U.S. Department of Agriculture
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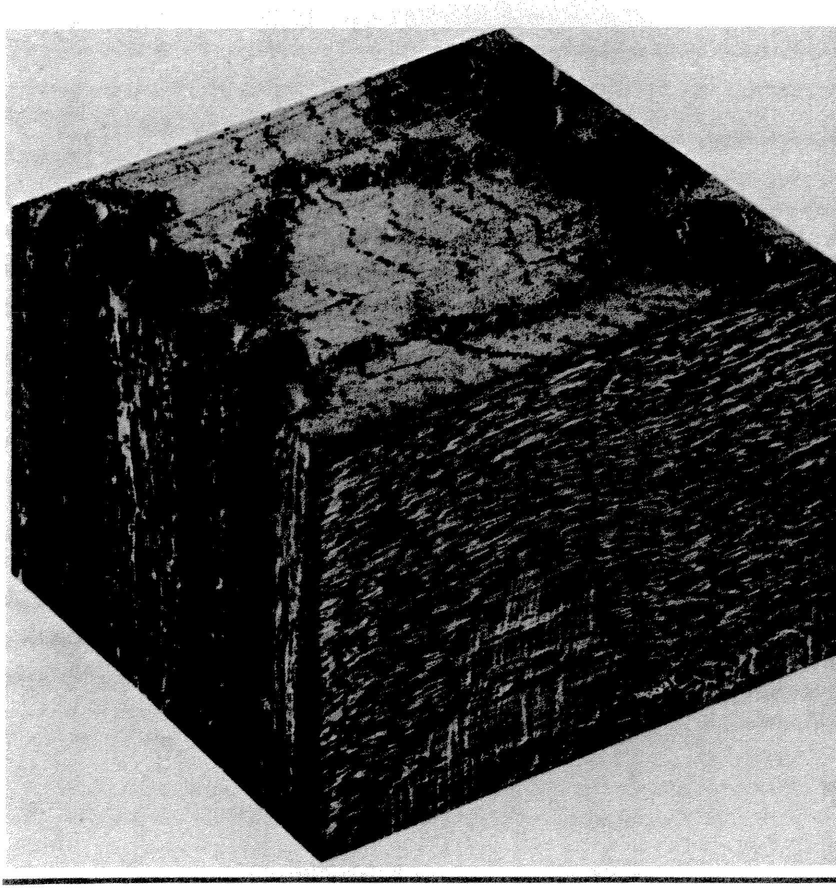
The Wood and Bark of Hardwoods Growing on Southern Pine Sites – A Pictorial Atlas

Charles W. McMillin
and Floyd G. Manwiller



Southern Forest Experiment Station

SUMMARY

A pictorial description of the structure and appearance of 23 hardwoods growing on pine sites is presented along with a brief overview of hardwood anatomy. Scanning electron microscopy is used to depict the radial, tangential, and transverse wood surfaces in a single three-dimensional presentation. Color photographs of the three surfaces and of the bark provide additional visual data useful in both product development and species identification. Data on the resource and certain important physical properties of the stemwood and bark are also tabulated for most species.

AFFILIATIONS

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ACKNOWLEDGMENT

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INTRODUCTION

Hardwoods growing on southern pine sites[1] constitute a vast forest resource of about 49 billion cubic feet. Twenty-three species or species groups (table 1) comprise about 90 percent of the resource with 11 oaks alone accounting for 49.1 percent. Of the oaks, all are members of the red oak group except post oak, chestnut oak, and white oak, which are members of the white oak group. The entire resource is typically small in diameter, slow in growth, and low in quality. For these and other reasons, few existing processes can economically convert significant volumes to useful forest products.

Yet, most economists agree that to meet future needs southern forests must yield substantially more wood than they do now. Research underway at the Southern Forest Experiment Station and elsewhere is developing new processes that will use these neglected pine-site hardwoods and thus greatly extend the nation's timber supply.

The purpose of this paper is to provide a pictorial description of the wood and bark of the pine-site hardwood resource. A scanning electron microscopy technique (Manwiller 1975a, McMillin 1977) was used to depict the anatomy of the radial, tangential, and transverse wood surfaces in a single three-dimensional presentation. Color photographs of the three surfaces and of the bark provide additional visual data useful in both product development and species identification. Data on the resource and certain important physical properties of the stemwood and bark are also tabulated for most of the 23 species.

An overview of hardwood structure is provided as introductory reading. Detailed discussions of wood anatomy and characterization of individual species may be found in more comprehensive texts (Panshin and de Zeeuw 1970; Core, Côté, and Day 1979). Readers interested in an illustrative monograph of the living tree should also find Southern Forest Experiment Station, General Technical Report SO-15, "Identifying Hardwoods Growing on Pine Sites" a useful source (Brown and Grelen 1977).

[1]For purposes of this paper, pine sites are defined as forested uplands, excluding those growing cove-type hardwoods, capable of growing southern pine as demonstrated by present or former occurrence on the site.

Table 1. — *The hardwood resource on southern pine sites, ranked according to percentage of total hardwood volume*

Common name	Botanical name	Percent[1]
Sweetgum	*Liquidambar styraciflua* L.	13.2
White oak	*Quercus alba* L.	12.3
Hickory	*Carya* spp.	8.5
Southern red oak	*Quercus falcata* Michx. var. *falcata*	8.1
Post oak	*Quercus stellata* Wangenh.	7.0
Yellow-poplar	*Liriodendron tulipifera* L.	7.0
Black tupelo	*Nyssa sylvatica* Marsh.	5.5
Water oak	*Quercus nigra* L.	4.7
Chestnut oak	*Quercus prinus* L.	4.2
Black oak	*Quercus velutina* Lam.	4.0
Scarlet oak	*Quercus coccinea* Muenchh.	3.6
Red maple	*Acer rubrum* L.	3.6
Northern red oak	*Quercus rubra* L.	2.4
Laurel oak	*Quercus laurifolia* Michx.	1.4
American elm	*Ulmus americana* L.	1.4
Winged elm	*Ulmus alata* Michx.	
Cherrybark oak	*Quercus falcata* Michx. var. *pagodaefolia* Ell.	1.2
Green ash	*Fraxinus pennsylvanica* Marsh.	.9
White Ash	*Fraxinus americana* L.	
Sweetbay	*Magnolia virginiana* L.	.6
Shumard oak	*Quercus shumardii* Buckl.	.2
Hackberry	*Celtis* spp.	.1
Other hardwoods including Blackjack oak	(*Quercus marilandica* Muenchh.)	10.1
TOTAL		100.0

[1]Percentages were derived from Staff, For. Resour. Res. Work Unit (1976).

OVERVIEW OF HARDWOOD STRUCTURE

How the cellular structure of wood is organized can best be understood from study of three surfaces — transverse, tangential, and radial. Figure 1-A shows a portion of a hardwood stem with an enlarged bark-to-pith, wedge-shaped section removed. The wedge (1B) locates the three study surfaces and illustrates their orientation within the stem.

Between the wood (xylem) and the bark, a sheath of tissue called the cambium repeatedly produces new layers of wood and inner bark. These layers increase stem diameter. Some cells (parenchyma) of the newly formed xylem perform living functions, but most die during the year they are formed. These dead cells have a rigid cell wall and a cavity, called a lumen, where the living protoplasm was during cell formation.

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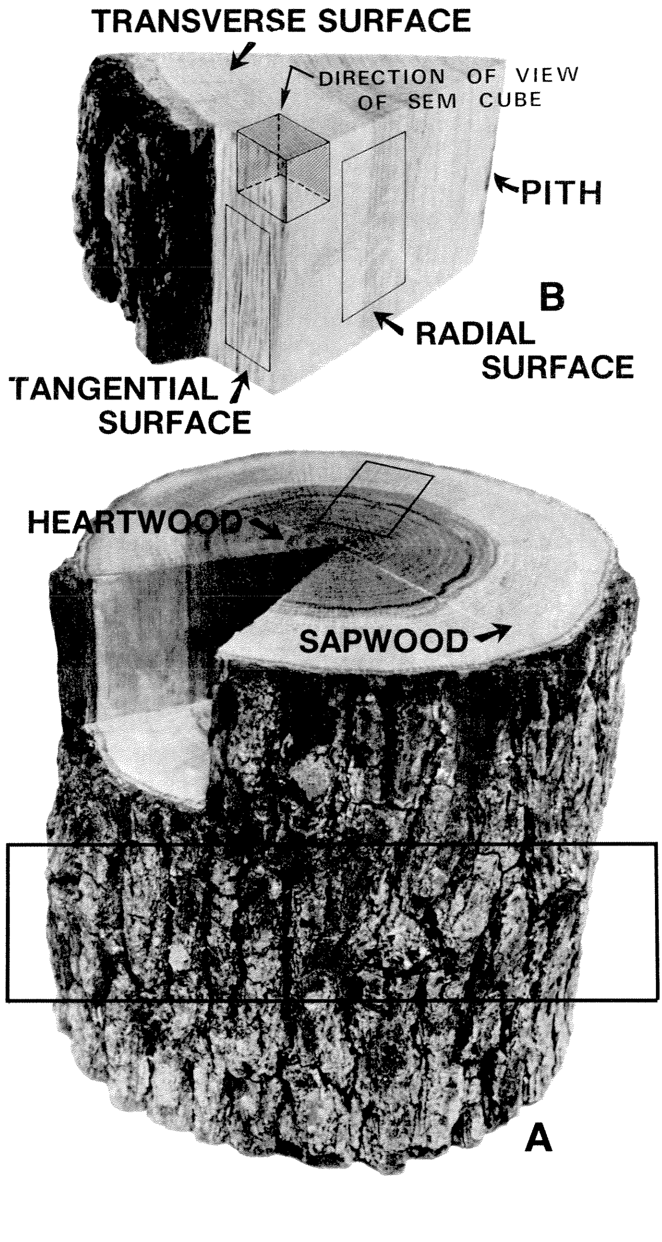


Fig. 1 — *Photograph showing orientation of study surfaces within a hardwood stem.*

That portion of xylem containing some living cells (parenchyma) is termed sapwood (fig. 1-A). The transformation from sapwood to heartwood occurs when all physiological functions of the sapwood xylem cease. At that time, food reserves stored in parenchyma cells are converted to extractives which make the heartwood of many species darker than their sapwood.

Heartwood may resist insect and fungal attack better than sapwood. But, the presence of extractives and certain anatomical structures (i.e., tyloses) may make heartwood less permeable than sapwood and impair preservation, drying, and pulping processes.

The scanning electron microscope, because of its great depth of field, enables one to observe all three study surfaces simultaneously in their proper spatial relationship and at sufficient magnification to see certain important anatomical features. Figure 2 shows a scanning electron micrograph of Shumard oak. The surfaces depicted in figure 2 are viewed from the direction of the pith (as indicated by the arrow in figure 1-B). The study surfaces are further identified by the hatched lines on the cube in figure 1-B.

Broad-leaved, deciduous hardwoods are anatomically more complex (as are all hardwoods) than coniferous softwoods because they are composed of more cell types. Several structures readily distinguish the two groups. Notably, hardwoods have vessels (fig. 2) – structures that conduct water within the stem. Also, the radial alignment of cells characteristic of softwoods is lacking or obscured in hardwoods. Lastly, hardwood rays are more variable in width and height than those of softwoods. Hardwood rays are frequently two or more cells wide and may be as wide as 30 or more cells in oaks.

The terms "hardwoods" and "softwoods" do not necessarily reflect the hardness of the wood. For example, yellow-poplar, a "hardwood," is softer and more easily indented than Pacific yew, a "softwood."

In figure 2, the transverse surface shows portions of two annual growth increments consisting of both earlywood and latewood. Earlywood is that portion of the annual ring produced in the spring, and latewood is formed towards the end of the growing season. The major anatomical elements and structures identified in figure 2 are discussed in subsequent text. The reader is also directed to micrographs of other species in the section on "Species Illustrations, Resource, and Selected Properties."

Fibers

Fibers (slender, elongated cells with pointed, closed ends) are oriented vertically in the stem, parallel to its long axis. Because of their thick walls and small-diameter lumens, fibers appear at low magnification to

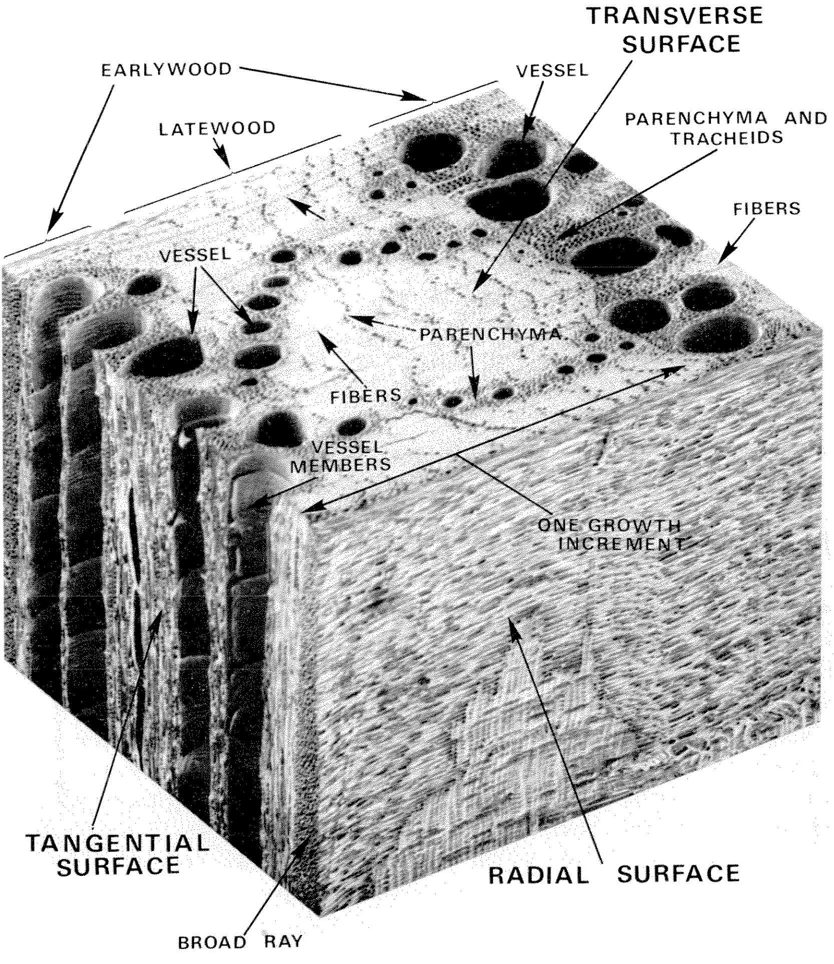


Fig. 2—*Scanning electron micrograph of Shumard oak cube.*

be background tissue to other cell types in both earlywood and latewood (transverse surface of fig. 2). Several different fiber types exist but are difficult to categorize, so separation is not attempted in this paper.

Fibers support the stem and are the most numerous anatomical element, comprising about 45 percent of the stemwood volume of the species surveyed. Average lengths vary from 0.8 mm in red maple to 1.8 mm in black tupelo (Manwiller 1974).

From the standpoint of hardwood utilization, fibers give strength to solid wood products and are the principal component of paper and other products derived from pulp.

Vessels

Vessels are structures of indeterminant length and are composed of a series of short cells, the vessel members (elements), whose end walls have partially disappeared, forming a vertical tube. Vessel openings in both earlywood and latewood are clearly visible on the transverse surface of figure 2, and vessel members may be seen on the tangential surface where vessels have been cut. For the species considered here, vessels comprise about 20 percent of the cell volume although values range from 11.2 percent for cherrybark oak to 46.2 percent for sweetgum.

The partial end wall remaining between two adjacent vessel members is a perforation plate, and the opening is a perforation. In most species considered here (the ashes, elms, hackberry, hickory, red maple, and oak), vessel members are joined by simple perforation plates—large round openings with only a narrow rim remaining from the original wall. Vessel members and simple perforation plates are easily seen on the radial surface of the green ash cube (p. 12).

In sweetbay, sweetgum, black tupelo, and yellow-poplar, vessel members are joined through scalariform (ladderlike) perforation plates where barlike remnants of the end wall separate long, slender, parallel perforations. This type of perforation plate is most clearly visible in cut vessels on the radial surface of sweetgum (p. 52).

Vessels are also called pores. If vessels are all of about the same diameter across the growth increment (as in red maple, sweetbay, sweetgum, black tupelo, and yellow-poplar) the species is said to be diffuse-porous. In the other species (the ashes, elms, hackberry, true hickory, and the oaks), the vessels in the earlywood are much larger than those in the latewood, and the change in diameter is abrupt. These species are termed ring-porous.

When the latewood tissue is wide enough for the pattern to be visible, the arrangement of latewood vessels in ring-porous wood varies considerably among species. The slow-grown hickory cube (p. 22) has solitary pores although other hickory samples may have pores in radial groups of two or three. In the ashes, latewood pores are also both solitary and in radial groups of two and three. Elms and hackberry have wavy, nearly continuous tangential bands of latewood vessels, while oaks have latewood vessels generally aligned in the radial direction. In the red oaks, latewood vessels occur as rows one cell wide or in flame-shaped groups and are easily seen because of their thick walls. White oaks have smaller, thin-walled latewood vessels, which occur in flame-shaped groups — an arrangement clearly visible on the transverse surface of post oak (p. 38).

The relative amounts of latewood and earlywood can affect important physical properties of ring-porous hardwoods. For example, the slow-grown northern red oak cube (p. 36) is essentially composed of four narrow rings, primarily earlywood tissue. This sample is much more porous and has a lower density than the fast-grown Shumard oak cube (p. 42), which is composed of virtually one wide growth ring containing much fibrous latewood.

Parenchyma

Longitudinal parenchyma cells have about the same diameter as fibers but are shorter and have thinner walls. The vertically oriented longitudinal parenchyma may be seen on the transverse surface of figure 2 as short series of cells interspersed among fibers. Parenchyma is also oriented horizontally in rays. Longitudinal stemwood parenchyma volume ranges from less than 2 percent in sweetgum to about 26 percent in the oaks.

Longitudinal parenchyma is sparse in diffuse-porous species such as red maple, sweetgum, and black tupelo. In sweetbay and yellow-poplar it forms a continuous band at the end of seasonal growth and appears as a white line at low magnification. Parenchyma is more apparent in the ring-porous species. Lumen diameter of parenchyma cells is larger than that of fibers but less than that of latewood vessels. In the ashes, parenchyma occurs in the latewood, where it encircles individual and multiple vessels and often extends outward from them in tangential rows. Parenchyma is present in the oaks as fine tangential lines throughout the latewood – also, most of the flame-shaped tissue surrounding latewood vessels is composed of parenchyma. In hickories, parenchyma is conspicuous as tangential lines throughout the latewood.

Tracheids

The small, large-lumened cells surrounding earlywood vessels in the oaks appear to be parenchyma on the transverse surface. They are, however, primarily vasicentric tracheids, which are longer and thicker walled than parenchyma cells and are not in longitudinal rows. They also appear among the flame-shaped areas of parenchyma.

Another type of tracheid, vascular, is found in the elms and hackberry. Vascular tracheids are similar to latewood vessel members except that end walls are not perforated. They may be intermixed in the same vertical series with the vessel members, are associated with vessel members in the wavy latewood bands, and cannot be distinguished from them on the transverse surface.

Rays

On the transverse surface, rays (fig. 2) appear as lines extending across growth increments from the cambium toward the pith. On the radial surface they appear as ribbons while the ends of rays are exposed on the tangential surface. Composed of horizontally-oriented parenchyma, rays are from several to many cells high and are generally tapered on their upper and lower edges. (See for example the tangential surface of the sweetbay cube on page 50.)

Rays vary from one to several cells wide. Of the species considered here, only the oaks contain broad rays—up to 30 cells wide and hundreds of cells high. Between these broad rays are many inconspicuous rays, usually one cell wide and less than 20 cells high. In all of the oak cubes except that of black oak the radial surface cuts through a broad ray.

Of the remaining 11 species, the rays of the two elms and hackberry are usually five or six cells wide, while those of the other eight species are mostly one to three cells wide.

Tyloses

Between any two adjacent cells, regardless of type, there are minute matching gaps in the contiguous walls of the two cells. The gaps are separated at the center by a membrane. The cavities in adjacent walls plus membranes are called pits. Tyloses are outgrowths of protoplasm from longitudinal or mainly ray parenchyma cells that expand or grow through the pit membranes and appear as membranelike material that partially or completely blocks the vessel cavity.

Tyloses block most of the earlywood vessels of the white oak group. Tyloses occur only occasionally in the red oaks—some may be seen in vessels of laurel oak (p. 34) and blackjack oak (p. 28). Tyloses are also present in some earlywood vessels of the hickory cube (p. 22).

SPECIES ILLUSTRATIONS

SPECIES ILLUSTRATIONS, RESOURCE, AND SELECTED PROPERTIES

Each species is illustrated by five pictures: a scanning electron micrograph magnified 100 times so one can see the cellular structure in perspective; a photograph of the transverse surface magnified five times (the surface and minimum magnification useful for species identification); unmagnified radial and tangential views that illustrate color and grain; and finally a picture of the bark, field-photographed from typical 6-inch (breast height) diameter trees. The location and orientation of each view in the tree is illustrated by the rectangles and the cube in figure 1.

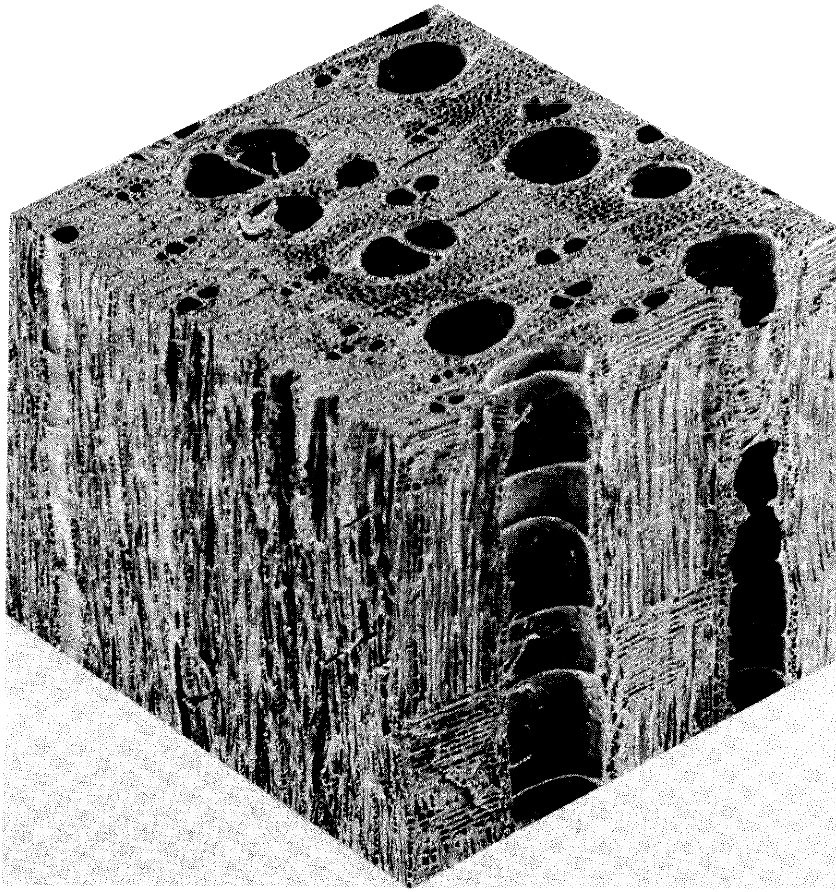
The species resource and selected stemwood and bark properties are listed in the lower part of the right-hand page. These data were obtained from the following sources.

RESOURCE
- Volume (million cubic feet) . . . .(Staff, For. Resour. Res. Work Unit, 1976)
- Percent of hardwood volume on pine sites . . . . (Derived from above)

STEMWOOD
- Specific gravity (ovendry weight and green volume) . . . . (Manwiller, 1979)
- Weight of bark-free stemwood when green (lbs/ft^3) . . . . (Manwiller, 1975b)
- Percent moisture content of green wood (ovendry basis) . . . . (Manwiller, 1975b)

BARK
- Specific gravity (ovendry weight and green volume) . . . . (Manwiller, 1979)
- Percent moisture content of green bark (ovendry basis) . . . . (Manwiller, 1975b)

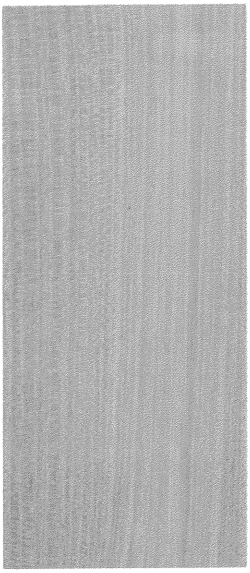
The resource estimates tabulated are for the species or species group growing on pine sites only and do not reflect the additional hardwood volume growing on cove hardwood sites. The survey data are from 12 southern states—Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, and Virginia. Volumes are expressed in cubic feet, inside bark, of trees from stump to minimum 4-inch top diameter (outside bark) of the central stem. All trees 5 inches in diameter at breast height and larger are included.



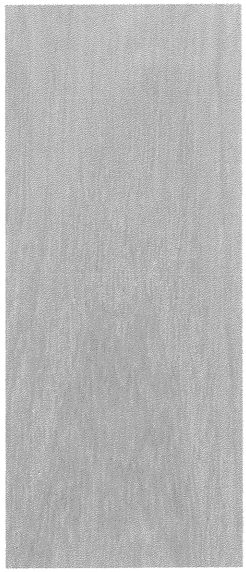
Mag. × 100

GREEN ASH

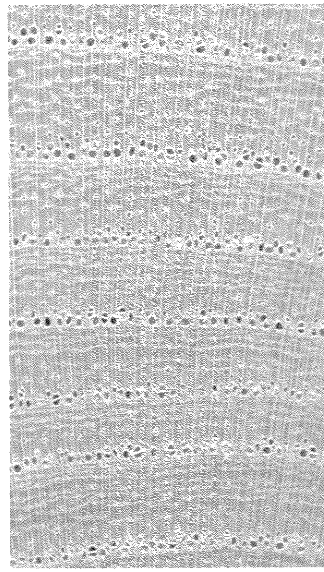
Fraxinus pennsylvanica Marsh.



Radial
Mag. ×1



Tangential
Mag. ×1



Transverse
Mag. ×5

Bark
Mag. ×0.3

RESOURCE
(With White Ash)

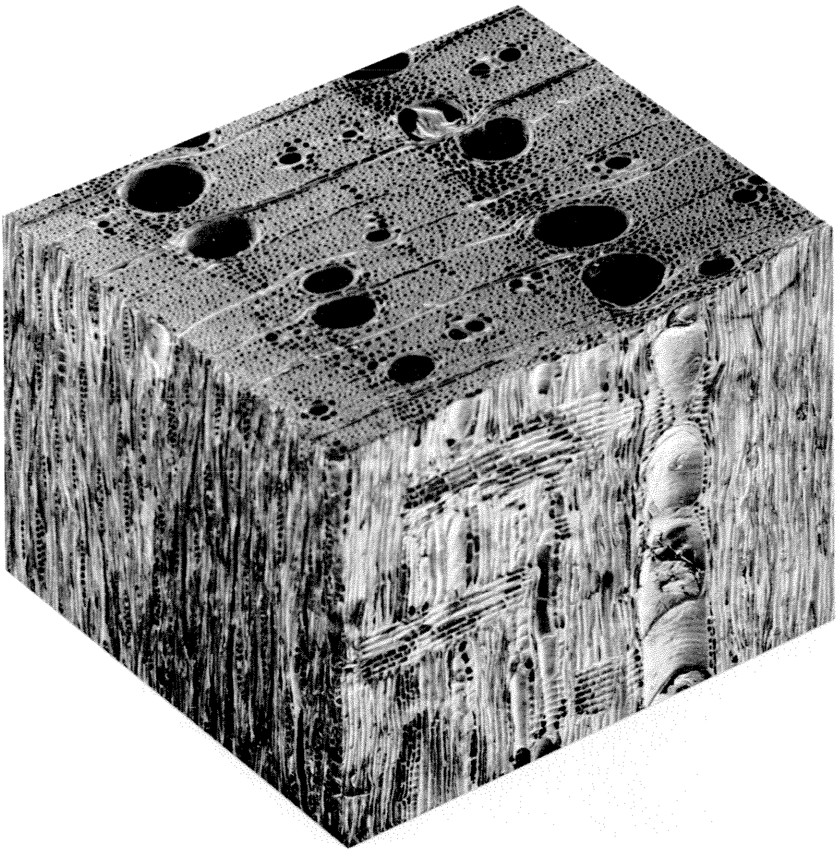
Volume *(million cubic feet)*	441
Percent of total hardwood volume on southern pine sites	0.9

STEMWOOD

Specific gravity *(ovendry weight and green volume)*	0.561
Weight of bark-free stemwood when green *(lbs/ft³)*	51.6
Percent moisture content of green wood *(ovendry basis)*	47.4

BARK

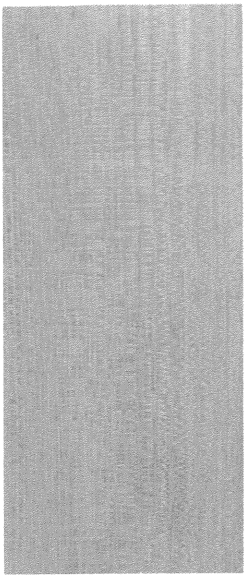
Specific gravity *(ovendry weight and green volume)*	0.407
Percent moisture content of green bark *(ovendry basis)*	75.9



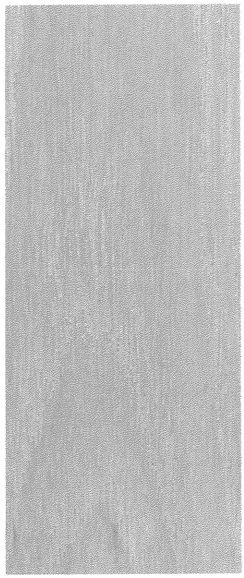
Mag. × 100

WHITE ASH

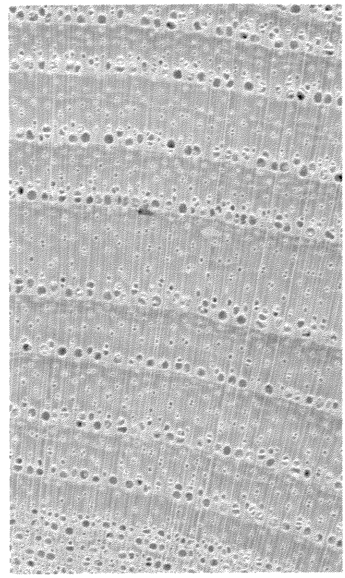
Fraxinus americana L.



Radial
Mag. ×1



Tangential
Mag. ×1



Transverse
Mag. ×5

Bark
Mag. ×0.3

RESOURCE
(With Green Ash)

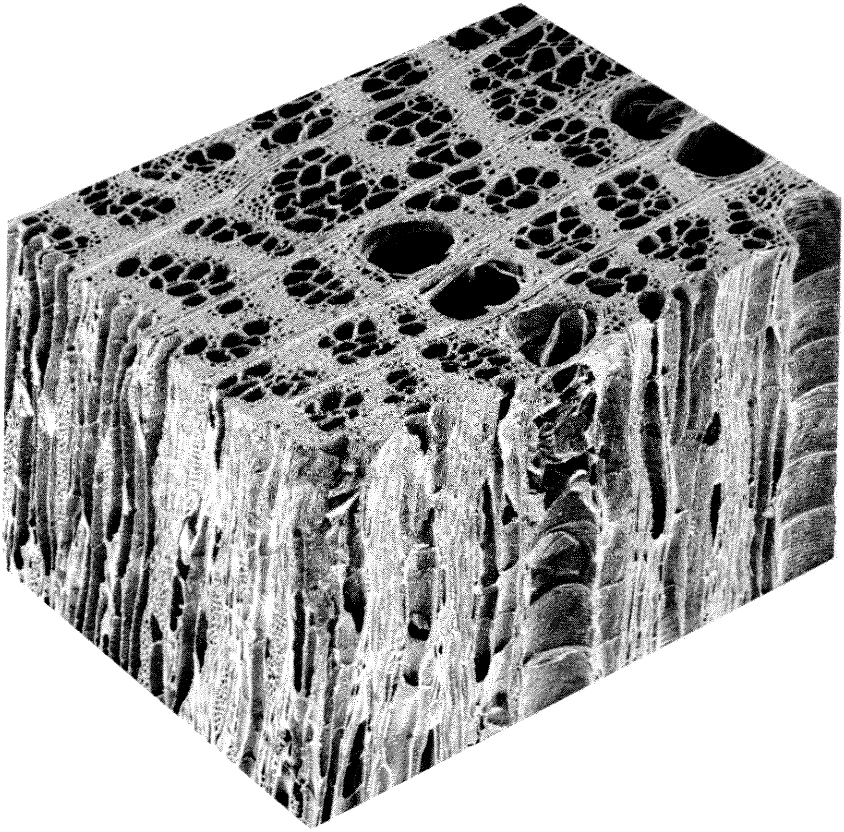
Volume *(million cubic feet)*	441
Percent of total hardwood volume on southern pine sites	0.9

STEMWOOD

Specific gravity *(ovendry weight and green volume)*	0.582
Weight of bark-free stemwood when green *(lbs/ft³)*	53.6
Percent moisture content of green wood *(ovendry basis)*	47.5

BARK

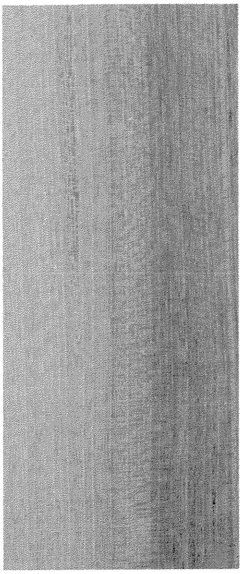
Specific gravity *(ovendry weight and green volume)*	0.397
Percent moisture content of green bark *(ovendry basis)*	68.4



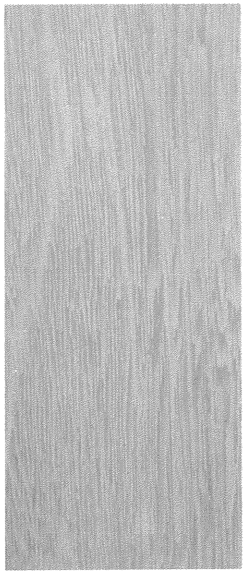
Mag. × 100

AMERICAN ELM

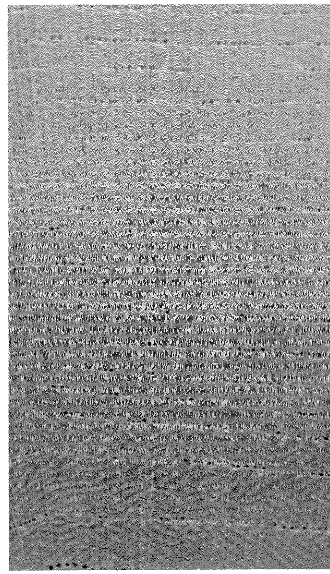
Ulmus americana L.



Radial
Mag. ×1



Tangential
Mag. ×1



Transverse
Mag. ×5

Bark
Mag. ×0.3

RESOURCE
(With Winged Elm)

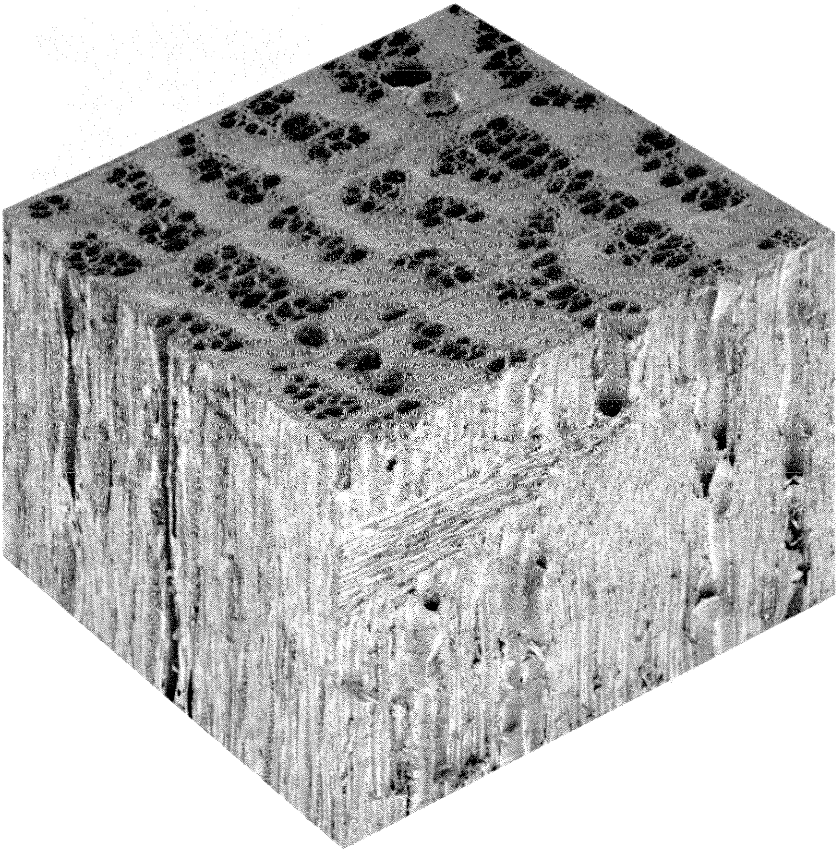
Volume *(million cubic feet)*	668
Percent of total hardwood volume on southern pine sites	1.4

STEMWOOD

Specific gravity *(ovendry weight and green volume)*	0.536
Weight of bark-free stemwood when green *(lbs/ft³)*	58.7
Percent moisture content of green wood *(ovendry basis)*	75.5

BARK

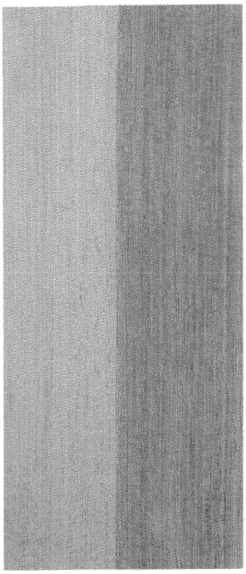
Specific gravity *(ovendry weight and green volume)*	0.395
Percent moisture content of green bark *(ovendry basis)*	86.9



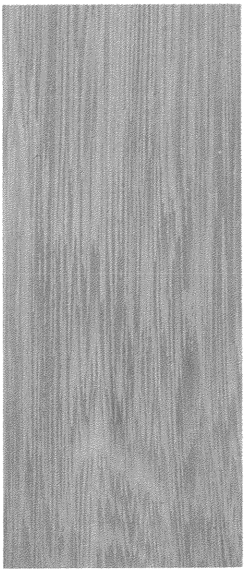
Mag. × 100

WINGED ELM

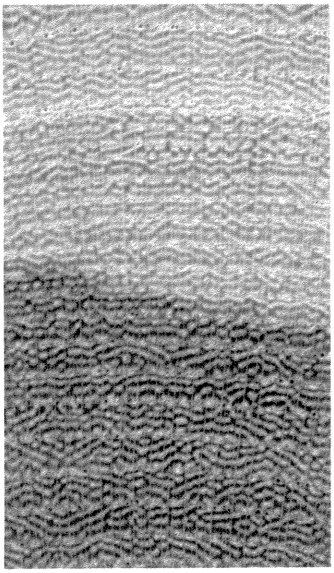
Ulmus alata Michx.



Radial
Mag. ×1



Tangential
Mag. ×1



Transverse
Mag. ×5

Bark
Mag. ×0.3

RESOURCE
(With American Elm)

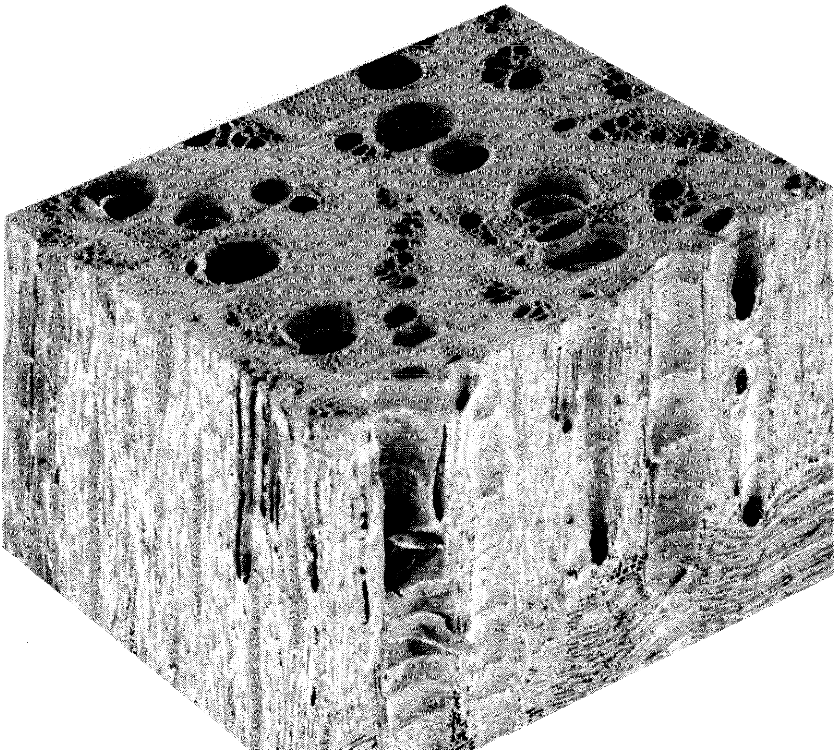
Volume *(million cubic feet)*	668
Percent of total hardwood volume on southern pine sites	1.4

STEMWOOD

Specific gravity *(ovendry weight and green volume)*	0.623
Weight of bark-free stemwood when green *(lbs/ft³)*	64.4
Percent moisture content of green wood *(ovendry basis)*	65.6

BARK

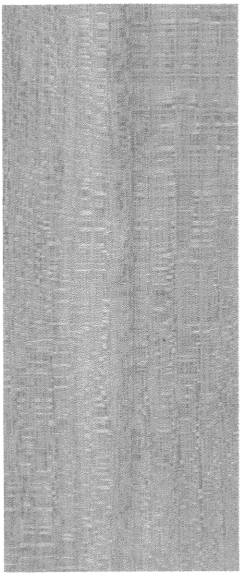
Specific gravity *(ovendry weight and green volume)*	0.341
Percent moisture content of green bark *(ovendry basis)*	76.0



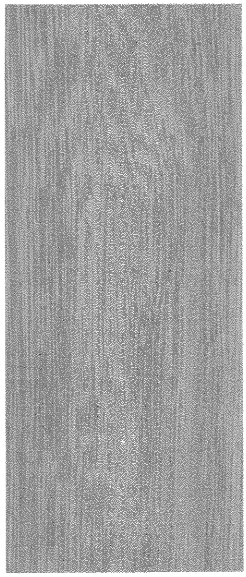
Mag. × 100

HACKBERRY

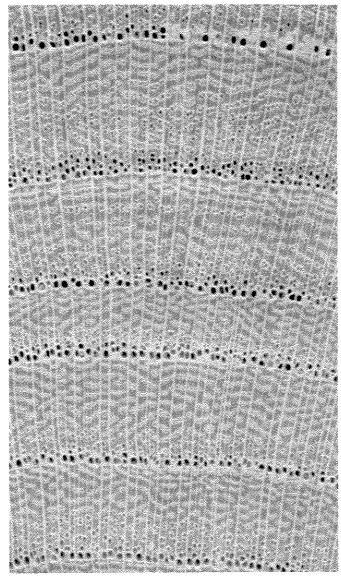
Celtis spp.



Radial
Mag. ×1



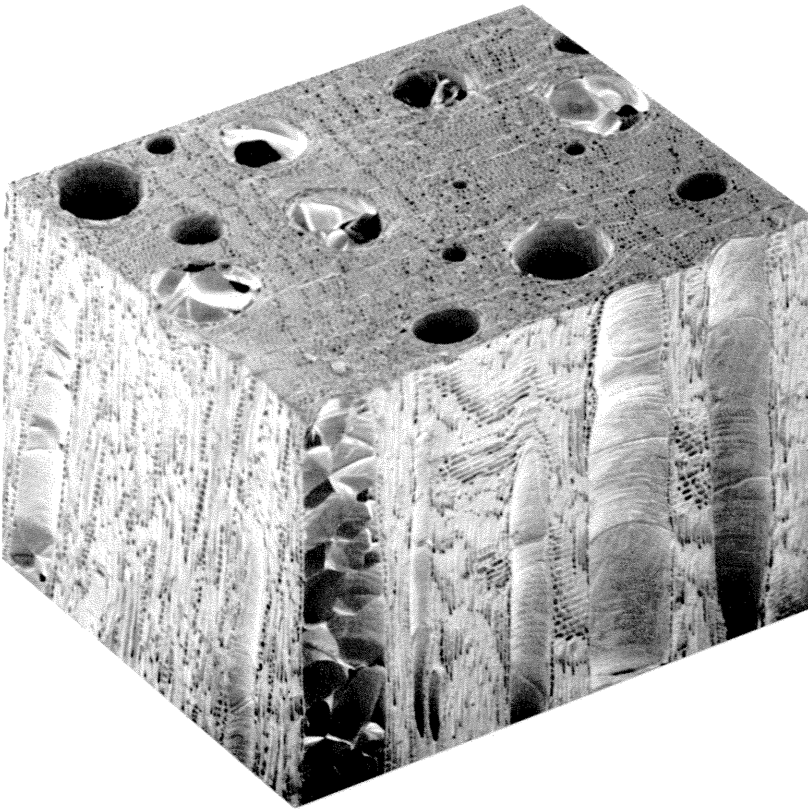
Tangential
Mag. ×1



Transverse
Mag. ×5

Bark
Mag. ×0.3

RESOURCE	
Volume *(million cubic feet)*	57
Percent of total hardwood volume on southern pine sites	0.1
STEMWOOD	
Specific gravity *(ovendry weight and green volume)*	0.525
Weight of bark-free stemwood when green *(lbs/ft³)*	56.6
Percent moisture content of green wood *(ovendry basis)*	72.6
BARK	
Specific gravity *(ovendry weight and green volume)*	0.606
Percent moisture content of green bark *(ovendry basis)*	55.5

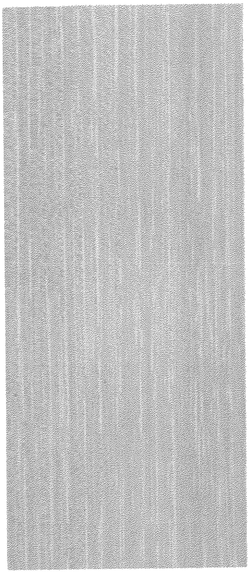


Mag. × 100

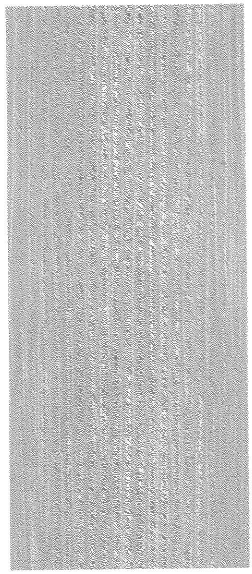
HICKORY

Carya spp.

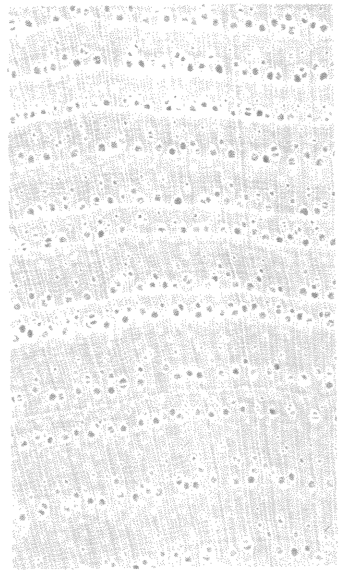
Bark photograph is that of mockernut hickory (Carya tomentosa Nutt.)



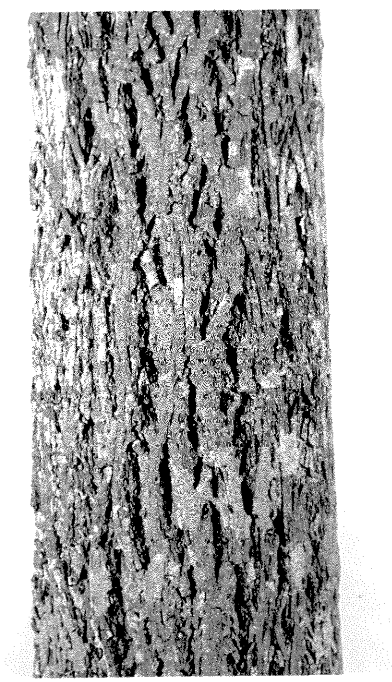
Radial
Mag. ×1



Tangential
Mag. ×1



Transverse
Mag. ×5



Bark
Mag. ×0.3

RESOURCE

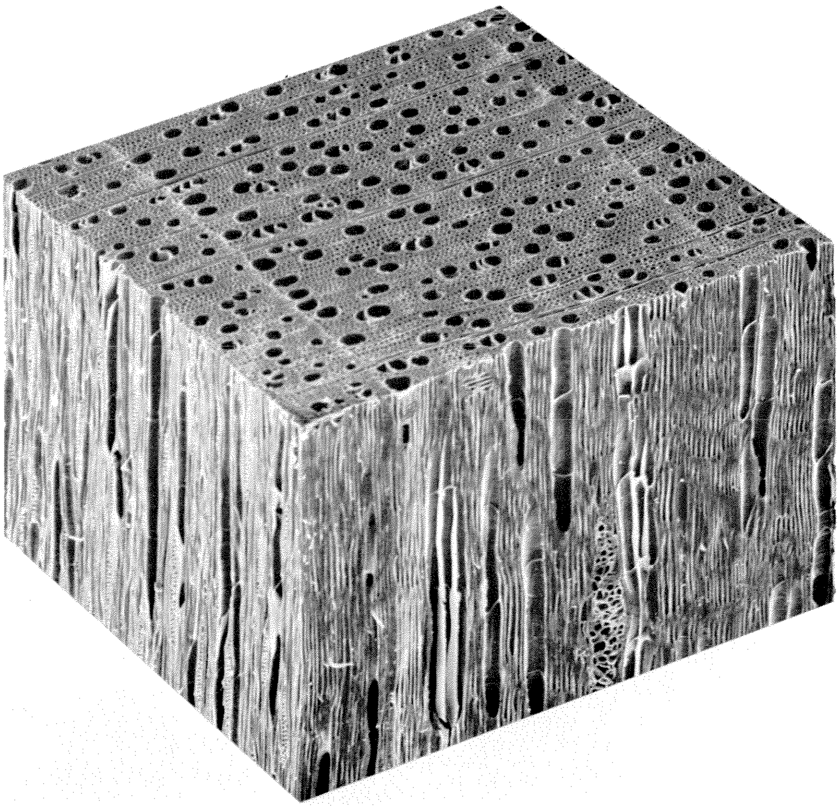
Volume *(million cubic feet)*	4173
Percent of total hardwood volume on southern pine sites	8.5

STEMWOOD

Specific gravity *(ovendry weight and green volume)*	0.643
Weight of bark-free stemwood when green *(lbs/ft³)*	60.8
Percent moisture content of green wood *(ovendry basis)*	51.5

BARK

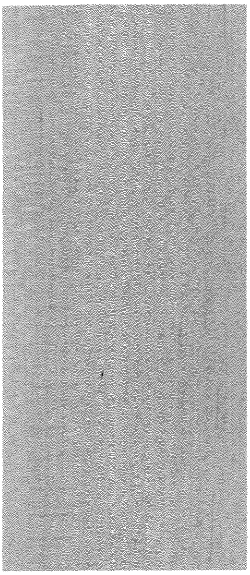
Specific gravity *(ovendry weight and green volume)*	0.522
Percent moisture content of green bark *(ovendry basis)*	72.9



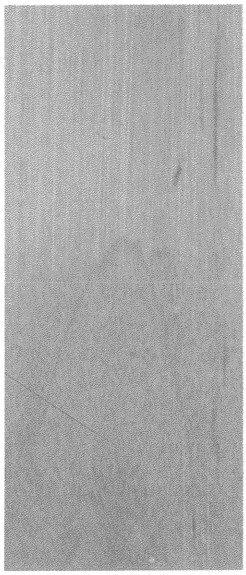
Mag. × 100

RED MAPLE

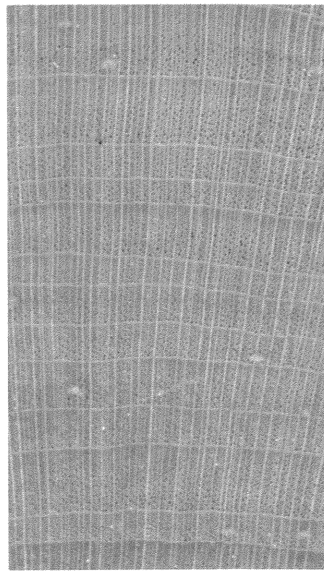
Acer rubrum L.



Radial
Mag. ×1



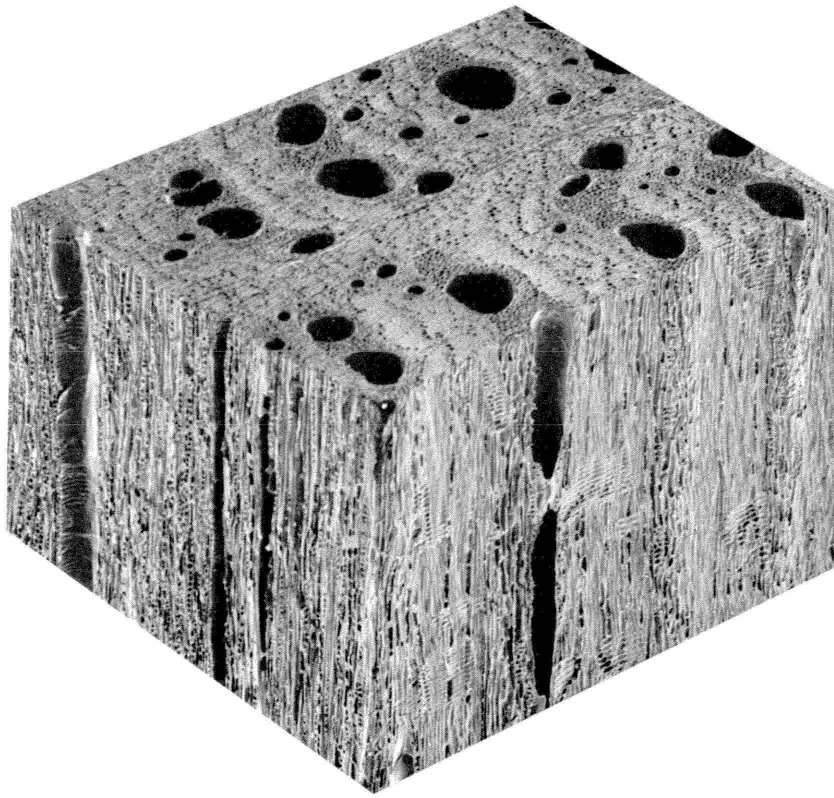
Tangential
Mag. ×1



Transverse
Mag. ×5

Bark
Mag. ×0.3

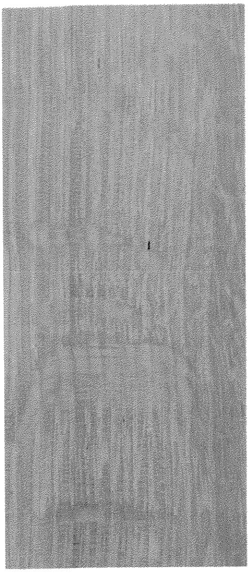
RESOURCE	
Volume *(million cubic feet)*	1751
Percent of total hardwood volume on southern pine sites	3.6
STEMWOOD	
Specific gravity *(ovendry weight and green volume)*	0.496
Weight of bark-free stemwood when green *(lbs/ft³)*	52.6
Percent moisture content of green wood *(ovendry basis)*	69.9
BARK	
Specific gravity *(ovendry weight and green volume)*	0.535
Percent moisture content of green bark *(ovendry basis)*	74.4



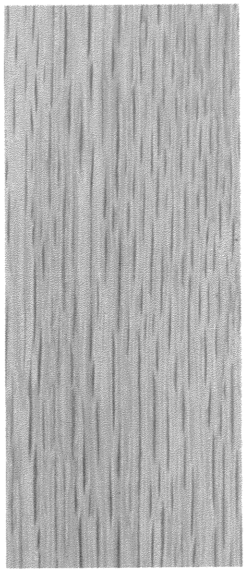
Mag. × 100

BLACK OAK

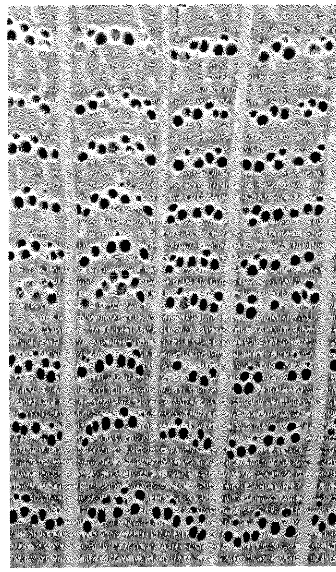
Quercus velutina Lam.



Radial
Mag. ×1



Tangential
Mag. ×1



Transverse
Mag. ×5

Bark
Mag. ×0.3

RESOURCE

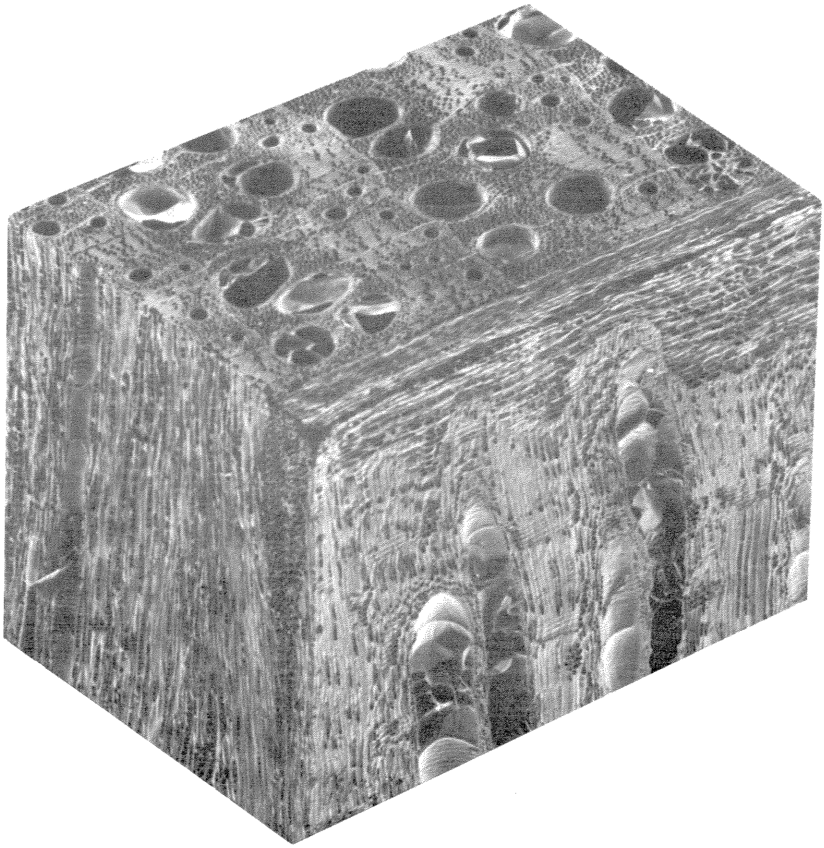
Volume *(million cubic feet)*	1949
Percent of total hardwood volume on southern pine sites	4.0

STEMWOOD

Specific gravity *(ovendry weight and green volume)*	0.620
Weight of bark-free stemwood when green *(lbs/ft³)*	65.5
Percent moisture content of green wood *(ovendry basis)*	69.2

BARK

Specific gravity *(ovendry weight and green volume)*	0.612
Percent moisture content of green bark *(ovendry basis)*	56.2

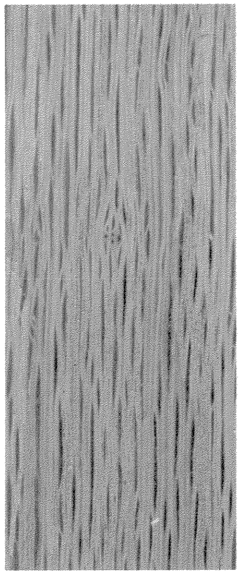


Mag. × 100

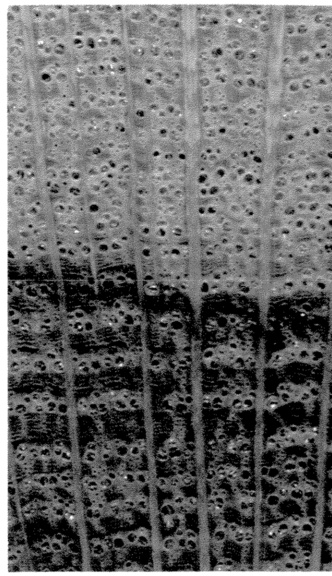
BLACKJACK OAK

Quercus marilandica Muenchh.

Radial
Mag. ×1



Tangential
Mag. ×1



Transverse
Mag. ×5

Bark
Mag. ×0.3

RESOURCE

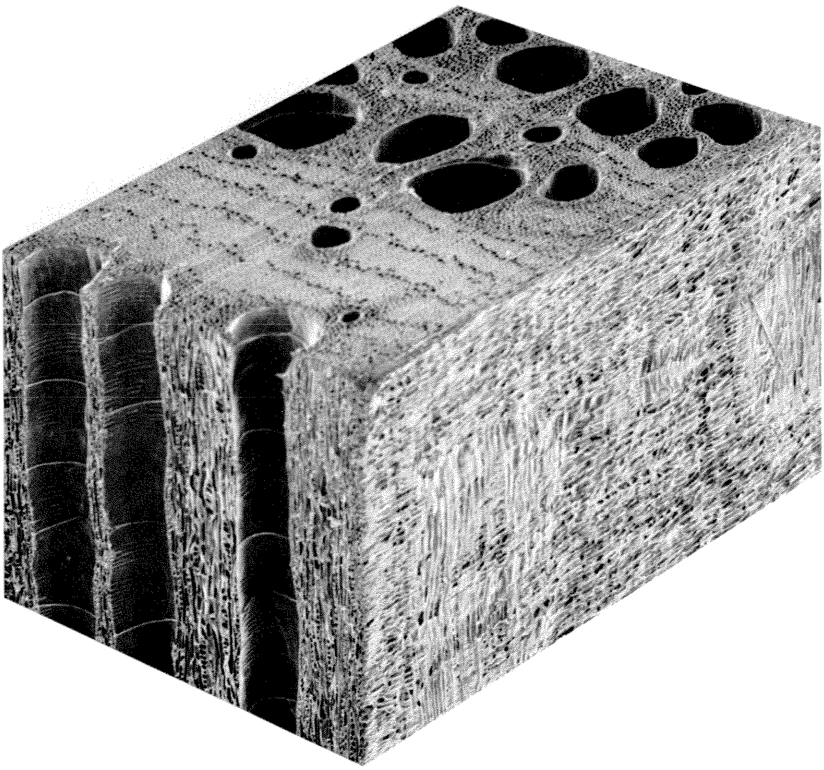
Volume *(million cubic feet)*	. . .
Percent of total hardwood volume on southern pine sites	. . .

STEMWOOD

Specific gravity *(ovendry weight and green volume)*	0.638
Weight of bark-free stemwood when green *(lbs/ft^3)*	69.4
Percent moisture content of green wood *(ovendry basis)*	74.2

BARK

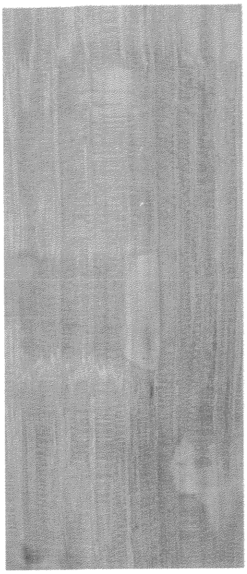
Specific gravity *(ovendry weight and green volume)*	0.642
Percent moisture content of green bark *(ovendry basis)*	43.6



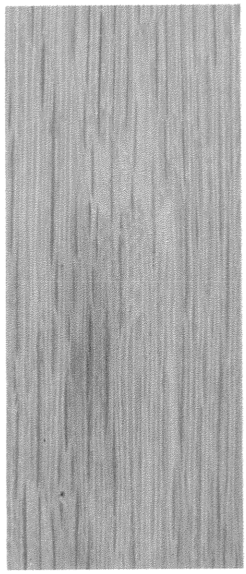
Mag. × 100

CHERRYBARK OAK

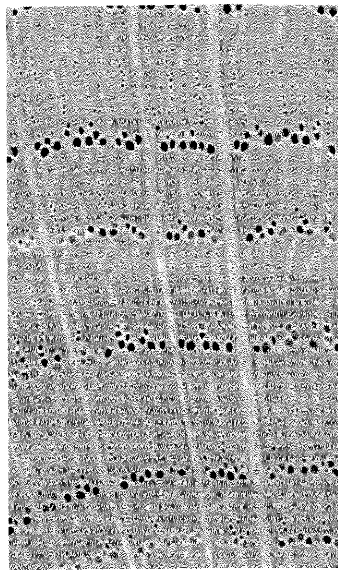
Quercus falcata var. *pagodaefolia* Ell.



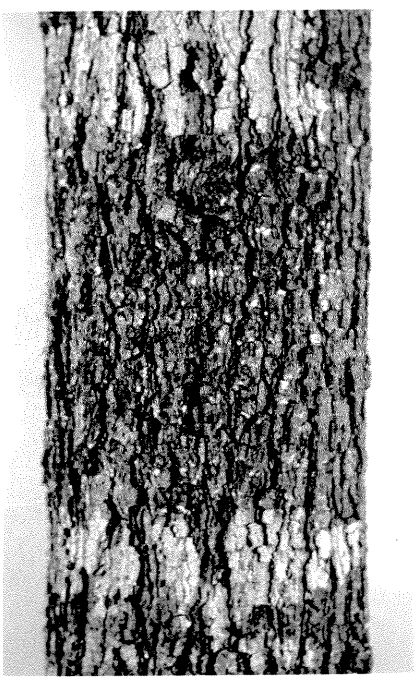
Radial
Mag. ×1



Tangential
Mag. ×1



Transverse
Mag. ×5



Bark
Mag. ×0.3

RESOURCE

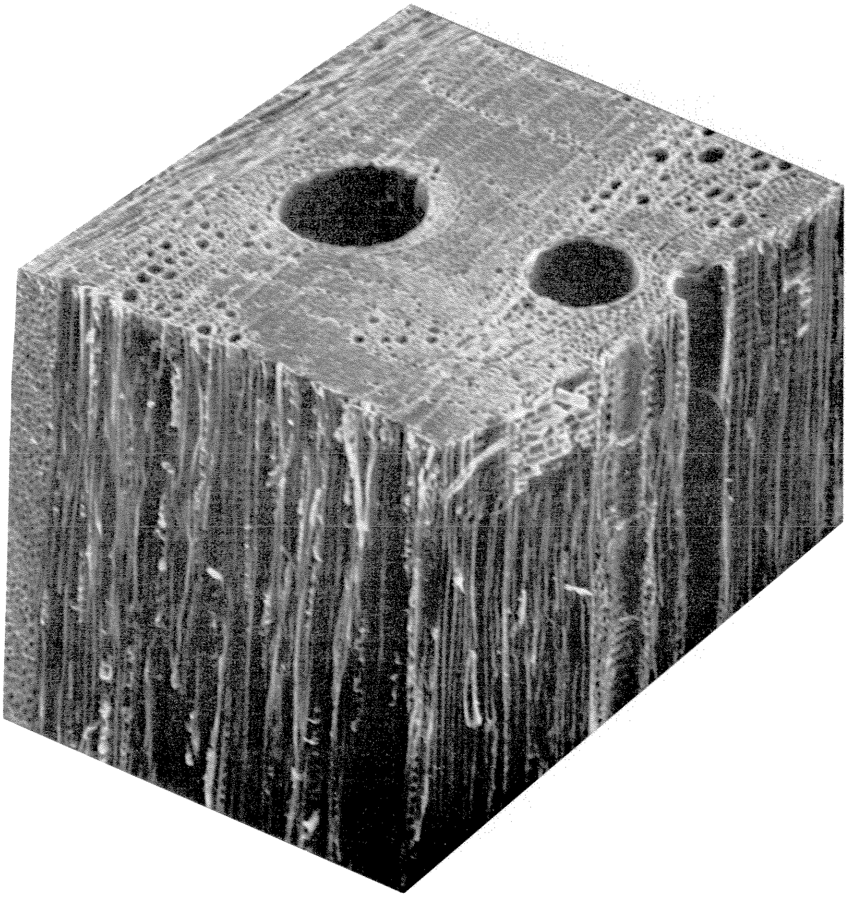
Volume *(million cubic feet)*	579
Percent of total hardwood volume on southern pine sites	1.2

STEMWOOD

Specific gravity *(ovendry weight and green volume)*	0.623
Weight of bark-free stemwood when green *(lbs/ft³)*	64.8
Percent moisture content of green wood *(ovendry basis)*	66.6

BARK

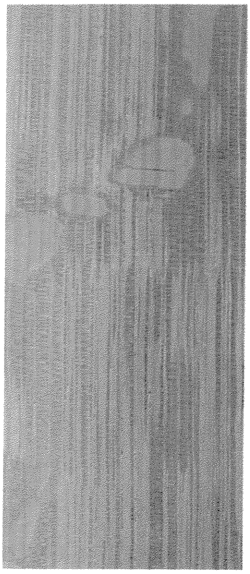
Specific gravity *(ovendry weight and green volume)*	0.622
Percent moisture content of green bark *(ovendry basis)*	54.1



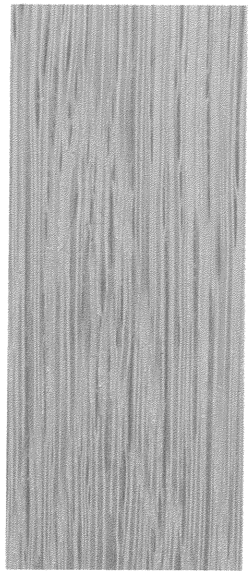
Mag. × 100

CHESTNUT OAK

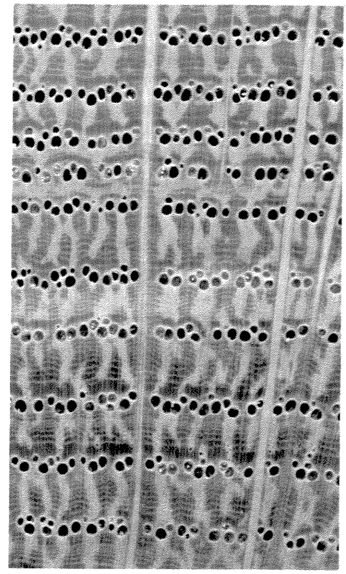
Quercus prinus L.



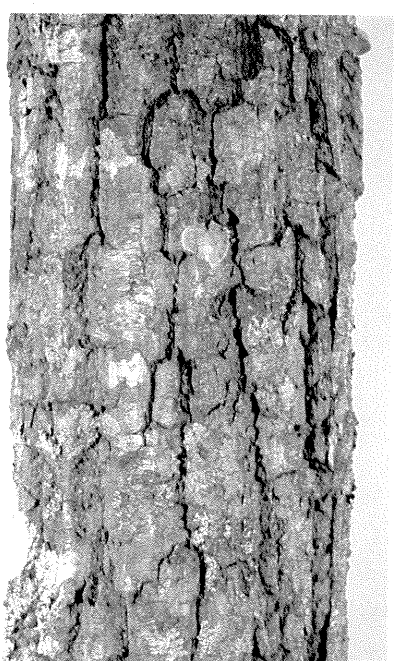
Radial
Mag. ×1



Tangential
Mag. ×1



Transverse
Mag. ×5



Bark
Mag. ×0.3

RESOURCE

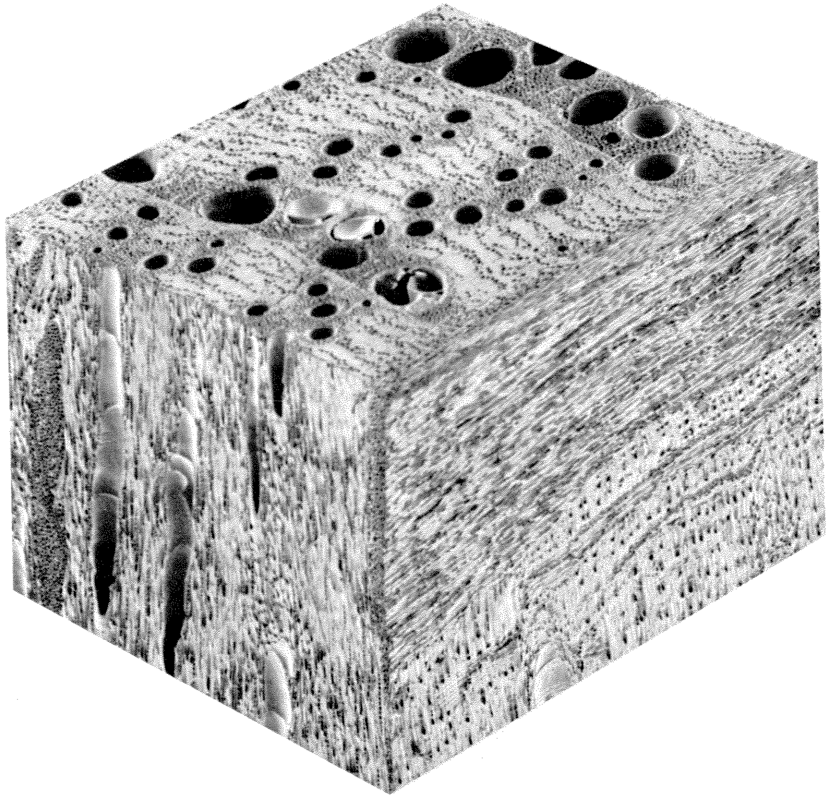
Volume *(million cubic feet)*	2102
Percent of total hardwood volume on southern pine sites	4.2

STEMWOOD

Specific gravity *(ovendry weight and green volume)*	. . .
Weight of bark-free stemwood when green *(lbs/ft³)*	. . .
Percent moisture content of green wood *(ovendry basis)*	. . .

BARK

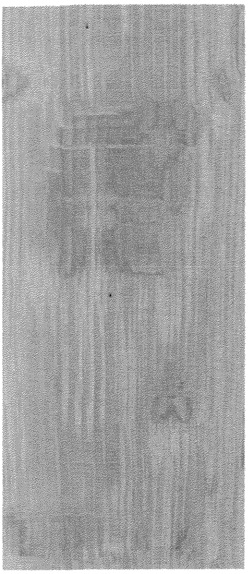
Specific gravity *(ovendry weight and green volume)*	. . .
Percent moisture content of green bark *(ovendry basis)*	. . .



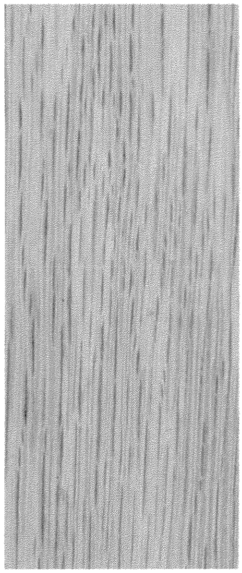
Mag. × 100

LAUREL OAK

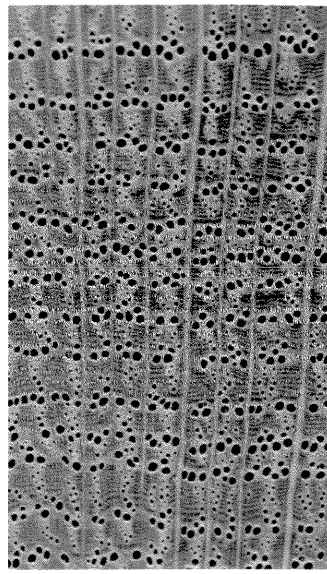
Quercus laurifolia Michx.



Radial
Mag. ×1



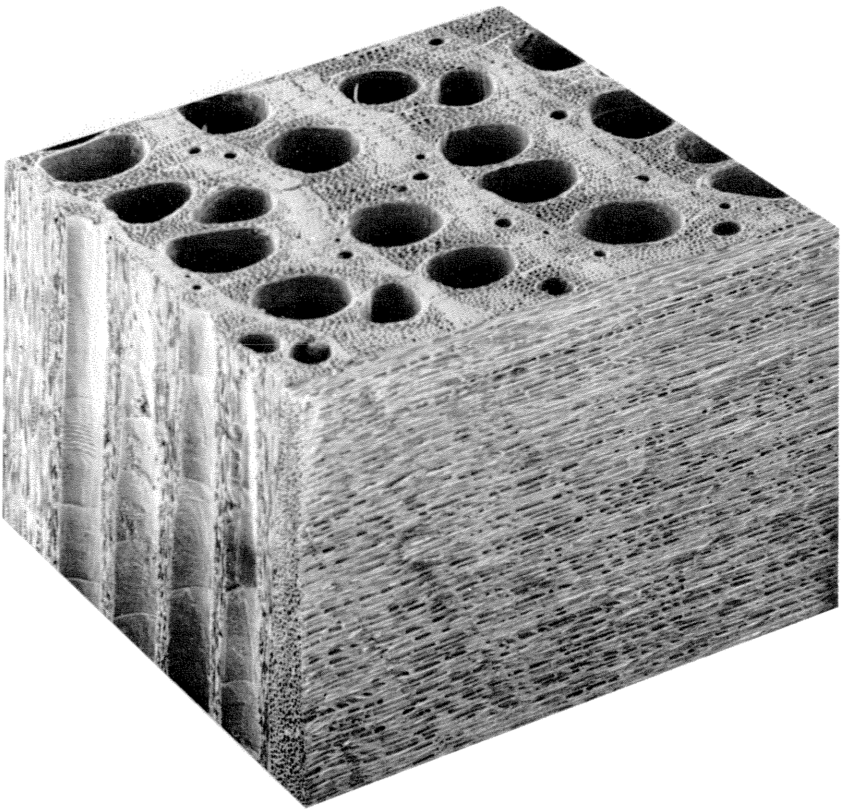
Tangential
Mag. ×1



Transverse
Mag. ×5

Bark
Mag. ×0.3

RESOURCE	
Volume *(million cubic feet)*	683
Percent of total hardwood volume on southern pine sites	1.4
STEMWOOD	
Specific gravity *(ovendry weight and green volume)*	0.582
Weight of bark-free stemwood when green *(lbs/ft³)*	63.4
Percent moisture content of green wood *(ovendry basis)*	74.4
BARK	
Specific gravity *(ovendry weight and green volume)*	0.630
Percent moisture content of green bark *(ovendry basis)*	57.4

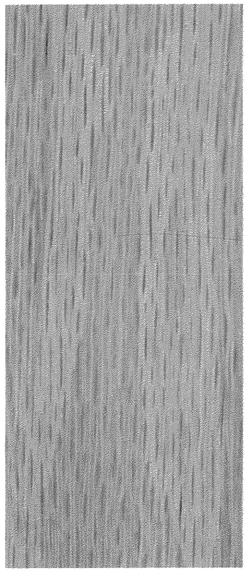


Mag. × 100

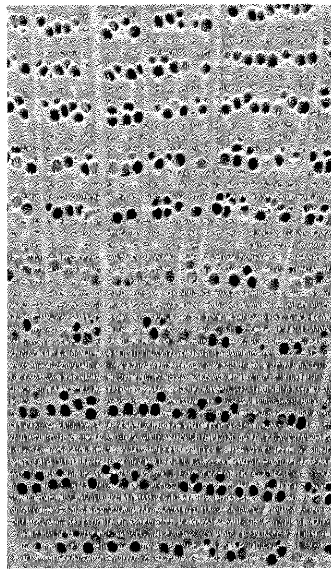
NORTHERN RED OAK

Quercus rubra L.

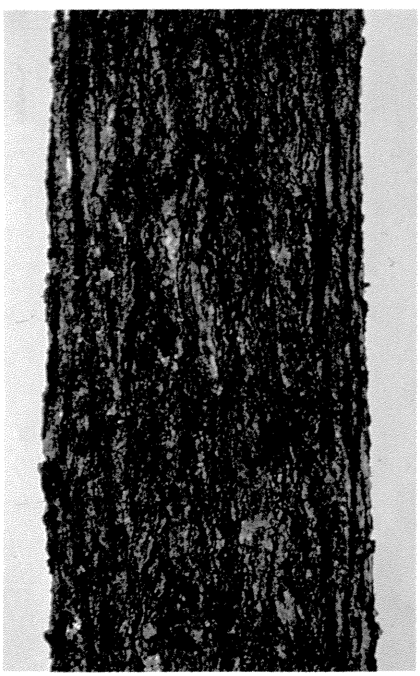
Radial
Mag. ×1



Tangential
Mag. ×1



Transverse
Mag. ×5



Bark
Mag. ×0.3

RESOURCE

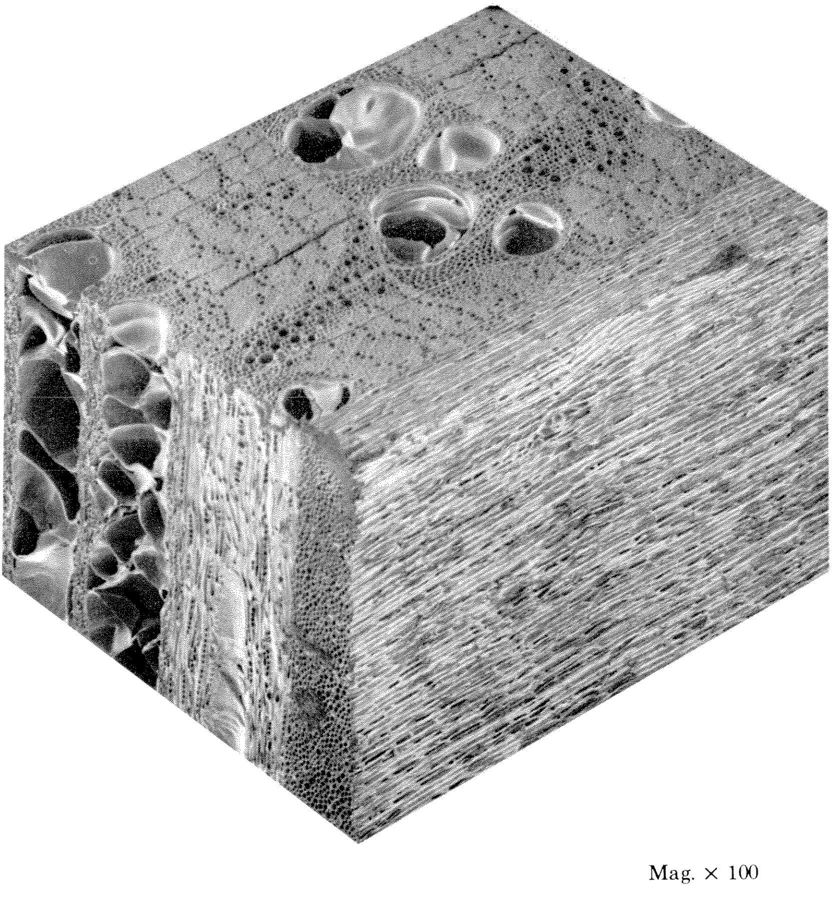
Volume *(million cubic feet)*	1169
Percent of total hardwood volume on southern pine sites	2.4

STEMWOOD

Specific gravity *(ovendry weight and green volume)*	0.605
Weight of bark-free stemwood when green *(lbs/ft³)*	64.1
Percent moisture content of green wood *(ovendry basis)*	69.7

BARK

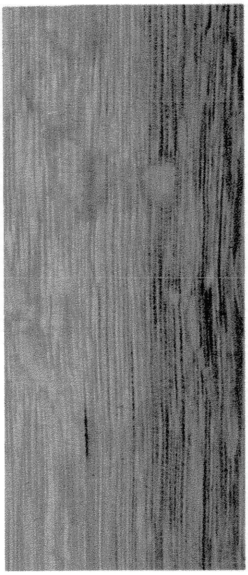
Specific gravity *(ovendry weight and green volume)*	0.644
Percent moisture content of green bark *(ovendry basis)*	55.7



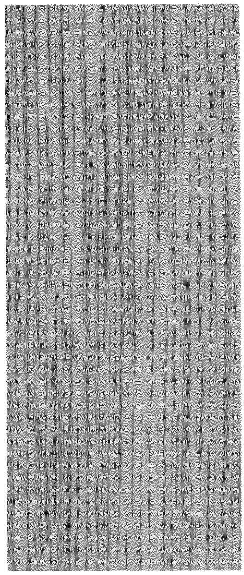
Mag. × 100

POST OAK

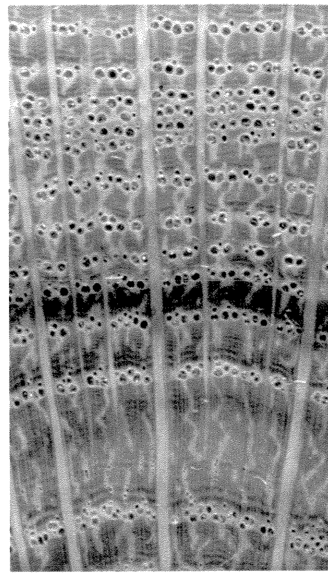
Quercus stellata Wangenh.



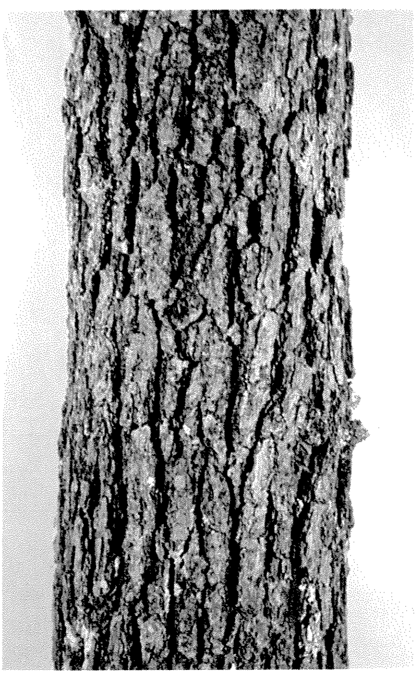
Radial
Mag. ×1



Tangential
Mag. ×1



Transverse
Mag. ×5



Bark
Mag. ×0.3

RESOURCE

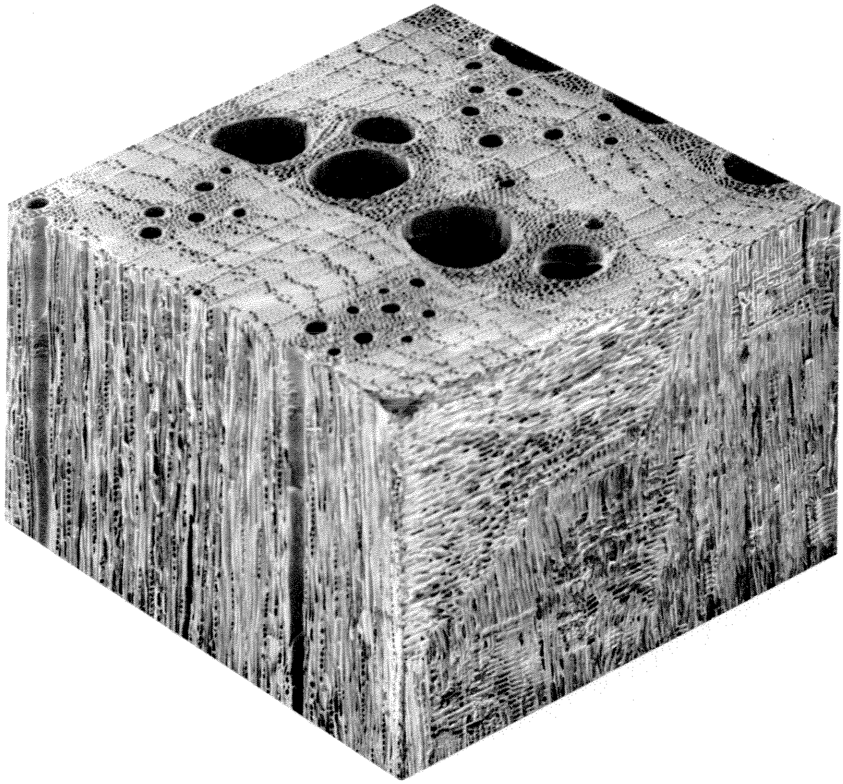
Volume *(million cubic feet)*	3444
Percent of total hardwood volume on southern pine sites	7.0

STEMWOOD

Specific gravity *(ovendry weight and green volume)*	0.659
Weight of bark-free stemwood when green *(lbs/ft³)*	68.1
Percent moisture content of green wood *(ovendry basis)*	65.6

BARK

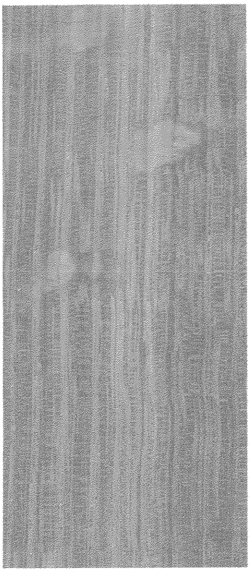
Specific gravity *(ovendry weight and green volume)*	0.498
Percent moisture content of green bark *(ovendry basis)*	48.9



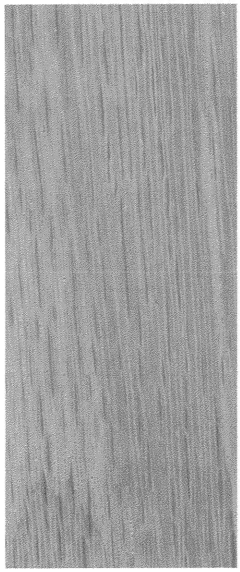
Mag. × 100

SCARLET OAK

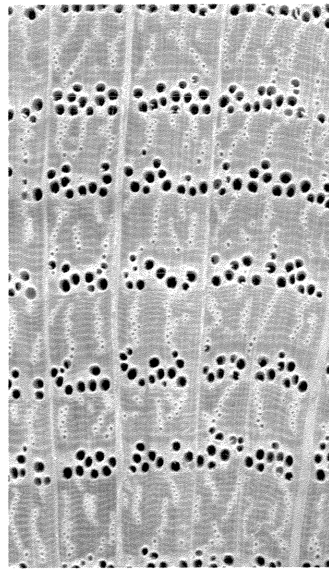
Quercus coccinea Muenchh.



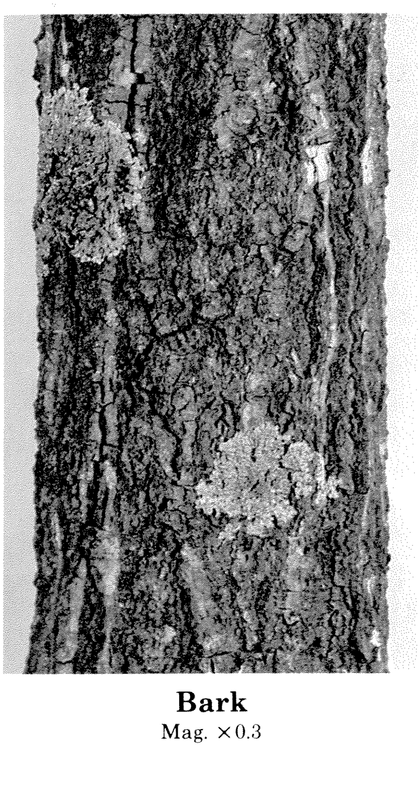
Radial
Mag. ×1



Tangential
Mag. ×1

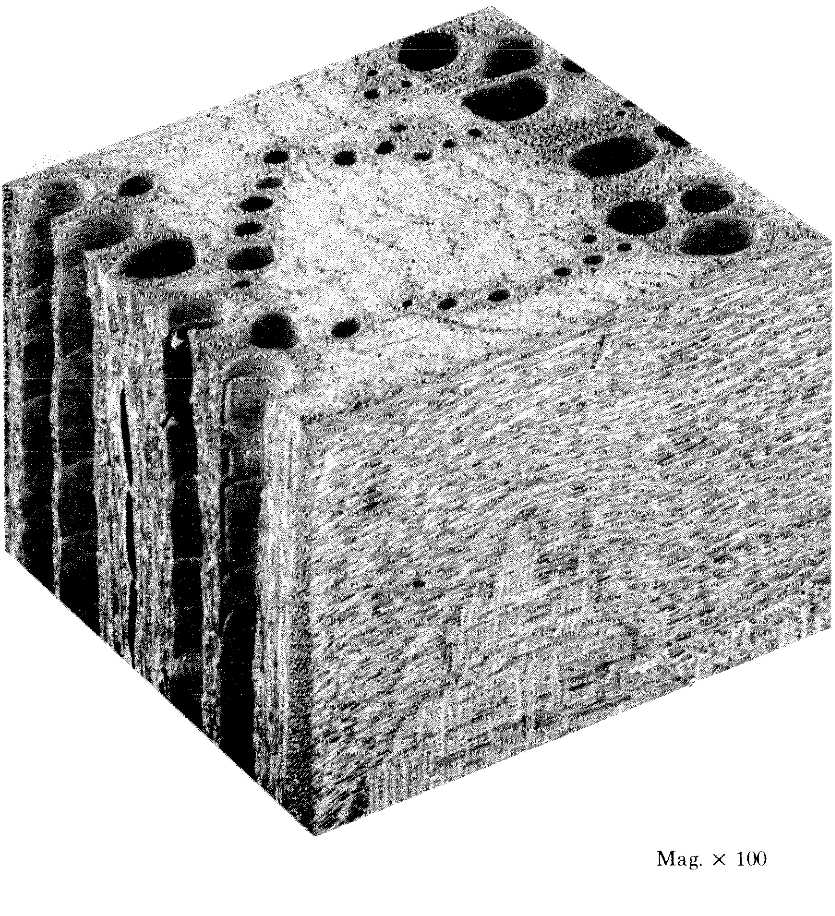


Transverse
Mag. ×5



Bark
Mag. ×0.3

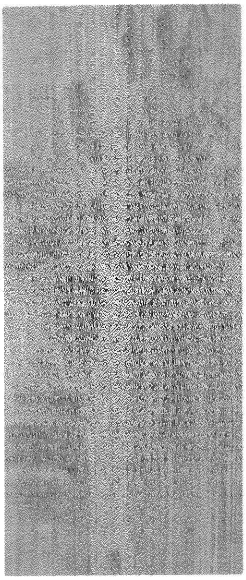
RESOURCE	
Volume *(million cubic feet)*	1799
Percent of total hardwood volume on southern pine sites	3.6
STEMWOOD	
Specific gravity *(ovendry weight and green volume)*	0.622
Weight of bark-free stemwood when green *(lbs/ft³)*	65.8
Percent moisture content of green wood *(ovendry basis)*	69.4
BARK	
Specific gravity *(ovendry weight and green volume)*	0.618
Percent moisture content of green bark *(ovendry basis)*	55.6



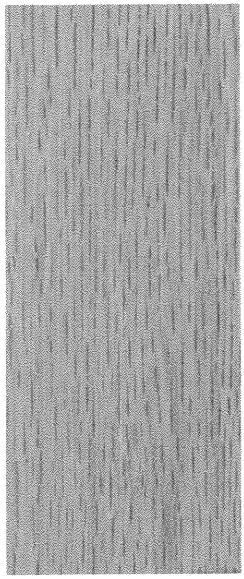
Mag. × 100

SHUMARD OAK

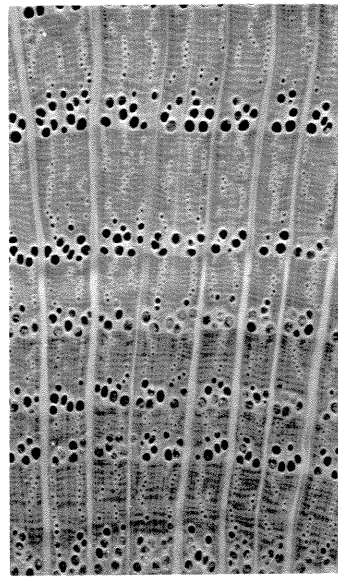
Quercus shumardii Buckl.



Radial
Mag. ×1



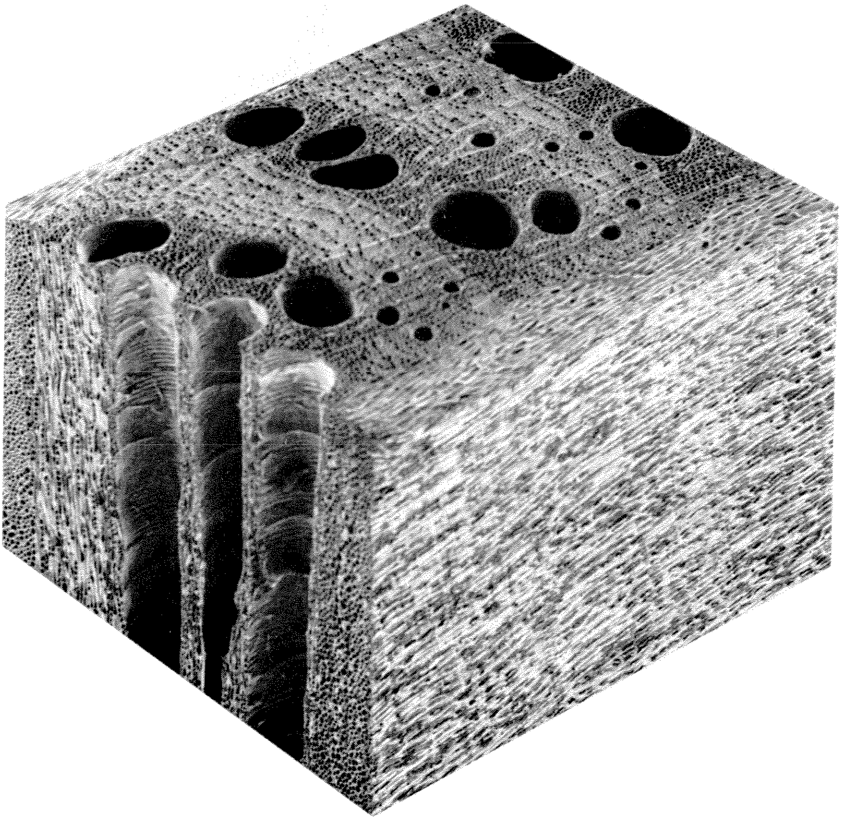
Tangential
Mag. ×1



Transverse
Mag. ×5

Bark
Mag. ×0.3

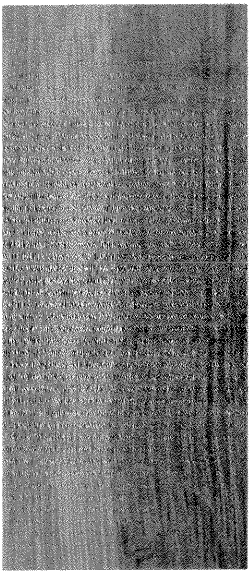
RESOURCE	
Volume *(million cubic feet)*	120
Percent of total hardwood volume on southern pine sites	0.2
STEMWOOD	
Specific gravity *(ovendry weight and green volume)*	0.625
Weight of bark-free stemwood when green *(lbs/ft³)*	66.0
Percent moisture content of green wood *(ovendry basis)*	69.1
BARK	
Specific gravity *(ovendry weight and green volume)*	0.644
Percent moisture content of green bark *(ovendry basis)*	52.2



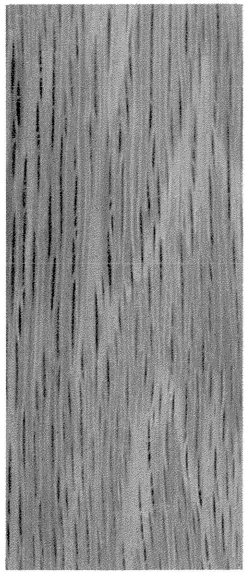
Mag. × 100

SOUTHERN RED OAK

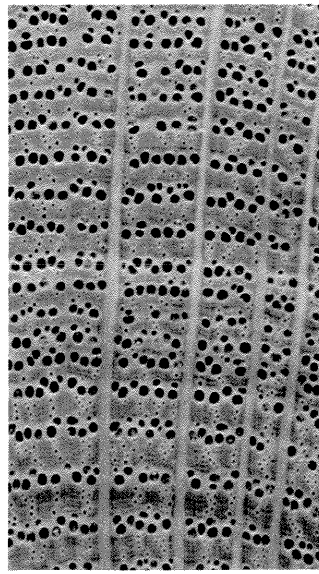
Quercus falcata Michx. var. *falcata*



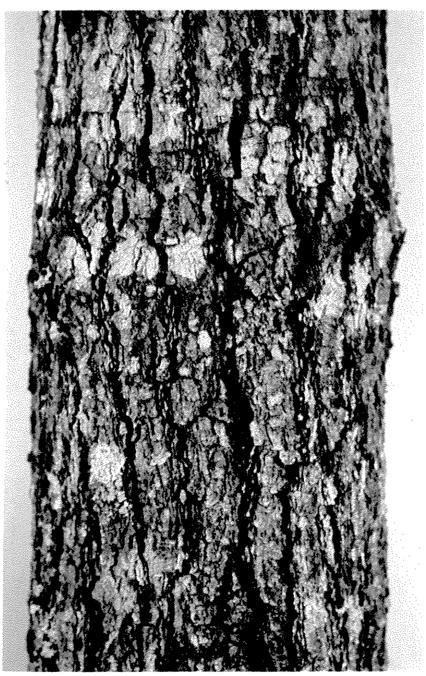
Radial
Mag. ×1



Tangential
Mag. ×1



Transverse
Mag. ×5



Bark
Mag. ×0.3

RESOURCE

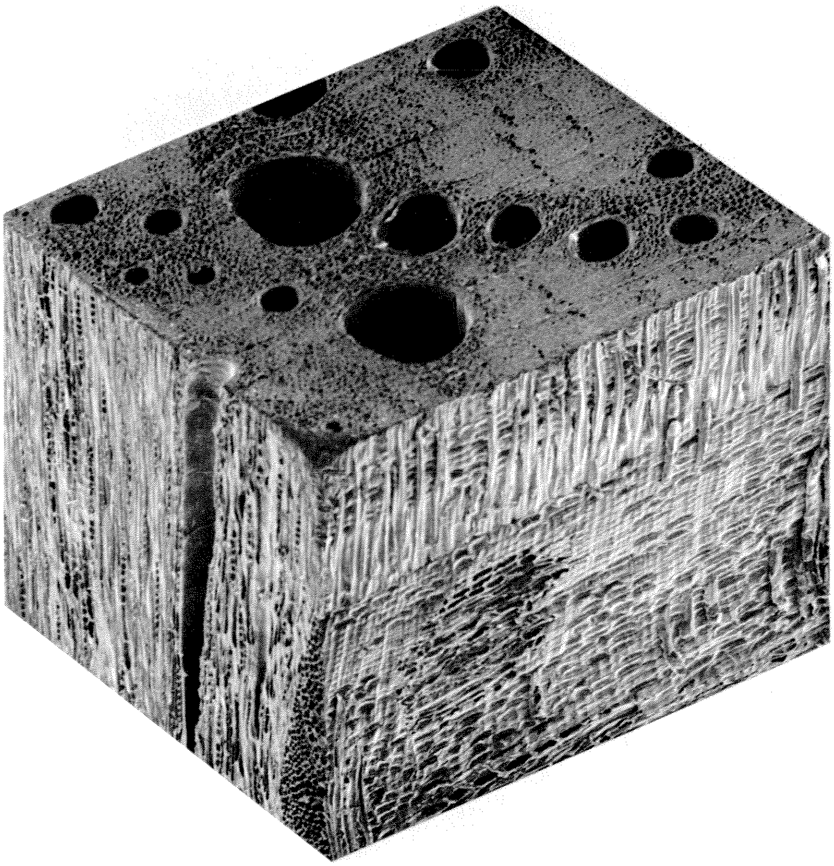
Volume *(million cubic feet)*	3994
Percent of total hardwood volume on southern pine sites	8.1

STEMWOOD

Specific gravity *(ovendry weight and green volume)*	0.609
Weight of bark-free stemwood when green *(lbs/ft^3)*	64.7
Percent moisture content of green wood *(ovendry basis)*	70.1

BARK

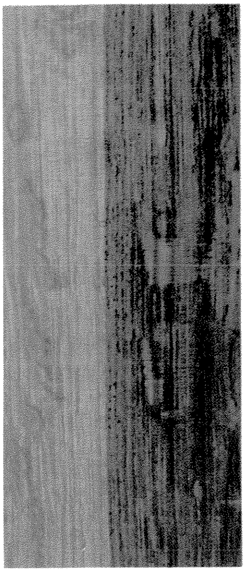
Specific gravity *(ovendry weight and green volume)*	0.601
Percent moisture content of green bark *(ovendry basis)*	52.9



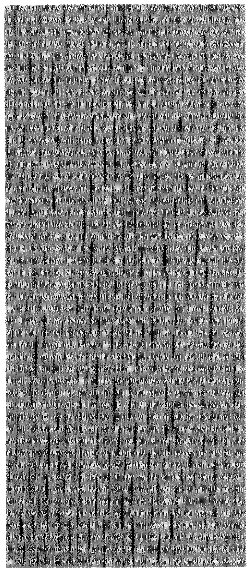
Mag. × 100

WATER OAK

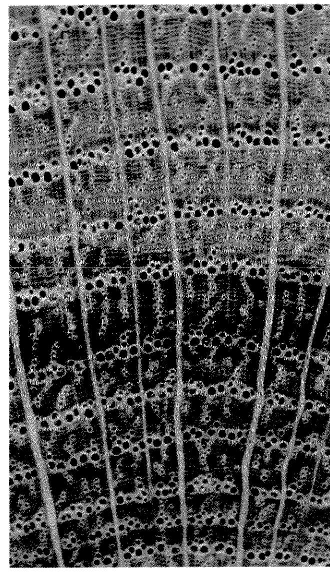
Quercus nigra L.



Radial
Mag. ×1



Tangential
Mag. ×1



Transverse
Mag. ×5

Bark
Mag. ×0.3

RESOURCE

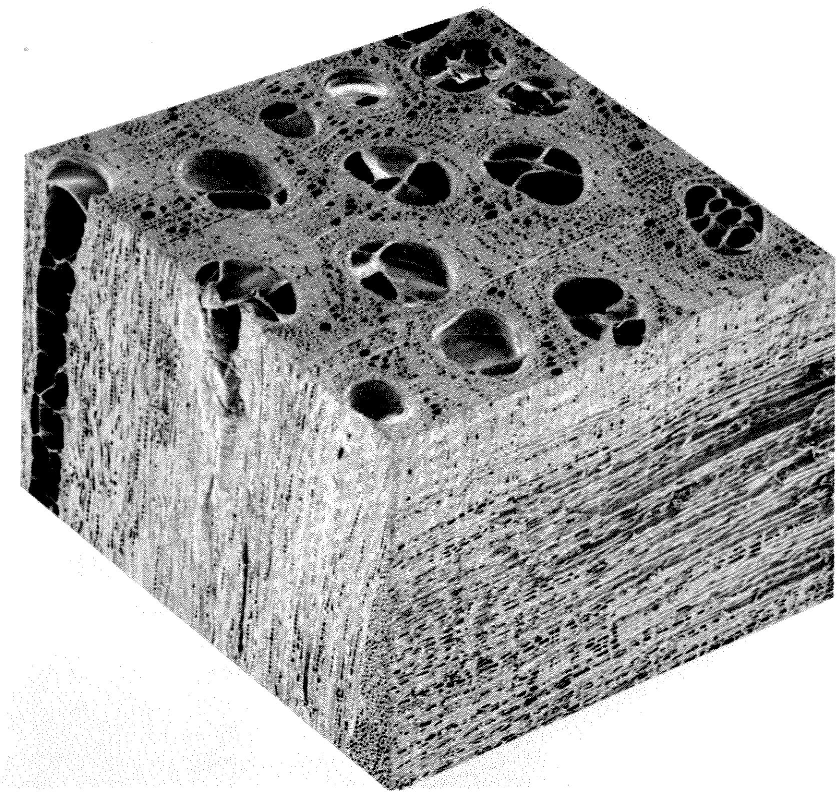
Volume *(million cubic feet)*	2332
Percent of total hardwood volume on southern pine sites	4.7

STEMWOOD

Specific gravity *(ovendry weight and green volume)*	0.587
Weight of bark-free stemwood when green *(lbs/ft³)*	63.6
Percent moisture content of green wood *(ovendry basis)*	73.6

BARK

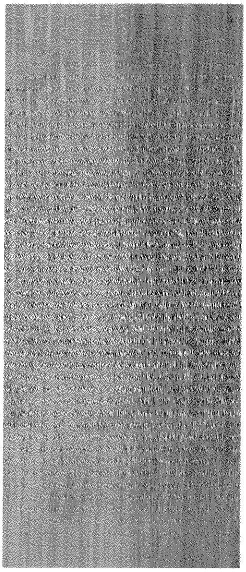
Specific gravity *(ovendry weight and green volume)*	0.628
Percent moisture content of green bark *(ovendry basis)*	54.4



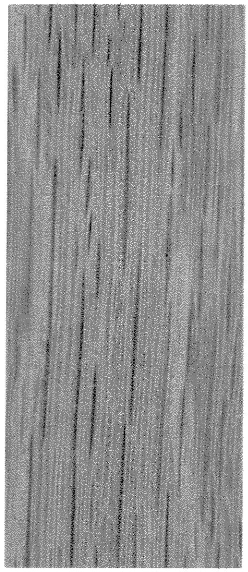
Mag. × 100

WHITE OAK

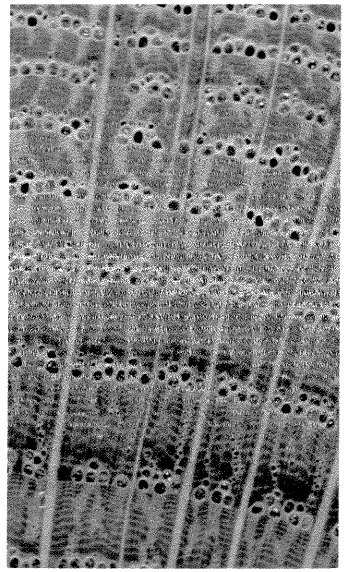
Quercus alba L.



Radial
Mag. ×1



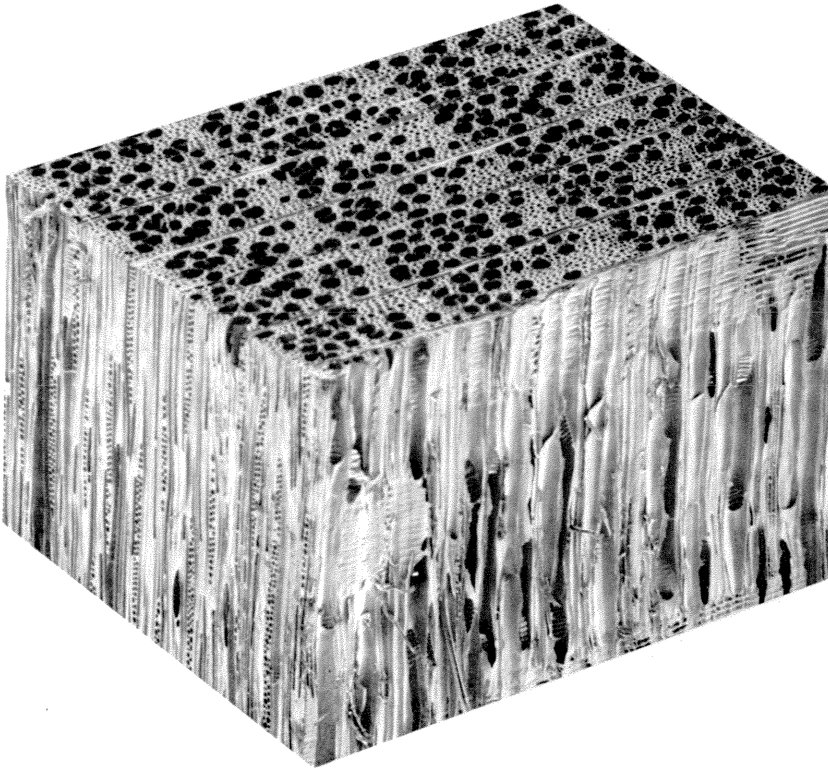
Tangential
Mag. ×1



Transverse
Mag. ×5

Bark
Mag. ×0.3

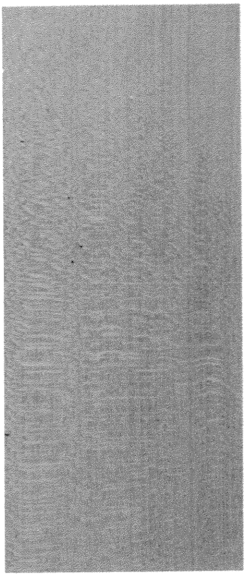
RESOURCE	
Volume *(million cubic feet)*	6058
Percent of total hardwood volume on southern pine sites	12.3
STEMWOOD	
Specific gravity *(ovendry weight and green volume)*	0.665
Weight of bark-free stemwood when green *(lbs/ft³)*	67.2
Percent moisture content of green wood *(ovendry basis)*	61.9
BARK	
Specific gravity *(ovendry weight and green volume)*	0.543
Percent moisture content of green bark *(ovendry basis)*	58.1



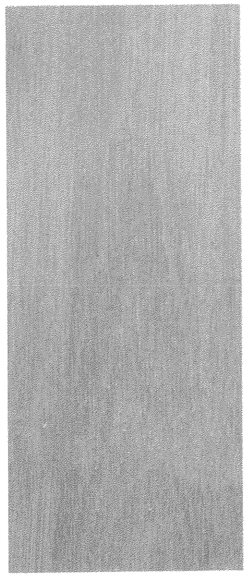
Mag. × 100

SWEETBAY

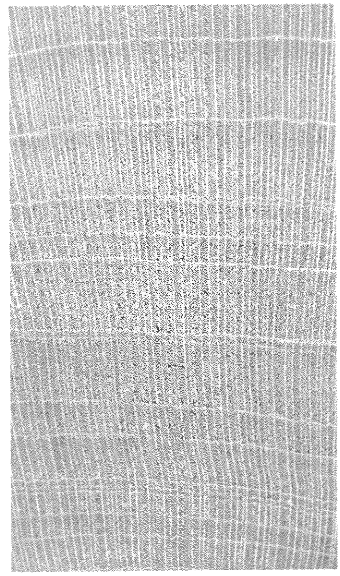
Magnolia virginiana L.



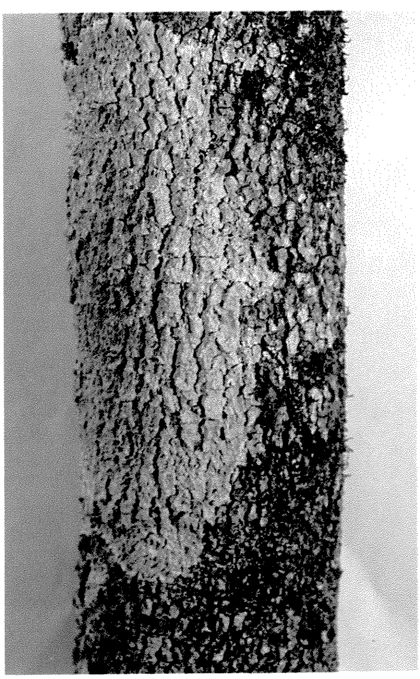
Radial
Mag. ×1



Tangential
Mag. ×1



Transverse
Mag. ×5



Bark
Mag. ×0.3

RESOURCE

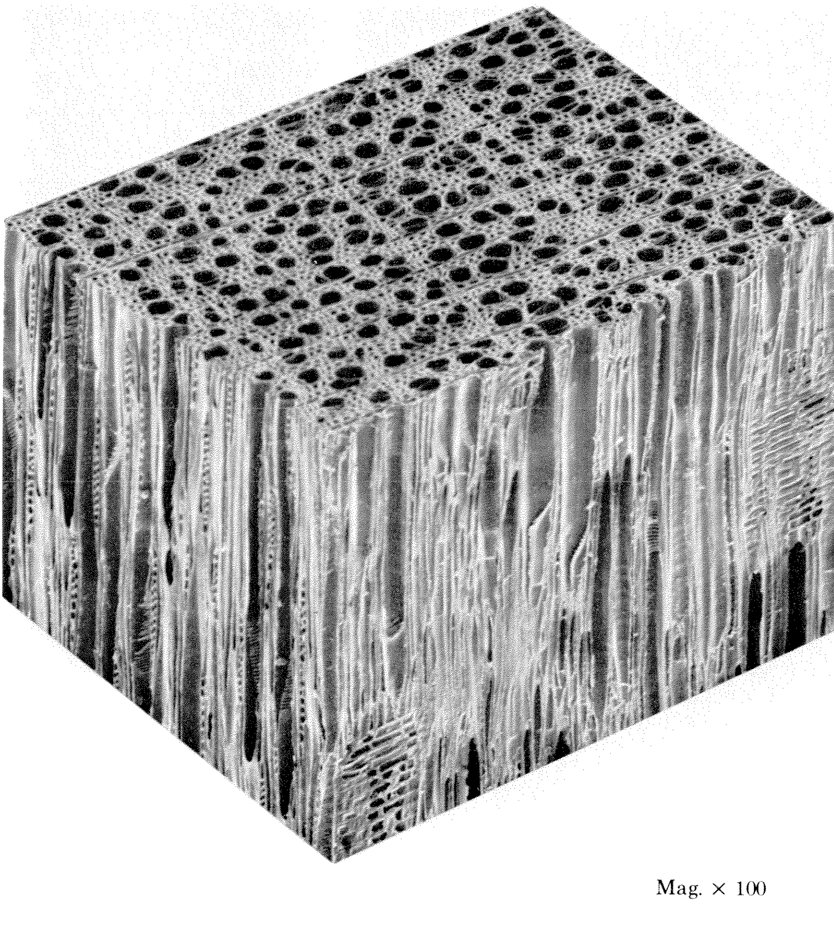
Volume *(million cubic feet)*	300
Percent of total hardwood volume on southern pine sites	0.6

STEMWOOD

Specific gravity *(ovendry weight and green volume)*	0.437
Weight of bark-free stemwood when green *(lbs/ft^3)*	54.8
Percent moisture content of green wood *(ovendry basis)*	100.8

BARK

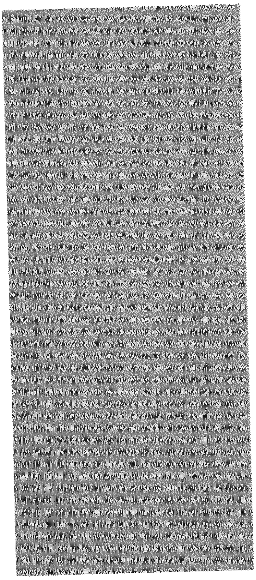
Specific gravity *(ovendry weight and green volume)*	0.440
Percent moisture content of green bark *(ovendry basis)*	102.1



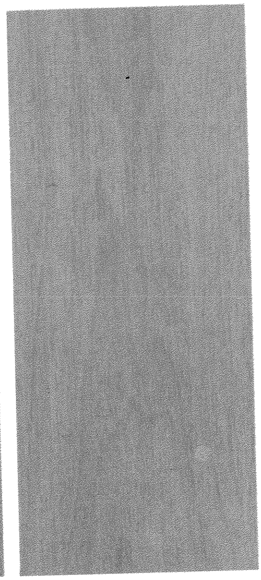
Mag. × 100

SWEETGUM

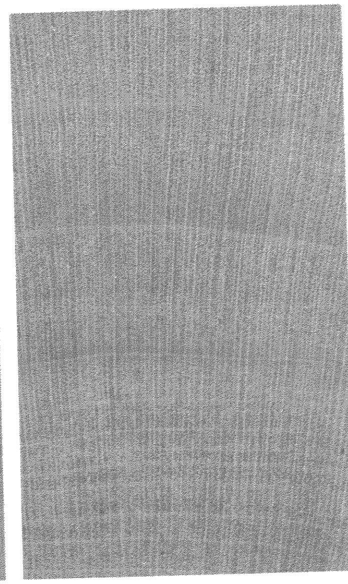
Liquidambar styraciflua L.



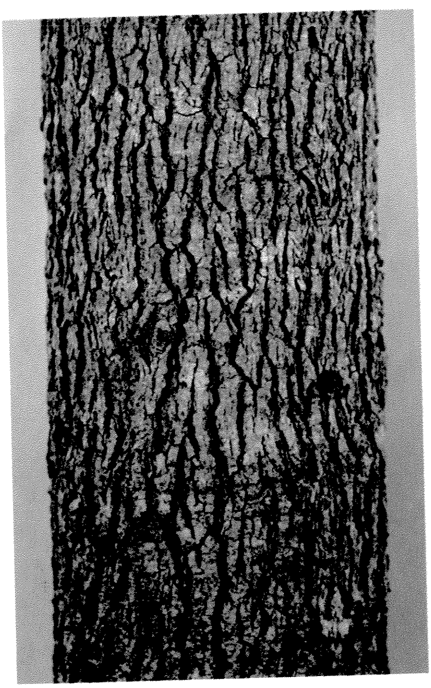
Radial
Mag. ×1



Tangential
Mag. ×1



Transverse
Mag. ×5



Bark
Mag. ×0.3

RESOURCE

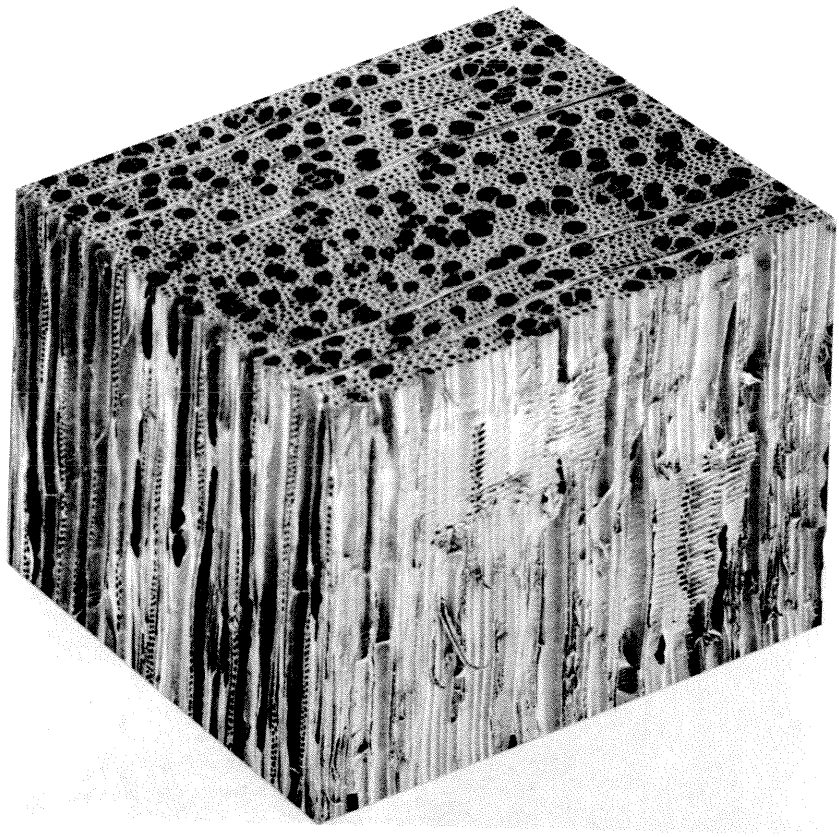
Volume *(million cubic feet)*	6508
Percent of total hardwood volume on southern pine sites	13.2

STEMWOOD

Specific gravity *(ovendry weight and green volume)*	0.453
Weight of bark-free stem-wood when green *(lbs/ft³)*	62.3
Percent moisture content of green wood *(ovendry basis)*	120.4

BARK

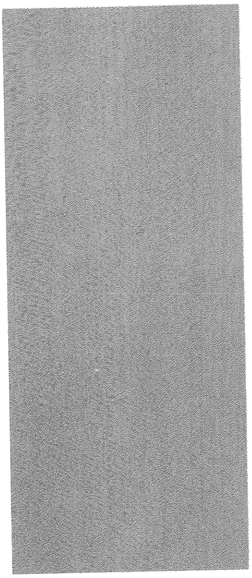
Specific gravity *(ovendry weight and green volume)*	0.369
Percent moisture content of green bark *(ovendry basis)*	89.3



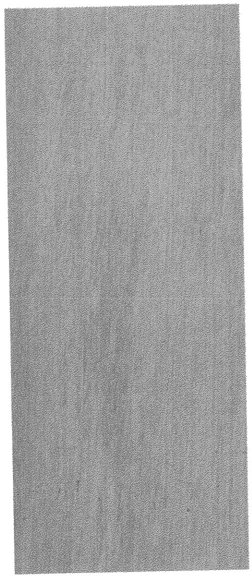
Mag. × 100

BLACK TUPELO

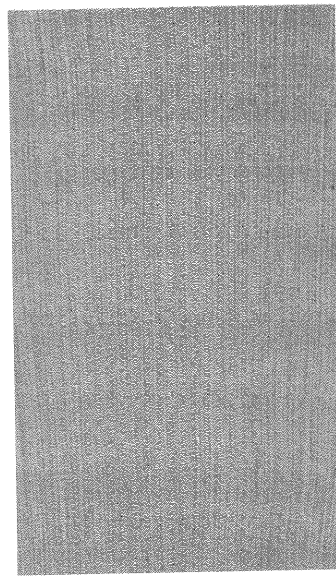
Nyssa sylvatica Marsh.



Radial
Mag. ×1



Tangential
Mag. ×1



Transverse
Mag. ×5

Bark
Mag. ×0.3

RESOURCE

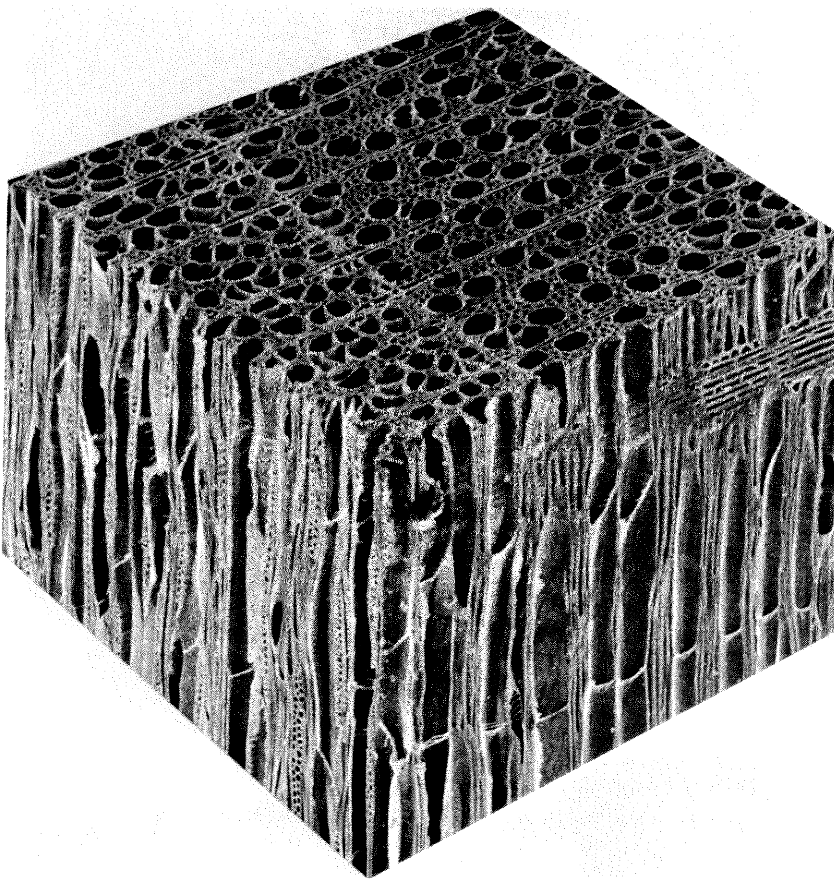
Volume *(million cubic feet)*	2710
Percent of total hardwood volume on southern pine sites	5.5

STEMWOOD

Specific gravity *(ovendry weight and green volume)*	0.500
Weight of bark-free stemwood when green *(lbs/ft³)*	59.3
Percent moisture content of green wood *(ovendry basis)*	90.0

BARK

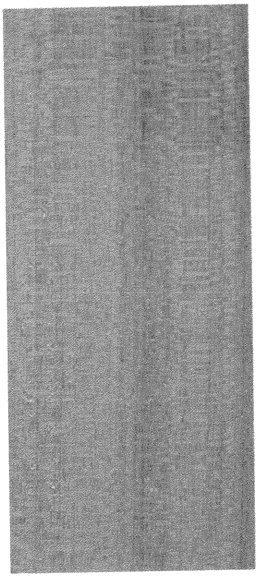
Specific gravity *(ovendry weight and green volume)*	0.428
Percent moisture content of green bark *(ovendry basis)*	69.8



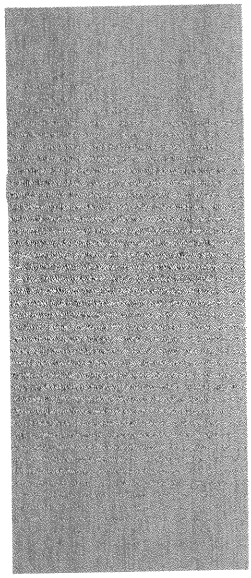
Mag. × 100

YELLOW-POPLAR

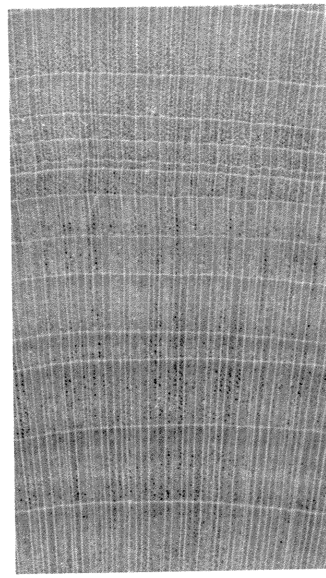
Liriodendron tulipifera L.



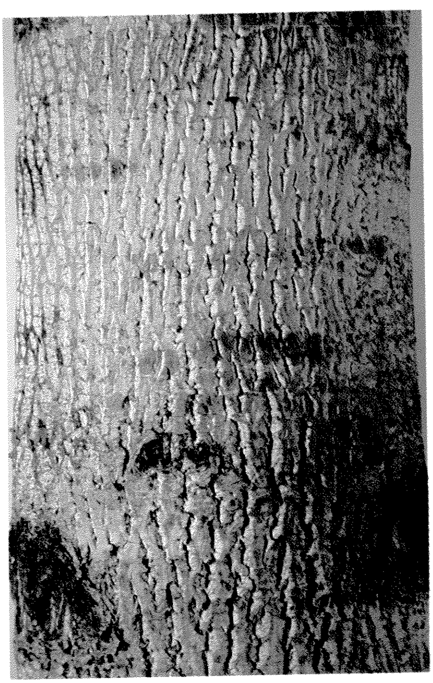
Radial
Mag. ×1



Tangential
Mag. ×1



Transverse
Mag. ×5



Bark
Mag. ×0.3

RESOURCE	
Volume *(million cubic feet)*	3421
Percent of total hardwood volume on southern pine sites	7.0
STEMWOOD	
Specific gravity *(ovendry weight and green volume)*	0.395
Weight of bark-free stem-wood when green *(lbs/ft^3)*	52.2
Percent moisture content of green wood *(ovendry basis)*	111.7
BARK	
Specific gravity *(ovendry weight and green volume)*	0.390
Percent moisture content of green bark *(ovendry basis)*	125.8

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Provides a pictorial description of the structure and appearance of 23 pine-site hardwoods, an overview of hardwood anatomy, and data on the resource and certain important physical properties of stemwood and bark.

Additional keywords: Southern hardwoods, anatomy, structure, color, appearance, wood properties, bark properties.

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