WOOD AT LIBERTY HALL

To my knowledge, this paper is in complete accordance with the honor system,
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4/3/75

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Introduction

The first part of this paper deals with fungus and bugs, as both of these factors were apparent in the osage orange sample of wood taken from underneath the ground at the Liberty Hall Archaeological dig. The type of fungus that appears to have infected the wood is termed soft rot and is common in the underground portions of fence posts. One of the major determinants of identifying this type of fungus on our osage-orange sample at Liberty Hall was the fact that, in the advanced stages this rot gives the wood an appearance of being charred, as is our sample.

None of the insects described herein seem to be like that insect seen on the actual Liberty Hall wood, though we describe all of the insects herein because preventing their attack will be a major factor in the preservation of any wood removed from the site in the future. The same is true of the fungi described -- we describe all that we do in order to understand their optimal conditions of attack so that we will be in a position to prevent such attack.

The final section of the paper is probably the most important, as it deals with the identification of the wood found at the site. This identification process is necessary in that we must know what kind of wood that we are dealing with before we can delve into the actual dendrochronological process of cross-dating the wood to find out when it was actually cut. It turned out that there were many complications in the necessary preliminary step of identifying the wood and it is the process of identification to which the second section of the paper is devoted.

The compiler takes no credit in any way for the explanations given in the first part of this paper and explains only how he used other people's work in identifying wood in the second section of this paper.

The Preservation of Wood[1]

Many times it occurs, in an historical archaeological site that wood taken from the site (whether it be from a well, above or below the ground) will be moist or wet, thus in need of quite immediate attention to prevent deterioration. There are, however, many possible causesor reasons why wood will deteriorate, and an understanding of its structure is thus important as a prerequisite of an understanding of deterioration.

A. Directional Properties of Wood

Wood has different properties according to the direction in which you measure it. That is, it contains different degrees of hardness, toughness, etc. in different directions. Looking at a cross-section (figure 1),[2] we can see that it is made up of heartwood and sap-wood. This sap-wood has a higher moisture content than the heart-wood, thus if a piece of wood is cut for its beauty, containing both heart-wood and sap-wood, and is left out to dry naturally, the moist parts of the wood (the sap-wood) will shrink more than the dry parts, thus causing the plank to warp. It is for this reason that wood must go through a process of controlled drying to prevent warping known as seasoning. The mistaken notion that wood loses all of its moisture should be abandoned here though, as moisture within the

Figure 1[2]

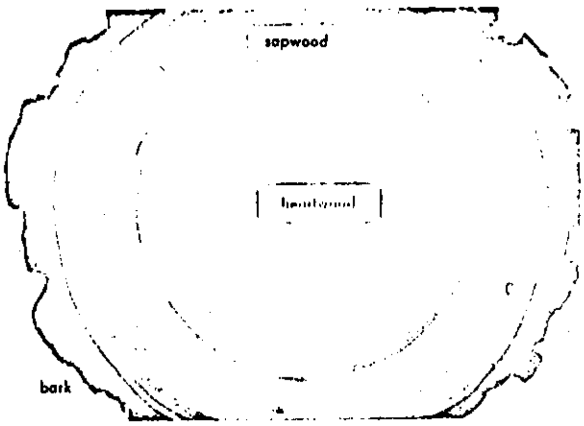

Figure 8.19. Cross section of a branch of mulberry (*Morus*). × ½.

individual cells remains to a degree which is dependent upon the relative humidity of the surrounding atmosphere.

It is in the early stages of seasoning that the sap-wood is most likely to be infected or attacked by fungi or algae or insects, because of its high moisture content, as well as its high content of nutrients. This will be discussed later.

Once the wood has been seasoned and adjusted to the climate and situation in which it is to be used, variation in atmospheric humidity should be avoided. This is the most important factor in preserving seasoned timber. If the wood is subjected to alternate humidities, it will constantly absorb and give up moisture, causing expansion and contraction across the grain (as opposed to along the grain), resulting in a warped board or plank. Indeed, in panel paintings this varying humidity causes "back and forward" movements due to absorbtion and "letting out" of water, significantly shortening the life of the painting.

The process of the elimination of warping may be a long process, but it may be a necessary conservation prerequisite. This is how it is accomplished:

Elimination of Warping

1. Moisten the concave side of the wood.
2. This moisture, slowly absorbed, swells the contracted tissue, possibly causing

the wood to return to its flat position.

3. Once the wood returns to a flat position, weights should be placed upon it to prevent a re-warping process, until the wood is dry.

A few notes on this process are necessary. First of all, it is a long process, the drying of the wood probably taking the longest period of time. Secondly, the wood very well might have a tendency to rewarp once its flat shape has been accomplished, though there are methods to combat this. Last of all the process is an uncertain one that may not work all of the time.

B. Attack by Fungi and Insects[3]

This is a major problem in the dendrochronological study as related to Liberty Hall, as the specimen from the site from which a cross-section has been taken for identification and tree-ring-study purposes, has an extrme problem of fungal attack. This is due to moisture in the wood. Insect attack is also quite apparent when the specimen is viewed under a low-power microscope.

Fungus does not, unlike green chorophyll containing plants, manufacture its own food; it is an organism that lives off of the organic substrate of, for example, wood. The kinds of fungus that attack wood may be divided into two groups;

1. Wood-destroying fungi and
2. Wood-staining fungi and true molds.

Wood-destroying fungi obtain their nourishment by breaking down the cell walls in wood. This is called decay. Wood-staining fungi live off material stored within the cell itself, therefore they do not actually break the wood down.

The attack by fungus of a piece of wood is dependent upon four factors:

1. A good, favorable temperature.
2. Good oxygen supply.
3. Adequate moisture.
4. Adequate food supply.

These factors being present, the fungus attacks by germinating filaments, individually called hyphae, collectively known as the mycelium. These filaments are the damaging part of the fungus.

To kill a fungus by temperature variation, heat is the most effective method, and the time needed to kill a fungus decreases with an increase in temperature. At $212^{O}F$ it takes only 5 minutes to kill most fungi.

The most effective method of protecting wood against fungal attack is to poison the wood with preservatives, but the treatment <u>must</u> be thorough and no untreated surface can be exposed.

1. <u>Wood-destroying fungi</u>

These fungi are further divided into (due to physical, chemical, and coloration changes in the wood) brown and white rots (produced by Basidiomycete Fungi) and soft rot (produced by Ascomycetes and Fungi Imperfecti).

a. Brown and White Rots

The brown rots, commonly associated with soft wood, attacks most normally the cell wall carbohydrates, leaving behind lignin and cellulose. When the wood dries after this type of fungal action its surface has a cube-like pattern. The final stages of brown rot leaves the wood as a powdery mass of different shades of brown.

White rot, which attacks hard wood, leaves behind a spongy, stringy mass after attacking both the cellulose and lignin of the cellwall.

In both white and brown rot, hyphae penetrate cell walls through pits, or they bore holes themselves. These hyphae do their work by chemical rather than physical action. This chemical action is accomplished by enzymes ("Enzymes are protein molecules produced by living cells; they act as organic catalysts, making it possible for the biochemical reactions necessary for physiological processes to take place."[4]) which actually convert the normally insoluable wood substances in the cell walls into a soluable form. This is done right before the hyphae, "cutting" a path through.

b. Dry Rot

This special type of brown rot is responsible for damage to many buildings in the U.S. and Europe. It probably gets its name from its ability to transport the necessary moisture for fungal growth through tubelike conducting veins called rhizomorphs. These tubes allow the fungus, once it is established in a moist section of the house, to spread to dry sections. Another important factor here is that dry rot may produce enough moisture simply from the decomposition of the wood itself. Indeed, there are some types of dry rot that can pentrate through plaster and other materials that do not contain food, in order to reach wood that may be located on the other side. This dry rot attacks both soft and hard woods, first indications of attack being fan-shaped sheets of light-colored mycelium on the surface of the wood. Advanced decay has the normal brown rot symptoms.

c. <u>Soft Rot</u>

Hardwoods disintegrate more rapidly when attacked by these fungi, though softwoods are also susceptible. The rot gets its name because the surface of the wood is typically softened. The soft-rot hyphae usually produce tunnels that run along the grain of the wood. An interesting factor that is applicable to our study at Liberty Hall is that this type of rot is common "in wood placed in contact with the soil, e.g., in the below-ground portion of fence posts and poles ... "[5] Indeed, much of the wood that we hope to find at Liberty Hall will be below the ground. Soft rot is generally found on wood surfaces consistently exposed to damp conditions giving this fungus an increased ability to tolerate a higher moisture content than most fungi.

The early stages of this rot are only effectively seen with the aid of a microscope. In later stages the surface becomes discolored and, when wet, it can be scraped off quite easily, leaving behind a relatively sound wood underneath. When the soft rotted surface is dry, it has a spongy feeling and takes the appearance of charred wood. This, it is believed, is the type of fungus that has infected the wood from the Liberty Hall site, identified as osage orange.

d. The Characteristics of Decayed Wood

It is important for our purposes at Liberty Hall to recognize the characteristics of decayed wood so that we can readily identify, in the field, the extent of dacay. There are many factors to look for:

1. Color: The changes in color during the early stages of white or brown rot are difficult to distinquish, however color changes resulting from advanced decay are quite obvious, though identification of the fungus cannot be accomplished by color change alone.

> These color changes are due to the color and concentration of the invading hyphae, its destruction, or to a chemical alteration of one or more of the principal cell wall components and the pigmented materials in the wood, or in some cases to the formation of distinctive coloring substances by fungi.[6]

2. Odor: Again referring to the advanced

stages of decay, we can identify, usually a characteristic odor of anise or wintergreen though they are, of course, quite variable as to intensity and character.

3. Water Conduction and Moisture-Holding Capacity: Wood decayed by fungi can absorb water more rapidly than sound wood because of the holes produced by the hyphae, therefore also allowing a higher moisture content.

4. Changes in Dimension: When a wood that has been decayed is dried, it will shrink more rapidly than will a sound wood because of the greater empty spaces (produced by hyphae) in the wood. This was quite apparent in the osage orange wood taken from the Liberty Hall site when it was dried.

5. Density: There is always a loss of density due to fungus attack because of the destruction of the actual substance of the wood.

6. Mechanical properties: "Toughness or resistence to impact is the strength property that is affected first by fungal infection; it is followed, in the approximate order of susceptibility, by reduction in bending strength, compression strength, hardness, and bending elasticity."[7]

7. Other: Decayed wood that is dry is more easily ignited by fire as well as being more susceptible to insects. Insects can more readily enter the softened wood as larvae and the fungus has already converted the wood into products that can be more readily assimilated by insects.

2. The second type of fungus that destroys wood has been known as wood-staining fungi and molds: The activity of this fungi is almost exclusively contained in the sapwood, therefore it is called sap-stain fungi and its resulting discoloration of wood is therefore called sap-stain. These fungi fall into two classes: (1) molds, growing on the surface of the wood, readily brushed off, and (2) true sap-stain fungi, which penetrate into the sap-wood causing a deep stain.

a. Molds: These fungi develop where the temperatures are mild, the air is still, where there is plenty of moisture, and the stains that they produce are mostly due to the colored spores of the fungi. It seems that molds do not affect the strength properties of wood, though its permeability seems to be increased.

b. True Sap-Stain Fungi: These fungi deteriorate the wood only slightly (not nearly as much as the wood destroying forms of fungus) as they derive their nourishment from the food stored in the cells of the actual wood. Though the hyphae of this type of fungus are usually larger than in the wood-destroying type, these filaments usually pass through the pits in the cell walls rather than boring through the walls like wood-destroying fungi. Figure 2[8] shows the common stains and their causes.

3. Attack of Wood by Insects

Pith flecks, pinholes, and grub holes are caused by insects that damage wood before it is utilized. Powder-post beetles and termites are examples of insects that attack wood after it has been put in service.

a. Damage to Wood by Insects Before it is Utilized.

1. Pith flecks, called medullary spots are usually only found in hardwood. These spots are found within the growth ring and are usually darker than the tissue surrounding.

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Figure 2[8]

Table 10-1 Common Sapwood Discolorations and Their Causes*

Color of stain	*Designation and miscellaneous characteristics*	*Sapwood in which it commonly occurs*	*Common cause*
Bluish black to steel gray principally; brown shades common	Blue stain—occurs in spots, streaks, or patches which cover all or part of the sapwood. Moldlike growths of causal fungi often present on surface of stained areas. May penetrate deeply	Lumber and logs of practically all commercial wood species	Dark hyphae of species of ***Ceratostomella, Endoconidiophora, Diplodia, Cladosporium, Hormodendron,*** and ***Graphium,*** principally
Inky blue	Iron tannate stain—inklike streaks or blotches where nails or iron equipment have contacted freshly cut stock. Without precautions may develop as general discoloration when dipping oak lumber with iron equipment. Usually shallow penetration	Various products of oak, chestnut, redgum, and other species with necessary tannin content	Chemical reaction between iron and tannins in the wood
Pale blue and brown	Chemical stain of hardwoods—most common as a general interior stain and may not be observed until lumber is surfaced. Frequently resembles light blue stain. Sometimes appears only under seasoning stickers. May penetrate deeply	Oak, birch, maple, basswood, tupelo gum, magnolia, and other hardwood lumber	Oxidation of certain wood substances during air seasoning or kiln drying
Greenish brown to greenish black	Mineral stain—occurs in lenticular streaks of all sizes or as a general discoloration	Living hardwood trees—hard maples principally†	Unknown. Possibly initiated by injuries
	Chemical stain of persimmon—occurs as a general discoloration. May penetrate deeply	Persimmon	Oxidation of certain wood substances upon contact with air during seasoning
Dull brown to gray	Weather stain—occurs as general surface discoloration on exposed portions of wood. Usually shallow penetration	Lumber of all commercial wood species†	Action of air, dust, rain, sunlight ("weathering")
	Mold stain—discoloration persisting in surface layers of molded wood after surfacing or brushing. Usually shallow penetration	Lumber of all commercial wood species†	Sporulation of mold fungi in vessels and resin ducts near the surface of the wood
Various, green predominating, black common	Molds—colored fungus growths present on surface of wood. Generally surfaces off readily or can be considerably removed by brushing	Various products of all commercial wood species	Presence of ***Trichoderma, Penicillium, Gliocladium, Aspergillus, Monilia,*** and other fungi sporulating on the surface of the wood
Various, brown or reddish shades principally	Seasoning coloration—frequently appears simply as a deepening of color. Essentially a chemical stain but generally not objectionable. May penetrate deeply	Lumber of hardwoods principally	Oxidation of certain wood substances during seasoning
Yellow-brown to dark brown	Brown seasoning stain of western and eastern pines—narrow margins of bright wood common at board surfaces and at juncture of heartwood and sapwood. May penetrate deeply	White pine, ponderosa pine, and sugar pine lumber	Oxidation of certain wood substances during air seasoning or kiln drying
	Kiln burn and machine burn—surface of wood has a scorched appearance. Usually shallow penetration	All lumber†	Light burning of wood due to excessive kiln temperature or to heat developed by planer knives
Red	Bright-colored chemical stain of hardwoods—appears more or less as a general discoloration. May penetrate deeply	Western alder lumber and other hardwoods	Oxidation of certain wood substances upon exposure to air
Reddish yellow to rusty		Birch logs	Oxidation of certain wood substances upon exposure to air. Promoted by warm weather
Purple to pink	Bright-colored fungus stain—occurs usually as blotches or small streaks. May penetrate deeply	Southern pine and redgum lumber and logs	Soluble pigment and colored hyphae of ***Fusarium moniliforme, F. solani, F. viride,*** and ***F. roseum***
Crimson to orange	Bright-colored fungus stain—occurs usually as blotches or small streaks. May penetrate deeply	Southern pine, gum, oak, and other hardwood lumber and logs	Soluble pigment of ***Penicillium roseum*** and ***P. aureum***
		Southern pine, southern cypress, and oak lumber†	Soluble pigment of ***Geotrichum*** sp.
Pale yellow	Bright-colored fungus stain—occurs usually as blotches or small streaks. May penetrate deeply	Lumber and logs of oak, birch, hickory, and maple†	Soluble pigment of ***Penicillium divaricatum***
Deep yellow		Southern pine and redgum lumber and logs	Colored hyphae and to some extent soluble pigment of a ***Gymnoascus***-like fungus

* By permission from T. C. Scheifer and R. M. Lindgren, Stains of Sapwood and Sapwood Products and Their control, ***U.S. Dept. Agr. Tech. Bull.*** 714, 1940.

† Also occurs in heartwood.

> This defect results from injury to the cambium by the larvae of flies belonging to the genies <u>Agromyza</u>. The female adult insect perforates the periderm of a young branch with her ovepositor and deposits an egg in the living tissue beneath. This hatches into a filiform larva which invades the cambium during the early part of the growing season and mines downward, leaving a burrow about the thickness of a darning needle. Eventually the larva emerges underground and pupates.[9]

As the larva travels down through the wood, some cambial and xylem cells are destroyed, but repair work by the cambium begins shortly after the passage of the larvae, leaving a small spot that looks like pith or modulla. Though the pith flecks do not materially affect the strength of the actual wood, it does affect its appearance.

2. <u>Pinholes</u> are formed in most any kind of timber by the attack of the Ambrosia beetle, which normally attacks recently killed trees, logs, and so on. There is no reduction in the strength of the wood unless the pinholes are extremely numerous, and, since the attack by these beetles is confined to freshly cut green wood, they will not damage dry seasoned wood. An interesting fact is that ...

> ...Ambrosia beetles do not consume wood; they derive nourishment from a mold-type fungus, introduced by the beetles into their tunnels, on the walls of which it grows. It is to this mold that the name <u>ambrosia</u> was applied, and later extended to the beetle.[10]

The damage by this beetle can be intensified however by the introduction by the beetle of staining fungi.

Damage by the Ambrosia beetle can be minimized by quickly putting the timber to its use followed by drying and chemical control.

3. <u>Grub Holes</u> - These holes may occur in both hardwood and softwood, and are actually tunnels of some

adult insects and the larvae of other types of insects. There are many different types of insects involved in producing these holes, and the extent of damage to the wood again depends on the number of holes present.

b. Damage by insects to wood already in Service.

1. The powder-post beetle - This term applies to two related families of beetles, the Bostrychidae and Lyctidae. For the most part, these beetles attack only the sapwood of hardwood, though they may sometimes attack the sapwood of softwood.

After the adult beetles deposit their eggs in the vessels of the wood, the larvae then obtain their norishment from the starch stored in the parenchyma cells. The name of the beetle is derived by the way that these larva go from cell to cell to get their food:

> ...the larvae bore through the wood and leave residual wood substance in a finely pulverized condition; the flourlike residue sifts out from the tunnels when the adults emerge during late spring and summer, leaving holes 1/16 to 1/12 in diameter.[11]

It should then be quite apparent that these beetles cause an extensive damage to wood; the best way to prevent this damage is to prevent the beetle from getting near the wood, for once infestation has occurred, it is expensive as well as uncertain in trying to get rid of the beetles.

2. Common Furniture Beetles - Though the name implies only furniture, these beetles will attack the sapwood of most any seasoned wood product, both softwood and hardwood. They will only attack the heartwood if there is nitrogen present in quantities necessary for their nutrition there.

3. Termites - These insects will attack the sapwood and heartwood of all species of wood, whether it is decayed or not. Termites use the cellulose and other carbohydrates in the wood for food.

These insects, as social insects, live in colonies made up of reproductive members, workers, and soldiers.

The workers penetrate the actual wood and destroy the inside, but leave the outside as a shell for protection. Because these workers do not attack the outside, detection of their actual presence is made difficult and normally they are not discovered until the outside shell collapses. The subterranean termite has an amazing ability to secrete a type of cement for the building of little tubes or passageways in order to reach wood not in contact with the soil.

4. Carpenter Ants - These ants cause damage to poles, posts, and other structures by establishing themselves quite soundly in the heartwood. Again these ants live in colonies in which the workers do all of the damage by extending galleries into the wood in order to make more room for the actual colony. Though the ants use wood for nesting, they do not "eat" or digest the wood; they instead live on the secretions of other insects.

The best way to secure wood from the extensive damage that these insects cause is to prevent them from ever entering the wood through application of DDT, Chlordane, or keeping the moisture content of the wood below 15%.

C. Strengthening the Wood

According to the nature of the specimen and the condition of the wood, timber that has been weakened by fungus and/or insects may be strengthened by one of two methods, or both methods combined. The first method is impregnation of the wood with a consolidating agent,the second mechanical reinforcement. Figure 3 gives us the mechanical reinforcement methods; we will look into the impregnation next.

The methods of consolidation of wood by impregnation may be applied to any porous materials, a good fact of this method being that it is suitable for dealing with intricate shapes, carvings, etc. -- artifacts that have been subjected to atmospheric exposure as well as artifacts filled with

Figure 3[12]

Consolidation by mechanical reinforcement

Of the mechanical methods for strengthening timber, the following are the most important.

1. Dowelling either with metal or wooden pegs, and refacing if necessary with wood.

2. Inlaying across cracks with solid X-shaped wedges to prevent the cracks from opening; or covering the joints by 'buttons' of wood, i.e. small palettes ca. 3 in. by 2 in. glued across the cracks.

3. Reinforcing with wooden splints, glued and/or screwed to the old wood. Special bracket irons, angle irons, &c. may be useful in repairing furniture.

4. Stopping irregular cavities with a gap-filling cement (see repairs, p. 132).

worm holes. Impregnation may be carried out by application with a brush, immersion, and injection.

1. Impregnation by Wax: In this method, any mechanical repairs needed by the wood must be made before the wood is immersed in wax. The only problem with this method is that it requires specialized equipment. Utilizing beeswax (unbleached) to which a resin content of not greater than 50% has been added, the tank in which the wax is melted must be heated electrically and controlled by a thermostat which would not let the wax get too hot.

> The object to be impregnated, which must of course be quite dry, is lowered into the molten wax and kept beneath the surface by weights or otherwise. As the temperature gradually rises the air is expelled in a stream of bubbles and wax enters the pores of the wood. Any traces of moisture are driven off by maintaining the temperature at about 105°C. till bubbling ceases, and it may then be allowed to rise to about 120°C. The time of immersion depends on the porosity and bulk of the timber. When the impregnation is considered to be complete the heating is shut off, the object raised from the tank, and the hot wax allowed to drain away. Finally, surplus wax is removed from the surface with turpentine.[13]

There are some precautions that must be observed with this method however. If the tank is heated from below and the wax is allowed to solidify, if any water was introduced it will have accumulated at the bottom of the tank, and, upon reheating, steam pressure will be generated below the semi-solidified wax, causing an explosion. That molten wax is flammable is another factor that is important in safety.

An excellent advantage of wax impregnation is that it is water proof, thereby protecting the wood from movement due to changes in humidity and the surrounding moisture content of the atmosphere.

The disadvantages of wax impregnation are, (1) an excessive amount of heat will melt the wax, causing a fire hazard, (2) wax has a tendency to creep out slowly from the inside, making the surface sticky and able to collect dirt, and finally, (3) wax has a high refractive index that lowers the tone of colors.

2. Impregnation by Synthetic Material: The synthetics that are used for this purpose are:

(a) polyvinyl acetate dissolved in a mixed solvent of 9 vols. of toluene and I of acetone, or

(b) Bedacryl 122X diluted with toluene to a suitable consistency ...

(c) Marco S.B. 26C,

(d) Bakelite 17449.[14]

One of these chemicals is placed in a container large enough to hold the wood object and then this container is placed in a vacuum tank, which is evacuated. The apparatus is left for one hour giving the wood a good opportunity to absorb as much of the solution as is possible. Now air is admitted into the vacuum tank which drives the synthetic solution even further into the wood. The wood object is then removed from the tank and allowed to drain.

The Actual Identification Process of the Specimen of Wood Taken from the Liberty Hall Dig

After obtaining a cross-section and a longitudinal section of the wood, a key to the identification of hardwoods -- figure 4 -- was used. This is the normal method of identification of wood.

Starting with #1 on the key, we found that, under 10x magnification, the early-wood pores were noticeably larger than the late-wood pores and that the transition from the early-wood pores to the late-wood pores was quite abrupt, therefore leading us to the conclusion that the wood is semi-ring-porous and, as can be seen on the key, marked by Roman numeral I, leads us to #2 on the key. Since we establsihed already that the wood is ring-porous, we go on to #3 on the key, as marked by Roman numeral II. There were no broad rays present on the wood, as #3 of the key makes us determine, therefore we go on to #4 on the key, as marked by Roman numeral III. Through #4, we establish that the late-wood is figured with wavy bands of pores which are mostly continuous and separated by bands of

Hardwoods—Keys and Descriptions by Species

IV. KEY TO HARDWOODS—GROSS FEATURES*

Woods porous (with vessels); cross section consisting of pores (vessels) embedded in a mass of fibers and parenchyma tissue; rays distinct or indistinct to the naked eye (Figs. 12-75 to 12-140, inc., pp 514–525).

1. Early-wood pores **conspicuously larger** than the late-wood pores, distinct with the naked eye† (ex., Figs. 12-101, 12-108, 12-130); (*a*) transition from large early-wood pores to small late-wood pores abrupt (**wood ring-porous**, ex., Figs. 12-101, 12-130); (*b*) transition from large early-wood pores to small late-wood pores somewhat gradual (**wood semi-ring-porous**, ex., Fig. 12-108) **2**

1. Early-wood pores **not conspicuously larger** than the late-wood pores and indistinct to the naked eye (ex., Fig. 12-87); early-wood zones not sharply defined (**wood diffuse-porous**) **13**

2. Transition in size of pores from early to late wood abrupt, wood ring-porous **3**

2. Transition in size of pores from early to late wood somewhat gradual, wood semi-ring-porous **12**

3. Broad rays present, conspicuous (*x*; Figs. 12-127 to 12-130, inc.) often 1 in. or more in height along the grain (*t*; Fig. 12-126), forming a broad ray fleck on the radial surface.

A. Late-wood pores distinct with a hand lens, not numerous, thick-walled, the orifices plainly visible, rounded; tyloses usually absent or sparse in the early-wood pores; heartwood usually pinkish or pale brown.

Red oak—*Quercus* spp. Figs. 12-128, 12-130. Desc. pp. 566–568

B. Late-wood pores indistinct with a hand lens, numerous, thin-walled, the orifices scarcely visible, angular; tyloses generally present in the early-wood pores (heartwood); heartwood rich light to dark brown, usually without flesh-colored cast.

* This key is designed for the separation of the more important temperate North American hardwoods based on features visible with a 10X hand lens or without magnification.

A series of photographs (Figs. 12-75 to 12-140, inc., pp. 514 to 525) at low magnification (5X) accompanies this key to illustrate the normal appearance of the various kinds of woods under a hand lens.

† In osage-orange and black locust (Figs. 12-112, 12-133) early-wood pores are large but poorly defined because of occlusion with tyloses.

White oak—*Quercus* spp. Figs. 12-127, 12-129. Desc. pp. 569–572.

3. Broad rays absent (ex., Fig. 12-77) **4**

4. Late wood figured with wavy concentric (tangential) bands of pores which are mostly continuous and separated by bands of mechanical tissue (*x*; ex., Fig. 12-137) **5**

4. Late wood not figured with wavy, concentric (tangential) bands of pores (ex., Fig. 12-103) **7**

5. Early-wood pores in a single line.

A. Early-wood pores plainly visible without a hand lens, approximately equal in size and quite evenly spaced in a more or less continuous row; tyloses sparse.

American elm—*Ulmus americana* L. Fig. 12-137. Desc. p. 572

B. Early-wood pores scarcely visible without a hand lens, the larger spaced at intervals in an interrupted row and separated by smaller pores; tyloses abundant.

Hard elm—*Ulmus* spp. Fig. 12-139. Desc. p. 575

5. Early-wood pores in several rows (ex., Fig. 12-138) **6**

6. Early-wood pores in the heartwood completely occluded with tyloses, their contours poorly defined.

A. Heartwood golden yellow to bright orange, darkening upon exposure, often with reddish streaks along the grain; coloring matter readily soluble in water.

Osage-orange—*Maclura pomifera* (Raf.) Schneid. Fig. 12-112. Desc. p. 580

B. Heartwood greenish yellow to dark yellowish or golden brown; coloring matter not readily soluble in water.

Black locust—*Robinia pseudoacacia* L. Fig. 12-133. Desc. p. 598

6. Early-wood pores in the heartwood not completely occluded with tyloses, their contours distinct.

A. Wood light brown to dark reddish brown; rays usually indistinct without a lens.

Slippery elm—*Ulmus rubra* Mühl. Fig. 12-138. Desc. p. 574

B. Sapwood pale yellow to grayish or greenish yellow; imperfectly developed heartwood yellowish gray or light brown streaked with yellow; rays distinct, visible to the naked eye (*x*).

Hackberry—*Celtis* spp. Fig. 12-95. Desc. p. 577

C. Sapwood yellowish, narrow; heartwood orange-yellow to golden brown, turning dull dark brown on exposure; ray fleck conspicuous on the radial surface.

Red mulberry—*Morus rubra* L. Fig. 12-115. Desc. p. 578

7. Late-wood parenchyma appearing under the lens as fine, numerous, continuous, or broken, light-colored, tangential lines (ex., Fig. 12-91), or closely and evenly punctate (ex., Fig. 12-98).

mechanical tissue. This leads us to #5 on the key, as is marked by Roman numeral IV. Noting that the early wood pores are in several rows, as we must establish by #5 of the key, we go to #6, marked by Roman numeral V. Finally, we note that the early-wood pores in the heartwood are completely occluded with tyloses, their contours being poorly defined. We have now come to a final point, and, if we are correct so far, the wood must be either osage-orange or black locust as defined in the key ... the only problem is that the distinction between these two species is extremely difficult unless the wood is fresh cut, the key gives only the method of identification if the wood is fresh cut and therefore, since our Liberty Hall specimen is not fresh cut, we must find some other way to distinguish between osage orange and black locust.

Noting that the key that we are using is identification by gross features of the wood, we now turn to a key that uses minute features of the wood for identification purposes -- Figure 5[16]. If we look at #32 of the minute key we see that the vessel elements of the Black locust have vestured intervessel pits while the vessel elements of the Osage-orange do not have vestured intervessel pits. This is the only way that we can differentiate between Osage-orange and Black locust if it is not fresh cut. Therefore, we tried to look at the pits on the vessel elements by taking scrapings of the wood and

Figure 516

18. Early-wood zone consisting essentially of large pores.
Slippery elm—*Ulmus rubra* Mühl. Desc. p. 574

18. Early-wood zone consisting of large and small pores.
American elm—*Ulmus americana* L. Desc. p. 572

19. Rays uniseriate or rarely in part biseriate........ 20

19. Rays 1–many-seriate........ 21

20. Early-wood vessels usually in one row, the largest 150–200 μ in diameter.
Golden chinkapin—*Castanopsis chrysophylla* (Dougl.) A. DC. Desc. p. 561

20. Early-wood vessels in several rows, the largest 240–360 μ in diameter.
American chestnut—*Castanea dentata* (Marsh.) Borkh. Desc. p. 559

21. Rays 1–4-seriate........ 22

21. Rays 1–5- or more-seriate........ 27

22. Parenchyma banded (*x*), in concentric rows distributed throughout the body of the growth ring.
Hickory—*Carya* spp. Desc. p. 541

22. Parenchyma not banded or, if banded, the rows restricted to short broken lines in the outer portion of the ring........ 23

23. Late-wood vessels in part with scalariform perforation plates; rays with oil cells.
Sassafras—*Sassafras albidum* (Nutt.) Nees. Desc. p. 587

23. Vessels in early and late wood with simple perforation plates; rays without oil cells........ 24

24. Early-wood vessels completely occluded with tyloses; tyloses small, appearing cellular........ 25

24. Early-wood vessels open or only partly occluded with tyloses; tyloses large, not appearing cellular........ 26

25. Intervessel pits vestured (Fig. 12-144).
Black locust—*Robinia pseudoacacia* L. Desc. p. 598

25. Intervessel pits not vestured (Fig. 12-145).
Osage-orange—*Maclura pomifera* (Raf.) Schneid. Desc. p. 580

26. Late-wood vessels with spiral thickening; vessels in the outer part of the growth ring associated with parenchyma forming tangential, several-seriate, more or less continuous bands (one or more bands in the outer portion of the ring occasionally consisting entirely of parenchyma); fibers with maximum diameter of more than 25 μ (range from 16–32).
Catalpa—*Catalpa* spp. Desc. p. 625

26. Late-wood vessels without spiral thickening, solitary or in radial rows of 2–several; fibers with maximum diameter of less than 25 μ (range from 12–22).
Ash—*Fraxinus* spp. Desc. pp. 621 to 625

27. Parenchyma banded (*x*), in concentric, 1–4-seriate bands distributed throughout the body of the growth ring (*x*); late-wood vessels solitary or in radial rows of 2–3, without spiral thickening.
Hickory—*Carya* spp. Desc. p. 541

27. Parenchyma not banded (*x*), late-wood vessels solitary, in radial rows, or in interrupted bands consisting largely of vessels or of vessels and parenchyma, with spiral thickenings........ 28

28. Early-wood vessels in one row; intervessel pits vestured.
Yellowwood—*Cladrastis lutea* (Michx. f.) K. Koch. Desc. p. 597

28. Early-wood vessels in several rows; intervessel pits vestured or not vestured........ 29

29. Early-wood vessels in the heartwood partly or wholly occluded with tyloses, with or without gummy deposits........ 30

29. Early-wood vessels without tyloses or tyloses only occasionally present, sometimes with gummy deposits........ 33

30. Early-wood vessels partly occluded with tyloses; tyloses large, not appearing cellular........ 31

30. Early-wood vessels completely occluded with tyloses; tyloses small, appearing cellular........ 32

31. Fibers [illegible]–52 μ in diameter, not gelatinous; rays 1–6-seriate (mostly 2–3).
Catalpa—*Catalpa* spp. Desc. p. 625

31. Fibers [illegible] μ in diameter, frequently gelatinous; rays 1–8-seriate (mostly 5–7).
Red mulberry—*Morus rubra* L. Desc. p. 578

32. Intervessel pits vestured.
Black locust—*Robinia pseudoacacia* L. Desc. p. 598

32. Intervessel pits not vestured.
Osage-orange—*Maclura pomifera* (Raf.) Schneid. Desc. p. 580

33. Rays [illegible]-seriate, the tallest more than 1200 μ in height; porous tissue toward the outer margin of the growth ring consisting of small vessels embedded in short, tangential bands of parenchyma.
Honeylocust—*Gleditsia triacanthos* L. Desc. p. 595

33. Rays [illegible]-seriate, the tallest less than 1200 μ in height; porous tissue toward the outer portion of the growth ring consisting mostly of vessels.
Kentucky coffeetree—*Gymnocladus dioicus* (L.) K. Koch. Desc. p. [illegible]

34. Early-wood vessels somewhat larger than those in the late wood; wood semi-diffuse-porous........ 35

34. Vessels exhibiting little or no variation in size (except in extreme outer portion of certain species); wood typically diffuse-porous........ 46

35. Rays 1–many-seriate; parenchyma present in the body of the ring, or wanting........ 36

35. Rays [illegible]-seriate; parenchyma confined to the outer margin of the r[illegible] looking at these under a magnification of 430. We found that, even if we did find any vessel elements, that we could not see the pit in the actual element sufficiently because all of the cells in on scraping were bunched so close together ... we had to find some way to look at the vessel elements alone so as to be able to differentiate between the pits. Figure 6.[17]

We used a maceration method of breaking down wood tissue to accomplish this task, the method is well defined in figure 6 and we did it with:

1. Fresh-cut Osage orange
2. Fresh-cut Black locust
3. The wood from the archaeological site at Liberty Hall.

Maceration is a process by which the "glue" that holds the cells together in wood -- the middle lamella -- is broken down so that each cell breaks away from the others. This makes it easy to isolate a vessel element from each of the above-mentioned specimens, and then to compare them so as to see if the pits in the vessel elements of the wood from the site are:

1. vestured, as in Black locust or
2. not vestured, as in Osage Orange.

Figure 7 is the result, and it shows a vessel element from each of the 3 above-mentioned specimens, magnified 1,000 times. Comparing them it is not very easy to see, but the vessel elements in the specimen of wood taken from the Liberty Hall are

Figure 6[17]

Technique for the Maceration of Wood Tissue

1. Twigs are cut into slivers no larger than a toothpick and and boiled in an Alconox solution for 10 or 15 minutes.

2. After boiling, pour the Alconox off and rinse the wood well with water. (Distilled water)

3. Pour the water off of the wood and allow the slivers to soak for two hours in full strength Chlorox.

4. Carefully pour off the Chlorox and wash the slivers with distilled water. A centrifuge is an aid in washing.

5. The slivers are then boiled in a 3% sodium sulphite solution for 15 minutes, according to Harlow's Method.

6. Wash using a centrifuge and distilled water.

7. Pour the water, carefully, off of the wood cells at the bottom of the centrifuge tubes and emply the cells into a beaker.

8. Add a little distilled water and enough crystals of aqueous Safranin to give a distinct red color.

9. Centrifuge and pour off liquid very gently.

10. Dump remaining contents of tubes into a beaker and add enough Glycerin to give an almost jelly-like consistency.

The present substance gives a good temporary mount.

not vestured, therefore we must come to the conclusion that the Liberty Hall specimen is, in fact, Osage Orange.

Summary

It is important to note as a conclusion to this study that, though one may start out with vigour towards a goal in an historical archaeological dig, there are many complications which may arise. The compiler of this paper was told that he would have no trouble whatsoever identifying the wood using the gross key alone ... it came as quite a surprise, therefore, when it was found that maceration and high magnification of the vessel elements would be necessary to identify the wood. The complications involved make the study of wood an endless though ever-interesting study at the Liberty Hall Archaeological Dig.

Footnotes

[1]H. G. Plenderleith, The Conservation Of Antiquities and Works of Art: Treatment, Repair, and Restoration, (London: Oxford University Press, 1962), pp. 116-143. (All information in this section comes from this source.)

[2]T. Elliot Weier, C. Ralph Stocking, and Michael G. Barbour, Botony: An Introduction to Plant Biology, (New York: John Wiley and Sons, Inc., 1970), p. 156.

[3]A. J. Panshin and Carl de Zeeuw, Textbook of Wood Technology, (New York: McGraw-Hill Book Co., 1964), pp. 338-389. (All information in this section comes from this source.)

[4]Ibid., p. 343.

[5]Ibid., p. 349.

[6]Ibid., p. 350.

[7]Ibid., p. 351.

[8]Ibid., pp. 354-355.

[9]Ibid., p. 367.

[10]Ibid., p. 367.

[11]Ibid., p. 373.

[12]Plenderleith, The Conservation of Antiquities, p. 127.

[13]Ibid., p. 128.

[14]Ibid., p. 130.

[15]Panshin and de Zeeuw, Textbook of Wood Technology, pp. 506-507.

[16]Ibid., pp. 528-529.

[17]This maceration method is called Harlow's method and was put in this form by Ted Delany of the Biology Dept. at Washington and Lee.

Bibliography

Panshin, A. J. and de Zeeuw, Carl. Textbook of Wood Technology. New York: McGraw-Hill Book Company, 1964.

Plenderleith, H. J. The Conservation of Antiquities and Works of Art: Treatment, Repairs, and Restoration. London: Oxford University Press, 1962.

Weier, T. Elliot, Stocking, C. Ralph, and Barbour, Michael G. Botony: An Introduction to Plant Biology. New York: John Wiley and Sons, Inc., 1970.