Molds and casts of ancient wood typically are mistaken for petrified wood (Figure 4B). Molds form when a log, stem, or root is buried in sand or mud and subsequently decays. If the surrounding sediment is consolidated enough not to collapse into the void left behind, a mold is formed. A cast forms when the mold is filled with sediment or mineral material. Although the mold and cast may preserve the outside texture of the wood, the woody organic material has not been mineralized and no original cellular structure remains. In many cases it is difficult to distinguish wood that has been so thoroughly petrified that no evidence of its original cellular structure remains from casts that formed when a mineral precipitated out of a solution that filled a void (mold) left after a piece of wood decayed. Pith casts are a particular kind of cast that forms when the pith (the spongy or hollow central part of some plants) is filled with sediment when the plant dies. The cast, therefore, preserves the structures on the inner surface of the woody, outer cylinder of the plant. In Oklahoma, pith casts of the Pennsylvanian sphenophyte (horsetails and their relatives) *Calamites* are relatively common in strata associated with the State's coal beds.

Two additional, but related, processes of wood fossilization are "charcoalification" and "carbonization" (or "coalification"). Charcoal is "an impure carbon residue of the burning of wood or other organic material in the absence of air. It is black, often porous, and able to absorb gases" (AGI Glossary, 2005). Fossilized charcoal, probably the result of ancient forest fires, is exceedingly rare in the geologic record. In contrast carbonized plant material, or coal (where it is thick enough to form discrete beds), is relatively common. Carbonization occurs when plant material is buried, the cells the make up the plant soften, collapse, and eventually lose any contained water or gas. With increased pressure the residue is altered and consolidated to a coaly material. As stated previously, this material may coat the outside of a limb compression or cast.

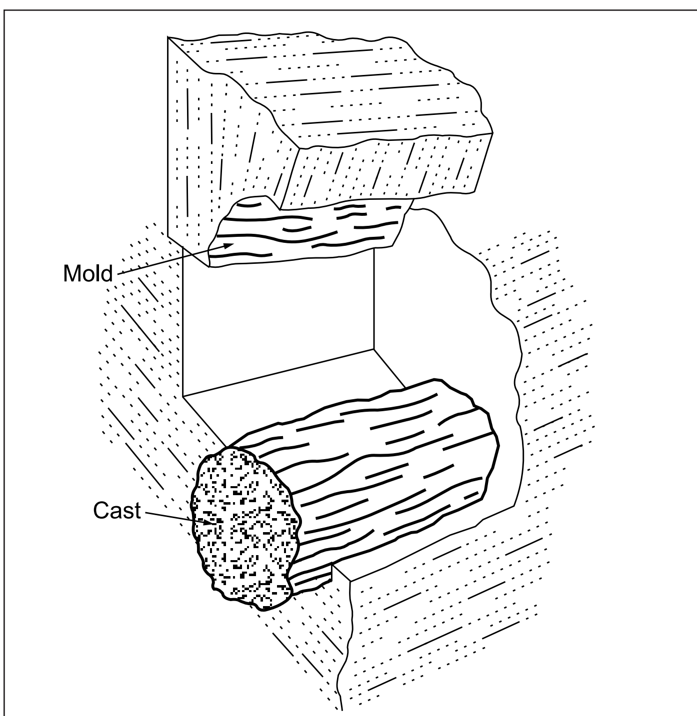


Figure 4. B. Origin of wood molds and casts showing cavity left in consolidated sediment following the decay of the wood. The cavity is filled with sand, mud, or mineral matter (e.g., opal) leaving an excellent replica of the wood (modified from Tidwell, 1998, fig. 28).

Mineralization

In Oklahoma, as elsewhere, most petrified wood is silicified, that is, the wood is replaced by silica minerals (opal-A, opal-CT, chalcedony, and quartz). Much Permian wood is replaced by hematite and other iron oxide minerals and some is associated with copper minerals. Oklahoma's state rock is the rose rock or barite rose; thus, it is not surprising that some petrified wood in Oklahoma is made up of barite. Calcite, a common wood-replacing mineral, also is a constituent of some Oklahoma petrified wood. However, wood replaced by these minerals is uncommon and the replacement process by these minerals is not well described in the geologic literature.

Silicification

Wood replacement by silica minerals is the most common type of petrifaction. For wood to become silicified several conditions must be met. 1) The wood, typically waterlogged, must be rapidly buried in sediment, typically gravel, sand, or mud, and not exposed to oxygen, in order to prevent fungal decomposition. This typically occurs in a fluvial environment, although some silicified wood (including some in Oklahoma) is found in marine sediments, including beach and deep-marine deposits. Rarely, silicified wood is found in volcanic rocks, including lava flows (e.g., at Ginkgo Petrified Forest State Park in Washington). 2) The pH of the water in the sediment must be near neutral. Water that is too acidic (pH $<<$ 7.0) promotes the growth of wood-destroying fungi. Very basic water (pH $>>$ 7.0) destroys the organic molecules that constitute wood. Thus, water with a pH between 6 and 9 probably is ideal for petrifaction to occur. 3) A source of dissolved silica must be present. Most deposits of silicified wood are associated with volcanic ash or other volcanic rocks which readily release silica upon alteration.

A detailed description of the chemical mechanism of silicification is beyond the scope of this report, and the following is a summary of how wood silicifies. Most geologic formations that contain silicified wood are associated with volcanic ash, much of which consists of volcanic glass. Volcanic glass is unstable under atmospheric conditions and readily absorbs water and devitrifies (or crystallizes). As this occurs, silica is released and goes into solution as monosilicic acid ($Si(OH)_4$)), the principle soluble form of silica in nature. (Silica is also released by the weathering of feldspar, a common mineral in many rocks.) The monosilicic acid molecules in solution combine (polymerize) forming large molecules and releasing water. The polymerized silicic acid chains contain OH (hydroxyl) bonding sites; these form hydrogen bonds with similar hydroxyl bonding sites on organic molecules in woody tissue (Leo and Barghoorn, 1976).

As bonding occurs, the organic molecules are "templated" (Figure 5) with layer upon layer of silicic acid monomers and/or polymers. Additional polymerization occurs, forming a silica gel coating on the cell walls. This gel loses water and solidifies to amorphous opal (opal-A). Over time the opal-A crystallizes and loses water, forming opal-CT (cristobalite and tridymite). Continued crystallization and water loss transforms the opal-CT into chalcedony. And over still more time, chalcedony crystallizes into quartz, at which point the degree of crystallization typically has destroyed the wood's cellular structure. Age clearly is an important factor controlling which silica mineral constitutes a particular specimen of silicified wood. Stein (1982, p. 1277) reported that "chalcedony and microgranular quartz are the most common (if not exclusive) forms of siliceous petrifaction in fossil woods older than Eocene," Pliocene and Upper Miocene woods consisted of opal-CT, and a recent petrified wood from Yellowstone consisted of opal-A.

Not all silicification occurs by templating; in addition to silica deposition on accessible cell surfaces, some silica penetrates and is deposited within cell walls and some silica fills voids within the wood, especially the cell lumina and intercellular spaces (Figure 5). As the woody template deteriorates, additional space is created that can be filled with silica. Thus, silicification is the result of infiltration, templating, and the filling of voids by silica-rich solutions. Depending on the timing of the various processes and the degree to which they progress, the cellular structure of the wood can be beautifully preserved or completely destroyed.

Evolution and Wood Types

Because the paleobotany of Oklahoma is so varied and because one of the oldest varieties of "true trees" occurs as petrified wood in Oklahoma, the following summarizes some modern concepts of plant evolution, particularly as they apply to Oklahoma.

The oldest recognizable "plants" (some varieties of algae) are about 1.5 billion years old and there is little doubt that they lived in a marine environment. The first land plants appear to have evolved from a group of microscopic freshwater green algae called the Charophyceae. Although microbes may have inhabited soils as long as 1.2 billion years ago, the first good evidence for the emergence of plants on to land are spores dated at ~470 mya (Middle Ordovician) (Kendrick and Davis, 2004). The earliest vascular plants appeared in the middle part of the Silurian (~420 mya); they lacked leaves and roots, were less than three feet high, and dispersed airborne spores. Most likely these were among the first land plants. There is some evidence, however, that the first vascular plants may be as old as Late Ordovician (~450 mya). The vascular plants became highly diversified during the Devonian (409 to 363 mya); root systems became more complex, leaves and seeds developed, and some increased in size. By the end of the Devonian, all the major classes except the flowering plants existed, including the arborescent lycopods (common in Pennsylvanian strata in Oklahoma) and true ferns. The first true "forests" also appeared during the Devonian and large logs of the progymnosperm tree *Callixylon** are present in some Devonian strata in Oklahoma.

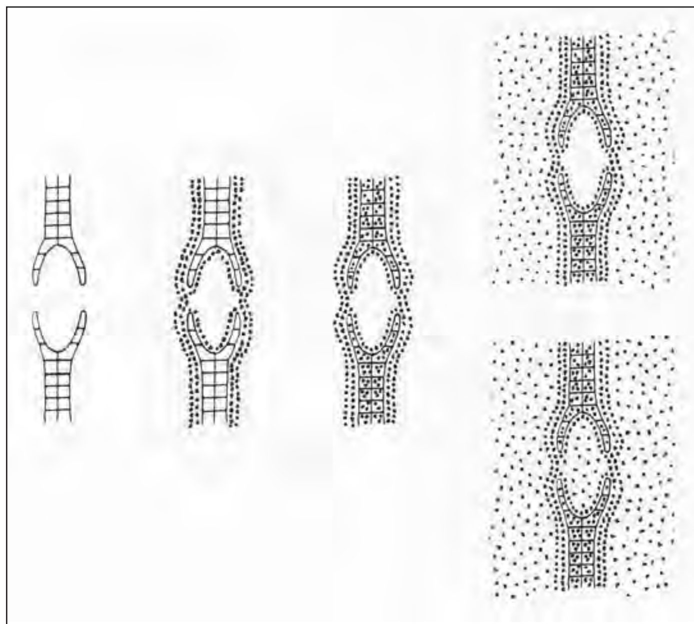


Figure 5. Templating of wood by silica polymers showing different parts of the wood cell being coated and/or filled. Original wood cell (on left) is coated by silica (middle-left). Cell lumina are then filled with silica (middle-right). Pore space between wood cells is filled (top-right) and cell pit chamber is filled (bottom-right). (modified from Jefferson, 1987).

*Botanists name plants according to the following classification scheme: Kingdom (Plantae), Division (e.g., Tracheophyta), Class (e.g., Gymnospersopsida), Order, Family, Genus, Species. Some schemes add the prefix super- or sub-, for example, Superfamily or Subdivision. This scheme is based on a thorough study of all the parts of a particular plant – roots, stem, leaves, seeds, etc. Fossil plants and petrified wood, in particular, are more difficult to classify because the different parts typically are not attached to each other. This unfortunate fact has resulted in paleobotanists giving separate names to the different plant parts; these names are called *form genera* and *form species*. An example of form genera is the Devonian tree *Callixylon*. In 1861, Canadian geologist Sir J.W. Dawson described a large, Late Devonian, fern-like frond that he named *Archeopteris*. Fifty years later, Russian paleobotanist M.D. Zalessky reported on a new type of petrified gymnospermous wood from the Donetz Basin in Russia that he called *Callixylon*. Beck (1960) discovered that the wood and foliage were physically attached; because the name *Archeopteris* was used before *Callixylon*, the entire plant is now known as *Archeopteris*, but *Callixylon* is still recognized as the stem-form genus of the wood. A Pennsylvanian plant commonly found in Oklahoma as compressions and casts is the stem-form genus *Lepidodendron*. The roots of this tree, however, are called *Stigmaria* and are common as casts.

(The progymnosperms are ancestral to the seed ferns and conifers (gymnosperms).)

Most petrified wood in Oklahoma is either a progymnosperm, gymnosperm, or angiosperm and the age of the formation that the wood occurs in provides strong evidence for what kind of wood it is. Most pre-Pennsylvanian petrified wood in Oklahoma is from the Devonian Woodford Shale and is the progymnosperm *Archeopteris* (stem genus *Callixylon*). Most of the Pennsylvanian petrified woods are reported to be cordaites (leaf genus *Cordaites*, stem genus *Cordaixylon*) or conifers (stem genus *Dadoxylon*), but future work may show some to be Voltziales (transitional between cordaites and conifers) (e.g., *Walchia*) or Glossopterids. These gymnosperm woods existed during all or part of the Pennsylvanian and Permian. Most Oklahoma petrified wood found in Cretaceous strata are conifers (gymnosperms) or hardwoods (angiosperms). It is important to remember that many Pennsylvanian and, to a lesser extent, Permain fossil plants (e.g., lycopods and sphenopsids) are not petrified wood but casts, and the roots (rhizomes) of some ferns and trunks of some large tree ferns (e.g., *Psaronius*) can be petrified but are not "wood."

Devonian Petrified Wood in Oklahoma

Devonian strata crop out in three general areas in Oklahoma. The Arkansas Novaculite is present near Broken Bow Lake, in the Potato Hills, and at Black Knob Ridge in the Ouachita Mountains in southeastern Oklahoma. The Chattanooga Shale is exposed in some of the deeper river valleys in the Ozarks, particularly along the Illinois River and Spavinaw Creek. The Woodford Shale is present around the margins of the Arbuckle Mountains (including the Lawrence Uplift near Ada) and in the Criner Hills. A variety of petrified wood known as *Callixylon whiteanum* (Arnold, 1934) is present in the lower part of the Woodford Shale (Figure 6A) and an unknown wood (but probably *Callixylon*) occurs at at least one locality in the Arkansas Novaculite (Figure 6B).

Callixylon is one of the oldest "true" petrified woods and probably formed the first forests of large vascular plants. Petrified wood similar to the *Callixylon whiteanum* of Oklahoma is found in strata similar to and about the same age as the Woodford Shale from New York to New Mexico, Idaho to North Dakota, and elsewhere (Hoskins and Cross, 1952). Most of these strata were deposited in a marine environment apparently far from land; this observation, plus the presence of attached crinoid holdfasts on specimens from Ohio and Indiana, are evidence that many of the Devonian *Callixylon* logs are pieces of driftwood.

Very little research has been done on Devonian petrified wood in Oklahoma despite its relatively widespread occurrence and, in some cases, rather impressive size. The only comprehensive work is by Arnold (1934), who identified *Callixylon whiteanum* logs as much as five feet in diameter. Devonian petrified wood from the Woodford Shale is present in Atoka County (Wilson, 1958), Pontotoc County (Morgan, 1924; Wilson, 1958; Lowe, 1968; Haas and Huddle, 1965), and Murray County (Kirkland and others, 1992). And recently the author was shown some petrified wood in the Arkansas Novaculite in the Potato Hills (Figure 6B).

An unusual Devonian "fossil" wood locality is in the Sylamore Sandstone Member of the Chattanooga Shale in Cherokee County (Huffman and Starke, 1960). This unit is approximately the same age as the Woodford Shale in southern Oklahoma. The fossils are molds of tree trunks that range from one to six feet in length and are five to ten inches in diameter. Huffman and Starke (1960) suggested the molds are of a tree that belongs to the genus *Cordaites*, but *Cordaites* first appear in the Mississippian, and the Sylamore is Devonian. To date, no definitive work has been done on these molds.

Figure 6. A. *Callixylon* from Woodford Shale (Devonian), Arbuckle Mountains (photograph courtesy Stan Paxton).

Figure 6. B. Petrified wood of unknown kind from Arkansas Novaculite, Potato Hills.

Mississippian Petrified Wood in Oklahoma

To date, no Mississippian petrified wood has been identified in Oklahoma. However, Dunn (2004) has identified two species of lycopsids, one sphenopsid, and the stems of ferns (rare) and seed ferns (common) from the Fayetteville Formation in northern Arkansas. (The Fayetteville also crops out in Oklahoma.) Interestingly, these specimens are preserved by calcite and pyrite, and not silica.

The Mississippian Stanley Group in southeastern Oklahoma contains rare impressions of *Lepidodendron*, *Archaeocalamites*, and *Calamites* (White, 1937), but no petrified wood.

Pennsylvanian Petrified Wood in Oklahoma

Pennsylvanian strata cover about 25% of Oklahoma, therefore, it is not surprising that most of the "fossil" wood in Oklahoma is Pennsylvanian in age. Most of the fossil (as opposed to "petrified") wood consists of molds and casts. Probably the most common plant mega-fossil is *Stigmaria*, a general name for the rootlike structures of the lycopods *Lepidodendron* and *Sigillaria* (Figure 7A). Other common plant fossils that resemble and are often mistaken for petrified wood are the lycopods *Lepidodendron* and *Sigillaria* (Figure 7B) and the sphenopsid *Calamites*. These plants, together with a wide variety of seed ferns and true ferns, are relatively common in the coal-bearing formations of eastern Oklahoma but are beyond the scope of this report. Classic or summary papers on the compression and impression flora of southeastern Oklahoma are by White (1899), White (1937), and Robison (1978), and a more recent paper is Lupia and others (2002). Wilson (1972) described the compression flora of the Seminole Formation in northeastern Oklahoma.

In contrast to the "fossil" wood molds and casts, Pennsylvanian petrified wood is much less common, although it is locally abundant. Petrified-wood-bearing formations can, in a general way, be divided into those that are north of Interstate 40 and those that are to the south. Much of the wood to the north is closely associated with some of the Pennsylvanian coal beds that are exposed there. To the south, most of the petrified wood is found near Ada and is not associated with coal.

The oldest Pennsylvanian petrified wood in northeastern Oklahoma is found in the Senora Formation, which contains many coal beds. Hemish (1990) identified some silicified tree stumps in the Tebo coal in Wagoner County. Hemish (1994) found "some fossilized pieces of wood" (probably petrified) in some interbedded limestone and coal just below the Mineral coal in Okmulgee County, and Rice (1971) found some petrified wood in a strip mine operated by the Bill Patch Coal Company about eight miles west of Welch in Craig County. Based on Hemish (1986), this coal probably is the Iron Post coal. An ususual occurrence of small, "permineralized" branches of some conifer and conifer-like plants, possibly of the form-genus *Walchia*, occur in the Wewoka Formation in Okmulgee County (Rothwell and others, 1997). The iron-sulfide minerals pyrite and/or marcasite, and not quartz, replaced the wood and later altered to iron oxides and hydroxides.

Petrified wood occurs in the younger Holdenville Formation where it is associated with the Dawson coal; Tynan (1959) identified the conifer *Cordaites michiganensis* in Okmulgee County and Hemish (1990) found scattered fragments of silicified wood in Tulsa County. (Tynan (1959) incorrectly stated that the Dawson coal is within the Semi-

Figure 7. A. Cast of base of tree and top of root system of lycopod from Boggy Formation (Desmoinesian), near Kinta.

Figure 7. B. Cast of lycopod stump from McAlester Formation (Desmoinesian), originally found near Alderson, and now on display in El Reno.

nole Formation; based on his published location and the report by Hemish (1994), Tynan's sample comes from the Dawson coal in the Holdenville Formation.) Silicified wood is locally associated with the Tulsa coal in Tulsa County (Hemish, 1994). Silicified tree trunks "are known" in the still younger Coffeyville Formation "a few miles to the north" of Prattville in Osage County (Eames and others, 1977). Recently, a large fragment of petrified wood apparently collected from the Nowata Shale near Jenks was donated to the Oklahoma Geological Survey by Shawn Story of Will Rogers Junior High School in Claremore.

The youngest Pennsylvanian petrified wood found in northeastern Oklahoma is the tree fern *Psaronius* Cotta. Vosburg (1958) identified a specimen from a sandstone within the Foraker Limestone near Fairfax in Osage County. Although he suggested the specimen was Lower Permian, the Foraker Limestone underlies the Red Eagle Limestone, which marks the Pennsylvanian – Permian boundary. (Petrified wood from near this locality may be the same as that described by Kennedy (1964a).) Immediately underlying the Foraker is the Admire Group, and Goldring (1921) identified *Cordaites recentium* collected from "just below the first heavy limestone in the Admire Formation" "near" Bartlesville. The Admire is exposed ~15 miles west of Pawhuska and 35 miles west of Bartlesville. The stratigraphic position of this petrified wood is unclear, exactly what is meant by the "first" limestone is unknown; it may be either the lowest or highest limestone in the Admire or a limestone immediately above or below the Admire.

Petrified wood is also relatively common near Ada in some of the same formations as in northeastern Oklahoma: from oldest to youngest, the Wewoka, Holdenville, and Seminole Formations. Neman (2002) identified petrified wood in the Wewoka Formation, and Lowe (1968) identified some wood in the same formation at another locality as *Dadoxylon adaense**. Petrified wood is also present in the immediately overlying Holdenville Formation (Naff, 1962; Lowe, 1968) (Figure 8) and in the next younger Seminole Formation (Wilson, 1963; Lowe, 1968; Jensen, 1982). Wilson (1963) was the first to recognize that the species of cordaitean-type wood in many of the Pennsylvanian formations near Ada was different from others around the world and named it *Dadoxylon adaense*. In addition, he suggested that the specimen preserved in Wintersmith Park in Ada (described below) is the largest log (58 feet, 5 inches long) of *Dadoxylon* known. Wilson and Clark (1960) also describe petrified wood from an Upper Pennsylvanian formation near Ada.

The youngest "fossil" (petrified?) wood in the area is located north of Wewoka in Seminole County, where Green (1936) identified wood in the Vamoosa Formation.

Figure 8. Petrified wood from Holdenville Formation (Desmoinesian), near Francis.

Permian Petrified Wood in Oklahoma

Permian strata cover about 46% of Oklahoma's land surface; despite this, Permian petrified wood is very rare and no silicified wood has been documented from the Permian. (The only report of Permian silicified(?) wood is from near Hardy (Kennedy, 1964a).) All reports of "fossil" wood are from the Wellington Formation: baritized wood has been found near Orlando (Kennedy, 1964b), hematized wood is present southwest of Stillwater (pers. comm., Stillwater Mineral and Gem Society), and "fossil wood" occurs near Fallis and Iconium (Patterson, 1933). The author has seen compressed and hematized *Calamites* near Iconium; whether this is the "fossil wood" referred to by Patterson (1933) is unknown.

"Carbonized" or "carbonaceous" wood replaced by copper minerals occurs at scattered localities within Lower Permian strata throughout Oklahoma (Figure 9). Most of the localities are in southwest Oklahoma (six in Cotton County, one in Jefferson County) or north-central Oklahoma (one in Grant County, four in Noble County, eight in Pawnee County, seven in Payne County). One site is in Garvin County. Most of the localities are outcrops or old mines, prospect pits, and trenches and are relatively small. The primary copper mineral is chalcocite (Cu_2S) that locally is replaced by malachite ($Cu_2CO_3(OH)_2$) and/or azurite ($Cu_3(CO_3)_2(OH)_2$ (Figure 9). Other copper minerals such as chalcopyrite, chalcanthite, native copper, and some uranium-bearing minerals are reported to locally replace the wood.

The origin of these unusual examples of "mineralized" wood is similar to that of "redbed" or "stratiform" copper deposits. These deposits form as sulfate-rich brine with a positive Eh and low pH passes through unconsolidated or poorly

**Dadoxylon* is the form-genus name given to the wood of Paleozoic *Cordaites* and transition conifers (Stewart and Rothwell, 1993, p. 416). It is similar to *Araucarioxylon* wood which is applied to Mesozoic woods with the same characteristics. *Araucarioxylon arizonicum* is the most common wood at Petrified Forest National Park in Arizona.

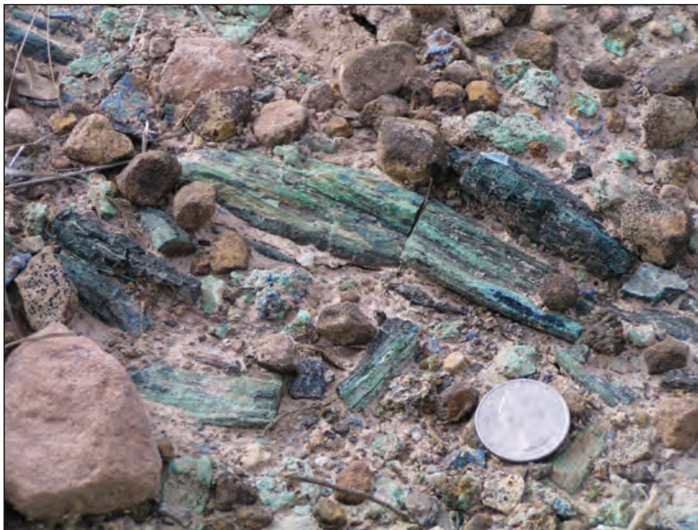


Figure 9. Malachite- and azurite-coated wood from near the base of the Matfield Shale (Wolfcampian), near Pawnee.

Figure 10. Specimens of petrified wood along the driveway of the Roberts' Ranch near Kenton. Most of these probably came from the Cheyenne Sandstone (Albian).

consolidated sediments. Under these conditions, copper is mobile and carried in solution. If the brine comes in contact with organic matter the Eh is reduced, and the copper is precipitated as a copper sulfide, typically chalcocite. At a later time, the chalcocite is oxidized under very near-surface conditions and the copper carbonates malachite and/or azurite replace or coat the chalcocite. Locally, stratiform copper deposits are large and rich enough to mine, e.g., the Nacimiento deposit in northwestern New Mexico. The literature on redbed copper and occurrence of Permian petrified wood in Oklahoma has been compiled by Fay (2000).

All of the Permian petrified wood in Oklahoma occurs near the base of the Garber Sandstone or in older strata. All of the cupriferous wood in southern Oklahoma occurs very close to the Garber Sandstone – Wellington Formation contact. In northern Oklahoma, wood occurs at several stratigraphic intervals in the Wellington Formation and Chase, Council Grove, and upper part of the Vanoss Groups.

Cretaceous Petrified Wood in Oklahoma

Most of the Cretaceous strata in Oklahoma occurs in the Panhandle (Cimarron County) and in the southeastern part of the State. In the Panhandle, petrified wood occurs in two formations – the Albian (Lucas and others, 1987) Cheyenne Sandstone (also called the Lytle Sandstone) and the younger Mesa Rica Sandstone, which is in the lower part of the Dakota Group. In southeastern Oklahoma, the Antlers Sandstone (Albian) and the overlying Woodbine (Cenomanian) and Tokio (Coniacian – Santonian) Formations (Scott and others, 1988; Fay, 1997) contain petrified wood.

Many early geologic mappers of Cimarron County noted petrified logs in the Cheyenne Sandstone (Rothrock, 1925; Bullard, 1928; Stovall, 1943) (Figure 10). The most complete description of petrified wood in the Cheyenne is from Stoval (1943, p. 76): "The Cheyenne sandstone contains abundant remnants of petrified logs, including many almost complete tree boles that measure 1 to 2.5 feet in diameter and from 10 to 85 feet in length. The fossil trees are mostly coniferous, with several species represented. They are most abundant near the base, but are present throughout the sandstone. No leaves were discovered in the sandstone member, but fossil wood is present at many localities." In addition to the logs, Stovall (1943) identified pebbles of petrified wood in conglomerate beds in the Cheyenne Sandstone.

Petrified wood in the Mesa Rica Sandstone (Dakota Group) has been noted by Stovall (1943), Kues and Lucas (1987), and Lucas and Hunt (1987). Fossil leaves occur in many localities in the Dakota Group and represent six species of angiosperms (Noe, 1925; Kues and Lucas, 1987); however, the kinds of leaves that are found do not necessarily represent the kind of wood that is present. To date, the petrified wood in the Cheyenne and Mesa Rica Sandstones in Oklahoma is virtually unstudied; the only preliminary identifications are *Sequoia* and cycads by Kennedy (1964a, 1966), but these should be confirmed by systematic paleobotanical work.

Throughout most of southeastern Oklahoma, the Antlers Sandstone (also called Paluxy sand) is the oldest Cretaceous formation present and unconformably overlies Permian and older strata. Petrified wood has been noted by Davis (1960) in McCurtain County, by Huffman and others (1975) in Choctaw County, by Prewitt (1961) in Bryan County, and by Huffman and others (1987) and Bullard (1926) in Marshall County. Petrified wood also is present in Carter County just west of Gene Autry (R.O. Fay, Oklahoma Geological Survey, unpub. mapping; Fragos, 2004, pers. commun.), south of Dickson, in Atoka County, and in Love County near Wilson. In places, pebbles of petrified wood are present in conglomerate beds in the Antlers. To date, the Oklahoma occurrences of petrified wood in the Antlers Sandstone, like those in the Cretaceous formations in the Panhandle, remain little studied.

Carbonized wood associated with uranium minerals is present in the Antlers Sandstone near Coleman in Johnston County (Totten and Fay, 1982).

The Woodbine Formation crops out between the west side of Lake Texoma west of Durant and the Arkansas state line east of Idabel. Carbonized wood and leave fossils are relatively common but petrified wood is rarely reported. The only report of petrified wood in the Woodbine Formation is in Choctaw County (Gibbs, 1950). Fossil leaves in the Woodbine Formation in Arkansas (Berry, 1917) and Texas (Berry, 1912; MacNeal, 1958) are relatively well studied and are dominated by angiosperms, although gymnosperms are present.

The Tokio Formation overlies the Woodbine and is present only in southernmost McCurtain County. Davis (1960) identified petrified wood in the Tokio Formation.

Tertiary Petrified Wood in Oklahoma

Most of the Oklahoma Panhandle and much of northwestern Oklahoma is covered by the Miocene – Pliocene Ogallala Formation. Fifteen genera of fossil leaves have been identified in the Ogallala along the Beaver River, but only one site southwest of Gate in Beaver County that contains petrified wood has been studied by paleobotanists, and all the wood there is of the genus *Robinia* (Matten and others, 1977). (*Robinia* is a locust in the pea family.) Petrified wood occurs locally in the Ogallala Formation in Roger Mills County (P. Thurman, 2004, pers. commun.) and Kennedy (1964a) reports petrified wood from near Laverne.

PETRIFIED WOOD ARCHITECTURE

Petrified wood has been used as a building stone and as a display item throughout Oklahoma. Several buildings are constructed largely, if not entirely, of petrified wood in Enid, Lexington, Purcell, Ardmore, and near Davis. Large logs or stumps of petrified wood are on display on the campus of East Central University and in Wintersmith Park in Ada, at the Oklahoma City Zoo, at the Philbrook Museum in Tulsa, and at Black Mesa State Park near Kenton. An interesting "logjam" of petrified wood has been constructed at the Goddard Youth Camp near Dougherty.

Buildings

The Midgley Museum in Enid is perhaps the best-known example in Oklahoma where petrified wood was used as a building stone. A group of Texas stone masons constructed the building in 1945 for Dan and Libbie Midgley, who moved to Oklahoma from Kansas in the late 1800's. They farmed wheat and hay and "traveled extensively each year to sell their harvests and began collecting exotic rocks on their expeditions" (museum brochure). The petrified wood and fossils come from a five-county area in Texas; "they hired semi-trailer trucks to haul up petrified logs (and) on their return trips they took back alfalfa hay to cattlemen" (Johnson, 1969). The 7000-pound petrified tree stump on display outside was found near Woodward (Johnson, 1969). (If this is accurate, the stump probably came from the Ogallala Formation and is therefore Tertiary.) Eva Fothergill (Dan and Libbie Midgley's daughter) built the house to the west in 1966 and began converting the Midgley home into a museum. Eva died in 1989 and willed the original building to the Masons, who completed its conversion to a museum and now operate and maintain it.

Equally impressive but perhaps less well known is Mrs. Nadine Scott's home in Lexington that was built by Mrs. Scott's husband John Bart Scott in 1939 (Figure 11). The walls are constructed almost entirely of petrified wood that came from near Lipan, Texas (Corbin, 1976). (Mr. I.E. Minor of Lipan sold Mr. Scott the petrified wood for $3.00 per ton.) Two similar buildings, also built by Mr. Scott, are present along Main Street in Purcell. In addition to having been a builder, Mr. Scott was "an oldtime aviator (having flown with Wiley Post from an airstrip along the Canadian River), a minnow vendor, a service station owner, a highway tollman, and a good mechanic" (Corbin, 1976).

Several buildings in Ardmore are constructed from petrified wood. One of these is Mitchell's Barber shop at 540 12th Ave. NW. The builder for most of these was Walter Day, an Ardmore stonemason (pers. commun., Thad Day, 1996). The building that now houses Mitchell's was built between 1932 and 1934. Several residents of Gene Autry remember that much of the wood used in the building came from just west of their town, then known as Berwyn (B. Fragos, pers. commun. 2004). (If true, the petrified wood was in the Cretaceous Antlers Sandstone (R.O. Fay, unpub. mapping).) The Stonewood Courts buildings were built between 1935 and

Figure 11. Home of Mrs. Nadine Scott, Lexington. Almost the entire house is built of petrified wood collected in Texas and shipped to Lexington.

1938 and the wood for these buildings was "picked up by T.E. Paschall and his wife from over Carter County and nearby states" (Oklahoman, Sept. 25, 1938, p. 85).

Thad Day, another Ardmore stonemason, built the office building for the (now) Canyon Breeze Motel near Davis around 1932. The petrified wood came from near the small town of Brock about 8 miles west-southwest of Ardmore (pers. commun., E.W. Pletcher, 1996). Brock is located in the lower part of the Antlers Sandstone; therefore, the petrified wood probably is Cretaceous.

A small house built of petrified wood is present along the lakeshore in Wintersmith Park in Ada. Built around 1940 as the Firefly Cabin (J. Gabbert, pers. commun., 2004), it is now owned and operated by the Campfire Girls. Although the origin of the wood is unknown, it probably is local and therefore Pennsylvanian.

Displays and Monuments

The largest stump (partly reconstructed) in the world of the primitive Devonian tree *Callixylon whiteanum* was erected at the entrance to East Central University in Ada in 1935 (Figure 12). It was found near Goose Creek south of Jesse, Oklahoma, in sec. 26, T. 1 N., R. 7 E. (Wilson, 1958). Mr. John Fitts, discoverer of the giant Fitts oilfield, presented the stump to East Central in honor of Dr. David White (1862-1935), Curator of Paleobotany at the Smithsonian Institution and Principal Geologist with the U.S. Geological Survey.

Possibly the largest log of the fossil wood *Dadoxylon* is present in Wintersmith Park (SE¼SW¼NW¼ sec. 2, T. 3 N., R. 6 E.), also in Ada. The log, discovered in the 1930's but not excavated until February 1962 (Wilson, 1963), is surrounded by a chainlink fence but nonetheless appears to be vandalized. The log is 58 feet, five inches long, is two feet, three inches in diameter at its base, and is broken into segments one to several feet long (Wilson, 1963). Wilson (1963) describes the occurrence, microscopic features, and attempts to locate possibly longer specimens. The log occurs in the Pennsylvanian Seminole Formation.

An upright petrified tree trunk about eight feet high is present at the Oklahoma City Zoo in front of the herpetarium. A plaque in front of the trunk reads, "Petrified Tree Trunk Found Near Berwyn, Oklahoma. Estimated By Geologists To Be More Than 5 Million Years Old. Presented To Oklahoma City By Will S. Guthrie, Board Of Park Commissioners, 1919 – 1934"." Barbara Fragos, a volunteer at the Zoo, is attempting to document the history of the petrified tree trunk. She believes that the trunk was given to the zoo between 1934 (date on the plaque) and 1942, when the town of Berwyn changed its name to Gene Autry. Based on interviews with residents, she learned that the tree trunk probably was collected from an area about two miles west of Gene Autry in an area underlain by the Cretaceous Antlers Sandstone. (R.O. Fay, Oklahoma Geological Survey, identified petrified wood in the same formation near Gene Autry.)

A large cast of a stump is on the grounds of the Canadian County Historical Society's museum in El Reno (Figure 7B). Although the specimen is labeled as a "petrified tree" it is, in fact, a cast. Branson (1958a) reported that a sign on the tree read "Petrified tree. This tree was found March 14, 1914 at a depth of 40 feet, while sinking shaft No. 9 of Rock Island Coal Mining Company, at Alderson, Oklahoma." Branson (1958b) identified the stump as *Cordaites*. The stump occurred in the lower part of the Middle Pennsylvanian Savanna Formation or upper part of the McAlester Formation. The stump was erected between 1914 when it was collected and 1939 when the photograph shown by Branson (1958a) was taken.

Figure 12. Stump of *Callixylon* on East Central University campus, Ada. This stump is reputed to be the largest stump of *Callixylon* in the world. (photograph courtesy of Dan Boyd)

Sign adjacent to stump:

Donated by the Chicago, Rock Island and Pacific Railroad Company to the El Reno Chamber of Commerce, 1959 (metal plaque)

Petrified Tree

This tree was found March 14, 1914, at a depth of forty feet while sinking shaft number 9, of Rock Island Mining Company at Alderson, Oklahoma.

Mr. C.W. Shannon, then Director of the Oklahoma Geological Survey, under date of July 28, 1914, commented as follows regarding the age of this tree:

"It is impossible to tell the age of the tree – and the time which has elapsed since it grew can only be given in millions of years. The stump and part of the roots of this large tree are from the geological periods (sic) known as the Carboniferous, and grew in a swamp millions of years ago. It often happens that plants were replaced by sandstone instead of passing through a process of carbonization and forming coal.

"Judging from the thickness and number of coal beds which are found in the rocks of the Carboniferous age, and basing calculations upon the time which it seems would be necessary for the accumulation of coal, and allowing an equal length of time for the formation of the associated rock, we would have figures something like two million to five million (sic) years as a conservative estimate for the duration of the Carboniferous Period, which means, at best, the coal period was very long.

"Since the close of the Carboniferous Age, time has been divided into about ten geologic ages, each representing long periods of several thousand years to millions of years. All estimates of years representing the great length of time are only roughly calculated. The time from the beginning of the Carboniferous to the present can only said to be millions of years, not a few thousand as is often given for the age of the world."

Chicago, Rock Island and Pacific Railroad Company

This petrified tree was presented as a gift (see permanent metal plaque) to the El Reno Chamber of Commerce by the Chicago, Rock Island and Pacific Railroad Company, receipt of which is gratefully acknowledged. It was moved from a location near the Rock Island Depot to the present site in June 1959, where it will be maintained in well kept surroundings for generations to come.

June 25, 1959

A large petrified log stands upright in the cascade rock garden at the Philbrook Museum in Tulsa. Very little is known about the log, but it was included in the original 1927 gardens (pers. commun., T.E. Young, 2004).

Several upright and prone petrified logs are on display at Black Mesa State Park near Kenton. Lucas and Hunt (1987) report that "park personnel have collected fossil logs from the Mesa Rica Sandstone (basal member of the Dakota Group) in this area and stood them upright on concrete platforms" (p. 57). Discussions with local ranchers suggest to the author that the logs more likely were collected from the Cheyenne Sandstone. The Dakota and Cheyenne are Early Cretaceous.

Mr. Wayne Edgar constructed an interesting "petrified wood logjam" at the Goddard Youth Camp near Dougherty. The wood is from the Cretaceous Antlers Sandstone and was collected in southwest Arkansas.

Table A. Definitions of silica minerals (from AGI Glossary, 2005)

Quartz – crystalline silica, an important rock-forming mineral: SiO_2. It is, next to feldspar, the commonest mineral, occurring either in transparent hexagonal crystals or in crystalline or cryptocrystalline masses. It is composed exclusively of silicon-oxygen tetrahedra with all the oxygens joined together in a three-dimensional network. It is polymorphous with cristobalite, tridymite, stishovite, coesite and keatite.

Cristobalite – a mineral: SiO_2. It is a high-temperature polymorph of quartz and tridymite. Cristobalite is stable only above 1470^{o}C; it has a tetragonal structure (alpha-cristobalite) at low temperatures and a cubic structure (beta-cristobalite) at higher temperatures.

Tridymite – a vitreous colorless mineral: SiO_2 . It is a high-temperature polymorph of quartz. Tridymite is stable between 870^o and 1470^{o}C; it has an orthorhombic structure (alpha-tridymite) at low temperatures and a hexagonal structure (beta-tridymite) at higher temperatures.

Chalcedony – (a) a cryptocrystalline variety of quartz. Varieties include carnelian, sard, chrysoprase, prase, plasma, bloodstone, onyx, and sardonyx. (b) A general name for crystalline silica that forms concretionary masses with radial-fibrous and concentric structure.

Opal – a mineral or mineral gel: $SiO_2 \cdot nH_2O$. It has been shown by electron diffraction to consist of packed spheres of silica; some so-called opal gives weak X-ray patterns of cristobalite or tridymite.

Opal-A – noncrystalline (amorphous) opal.

Opal-CT – opal in which the silica spheres consist of microcrystalline blades of cristobalite and tridymite.

REFERENCES CITED

Arnold, C.A., 1934, *Callixylon whiteanum* Sp. Nov., from the Woodford Chert of Oklahoma: Botanical Gazette, v. 96, p. 180-185.

Arnold, C.A., 1947, An introduction to paleobotany: McGraw-Hill Book Company, Inc., New York, 433p.

Beck, C.B., 1960, The identity of *Archeopteris* and *Callixylon*: Brittonia, v. 12, p. 351-368.

Berry, E.W., 1912, Contributions to the Mesozoic flora of the Atlantic Coastal Plain; VIII, Texas: Bulletin of the Torrey Botanical Club, v. 39, p. 387-406.

Berry, E.W., 1917, Contributions to the Mesozoic flora of the Atlantic Coastal Plain; XII, Arkansas: Bulletin of the Torrey Botanical Club, v. 44, p. 167-190.

Branson, C.C., 1958a, Ancient fossil stump at El Reno: Oklahoma Geology Notes, v. 18, p. 125.

Branson, C.C., 1958b, *Cordaites*, not *Calamites*: Oklahoma Geology Notes, v. 18, p. 144.

Bullard, F.M., 1926, Geology of Marshall County, Oklahoma: Oklahoma Geological Survey Bulletin 39, 101p.

Bullard, F.M., 1928, Lower Cretaceous of western Oklahoma: Oklahoma Geological Survey Bulletin 47, 116p.

Corbin, J.J., 1976, Unusual house petrified wood: Norman Transcript, September 10, 1976, p. 6-7.

Davis, Leon, 1960, Geology and ground-water resources of southern McCurtain County, Oklahoma: Oklahoma Geological Survey Bulletin 86, 108p.

Dernbach, Ulrich, 1996, Petrified forests – the world's 31 most beautiful petrified forests: D'Oro – Verlag, Heppenheim, Germany, 187p.

Dunn, M.T., 2004, The Fayetteville flora I: Upper Mississippian (middle Chesterian/lower Namurian) plant assemblages of permineralized and compression remains from Arkansas, USA: Review of Paleobotany and Palynology, v. 132, p. 79-102.

Eames, L.E.; Hedlun, R.W.; Scott, R.W.; Thomas, J.B.; and Upshaw, C.F., 1977, Tenth anniversary annual meeting field trip, Tulsa area: American Association of Stratigraphic Palynologists, 21p.

Fay, R.O., 1997, Stratigraphic units in Oklahoma, Texas, Arkansas, and adjacent areas: Oklahoma Geological Survey Open-File Report OF1-97, 229p.

Fay, R.O., 2000, Bibliography of copper occurrences in Pennsylvanian and Permian red beds and associated rocks in Oklahoma, Texas, and Kansas (1805 to 1996): Oklahoma Geological Survey Special Publication 2000-1, 16p.

Gibbs, H.D., 1950, A field study of the Goodland Limestone and the Washita Group in southeastern Choctaw County, Oklahoma: unpub. M.S. thesis, University of Oklahoma, Norman, 72p.

Goldring, Winifred, 1921, Annual rings of growth in Carboniferous wood: Botanical Gazette, v. 72, p. 326-330.

Green, D.A., 1936, Permian and Pennsylvanian sediments exposed in central and west-central Oklahoma: American Association of Petroleum Geologists Bulletin, v. 20, p. 1454-1475.

Hass, W.H.; and Huddle, J.W., 1965, Late Devonian and Early Mississippian age of the Woodford Shale in Oklahoma, as determined by conodonts: U.S. Geological Survey Professional Paper 525-D, p. D125-D132.

Hemish, L.A., 1986, Coal geology of Craig County and eastern Nowata County, Oklahoma: Oklahoma Geological Survey Bulletin 140, 131p.

Hemish, L.A., 1990, Coal geology of Tulsa, Wagoner, Creek, and Washington Counties, Oklahoma: Oklahoma Geological Survey Map GM-33, 5 sheets, scale 1:63,360.

Hemish, L.A., 1994, Coal geology of Okmulgee County and eastern Okfuskee County, Oklahoma: Oklahoma Geological Survey Special Publication 94-3, 86p.

Hoskins, J.H.; and Cross, A.T., 1952, The petrifaction flora of the Devonian – Mississippian black shale: The Paleobotanist, v. 1, p. 215-238.

Huffman, G.G.; Alfonsi, P.P.; Dalton, R.C.; Duarte-Vivas, Andres; and Jeffries, E.L., 1975, Geology and mineral resources of Choctaw County, Oklahoma: Oklahoma Geological Survey Bulletin 120, 39p.

Huffman, G.G.; Bridges, K.F.; Ganser, R.W.; Holtzman, A.M., Jr.; and Merritt, M.L.; 1987, Geology and mineral resources of Marshall County, Oklahoma: Oklahoma Geological Survey Bulletin 142, 126p.

Huffman, G.G.; and Starke, J.M., Jr., 1960, A new fossil plant locality in the Sylamore Sandstone Member, Chattanooga Formation, northeastern Cherokee County, Oklahoma: Oklahoma Geology Notes, v. 20, p. 89-91.

Jefferson, T.W., 1987, The preservation of conifer wood: examples from the Lower Cretaceous of Antarctica: Palaeontology, v. 30, p. 233-249.

Jensen, K.N., 1982, Growth rings in Pennsylvanian fossil wood in Oklahoma: Oklahoma Geology Notes, v. 42, p. 7-10.

Johnson, F.V., 1969, The Midgley museum: unpublished manuscript, 3p.

Kendrick, Paul; and Davis, Paul, 2004, Fossil plants: Smithsonian Books, Washington, D.C., 216p.

Kennedy, Marie, 1964a, Petrified wood of Oklahoma: Lapidary Journal, August, p. 558-563.

Kennedy, Marie, 1964b, Sequel to find of baritized wood in Oklahoma: Lapidary Journal, October, p. 833.

Kennedy, Marie, 1966, Oklahoma's forest of stone: Lapidary Journal, December, p. 1082-1089.

Kirkland, D.W.; Denison, R.E.; Summers, D.M.; and Gormly, J.R., 1992, Geology and organic geochemistry of the Woodford Shale in the Criner Hills and western Arbuckle Mountain, Oklahoma, *in* Johnson, K.S.; and Cardott, B.J. (eds.), Source rocks in the southern midcontinent, 1990 symposium: Oklahoma Geological Survey Circular 93, p. 38-69.

Kues, B.S.; and Lucas, S.G., 1987, Cretaceous stratigraphy and paleontology in the Dry Cimarron Valley, New Mexico, Colorado and Oklahoma, *in* Lucas, S.G.; and Hunt, A.P., (eds.), Northeastern New Mexico: New Mexico Geological Society Thirty-eighth Annual Field Conference, September 24-26, 1987, p.167-198.

Leo, R.F.; and Barghoorn, E.S., 1976, Silicification of wood: Botanical Museum Leaflets, Harvard University, v. 25, no. 1, p. 1-47.

Lowe, K.L., 1968, Geology of the Ada area, Pontotoc County, Oklahoma: unpub. M.S. thesis, University of Oklahoma, Norman, 81p.

Lucas, S.G.; and Hunt, A.P., 1987, Supplemental road log 2, to Black Mesa State Park, Oklahoma, *in* Lucas, S.G.; and Hunt, A.P., (eds.), Northeastern New Mexico: New Mexico Geological Society Thirty-eighth Annual Field Conference, September 24-26, 1987, p. 56-57.

Lucas, S.G.; Hunt, A.P.; and Kues, B.S., 1987, Stratigraphic nomenclature and correlation chart for northeastern New Mexico, *in* Lucas, S.G.; and Hunt, A.P., (eds.), Northeastern New Mexico: New Mexico Geological Society Thirty-eighth Annual Field Conference, September 24-26, 1987, p. 351-354.

Lupia, Richard; Brinkley, Rhiannon; Neaher, Tiffany; and Burkhalter, Roger, 2002, Preliminary survey of a Desmoinesian flora from the upper Savanna Formation (Pennsylvanian) of Oklahoma: Oklahoma Geology Notes, v. 62, p. 19-26.

MacNeal, D.L., 1958, The flora of the Upper Cretaceous Woodbine sand in Denton County, Texas: Academy of Natural Sciences, Philadelphia Monographs, v. 10, p. 1-152.

Matten, L.C.; Gastaldo, R.A.; and Lee, M.R., 1977, Fossil *Robinia* wood from the western United States: Review of Palaeobotany and Palynology, v. 24, p. 195-208.

Morgan, G.D., 1924, Geology of the Stonewall quadrangle, Oklahoma: Bureau of Geology, Oklahoma, Bulletin 2, 248p.

Naff, J.D., 1962, Geology and paleontology of the Upper Boggy drainage area, Coal and Pontotoc Counties, Oklahoma: upub. Ph.D. dissertation, University of Kansas, Lawrence, 455p.

Neman, R.L., 2002, Guidebook for geological field trips in south-central Oklahoma: Arbuckle Geosciences, Ada, Oklahoma, 140p.

Noe, A.C., 1925, Dakota sandstone plants from Cimarron County, Oklahoma: Oklahoma Geological Survey Bulletin 34, p. 93-107.

Patterson, J.M., 1933, Permian of Logan and Lincoln Counties, Oklahoma: American Association of Petroleum Geologists Bulletin, v. 17, p. 241-253.

Prewitt, B.N., 1961, Subsurface geology of the Cretaceous coastal plain, southern Oklahoma: unpub. M.S.thesis, University of Oklahoma, Norman, 82p.

Rice, Bob, 1971, Rainbow wood in Oklahoma: Lapidary Journal, July, p. 601.

Robison, C.R., 1978, A survey of the paleontological resources of southeastern Oklahoma: final report to the Bureau of Land Management, U.S. Department of the Interior: Oklahoma Geological Survey Open-File Report 428, 146p.

Rothrock, E.P., 1925, Index of Cimarron County: Oklahoma Geological Survey Bulletin 34, 110p.

Rothwell, G.W.; Mapes, Gene; and Mapes, R.H., 1997, Late Paleozoic conifers of North America: structure, diversity, and occurrences, *in* Lyons, P.C.; and Zodrow, E.L. (eds.), Euramerican Carboniferous paleobotany and coal geology: Review of Paleobotany and Palynology, v. 95, p. 95-113.

Scott, R.W.; Frost, S.H.; and Shaffer, B.L., 1988, Early Cretaceous sea-level curves, Gulf Coast and southeastern Arabia, *in* Wilgus, C.K.; Posamentier, H.W.; Ross, C.A.; and Kendall, C.G., St. C. (eds.), Sea-level changes: an integrated approach: Society of Economic Paleontologists and Mineralogists Special Publication No. 42, p. 275-284.

Scurfield, G., 1979, Wood petrifaction: an aspect of biomineralogy: Australian Journal of Botany, v. 27, p. 377-390.

Stein, C.L., 1982, Silica recrystallization in petrified wood: Journal of Sedimentary Geology, v. 52, p. 1277-1282.

Stewart, W.N.; and Rothwell, G.W., 1993, Paleobotany and the evolution of plants: Cambridge University Press, Cambridge, U.K., 521p.

Stovall, J.W., 1943, Stratigraphy of the Cimarron Valley, *in* Schoff, J.W., Geology and ground water resources of Cimarron County, Oklahoma: Oklahoma Geological Survey Bulletin 64, p. 43-132.

Tidwell, W.D., 1998, Common fossil plants of western North America: Smithsonian Institution Press, Washington, D.C., 299p.

Totten, M.W.; and Fay, R.O., 1982, Map of Oklahoma showing localities of reported uranium and radioactivity values: Oklahoma Geological Survey Geologic Map GM-25, 1 sheet, scale 1:750,000.

Tynan, E.J., 1959, Occurrence of *Cordaites michiganensis* in Oklahoma: Oklahoma Geology Notes, v. 19, p. 43-46.

Vosburg, D.L., 1958, A record of *Psaronius* in the Wolfcampian of Oklahoma: Oklahoma Geology Notes, v. 18, p. 77-79.

White, David, 1899, Report on fossil plants from the McAlester coal field, Indian Territory, collected by Messrs. Taff and Richardson in 1897: U.S. Geological Survey, 19th Annual Report, pt. 3, p. 457-538.

White, David, 1937, Fossil plants from the Stanley Shale and Jackfork Sandstone in southeastern Oklahoma and western Arkansas: U.S. Geological Survey Professional Paper 186-C, p. 43-67.

Wieland, G.R., 1916, American fossil cycads, volume II: Carnegie Institution of Washington Publication no. 34, Washington, D.C., 276p.

Wilson, L.R., 1958, Oklahoma's oldest fossil trees: Oklahoma Geology Notes, v. 18, p. 172-176.

Wilson, L.R., 1963, A new species of *Dadoxylon* from the Seminole Formation (Pennsylvanian) of Oklahoma: Oklahoma Geology Notes, v. 23, p. 215-220.

Wilson, L.R., 1972, Fossil plants of the Seminole Formation (Pennsylvanian) in Tulsa County, Oklahoma: Tulsa Geological Society Digest, v. 37, p. 151-161.

Wilson, L.R.; and Clarke, R.T., 1960, Siliceous spherules in tracheids of Cordaitean wood: Oklahoma Geology Notes, v. 20, p. 106-110.

Wyckoff, Dorothy, trans., 1967, Albertus Magnus Book of Minerals: Clarendon Press, Oxford, 309p.

NEIL H. SUNESON

Neil Suneson has worked for the Oklahoma Geological Survey since 1986. His first major project with the Survey was mapping part of the frontal belt of the Ouachita Mountains and the very southern part of the Arkoma Basin, and many of his current interests focus on that part of Oklahoma. Prior to coming to Oklahoma he worked for Chevron USA as a development geologist in the San Joaquin Basin. He graduated from Amherst College in 1972, received his M.S. in geology from Arizona State University in 1976, and Ph.D. in geology from the University of California – Santa Barbara in 1980.

Dr. Neil H. Suneson (left, wearing the green ***Shale Shaker*** *Team hat), examining an outcrop with Dr. Stan Paxton, USGS in Oklahoma City.*

He first became interested in petrified wood in grammar school when he bought a small piece at a gift shop at a nature center in the Watchung Mountains in northern New Jersey. His interest intensified when he went on a tour of western U.S. national parks with his family when he was 13, a tour that included the petrified forest in Arizona. He has visited and collected at sites throughout the western U.S. and given numerous presentations to rock and mineral clubs throughout the state. This paper is part of a "retirement" book he is writing that will be titled something like "Everything you wanted to know and lots you never wanted to know about petrified wood in Oklahoma."

ACKNOWLEDGEMENTS

The Oklahoma Geological Survey would like the thank Mike Root, Editor of the Oklahoma City Geological Society's Shale Shaker for permission to reprint this article. I am "indebted" to Rick Andrews and Dan Boyd, OGS geologists, for encouraging me to publish this article in the Shale Shaker, despite my protestations of it being incomplete and the likelihood of it being of little interest to anyone other than myself. I am very grateful to Jim Anderson, OGS cartographer, for the frontispiece photographs and the layout of this publication. I would like to thank the many Oklahoma rockhounds who have listened to my lunatic powerpoint rhapsodies about petrified wood, for encouraging me to write a book about it, and for sharing with me some localities where it occurs. I would especially like to thank my wife, Judy, for indulging me on our western vacations when I would occasionally "disappear" for a couple of hours to check out a formation that I thought may have contained a specimen that I could add to my collection.

- Neil Suneson

Shale Shaker

SUBSCRIPTION FORM ~ FISCAL YEAR 2010 – 2011

Subscription Rates:

U.S. Mailing: One (1) Year (Six Issues): $35.00 U.S.

$45.00 U.S. for Foreign Mailing

Subscriber's Name: ______________________________

Company Name: ______________________________

Mailing Address: ______________________________

____

City:____________________ State:__________ Zip Code:__________

Telephone:____________________ Fax:____________________

E-mail:______________________________

[___] My Check Is Enclosed; or

[___] Charge My Credit Card, No.:____________________ Exp. Date:_____/_____

Card Security Code:__________

I agree to the TOTAL CHARGE of: $____________.00

Signature:______________________________

Please complete and return this Subscription Form, along with your payment (checks in full, made payable to the Society), to:

Oklahoma City Geological Society
Attn.: Michelle Hone
120 North Robinson, Suite 900 Center, Oklahoma City, OK 73102