Commercial Timbers of West Africa

EDWARD S. AYENSU

and

ALBERT BENTUM

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ABSTRACT

Ayensu, Edward S., and Albert Bentum. Commercial Timbers of West Africa. *Smithsonian Contributions to Botany*, number 14, 69 pages, 28 plates, 1974.—The xylem anatomy of 28 species of commercially and potentially commercial timbers of West Africa is described together with information pertaining to seasoning qualities, durability and working properties, as well as the uses of wood. A comprehensive discussion on the mechanical properties, establishing the methodologies for evaluating the potential utilization of these woods, has been included. Shrinkage and swelling in wood have always presented problems in the utilization of woods. A discussion relating to the differences among (a) moisture content change and shrinkage, (b) the effect of drying conditions on shrinkage and (c) the variation in shrinkage in different species is presented. To aid both beginning students and to refresh the minds of practicing wood technologists, a glossary of the principal terms used in describing the minute features of timbers has also been added.

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Edward S. Ayensu and Albert Bentum

Introduction

In several developing countries the tendency to concentrate on using a few well-known woods for internal consumption and for export has virtually killed every initiative by students of wood technology to explore the numerous potentially commercial woods available in the forests. In West Africa, for example, the mere mention of "commercial timbers" focuses attention on the African mahogany and the African white wood. In recent years, however, attempts have been made by the forest products institutes and wood technologists to explore the utility of every available timber in developing countries.

This work includes the anatomical descriptions of both the known commercial timbers and many potentially commercial woods of West Africa. Other information, such as the habitat of the trees, the general distributional range, durability, working qualities, and the effects of seasoning, as well as the known uses of each species, is included. Apart from xylem anatomy, two major areas that concern wood technologists are the mechanical properties and the shrinkage and swelling of woods. In order to aid students we have included general accounts on these topics.

The accompanying photomicrographs are intended to help in the microscopic identification of the secondary xylem in laboratory work.

We are most grateful to Dr. David B. Lellinger and Ms. Cynthia Ostroff for reading the manuscript and for their most useful suggestions.

Mechanical Properties of Wood

In West Africa there are large areas of unexploited tropical forests with substantial volumes of lesser known timber species. In order to evaluate the potential utilization of those species, a knowledge of their properties is an absolute necessity for feasibility studies on the establishment of wood industries.

Tests are performed in accordance with international standards recommended by the Third Conference on Wood Technology under FAO auspices. The standard tests, usually conducted on clear specimens that are 2 × 2 cm (2 × 2 in) in section, are the static bending, compression parallel to grain, compression perpendicular to grain, impact bending, hardness (or Janka indentation), shear parallel to grain, cleavage, and tensile tests.

All these tests must record the direction in which the sample is tested, for, owing to the anisotropic nature of wood, any figure denoting the strength of a piece of timber is valueless unless the direction relative to the grain in which the tests were made is definitely stated (Henderson, 1939:77).

Data from these tests afford comparisons among various species and allow the establishment of correct strength functions, which are used in conjunc-

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tion with test results of structural size timbers to furnish the basis for fixing allowable stresses.

Generally, three important properties are computed under each test; they are the modulus of rupture, the load to the elastic limit, and the modulus of elasticity. Other special values demanded by special use may also be computed.

The modulus of rupture is the maximum load (weight) the test specimen will bear in the center when the two ends are supported. For any timber, a characteristic figure is obtained from the test results, which enables comparison to be made with any other kind of timber, and from which the size of beams for different structural purposes can be computed. The modulus of rupture is considered to be, in some respects, the average measure of the stress to which the wood fibers are subjected at the moment of their failure.

The elastic limit shows what load a beam can safely carry without any permanent deformation. When a beam carries a load below this limit, it will regain its previous position undeformed when the load is removed; should the load be in excess of the limiting value, the fibers will be distorted and the wood will not regain its original shape.

The modulus of elasticity gives an indication of the stiffness of the timber and is a theoretical figure expressing the load required to stretch a section 1 cm^2 (1 in^2) to double its length (Henderson, 1939:83). The speed with which the load is applied in the following tests is very important. As long as the limit of elasticity is not reached, the speed is not too important. However, above the limit of elasticity the rate of loading affects the strength, so that in all tests the loading must be continuous and at a standard rate.

Properties of the wood such as strength, hardness, tension, and compression are significantly affected by moisture content. As moisture content increases these values decrease, although not to the same extent. For example, compression values decrease to a lesser extent with increase in moisture content than do tension values. Average moisture content while testing must, therefore, be stated so that, where necessary, corrections may be made in the calculations if they differ appreciably from standard test-pieces.

The static bending test, by international requirements, must be conducted on specimens having a span-depth ratio of 1:14. Center loading must be used for this test. This means that the two supports must be 28 cm (28 in) apart, and the cross-section of the small, clear specimens must be 2 cm^2 (2 in^2). During the test the load is applied at one point in the center and gradually increased until the specimen fails. For actual test procedure the reader is referred to standard test procedures described in the British Standard 373, *Methods of Testing Small Clear Specimens of Timber* (published by the British Standards Institution, 1957), and *Wood, Wood Preservatives and Related Materials* (published by the American Society for Testing Materials).

The laboratory tests are carried out on small straight-grained specimens chosen for their freedom from defects. It is practically impossible to come across pieces of wood more than 20 or 30 cm long without variations in grain, texture, and other properties, all of which may greatly affect the strength of wood. Figures obtained from these laboratory tests must, therefore, be applied with care to actual structural timbers.

Compression tests are carried out both parallel and perpendicular to the grain. Compression parallel to the grain specimens is required to be 2 × 2 × 6 cm (2 × 2 × 6 in). The load is gradually applied on the end until the specimen fails by buckling or cracking. The values from these tests are required for pit-props, columns in buildings and bridges, wagon spokes, etc.

Compression perpendicular to the grain specimens has the same dimensions, and the test is carried out in a somewhat similar manner. A rectangular plate is gradually pressed to the side of the block until the cells are crushed beyond recovery. Values from these tests are required for railway cross-ties and similar uses in which pressure is placed on the side face of the timber.

Impact test pieces are usually 2 × 2 × 30 cm (2 × 2 × 30 in). The specimen is supported on both ends, with the distance between the centers of the two supports being 24 cm (24 in) apart. The load is applied at the center of the test piece. A 3.3-lb weight is allowed to fall freely from successive heights which increase by regular intervals until either complete failure or deflection of 6 cm (6 in) has been reached. The data obtained from this test are used to compute the toughness value (the ability to withstand shocks) of timber used for sporting goods and other purposes for which toughness is needed.

The hardness test determines the load needed to press into the block a small steel ball 1.13 cm (0.444 in) in diameter to a depth one half its diameter. The load is applied continuously during the test at a speed of 0.25 in per minute. The figure obtained in this way indicates the resistance of the wood to penetration of foreign bodies and serves as a basis for comparison with other timbers.

Shear tests utilize a block of wood, usually 2 cm^3 (2 in^3), which is subjected to pressure in such a way that one-half of the block is slid over the other half. The maximum load is recorded and the apparent shearing stress is computed in kg/cm^2 (lb/in^2).

In compression and also in tension (tensile) tests, wood shows its maximum strength along the grain, but under shearing tests greater strength is shown across the grain. This may be explained by the fact that it is easier to slide wood fibers along one another than to shear them crosswise.

Cleavage tests indicate the strength per cm of width (or per inch of width) to resist splitting. The load is applied gradually but continuously until fracture occurs. The maximum load only is recorded.

Tensile tests of two types are usually conducted: tension parallel to the grain and tension perpendicular to the grain. The maximum loads recorded enable the resistance to tension or tensile strength in each case to be computed.

Shrinkage and Swelling in Wood

WHAT IS SHRINKAGE?—When we talk about shrinkage and swelling in wood we refer to the behavior of wood in relation to the changes in moisture content. For example, if a piece of wet wood is kept in the air it will lose moisture; on the other hand, if dry wood is kept in a moist, humid atmosphere, the wood will absorb moisture. Thus the moisture content of the wood will change with changes in the atmospheric conditions until the wood reaches a moisture content which is in equilibrium with the amount of moisture content in the surrounding atmosphere. The moisture content of the wood at this stage is known as the equilibrium moisture content (EMC).

The most important elements of the wood that play significant roles in these phenomena are the fibers (the structural elements in hardwoods) and the tracheids (the structural and conducting tissue in softwoods).

Most of the degrade (cracking and distortion), which often takes place during drying of timber, would not occur if shrinkage and the accompanying stresses could be eliminated. Although elimination of shrinkage is not possible, drying conditions can be controlled to keep degrade to a minimum. Changes of shape such as bowing, cupping, and twisting are sometimes aggravated by grain direction or method of sawing, i.e., whether flatsawn or quartersawn. Opening of glued joints and the sticking of drawers, windows, and doors may be caused by distortion or swelling as a result of changes in the moisture content of the wood.

MOISTURE CONTENT AND SHRINKAGE.—In freshly felled timber the moisture can be conveniently divided into two parts: the free water, which is held in the cell cavities, and the bound water, which is absorbed into the cell walls. During drying all the free water in the cell cavities is gradually removed and the wood is said to have reached the fiber saturation point. The remaining moisture is contained in the cell wall in the form of bound water. Based on the weight of dry wood the equilibrium moisture content at this point usually varies between 25 and 30 percent of the original free and bound water content. In most cases, the loss of free water in the cell cavities does not affect the structure of the wood. When, however, drying progresses below the fiber saturation point and bound water is removed from the cell walls, appreciable shrinkage of the wood occurs, and changes in other physical characteristics, such as strength and electrical resistance, take place (Johnston, 1970). To better understand this, it is necessary to consider the structure of the cell wall. It is made up of small particles of cellulose strands called microfibrils, which are separated by a film of water. As the water is removed, the microfibrils move closer together and the sum total of these small contractions is the shrinkage observed. Generally speaking, then, normal shrinkage does not take place during drying until the fiber saturation point is passed.

DRYING CONDITIONS AND SHRINKAGE.—When moisture evaporates from the surface of a piece of wet wood, there is a lowering of moisture concentration in the outer layers. This causes moisture to move from the wetter interior (a region of high concentration) towards the drier surfaces. The structure of wood, however, is such that it offers some resistance to the passage of moisture; in some species this resistance is considerable. If evaporation from the surfaces occurs at a faster rate than the flow of moisture from the interior zones to these surfaces, the moisture gradient within the wood will increase. If the outer layers are dried below the fiber saturation point, they will have a marked tendency to shrink. This shrinkage is resisted by the wetter interior, so that a state of stress develops with the outer layers in tension and the inner core in compression. If the stresses become sufficiently severe, the outer layers may break (surface checking) or they may become stretched without breaking. In this latter case the wood is said to be case-hardened (Johnston, 1970).

The rate at which moisture moves in the wood depends on (1) the relative humidity of the surrounding air, (2) the steepness of the moisture gradient, and (3) the temperature of the wood. The difference between the relative humidity of the air and the moisture content in the wood is of utmost importance. Low relative humidity increases the capillary flow of moisture from the wood and stimulates diffusion of water by lowering the moisture content at the surface (Panshin and De Zeeuw, 1964:171).

Air has a definite maximum capacity for holding water vapor at a given temperature. The partial pressure that may be exerted by the vapor at the given temperature is referred to as the saturation vapor pressure. The total pressure of a mixture of air and water vapor is the sum total of the partial pressures exerted separately by the air and vapor. If the water vapor pressure in a quantity of air is less than saturation vapor pressure, then that air is capable of taking up more moisture and the difference between the actual vapor pressure and the saturation pressure can be regarded as the "drying potential" of the air. (The relation of the actual vapor pressure to the saturation pressure, expressed as a percentage, is known as the relative humidity of the air; Johnston, 1970). Therefore, for wood to dry to the point where shrinkage takes place, i.e., at and below fiber saturation point, drying potential of the air must exist. It is obvious that when this drying potential is zero, evaporation of moisture and, therefore, drying will cease.

The capacity of air to hold water vapor increases rapidly with a rise in temperature. Its drying potential at any given absolute humidity similarly increases with increasing temperature.

In swelling, the wood absorbs moisture and the reverse process takes place. The vapor pressure at the wood surfaces is lower than the vapor pressure of the air. The rate of absorption of moisture by the wood depends largely on the magnitude of the vapor pressure difference existing.

If a piece of absolutely dry wood is placed in a completely saturated atmosphere, it will gradually absorb water vapor from the air up to about 15 percent of its dry weight. In half saturated air (50% relative humidity), the piece of wood will absorb half that amount, or 7½ percent of its dry weight. Both the amount of moisture absorbed and the amount of swelling is, therefore, proportional to the humidity of the air (Henderson, 1939:67). It is thus clear that, during evaporation (drying) and absorption (swelling), the magnitude of the vapor pressure difference existing at a particular time is very important.

Shrinkage Due to Grain.—Wood, being anisotropic, has varying shrinkage in all three directions. Along the grain of a straight-grained board, shrinkage is usually negligible for any practical purpose except in reaction wood. Shrinkage across the grain, however, is appreciable, even though it is not uniform.

In the flatsawn or tangential direction, shrinkage is greater than in the radial direction, the ratio of shrinkage being generally about 2:1. This ratio may, however, vary in different species. In addition to the major wood components, such as vessels and fibers, which have their axes more or less vertical in the standing tree, there are the medullary rays, which run in a radial direction and have axes at right angles to the fibers. During drying below fiber saturation point, the rays tend to shrink very little in length and so tend to restrain the shrinkage of wood in the radial direction. Hence shrinkage is less in the direction of the rays than in the direction of the growth rings.

Shrinkage among Species.—It is a well-known fact that some woods shrink much more than others

TABLE 1.—*Approximate average shrinkage values from green to oven-dry* (data from Forest Product Research Institute, Kumasi, Ghana)

Terminalia ivorensis (Amire)	*Percentage of shrinkage*	
	Radial	*Tangential*
Tree No. 1*	2.049	3.933
Tree No. 2	1.856	3.996
Tree No. 3	3.407	5.232
Tree No. 4	2.685	5.173
Tree No. 5		
Specimen 1**	1.770	3.920
Specimen 2	2.080	3.990
Specimen 3	2.490	3.970

* Tree Nos. 1 and 2 are from the same locality.

** The specimens were taken at the same level in the tree but from different positions.

TABLE 2.—*Approximate average shrinkage values from green to 12 percent moisture content* (data from FPRL, 1956)

Species and local name	*Percentage of shrinkage*	
	Radial	*Tangential*
Mitragyna ciliata (Anura)	3.5	6.5
Afrormosia elata (Kokrodua)	1.5	2.5
Tristania conferta (Brush Box)	4.0	7.0
Nauclea diderrichii (Opepe)	0.9	1.8
Mansonia altissima (Mansonia)	1.5	3.0
Cylicodiscus gabunensis (Okan)	3.0	3.5

(Tables 1 and 2). Shrinkage also varies from tree to tree in the same species and in wood taken from different parts of the same tree. Generally, the denser the wood, the greater the shrinkage, although there are many exceptions to this rule, e.g., the genus *Eucalyptus,* in which the denser wood normally shrinks very little, indicating no correlation between density and normal shrinkage.

Any shrinkage figures must be used, however, with care since this property as indicated above can be influenced by a number of factors. Even average figures based on many samples indicate only general behavior, and not necessarily that of an individual sample.

COLLAPSE.—Whereas shrinkage implies the normal contraction of the wood due to loss of moisture, abnormal shrinkage may be caused by the phenomenon known as "collapse," in which, due to very large liquid tension generated by water leaving the cell cavity, the cell walls are drawn together or collapse. The phenomenon can be compared to a canvas water hose collapsing as the water is emptied from the hose.

The two phenomena must be recognized as being distinct, for, whereas normal shrinkage occurs below the fiber saturation point (25–30% MC), collapse always occurs at moisture contents high above the fiber saturation point.

SHRINKAGE IN REACTION WOOD.—Shrinkage is also affected by the presence of growth abnormalities due to compression or tension. Lumber containing compression wood has a great tendency to bend, twist, and split. Differential shrinkage in the longitudinal direction between normal and reaction wood accounts for this. Compression wood exhibits extremely high longitudinal shrinkage which may, in certain cases, reach as high as 6 to 7 percent, as compared to the negligible amount of shrinkage (0.1 to 0.2%) in this direction in normal wood adjacent to it (Côté, 1965:392).

Pillow and Luxford (1937:17) reported that radial and tangential shrinkages in compression wood were less than in normal wood.

Although in tension wood longitudinal shrinkage is not as great as in compression wood, it may be as high as 1 percent, which is considerably higher than the longitudinal shrinkage of normal wood. Another industrial problem related to the seasoning of tension wood from the green condition is collapse (Dadswell and Wardrop, 1955). Some species have a greater tendency to collapse than others, but this tendency is always increased by the presence of tension wood.

THE MEASUREMENT OF SHRINKAGE.—Wood shrinkage is expressed as a percentage of its green size in the tangential, radial, and longitudinal directions when dried to a particular moisture content (MC). The standard method is to calculate the shrinkage when the wood is dried to 12% MC or to the oven-dry condition (0% MC). Shrinkage is sometimes also expressed on a volumetric basis, that is, as a percentage loss of the original volume.

Let us consider the following examples: Suppose a flatsawn board measured 20 cm long when green, and when dried to 12% MC it measured 19 cm. The percent shrinkage would be as follows:

$$\frac{\text{loss in size}}{\text{green size (original size)}} \times 100\%,$$

which will be $$\frac{20 - 19 \text{ cm}}{20 \text{ cm}} \times 100\%,$$

$$= \frac{1}{20} \times 100\%$$
$$= 5\% \text{ at } 12\% \text{ MC}.$$

Suppose in drying to 0% MC the size reduced further to 18.5 cm. Percent shrinkage at oven-dry would then be

$$\frac{\text{loss in size}}{\text{green size (original size)}} \times 100\%,$$

that is $$\frac{20 - 18.5 \text{ cm}}{20 \text{ cm}} \times 100\%$$

$$= \frac{1.5}{20} \times 100\%$$
$$= 7.5\% \text{ at } 0\% \text{ MC}.$$

In determining volumetric shrinkage the same principle applies. Usually the measurements of the three dimensions of a block of wood are taken using the vernier callipers at green and also at 12% MC or oven-dry. The volumes at both conditions (i.e., at green and at 12% MC or oven-dry) are calculated, and then the percent shrinkage determined as before. Sometimes the volume is determined by the amsler volume meter.

Since longitudinal shrinkage of a normal wood is negligible, approximate volumetric shrinkage of a piece of wood may be determined by adding together the tangential and radial percentage shrinkages.

Descriptions of Species Arranged by Families

PLATES 1–28

The top center portion of each plate represents the cross-section of the wood. Lower left: longitudinal tangential. Lower right: longitudinal radial.

PLATE 1

ANACARDIACEAE

Antrocaryon micraster A. Chevalier & A. Guillaumin

Standard trade name: Antrocaryon
Local name: Aprokuma (Ghana)

A common, large, dry closed-forest tree growing up to 150 ft high and 7–9 ft in girth. In Ghana, antrocaryon is quite common along the northern edge of the high forest zone. It is also present in the southern portion of the Boumfum Forest Reserve along the Kwahu Scarp and in the Worobong Forest Reserve. Its distribution ranges from Sierra Leone to the Cameroons. The leaves are terminal with entire, acuminate, pinnate leaflets in 9 or 10 opposite pairs. The flowers are small, numerous, and greenish white.

General Description.—The sapwood is greenish to yellowish white and the heartwood is grayish pink to reddish brown. The planed surface is lustrous. The texture is described as medium and it is straight-grained. The wood has neither a distinct taste nor odor. The air-dried wood is light weight and has an average weight of 31 lb/ft^3.

Seasoning.—This wood dries quite rapidly with slight distortion. British Forest Products Laboratory kiln schedule L is recommended (FPRL, 1956).

Durability.—The wood is not very durable and is also easily impregnated.

Working Qualities.—Although the wood is woolly when sawed, it generally works well with hand and machine tools. Nail and screw-holding qualities are good. The wood takes glue and responds to finishing treatments well.

Uses.—The timber is used for planks and for furniture. It is also used for the preparation of packing cases.

Xylem Anatomy.—Growth rings absent. Wood diffuse-porous. Vessels: solitary but with a few radial multiples of 3 to 5 small pores; circular in outline, rarely angular; average pore diameter 196μm, range 112μm–238μm; average vessel element length 560μm, range 366μm–666μm; vessel wall thickness 3μm–4μm; perforation plates exclusively simple; vessel element end wall inclination slightly oblique to transverse; intervascular pitting alternate, rather large. Imperforate tracheary elements: septate fiber tracheids, average length 1269μm, range 966μm–1465μm; fibers with very few simple pits on tangential walls. Vascular rays: heterogeneous, mainly multiseriate, generally 3 cells wide, 5 to 20 cells high, but biseriate and uniseriate cells also present; fusiform rays up to 10 cells wide containing intercellular canals. Axial parenchyma: paratracheal, scanty, cells containing dark amorphous deposits. Crystals: abundant, generally cubiodal, present in ray cells as well as in fibers. Special note: Intercellular canals occur in some rays.

PLATE 1

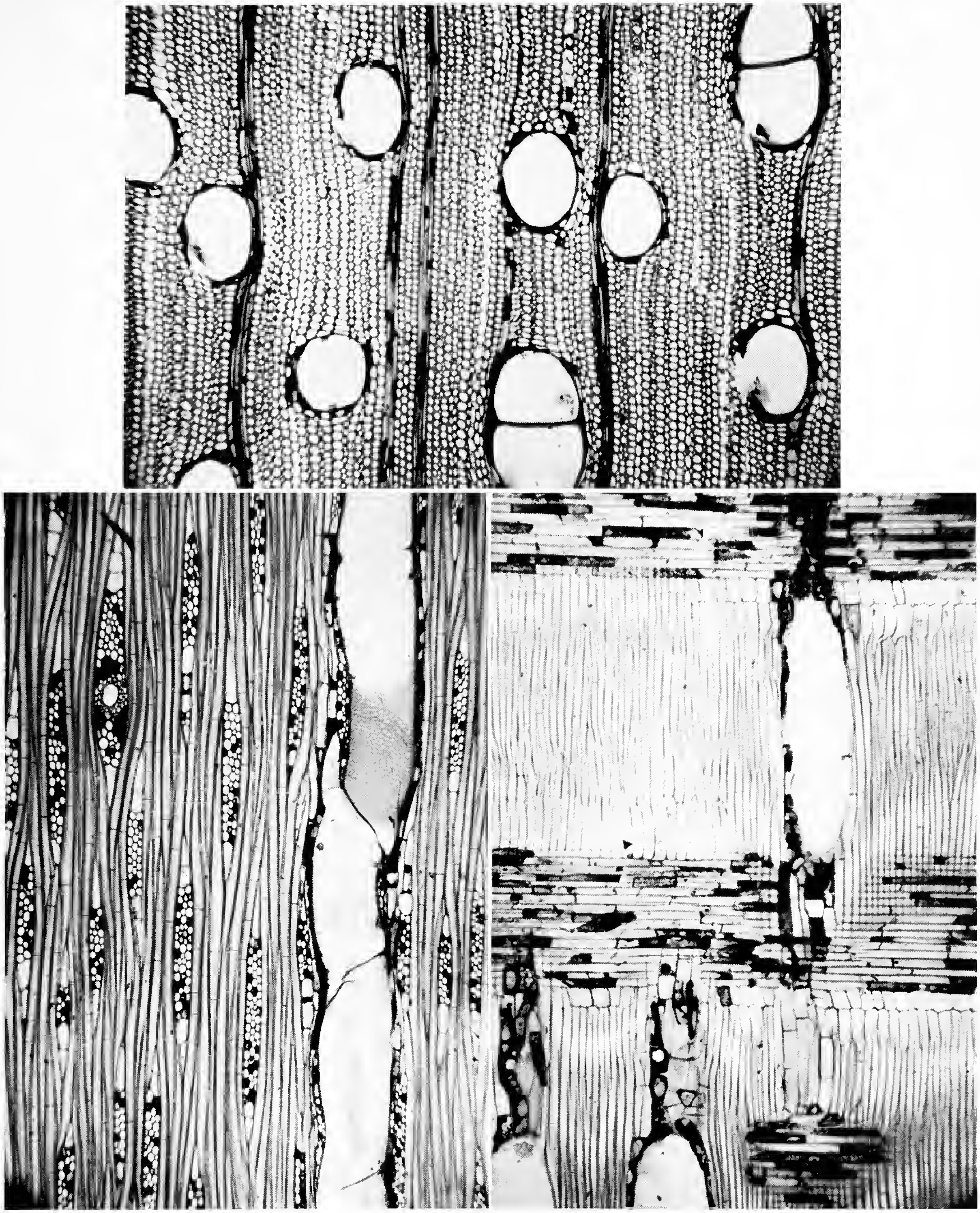


PLATE 2

BURSERACEAE

Canarium schweinfurthii Engler

Standard trade name: Canarium
Local names: Bediwunua (Ghana), Abel (French West Africa), Elemi (Nigeria)

An evergreen and deciduous forest tree growing to 120–160 ft high and 12–15 ft in girth. Although the trees are not very common, they can be found in the high forest zone and in the savanna-woodland. They are often located in the *Antiaris-Chlorophora* association. The leaves are pinnate, oblong or oblong-lanceolate, acuminate, generally in terminal whorls. The flowers are creamy white and are borne in axillary panicles.

General Description.—The sapwood is whitish, up to 3–4 in; the heartwood is pale pink darkening to light brown. The surface is highly lustrous and the wood is highly scented, especially when it is freshly cut. The texture is somewhat coarse and sometimes may appear woolly. The grain is often interlocked. The wood is light to medium, weighing 31–38 lb/ft ^{3} averaging 33 lb/ft ^{3} when seasoned.

Seasoning.—This wood dries quite easily either when air seasoned or kiln dried. Because of a tendency to warp, it is recommended that initial exposure should be at low temperatures.

Durability.—The wood is not very durable since it is easily attacked by pinhole borers and powder-post beetles. It is very resistant to impregnation, especially the heartwood by the open-process, but the sapwood is fairly permeable.

Working Qualities.—The wood is not very difficult to work when sharp edged tools are used. Sawing difficulties are encountered because of the presence of silica. The wood cuts well with rotary and veneer machines. It has good nail-holding properties and can be easily glued. Planing is comparatively easy and when the wood is brought to a good surface it takes a high polish.

Uses.—With an average exploitable girth of 8–10 feet, the wood is used for flooring, interior joinery, and furniture. Quarter-sawn material presents a decorative surface which, when suitably stained, can serve as a substitute for mahogany.

Xylem Anatomy.—Growth rings absent. Wood diffuse-porous; vessels mostly solitary or in radial multiples of 2 or 3 pores; elliptical to circular in outline; average pore diameter 210μm, range 98μm–280μm; average vessel element length 420μm, range 224μm–630μm; vessel wall thickness 2μm–4μm; perforation plates exclusively simple; vessel element end wall inclination slightly oblique to transverse; intervascular pitting alternate, apertures somewhat elliptical or slit-like. Imperforate tracheary elements: septate libriform fibers, average length 1540μm, range 1313μm–1875μm. Vascular rays: heterogeneous, mainly multiseriate, generally 3 cells wide, 9 to 20 cells high, few biseriate. Axial parenchyma: paratracheal, sparse, usually 1 or 2 cells ensheathing vessels. Tanniniferous substances: observed in ray cells as well as parenchyma cells.

Crystals.—Cuboidal, many, present in ray cells as well as fibers.

PLATE 2

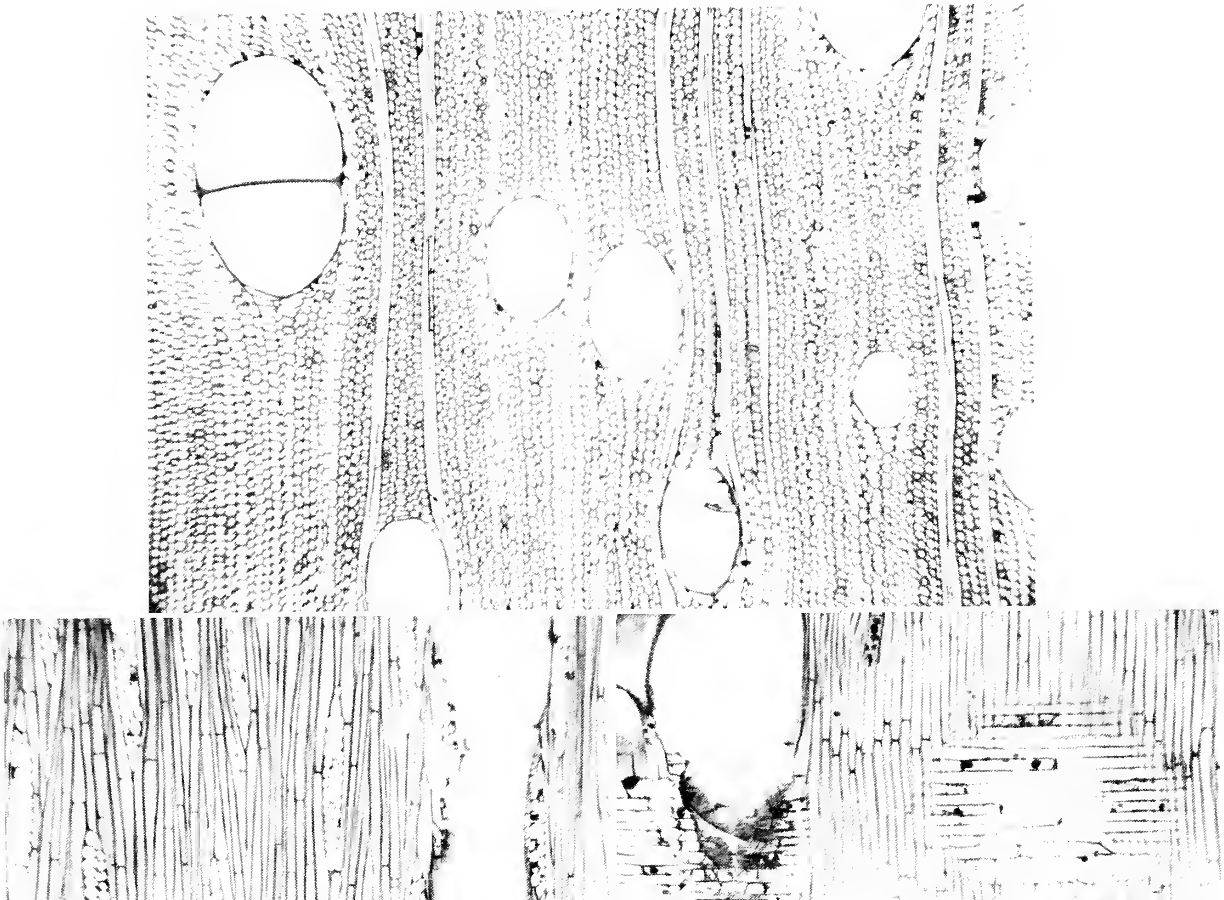


PLATE 3

COMBRETACEAE

Terminalia ivorensis A. Chevalier

Standard trade name: Idigbo
Local names: Amire (sometimes wrongly written "emeri") (Ghana), Framire (Ivory Coast)

A closed-forest tree growing up to 150 ft high and 15 ft in girth. Buttresses blunt and extending up the bole, which is frequently narrowly fluted. Leaves are obovate, acuminate and fairly puberulous. Flowers are in slender racemes 4–5 in long. They are white and fragrant.

General Description.—The light-weight timber has pale yellow to light brown sapwood with the heartwood slightly darker. The sapwood is usually 1–2 in thick. The grain of the timber is fairly straight but sometimes slightly interlocked. The texture is medium to coarse and the growth rings unusually distinct for a tropical timber. The weight varies between 30 and 39 lb/ft ^{3} and the average is about 34 lb/ft ^{3} seasoned. The green weight may be about 50 lb/ft ^{3}.

Seasoning.—The timber is known to season rapidly and well with little or no checking. British Forest Products Laboratory kiln schedule J gives good results (FPRL, 1956).

Durability.—Idigbo is durable. The sapwood is susceptible to attack by powder-post beetles. Data on its resistance to termite attack in West Africa are conflicting.

Working Qualities.—The timber works fairly easily with all hand and machine tools, having only a small blunting effect on their cutting edges. It finishes cleanly in other operations and stains and polishes well if the grain is suitably filled. It takes nails and screws well. It also glues satisfactorily.

Uses.—The timber, which is weather resistant, is used for house building, shingles, greenhouses, furniture, paneling, cabinet and interior work. It may also be used for plywood manufacture.

Xylem Anatomy.—Growth rings present. Wood ring-porous. Vessels: solitary or in pairs, rarely in threes; circular in outline, rarely angular; average pore diameter 119μm, range 40μm–160μm; average vessel element length 444μm, range 300μm–575μm; vessel wall thickness 3μm–4μm; perforation plates simple; vessel element end wall inclination slightly oblique to transverse; intervascular pitting alternate, rather small. Imperforate tracheary elements: nonseptate fiber tracheids, average length 1185μm, range 1000μm–1375μm; fibers with very few simple pits on tangential walls. Vascular rays: homogeneous, primarily multiseriate, 3 cells wide, 3 to 27 cells high, biseriate and uniseriate cells also present. Axial parenchyma: paratracheal, cells containing dark, amorphous deposits.

PLATE 3

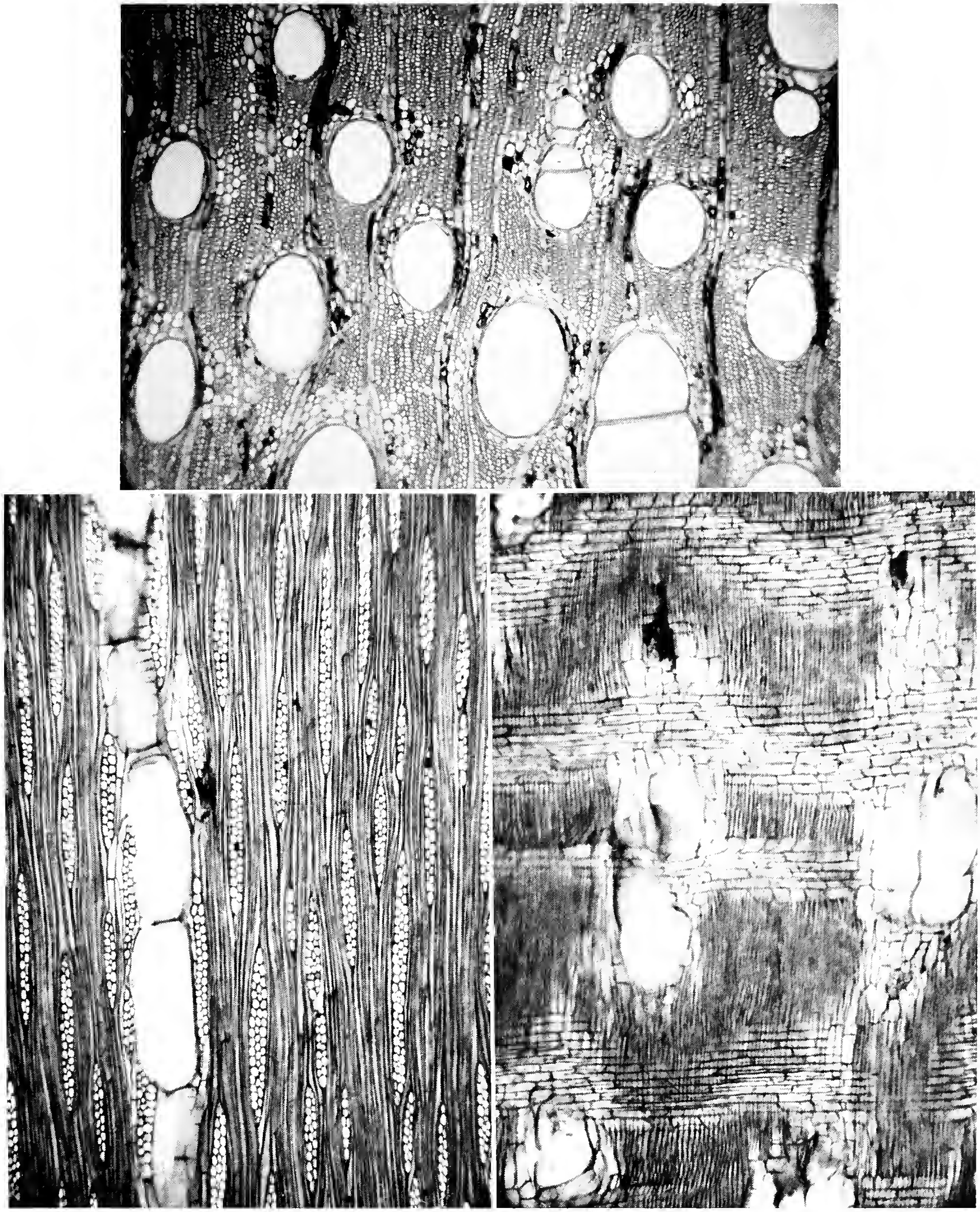


PLATE 4

COMBRETACEAE

Terminalia superba Engler & Diels

Standard trade name: Afara

Local names: Ofram (Ghana), Akom (Cameroons), Limbo, Chene-limbo, Frake, Noyer du Mayombe (French-speaking West Africa), Ka-ronko (Sierra Leone), Afara, Eji, Edo, Ojiloko (Nigeria)

A forest tree growing to 150 ft (rarely to 200 ft) high, with large, thin buttresses, a clean, straight bole, and a rather flat crown; bark ashy gray. Plants in the family Combretaceae are recognized by their exstipulate simple leaves, inferior ovary and often winged fruits.

General Description.—The timber is grayish white or light yellowish brown with no distinct demarcation between heartwood and sapwood. Depending on locality, some woods have dark walnut-brown zones in the center. Therefore, the timber is divided into two groups depending upon the proportion of the log containing the dark coloration.

"Limba clair" or "White afara" is the term applied to timber with little or no dark coloration and "Limba noir" or "Dark afara" is applied to logs with extensive dark colored wood. The wood varies in weight. The recorded range is 25–49 lb/ft ^{3}, seasoned, and the green weight is about 55 lb/ft ^{3}.

Seasoning.—Although seasoning properties are not fully known, it is believed to kiln-season similarly to *Terminalia ivorensis*. The wood is commonly straight-grained.

Durability.—Nondurable. Both sapwood and heartwood are susceptible to pin-hole borers; the sapwood is also susceptible to powder-post beetle attack. Preservative treatment in Nigeria indicates that afara is resistant to penetration of creosote by the open tank method but less resistant to treatment with aqueous solutions.

Working Qualities.—Generally the working properties of the wood are good. The straight-grained wood machines easily without pick-up. It holds nails and screws firmly, although there is sometimes a tendency to split. It is reported to have satisfactory veneer-cutting qualities by either the rotary or slicing methods. Afara finishes and glues well.

Uses.—Afara is used for furniture, school furnishings, shop fittings, and joinery. It has been tried as railway cross-ties in Ghana and has proved satisfactory.

Xylem Anatomy.—Growth rings present. Wood diffuse-porous. Vessels: solitary but with a few radial multiples of 2 to 5 pores; circular or ovate in outline; average pore diameter 175μm, range 150μm–250μm; average vessel element length 703μm, range 433μm–866μm; vessel wall thickness averages 6.0μm; perforation plates simple; vessel element end wall inclination mostly slightly oblique; intervascular pitting alternate. Vascular rays: homogeneous, uniseriate, varying greatly in height, 2 to 25 cells high. Imperforate tracheary elements: fiber tracheids, average length 1645μm, range 1432μm–1998μm, without pits. Axial parenchyma: apotracheal, banded, abundant.

PLATE 4

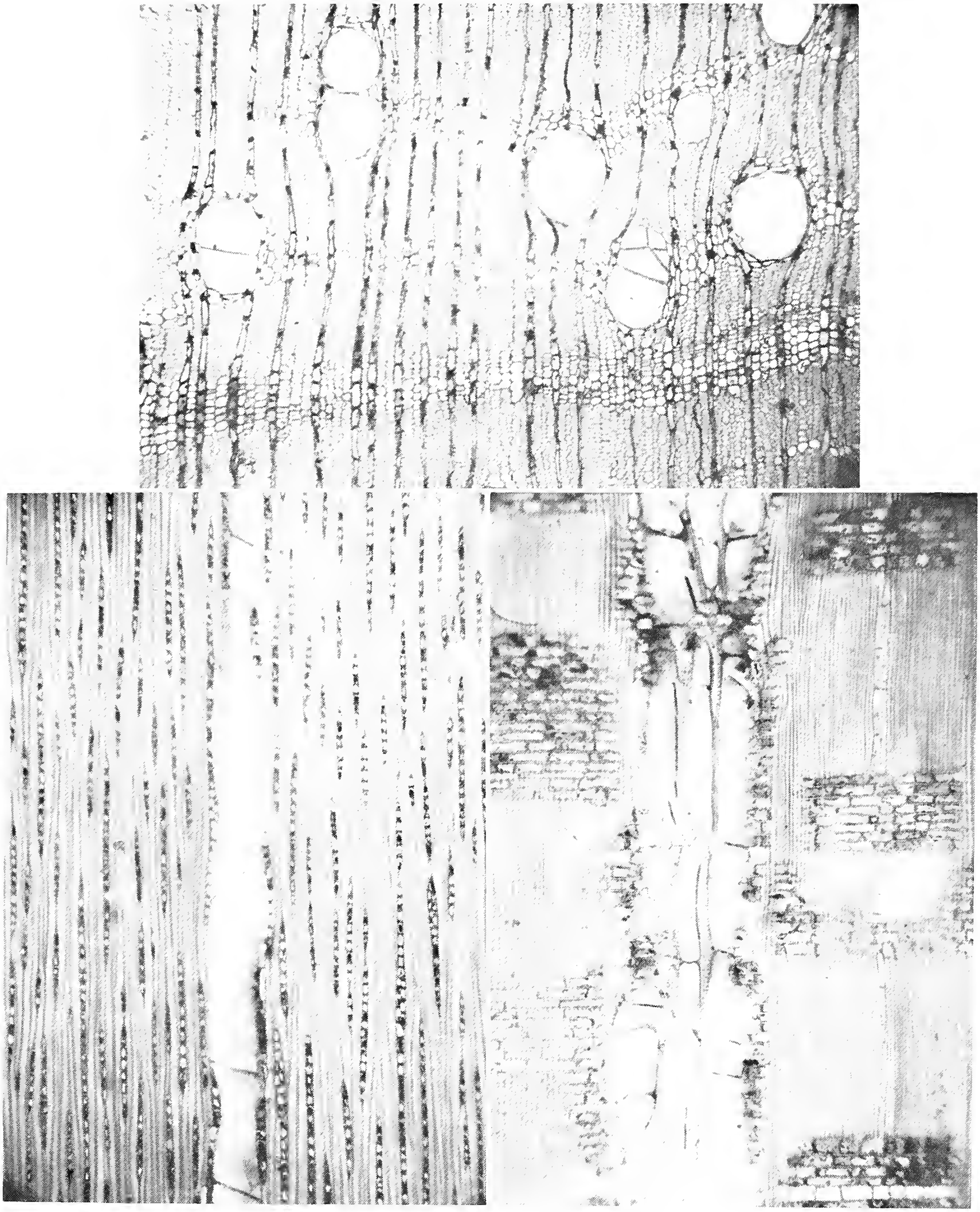


PLATE 5

LECYTHIDACEAE

Combretodendron macrocarpum (Palisot de Beauvois) Keay

(Syn. *C. africanum* Welwitsch ex Bentham)
Standard trade name: Essia
Local name: Esia (Ghana)

A tree up to 150 ft high, usually 3 ft in diameter with a 12 ft girth around the buttressing. The tree displays a well-developed crown and a straight bole with buttresses. The leaves are 6 × 3 inches, obovate, and glabrous, with shallowly serrate margins. The white flowers are abundant in short, axillary racemes.

GENERAL DESCRIPTION.—The reddish brown heartwood is clearly delineated from the pale white sapwood, which is 3 in or more thick. Essia has a powerful, unpleasant odor when freshly felled. It is hard and heavy, weighing about 44–50 lb/ft ^{3} seasoned and about 611 lb/ft ^{3} green. The grain is interlocked and the texture medium.

SEASONING.—Dries slowly and very prone to check and split.

DURABILITY.—Moderately resistant. Damage by ambrosia beetles is sometimes present. The sapwood is permeable but the heartwood is extremely resistant to preservative treatment.

WORKING QUALITIES.—The timber is hard to work with hand and machine tools, but logs are sawed with little difficulty. The wood planes to a smooth finish using a 20° cutting angle. It does not take nails easily and requires prebored holes. It glues satisfactorily and takes stains effectively. It polishes to a satisfactory finish when a filler is used.

USES.—Used locally for heavy and general construction work by the mining companies. It is not suitable for peeling.

XYLEM ANATOMY.—Growth rings absent. Wood is diffuse-porous, as in many tropical woods. Vessels: solitary and multiples of two to eight, minute pores which are circular to ovate in shape with a few irregularly angular. Average pore diameter 68μm, range 18μm–89μm; average vessel element length 435μm, range 340μm–600μm; vessel wall thickness 3μm–4μm; perforation plates exclusively simple; vessel element end wall inclination is oblique to transverse with intervascular pitting alternate and small.

PLATE 5

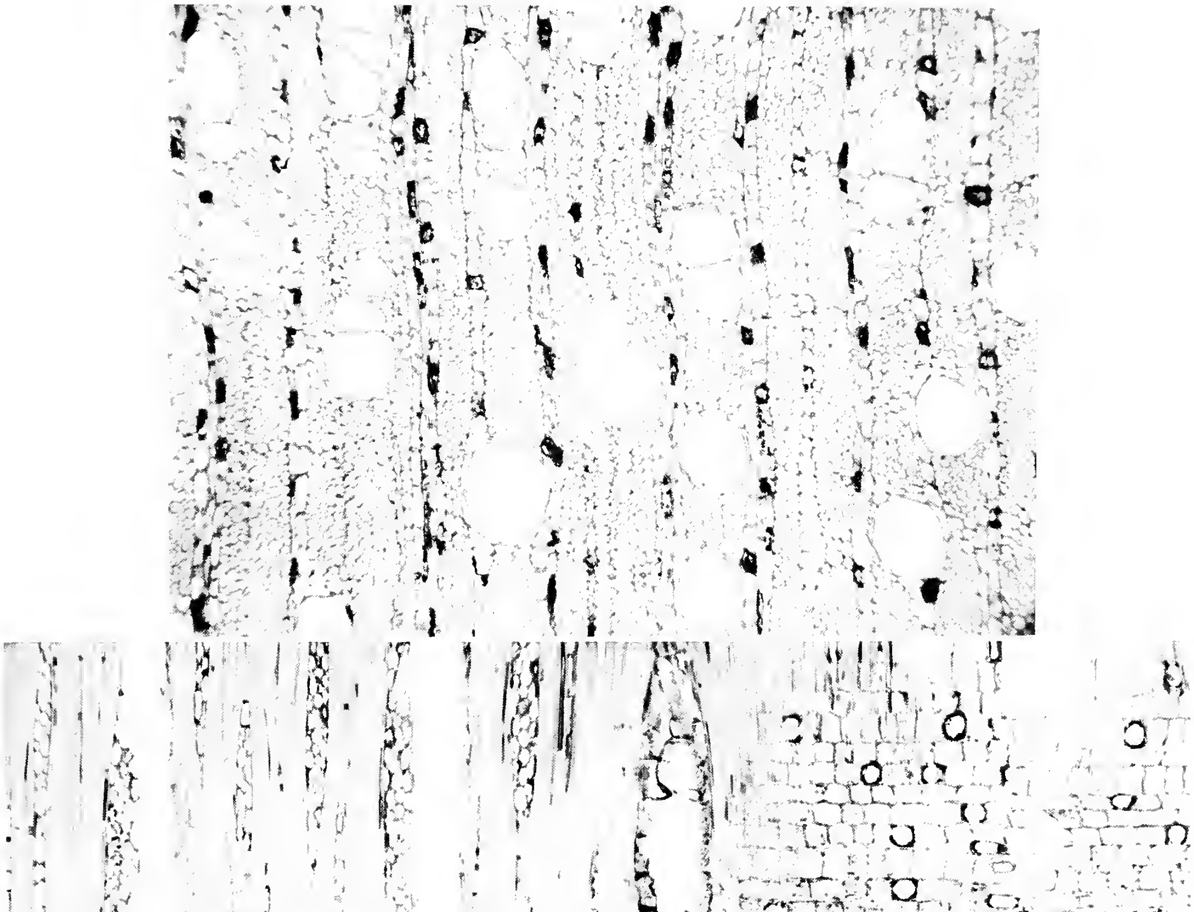


PLATE 6

LEGUMINOSAE

Copaifera salikounda Heckel

Standard trade name: Bubinga
Local name: Entedua (Ghana)

The tree grows to a height of about 140 ft and has a 9 ft girth; bark fibrous and wrinkled, leaves pinnate, leaflets 12–14, elliptic, sides unequal, emarginate at tip, shining surfaces, slender lateral nerves numerous. Flowers conspicuous and in simply branched panicles. Fruits are brownish, woody, flat and oval shaped.

General Description.—The wood is very hard and heavy. The heartwood is light reddish brown or darker in color veined with pink or red stripes. The sapwood is paler. The grain is often interlocked or wavy producing fine figures. The seed after the removal of the wavy red aril has an aromatic odor, especially when dry. The bark and the wood also give off a similar odor.

Seasoning.—The wood seasons slowly and would require mild drying conditions.

Durability.—Durable, but sapwood is susceptible to attack by insect borers. Little is known about its preservative qualities.

Working Qualities.—Works well with hand and machine tools though it has a tendency to chip off and to blunt their cutting edges. Glues and polishes well. It is advisable to prebore before nailing and screwing.

Uses.—*Copaifera* produces beautiful veneer for paneling, fine furniture and cabinets.

Xylem Anatomy.—Growth rings marked by bands of parenchyma. Wood diffuse-porous. Vessels: about half solitary, half radial multiples, of 2 to 5 pores, but mostly 2; frequency about 2–4 per mm ^{2}. Average pore diameter 202μm, range 142μm–265μm, average vessel wall thickness about 4μm–8μm; perforation plates simple. Intervascular pitting alternate, pit aperture slit-like, included. Intervascular spaces filled with gum. Vascular rays: homogeneous multiseriate, generally 2 or 3 cells wide, average length about 427μm, range 258μm–727μm. Axial parenchyma: paratracheal, vasicentric, rarely aliform, terminal bands about 5 to 10 cells wide concurring with intercellular canals. Fiber cells radially arranged; crystals present; chambered cells containing about 4 to 10 diamond-shaped crystals.

PLATE 6

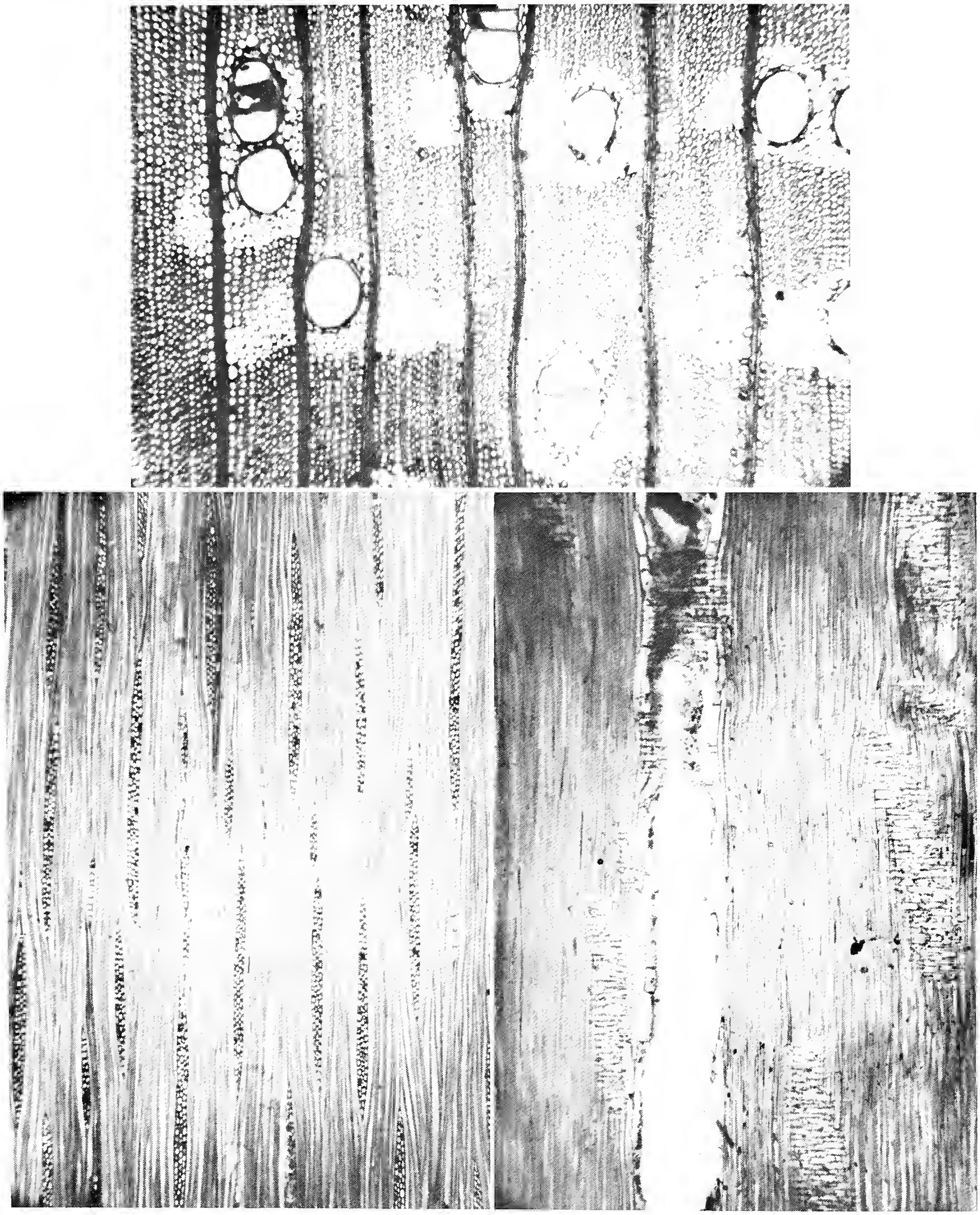


PLATE 7

LEGUMINOSAE

Cylicodiscus gabunensis (Taub) Harms

Standard trade name: Okan

Local names: Denya (Ghana), Imbeli-deli (Sierra Leone), Bouemon (Ivory Coast), Olosan, Okan, (Nigeria), Adum (Cameroons)

This large tree has a clear bole about 120 ft high and about 10 ft in diameter. Crown somewhat flat, wide-spreading, and fairly open. Buttresses short, slash pale yellow, stringy, giving an offensive smell. Young bark ashy white turning reddish brown or almost black, rough and scaly later. Saplings have brown thorns on the stems. Leaves bipinnate, pinnae 1 pair, opposite, leaflets alternate, ovate, long-pointed, glabrous above, reddish on young seedling trees. Flowers small, numerous, yellowish or greenish white, in slender spike-like and paired racemes up to 6 in long; stamens 10. Fruits up to 3 ft × 1¾ in, yellow at first, turning brown, with irregular longitudinal raised nerves and covered with rusty scales; seeds flat, up to 3 in or more long, thinly winged.

General Description.—The sapwood, 2–3 in wide, is pinkish and the heartwood is yellow-brown with dark brown or reddish brown streaks. The wood is exceedingly heavy, averaging about 591 lb/ft^3 air dry, and about 781 lb/ft^3 green (45% mc). The grain is typically interlocked, and the texture moderately coarse.

Seasoning.—Okan seasons slowly with a marked tendency to split and check. British Forest Products Laboratory kiln schedule B is recommended (fprl, 1956).

Durability.—Okan is rated very durable. The sapwood is susceptible to attack by powder-post beetles (*Bostrychidae* and *Lyctidae*). It is extremely resistant to preservative treatment. The sapwood is also resistant.

Working Qualities.—The timber is very hard and difficult to cut with machine and hand tools and dulls their cutting edges fairly quickly. The pronounced interlocked grain makes it difficult to obtain a clean finish in a number of operations. Okan stains and polishes satisfactorily but requires preboring before nailing.

Uses.—It is most suitable for piling and wharf decking as it can be used without preservative treatment. Its resistance to wear is very high and it is recommended for heavy-duty flooring in factories and warehouses. Its density and interlocked grain make it unsuitable for plywood manufacture.

Xylem Anatomy.—Growth rings absent. Wood diffuse-porous. Vessels: mostly solitary, occasionally in multiples of 2 or 3, oval in outline; average pore diameter 224μm, range 168μm–322μm; vessel wall thickness 4μm, perforation plate simple; vessel element end wall inclination slightly oblique to transverse; intervascular pitting alternate. Imperforate tracheary elements: fiber tracheids, average length 420μm, range 294μm–630μm. Vascular rays: predominantly biseriate but with few uniseriate, biseriate rays 8 to 55 cells high, uniseriate rays 5 to 15 cells high. Axial parenchyma: paratracheal, sometimes vasicentric, conspicuously banded. Tanniniferous material present in some vessels and ray cells.

PLATE 7

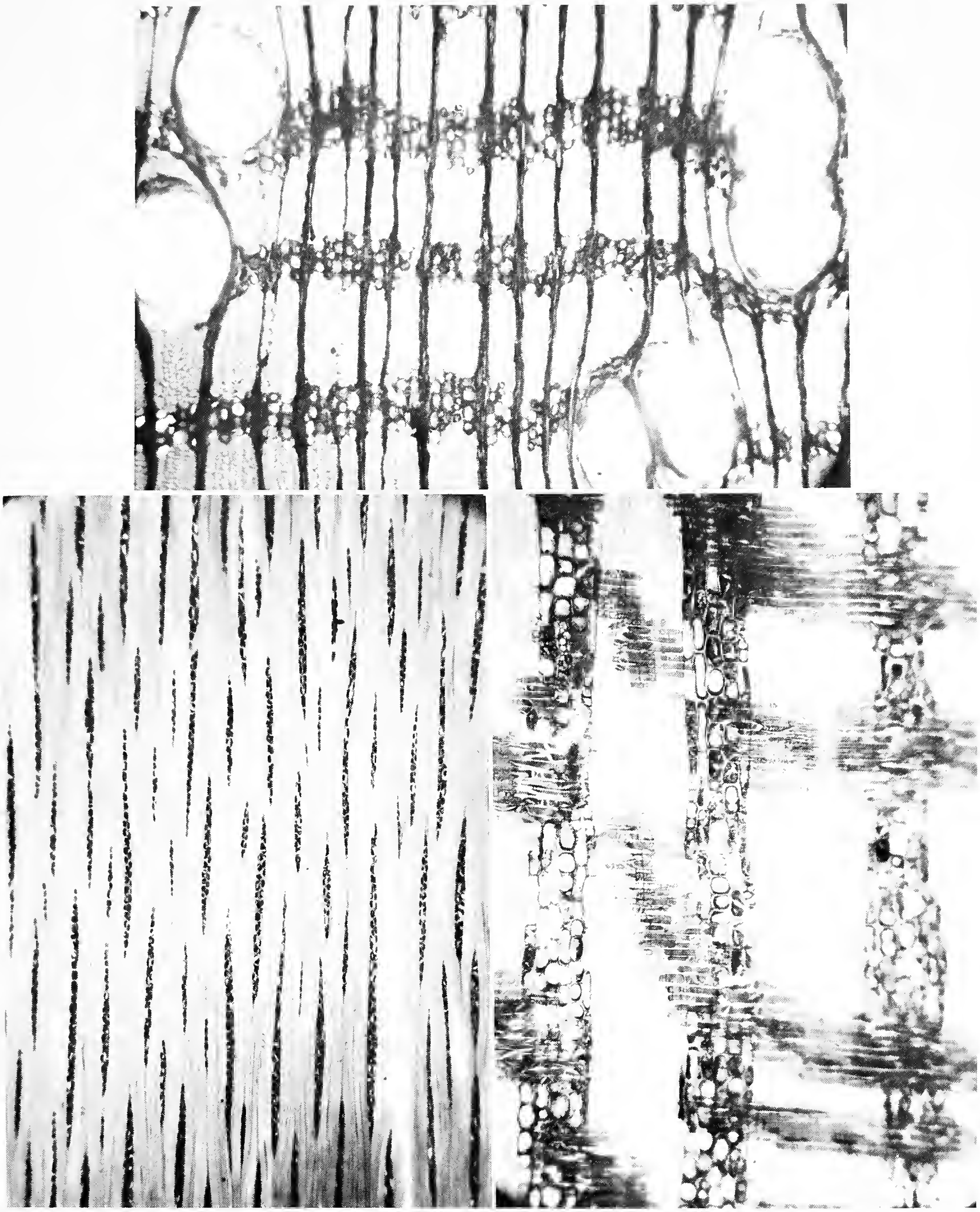


PLATE 8

LEGUMINOSAE

Distemonanthus benthamianus Baillon

Standard trade name: Ayan

Local names: Barre (Ivory Coast), Dua anyan, Bonsamdia (Ghana), Ayan, Anyaran, Edo (Southern Nigeria), Basong (Cameroons), Oqueminia (Gabon)

A tall slender tree over 100 ft high and about 2½ ft in diameter. The bole is reasonably straight and cylindrical. Ayan occurs in the rain forests. It has weakly developed buttresses. The bark is smooth and shining, dark green with a reddish tinge when young, turning orange or red later. The bark peels off in large patches. Leaves pinnate, leaflets 9–11, ovate-lanceolate, alternate, acuminate, with numerous conspicuous lateral nerves. Flowers in loose panicles, creamy white and red or pinkish, sepals 5, pinkish brown and unequal, 3 narrow petals, papery in texture, unequal, longer than sepals, 2 fertile stamens. Fruit pods reddish brown, hairy when young. Single-seeded, seeds small and brown.

General Description.—The narrow sapwood is creamy and the heartwood dull yellow or yellowish brown. The wood is highly lustrous and finely textured. The grain is commonly irregular and interlocked. Ayan is hard and moderately heavy, ranging from 37–481 lb/ft ^{3} averaging about 421 lb/ft ^{3} seasoned. The wood often contains a yellow extract, which under most conditions acts as a direct dye on clothing. It is readily bleached by hypochlorites.

Seasoning.—The timber seasons satisfactorily, but not rapidly. It has a tendency to split or warp. The British Forest Products Laboratory kiln schedule F is suggested (FPRL, 1956).

Durability.—Ayan is moderately durable. It is moderately resistant to preservative treatment.

Working Qualities.—The timber works well with all tools, though tending to blunt them. It is liable to pick-up under the plane. It finishes cleanly in most operations but tends to char when bored. Some specimens contain a high proportion of silica. Such material can only be sawed satisfactorily with teeth tipped with tungsten carbide. In planing and molding, tearing occurs on quarter-sawn material but a reduction of the cutting angle to 20° usually insures a clean surface. It has some tendency to split when nailed. It takes stain and polish well, requiring only a moderate amount of filler.

Uses.—Ayan is a useful joinery and cabinet timber. It is also used for door-frames, windows and sills, interior decoration, turnery, and furniture. For flooring it is suitable for domestic buildings. It is also used for lorry bodies. As it stains fabrics it is not suitable as a draining board.

Xylem Anatomy.—Growth rings absent. Wood diffuse porous. Vessels: mainly solitary and multiples of 2 or 3; average pore diameter 195μm, circular in outline; average vessel length 294μm; range 252μm–308μm; vessel wall thickness 8μm; perforation plates simple. Vessel end wall inclination slightly oblique to transverse; intervascular pitting alternate, small. Imperforate tracheary elements: fiber tracheids, few, septate; average length 350μm, range 308μm–490μm. Vascular rays: heterogeneous, mostly multiseriate, 3 or 4 cells wide, 5 to 15 cells high. Axial parenchyma: paratracheal, moderately abundant, tendency towards aliform but generally banded. Tanniferous material present in vessels.

PLATE 8

PLATE 9

MELIACEAE

Entandrophragma angolense (Welwitsch) A. C. DeCandolle

Standard trade name: Gedu nohor

Local names: Edinam (Ghana), Gedu lohor, Gedunoha (Nigeria), Tiama (France and Ivory Coast.)

A deciduous forest tree growing to 160 ft tall with a clean bole up to 80 ft in height, girth of 15 ft above buttresses; bark smooth, pale gray-brown with pinkish or rusty orange patches; leaves alternate, exstipulate, paripinnate; inflorescence a large, lax panicle; flowers small, greenish white, scented.

GENERAL DESCRIPTION.—The heartwood is typically dull reddish brown and the light colored sapwood is about 4 in wide. Gedu nohor is of plain appearance compared to sapele but very similar to the African mahoganies. It is medium hard and medium heavy, varying in weight from 32–36 lb/ft ^{3} (average about 34 lb/ft^3) when seasoned and about 54 lb/ft ^{3} green. The surface is lustrous. It has no distinct odor or taste.

SEASONING.—Gedu nohor seasons fairly rapidly with a tendency to distort. The British Forest Products Laboratory kiln schedule A is recommended (FPRL, 1956).

DURABILITY.—The wood is moderately durable. Damage by ambrosia beetles is occasionally present. It has been recorded in Nigeria as moderately resistant to preservative treatment.

WORKING QUALITIES.—Works fairly easily with machine and hand tools. It planes and turns well, but may have a tendency to pick-up on the quarter. It bores and takes nails and screws well. Gluing is satisfactory.

USES.—Its uses are similar to sapele. Being a decorative timber, it is used for paneling, interior and decorative work, furniture and superior joinery.

XYLEM ANATOMY.—Growth rings absent. Wood diffuse-porous rarely. Vessels: solitary or in radially oriented groups of 2 or 3, pores circular in outline; average pore diameter 82μm, range 45μm–110μm; average vessel element length 556μm, range, 400μm–900μm; vessel wall thickness 4μm; perforation plates not seen; vessel element end wall inclination transverse; intervascular pitting alternate, pits ca. 1.25μm. Imperforate tracheary elements: septate fiber tracheids with dark amorphous substance in some; average length 1798μm, range 1375μm–2225μm; pits moderately abundant, only on radial walls, slits extending beyond pit boundary. Vascular rays: heterogeneous, multiseriate (only 1 uniseriate ray seen), 3 or 4 cells wide, 20 to 39 cells high including tails, which are 1 or 2 cells in length. Axial parenchyma: apotracheal, bands 2 or 3 cells wide; also paratracheal, vasicentric and somewhat aliform.

PLATE 9

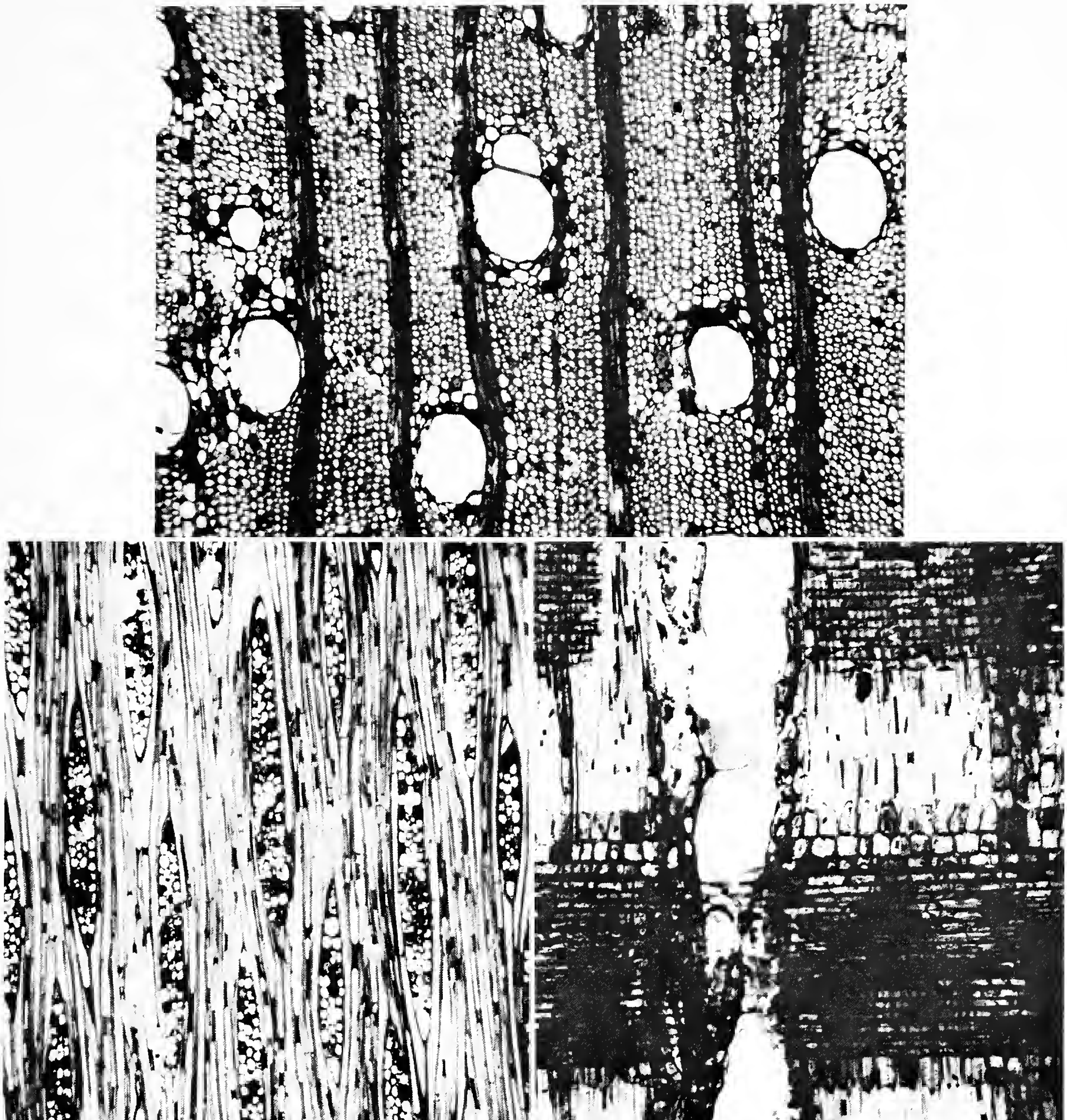


PLATE 10

MELIACEAE

Entandrophragma candollei Harms

Standard trade name: Omu

A huge evergreen and deciduous forest tree growing up to 200 ft high and 23 ft in girth. The leaves are terminal with pinnate leaflets in 6 to 8 opposite to subopposite pairs, up to 3.5 in long, oblong elliptic or oblong-ovate with a rounded apex. Leaf base rounded or sides slightly unequal, conspicuous parallel reddish nerves below, rachis and buds brownish tomentose. The flowers are yellow in short pubescent panicles.

General Description.—The heartwood is dark red-brown in color and is distinct from the pinkish red sapwood. It is hard and of medium weight which averages about 39 lb/ft ^{3} seasoned. Green weight is about 60 lb/ft ^{3}. It has an even, medium to coarse texture. The grain is generally interlocked.

Seasoning.—Omu seasons very slowly with a marked tendency to distort. The British Forest Products Laboratory kiln schedule A is recommended (FPRL, 1956).

Durability.—Moderate.

Working Qualities.—Compared to sapele, omu is more difficult to saw, but works easily with machine and hand tools. It has a tendency to tear in planing and molding. For the best finish, therefore, a cutting angle of about 20° should be employed. It takes nails, stains, and polishes well.

Uses.—As a superior timber, omu produces beautiful veneer for paneling, furniture, cabinets, and fine interior woodwork. It is employed for flooring and is moderately to highly durable.

Xylem Anatomy.—Growth rings absent. Wood diffuse-porous. Vessels: about half in radial multiples of 3 to 8 pores, and about half solitary; solitary pores circular in outline, smaller pores in chains. usually angular; average pore diameter 82.4μm. range 40μm–140μm; average vessel element length 690μm, range 538μm–850μm; vessel wall thickness 2μm–3μm; perforation plate simple; vessel element end wall inclination slightly oblique to strongly oblique, few transverse; intervascular pitting alternate, relatively small. Imperforate tracheary elements: nonseptate fibers, average length 1255μm, range 1130μm–2325μm. Vascular rays: heterogeneous, mostly multiseriate, generally 4 or 5 cells wide, 11–24 cells high, but a few biserate cells also present. Axial parenchyma: apotracheal, banded, cells with dark amorphous deposits. Crystals absent.

PLATE 10

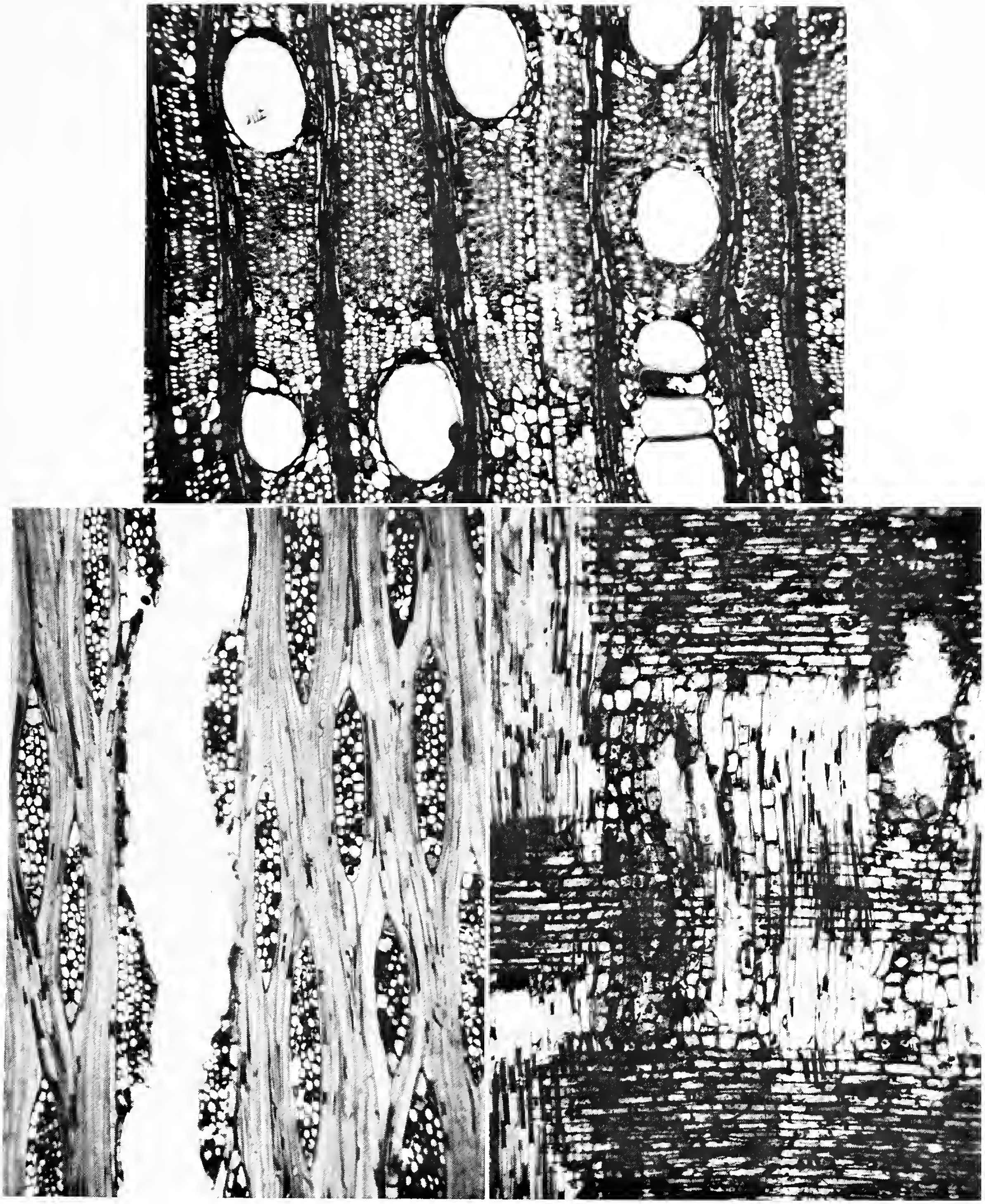


PLATE 11

MELIACEAE

Entandrophragma cylindricum Sprague

Standard trade name: Sapele
Local name: Penkwa (Ghana)

A tree about 180 ft with a cylindrical, straight clean bole 80–100 ft high. The average diameter is about 3–4 ft but diameters of up to 20 ft have been reported (Dalziel, 1937:320; Kennedy, 1936:176). Buttresses are broad and low. Leaves up to 20 in long, pinnate, leaflets 6 to 9 pairs, opposite or sub-opposite, 6 × 3 in, lateral nerves 6 to 12 pairs, prominent below, hairs only in axils. Starlike flowers are yellowish white, small and numerous. Fruit capsules cylindrical and pendulous.

General Description.—The sapwood is pale in color with a pinkish tint; the heartwood being more reddish when freshly cut, darkening to rich red-brown when exposed. The most striking feature of sapele is the regular stripes on the quarter-sawn lumber or veneer. Logs with wavy grain yield highly decorative veneers. The texture is fine to medium. The average weight is about 391 lb/ft^3 seasoned, and usually ranges between 35 and 431 lb/ft^3. The green weight is about 551 lb/ft^3. The wood is harder and heavier than African mahogany.

Seasoning.—The wood dries slowly thus requiring mild drying conditions and good stacking practices. The wood has a marked tendency to warp.

Durability.—Moderately durable. The sapwood is susceptible to attack by powder-post beetles (*Lyctidae* and *Bostrychidae*) and termites. It is resistant to impregnation.

Working Qualities.—Sapele works fairly easily by hand and machine tools with relatively little dulling effect on their cutting edges. Material with interlocked grain is often troublesome to plane and mold as it causes picking-up of quarter-sawn surface and also some chipping out. However, with a cutting angle of 15° uniformly good results are achieved. It takes nails, screws and glues satisfactorily and finishes well.

Uses.—Suitable for uses to which omu (*E. candollei*) is applied, that is, superior joinery, cabinet work, furniture, and flooring.

Xylem Anatomy.—Growth rings absent. Wood diffuse-porous. Vessels: about one-fourth solitary, rest in clusters or sometimes radial multiples of 2 or 3 pores, solitary pores more or less circular in outline; average pore diameter 168μm, range 98μm–182μm; average vessel element length 420μm, range 252μm–560μm; vessel wall thickness 4μm–8μm; perforation plates simple; vessel end wall inclination slightly oblique to almost transverse; intervascular pitting alternate, very small. Imperforate tracheary elements: septate fibers present with scanty, simple pitting on radial walls. Vascular rays: homogeneous multiseriate, generally 2 to 4 cells wide, tendency towards storied arrangements. Axial parenchyma: apotracheal, banded with dark amorphous deposits. Crystals present, rectangular, often embedded at ends of rays.

PLATE 11

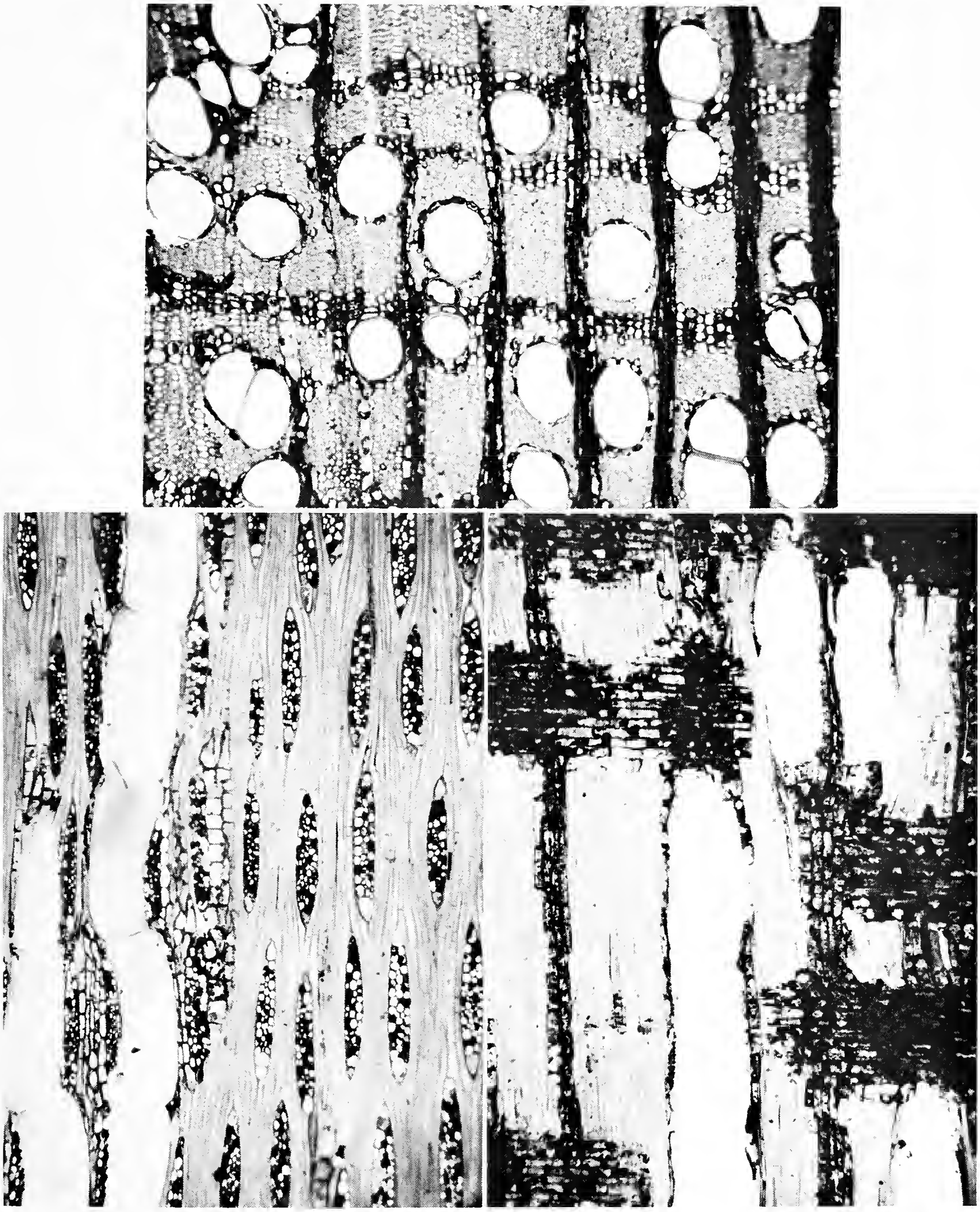


PLATE 12

MELIACEAE

Entandrophragma utile (Dawe & Sprague) Sprague

Standard trade name: Utile

A large tree of moist-dry to dry closed forests growing up to 210 ft high and 25 ft in girth. The deciduous leaves are pinnate, up to 30 in long, the leaflets 12 pairs or more, up to 6 in long, shortly acuminate or rounded at apex. The flowers are whitish, in terminal inflorescences.

General Description.—Seasoned, the average weight is about 42 lb/ft ^{3} and the green weight about 50 lb/ft ^{3}. The rich, red-brown timber resembles sapele, but lacks the cedar-like scent of the latter. The sapwood is distinct from the heartwood and is light brown in color. Utile has broad, interlocked grain and produces a stripe figure on the quarter-sawn lumber.

Seasoning.—It seasons at a moderate rate with a definite tendency for original shakes to extend during drying. British Forest Products Laboratory kiln schedule A is recommended (fprl, 1956).

Durability.—Utile is moderately resistant to insect attack. The sapwood is, however, liable to attack by powder-post beetles. It is resistant to preservative treatment.

Working Qualities.—Utile works fairly readily with hand and machine tools and has a comparatively small blunting effect on their cutting edges. It takes nails and glues satisfactorily, stains readily and polishes well after the grain has been suitably filled.

Uses.—It is similar to omu *(E. candollei)* in its general uses, but is rather less suitable for decorative work. It is mainly used for interior furniture, truck frames, door frames, and for interior joinery and fittings. It is a good source of rotary-cut plywood.

Xylem Anatomy.—Growth rings absent. Wood diffuse-porous. Vessels: solitary, or often in multiples of 2 to 4, tyloses present, circular in outline, rarely angular; average pore diameter 225μm, range 80μm–250μm; average vessel element length 636μm, range 413μm–788μm; vessel wall thickness about 6μm; perforation plates simple; vessel element end wall inclination transverse to slightly oblique; intervascular pitting alternate. Imperforate tracheary elements: septate fibers present with scanty, simple pitting on radial walls. Vascular rays: homogeneous, biseriate, occasionally multiseriate or uniseriate, 5 to 20 cells high. Axial parenchyma: paratracheal, abundant, in multiseriate tangential bands, occasionally uniseriate; stained amorphous deposits in most. The wood is an advanced one.

PLATE 12

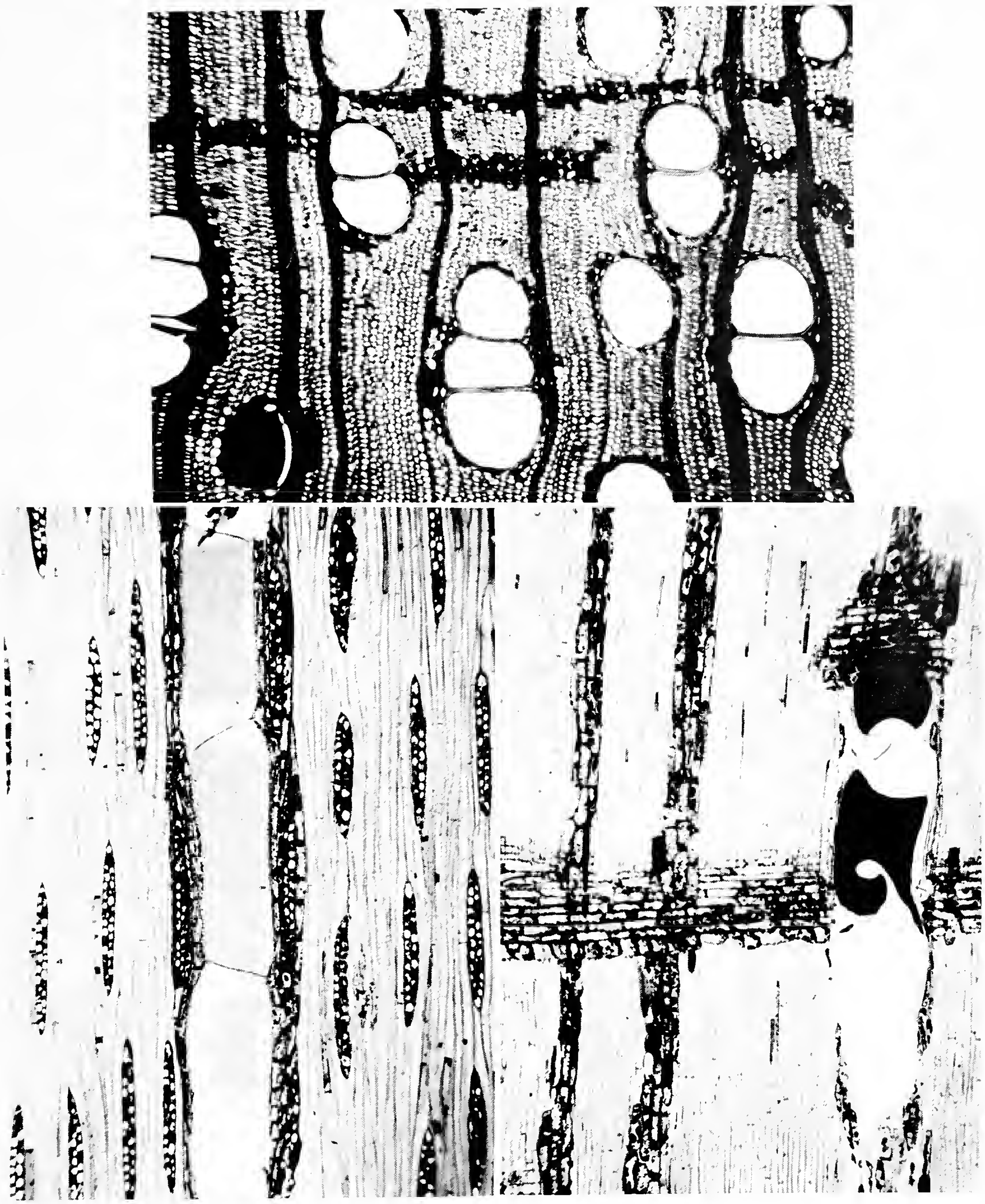


PLATE 13

MELIACEAE

Guarea cedreta (A. Chevalier) Pellegrini

Standard trade name: Scented Guarea
Local names: Kwabohoro (Ghana), Bosse (France & Ivory Coast), Obobonufua (Nigeria)

A heavily buttressed tree up to 160 ft tall and up to 8.5 ft in girth; bole clear, considerably fluted at the base; crown dense; bark silvery gray; leaves pinnate with 4 to 6 pairs of leaflets; flowers green, with few-flowered inflorescences.

General Description.—Guarea is medium hard and of medium weight, about 36 lb/ft^3 seasoned and about 60 lb/ft^3 green. The pinkish brown heartwood is like pale African mahogany. The sapwood is lighter in color than the heartwood. Freshly sawn, guarea has a strong cedar-like scent, which tends to disappear on exposure. The timber has a medium-fine texture and a high luster. The grain may be straight or wavy, and a mottled or curly figure may be present.

Seasoning.—The timber appears to season fairly rapidly with very little degrade. Resin exudation may cause some degrade in the appearance of the wood. The British Forest Products Laboratory kiln schedule E has given satisfactory results (FPRL, 1956).

Durability.—Moderately durable, but damage by ambrosia beetles is sometimes present. It is extremely resistant to preservative treatment. The sapwood is permeable.

Working Qualities.—Generally it saws and planes fairly easily. It works satisfactorily with hand and machine tools, but dulls their cutting edges. There is a slight tendency to pick-up in planing quarter-sawn material, but generally a good finish is obtained in most operations. It takes nails and screws well and stains readily. Polishing, however, needs care because of possible resin exudation.

Uses.—Guarea is a superior joinery timber and is used for furniture, interior fittings, boats and vehicles, as well as for good quality plywood and decorative veneer.

Xylem Anatomy.—Growth rings present. Wood diffuse-porous. Vessels: solitary to groupings of 3, rarely more; average pore diameter 122μm; circular to narrowly elliptical in outline; average vessel length 536μm, range 300μm–788μm; vessel wall thickness 5μm; perforation plates, unable to determine with certainty but they appear simple. Vessel end wall inclination transverse to oblique; intervascular pitting alternate, simple, small and numerous. Imperforate tracheary elements: septate fiber tracheids; average length 1668μm, range 1325μm–2000μm. Vascular rays: homogeneous, generally one celi in thickness, but frequently with 2 or 3 small cells abreast. Axial parenchyma: apotracheal, banded, moderately abundant pitted. Crystals and inclusions: no crystals apparent; however, some ray cells contain dark staining deposits.

PLATE 13

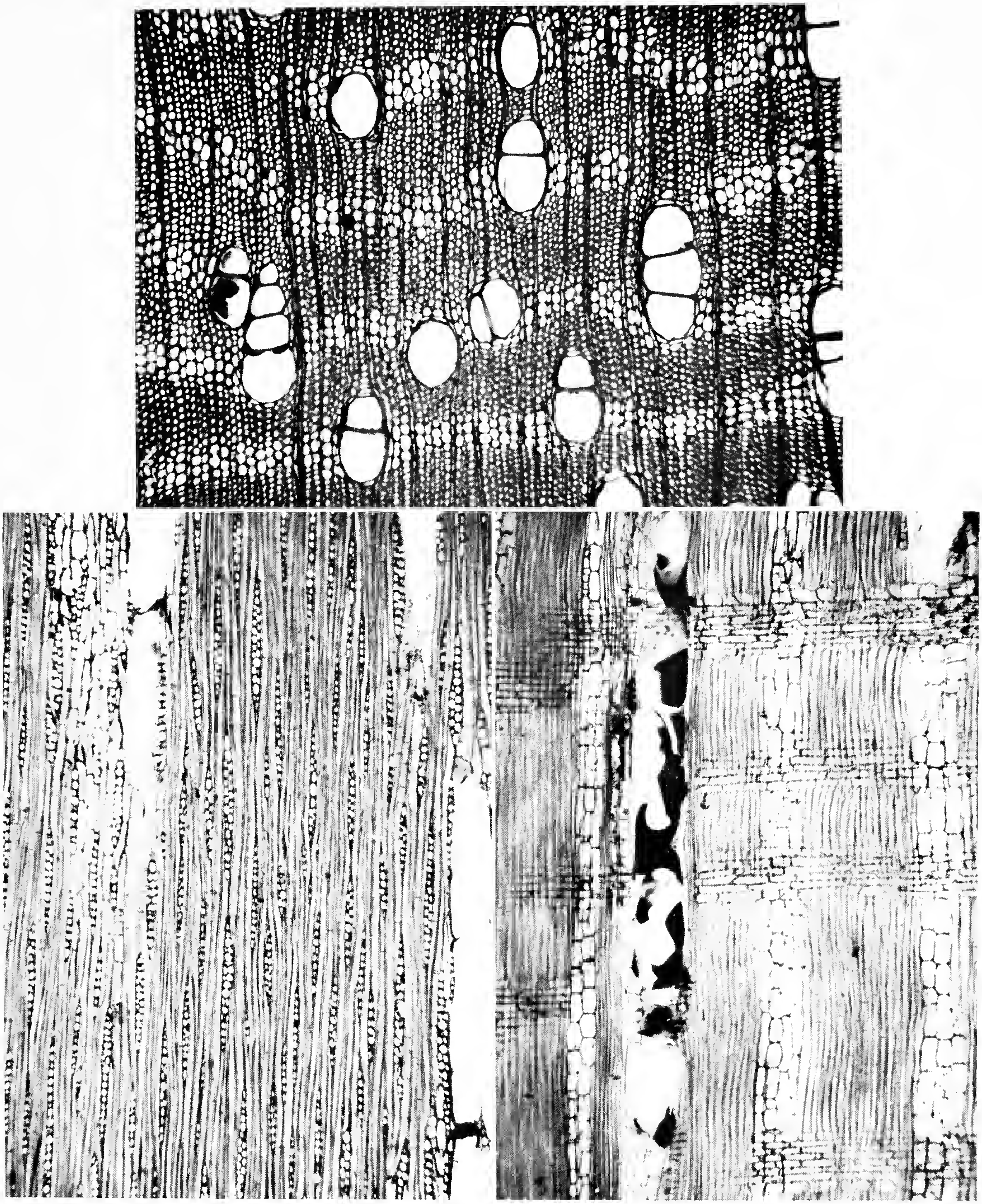


PLATE 14

MELIACEAE

Khaya grandifolia A. C. DeCandolle

Standard trade name: African mahogany, which is also applied to *K. anthotheca* and *K. ivorensis*

A common tree of dry closed forests growing up to 130 ft high and up to 28 ft in girth. The leaves are about 16 in long, pinnate, shining, with leaflets up to 14 pairs, plus a terminal leaflet, 10–12 in × 5 in, elliptic to ovate-elliptic, the tips shortly acuminate. The flowers are numerous, in axillary panicles 8–10 in long. The wood is used as a substitute for true mahogany *(Swietenia mahogani)*.

General Description.—*Khaya grandifolia* tends to be a little darker and appreciably heavier than *K. ivorensis,* the weight per cubic foot averaging about 44 lb/ft^3 seasoned. The heartwood is reddish brown; it is pinkish white when freshly felled. It is not always easy to spot the demarcation line between sapwood and heartwood when freshly felled. The grain is usually interlocked, but some of the timber is fairly straight-grained. The texture is medium to coarse.

Seasoning.—Like all African mahoganies, it generally seasons fairly rapidly with little degrade.

Durability.—It is moderately durable and extremely resistant to preservative treatment.

Working Qualities.—The timber works fairly easily with hand and machine tools. Generally its dulling effect on cutting edges is relatively small. When planing quarter-sawn material, and especially when the grain is interlocked, a reduction in cutting angle to about 15° is advisable to avoid pick-up. The timber has good nailing, screwing, and glueing qualities. It responds well to usual finishing treatments. It glues satisfactorily.

Xylem Anatomy.—Growth rings absent. Wood diffuse-porous. Vessels: mainly in two's, but range from 1 to 4; oval in outline, sometimes circular; average pore diameter 71.5μm, range 50μm–90μm; average vessel element length 564μm, range 350μm–763μm; vessel wall thickness undetermined; perforation plates simple; vessel element end wall inclination slightly oblique; no intervascular pitting. Imperforate tracheary elements: septate fiber tracheids; average length 1893μm, range from 1638μm–2250μm; fibers with numerous pits. Vascular rays: homogeneous, multiseriate, generally 3 to 5 cells high, but unseriate and biseriate rays present, no fusiform rays. Axial parenchyma: paratracheal, numerous, cells containing amorphous deposits. Crystals: none present.

PLATE 14

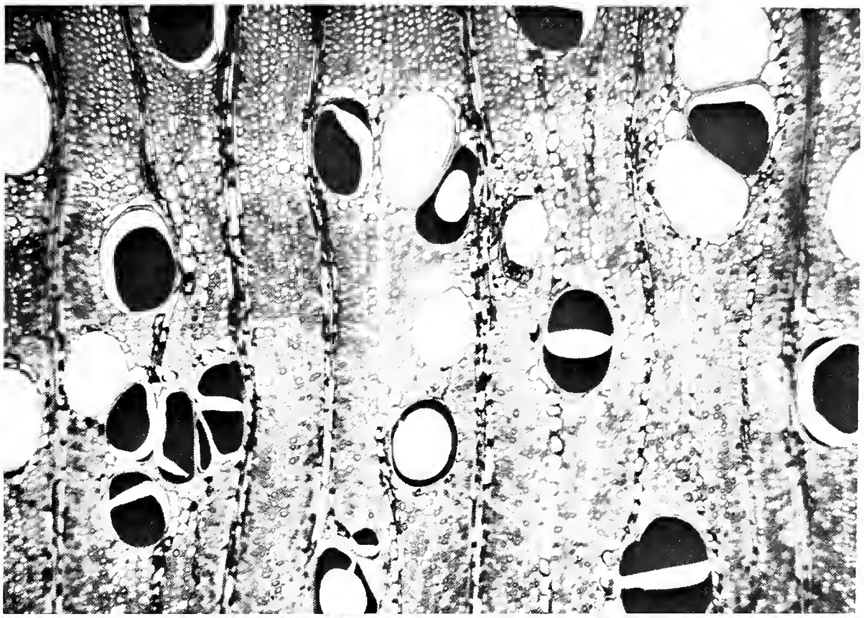


PLATE 15

MELIACEAE

Khaya ivorensis A. Chevalier

Standard trade name: African mahogany, which is also applied to *K. anthotheca* and *K. grandifolia*

A dominant tree, up to 200 ft high and 15 ft in girth above the large buttresses, with long clear bole up to 90 ft. It is a rain-forest tree found in low-lying grounds in West Africa.

General Description.—The timber is medium hard and has a medium weight varying between 32 and 45 lb/ft^3. The average weight is about 35 lb/ft^3 seasoned. The green weight is about 44 lb/ft^3. The sapwood is about 2 in wide and the color is yellowish brown. The timber has a similar, if not the same, general description as *K. grandifolia* and the other African mahogany species.

Seasoning.—All the species of African mahogany season fairly rapidly and well with little degrade.

Durability.—Logs are susceptible to attack by pin-hole borers and powder-post beetles. Moderately resistant. It is extremely resistant to preservative treatment.

Working Qualities.—The timber works fairly easily with both hand and machine tools. Most of the working qualities of *K. grandifolia* also apply to this timber.

Uses.—It is very useful for furniture and interior decoration, and forms a good quality joinery wood suitable for ships' cabins and railway coaches. It is also used for boat planking and for the manufacture of veneer and plywood.

Xylem Anatomy.—Growth rings absent. Wood diffuse-porous. Vessels: solitary but with a few radial multiples of 2 or 3 small pores; circular in outline, rarely angular; average pore diameter 100μm, range 80μm–130μm; average vessel element length 511μm, range 388μm–588μm; perforation plates exclusively simple; vessel element end wall inclination almost transverse; intervascular pitting alternate. Imperforate tracheary elements: septate fibers; average length 1448μm, range 1250μm–1650μm. Fibers with simple pits on tangential walls. Vascular rays: heterogeneous, mainly multiseriate, generally 5 cells wide, 5 to 18 cells high.

PLATE 15

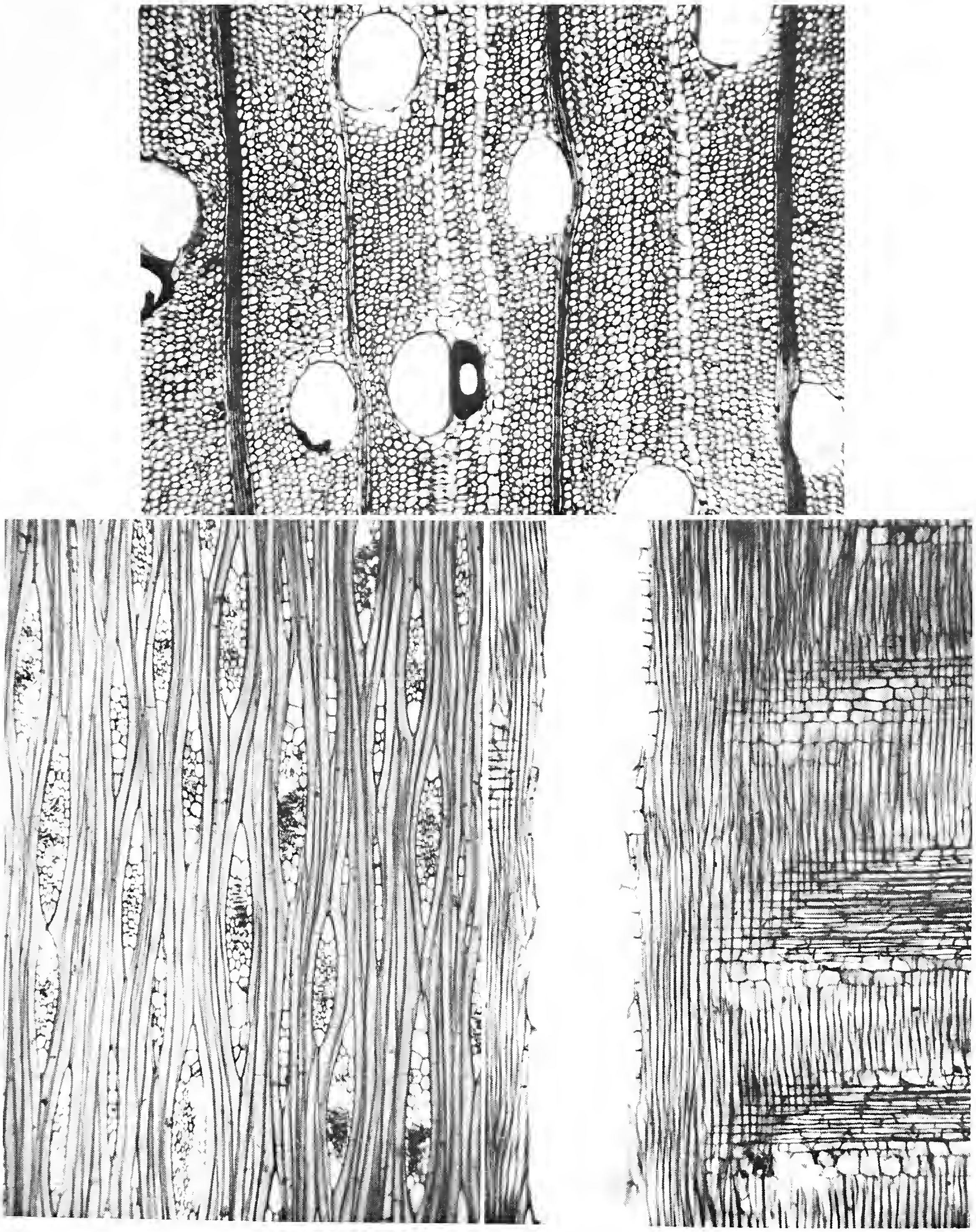


PLATE 16

MELIACEAE

Lovoa trichilioides Harms

(Syn. *L. klaineana* Pierre)
Standard trade name: African walnut
Local names: Apopo, Sida (Nigeria), Dibetou, Noyer d'Afrique, Noyer de Gabon (France, French-speaking West Africa), Akwantanuro, Dubinibiri, Pepedom (Ghana)

A large, evergreen tree with a heavy crown up to 150 ft high, attaining a girth of up to 12 ft. The bole is 60–90 ft. The buttresses are rather short and blunt. Leaves are pinnate with 6 pairs of subopposite and elliptic leaflets, 3.5–8 in long. Flowers are greenish white or white, numerous and small, in large, lax panicles.

General Description.—The golden-brown heartwood, often with dark streaks, sometimes contains "snakeholes" of ½ in diameter and several inches long, probably due to insect attacks. The sapwood, which is distinguishable from the heartwood, is buff or light brown in color. In most other respects the wood resembles African mahogany. It is medium hard and of medium weight, the average weight being about 34 lb/ft ^{3} seasoned, and about 49 lb/ft ^{3} green.

Seasoning.—African walnut seasons fairly rapidly without much degrade. The British Forest Products Laboratory kiln schedule E is recommended (FPRL, 1956).

Durability.—Moderately durable. It is extremely resistant to preservative treatment. Sapwood is moderately resistant.

Working Qualities.—The timber works satisfactorily with hand and machine tools. Interlocked grain material, especially quarter-sawn, has a tendency to pick-up in machine operations. To avoid pick-up, a cutting angle of about 15° should be used. It takes nails and screws, stains and polishes satisfactorily.

Uses.—It is used for furniture, joinery, cabinet work, paneling, veneers, gunstocks, inlay-work, and flooring.

Xylem Anatomy.—Growth rings absent. Wood diffuse-porous. Vessels: mixed multiples of 2 to 6 and solitary small pores; circular in outline, rarely angular; average pore diameter 62μm, range 13μm–94μm; average vessel element length 444μm, range 200μm–725μm; vessel wall thickness 3μm–4μm; perforation plates exclusively simple; vessel element end wall inclination oblique to transverse; intervascular pitting alternate, rather large. Imperforate tracheary elements: pitted fiber tracheids, average length 1914μm, range 1375μm–2438μm; fibers have no or extremely minute pores on tangential walls. Vascular rays: heterogeneous, mainly multiseriate, generally 3 cells wide, 15 to 38 cells high, but biseriate and uniseriate cells also present; fusiform rays up to 4 cells wide containing intercellular canals. Axial parenchyma: paratrachial and apotrachial, abundant, cells void of amorphous material. Crystals: no crystals were found in tissues.

PLATE 16

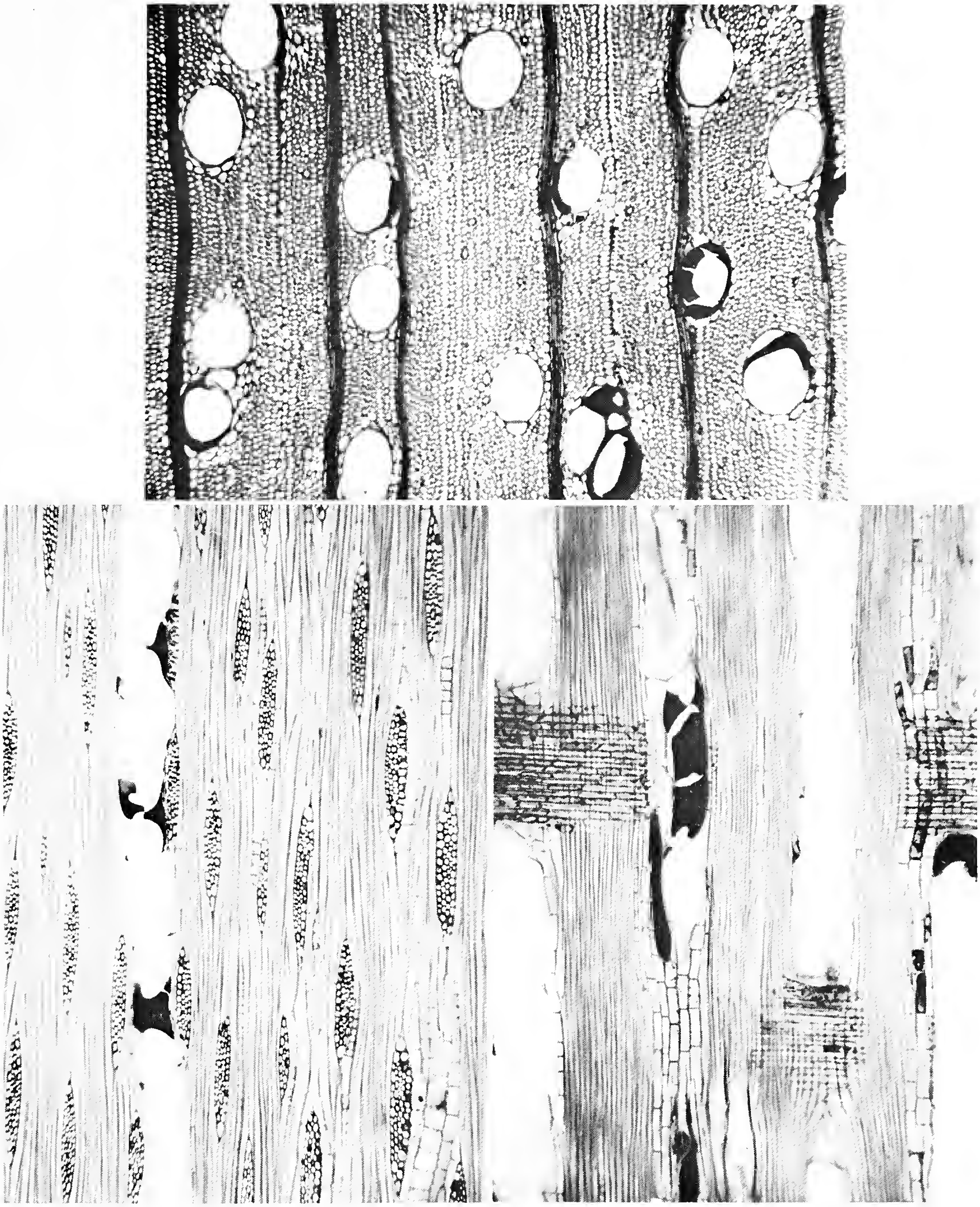


PLATE 17

MELIACEAE

Turraeanthus africanus Hutchinson & Dalziel

Standard trade name: Avodire
Local name: Apapaye

A medium size tree 2–2.5 ft in diameter, branching low with a spreading crown. Leaves are pinnate with long-acuminate or elongate-oblong leaflets, rounded or shortly cuneate at the base. Flowers are small, dull yellow, and densely pubescent. The timber is used for building. The bark and leaves are used as fish poison.

General Description.—There is no distinction between sapwood and heartwood. The pale cream wood has a natural luster and darkens to a golden yellow. The grain is often wavy or interlocked but is sometimes straight. The figured material is more distinctive and very attractive. The average weight is about 34 lb/ft^3 seasoned.

Seasoning.—Avodire can be seasoned fairly rapidly but tends to cup and twist. British Forest Products Laboratory kiln schedule E is recommended (FPRL, 1956).

Durability.—The timber is not durable. It is extremely resistant to preservative treatment, although the sapwood is permeable.

Working Qualities.—Avodire works fairly easily with hand and machine tools and has a very small dulling effect on their cutting edges. It produces a smooth finish, polishes and glues well.

Uses.—Being a superior joinery timber, it is used for interior and cabinet work. It is also used for decorative veneer.

Xylem Anatomy.—Growth rings absent. Wood diffuse-porous. Vessels: solitary or in multiples of 2 or 3 pores; circular in outline, rarely angular; average pore diameter 70μm, range 50μm–110μm; average vessel length 625μm, range 413μm–838μm; vessel wall thickness 3μm–4μm; perforation plates simple; vessel element end wall inclination slightly oblique; intervascular pitting alternate, rather small. Imperforate tracheary elements: nonseptate fiber tracheids; average length 1435μm; range 1100μm–1713μm; fibers with few simple pits on tangential walls. Vascular rays: homogeneous, generally biseriate, 3 to 17 cells high, but uniseriate and multiseriate cells also present. Axial parenchyma: apotracheal, cells without dark amorphous deposits.

PLATE 17

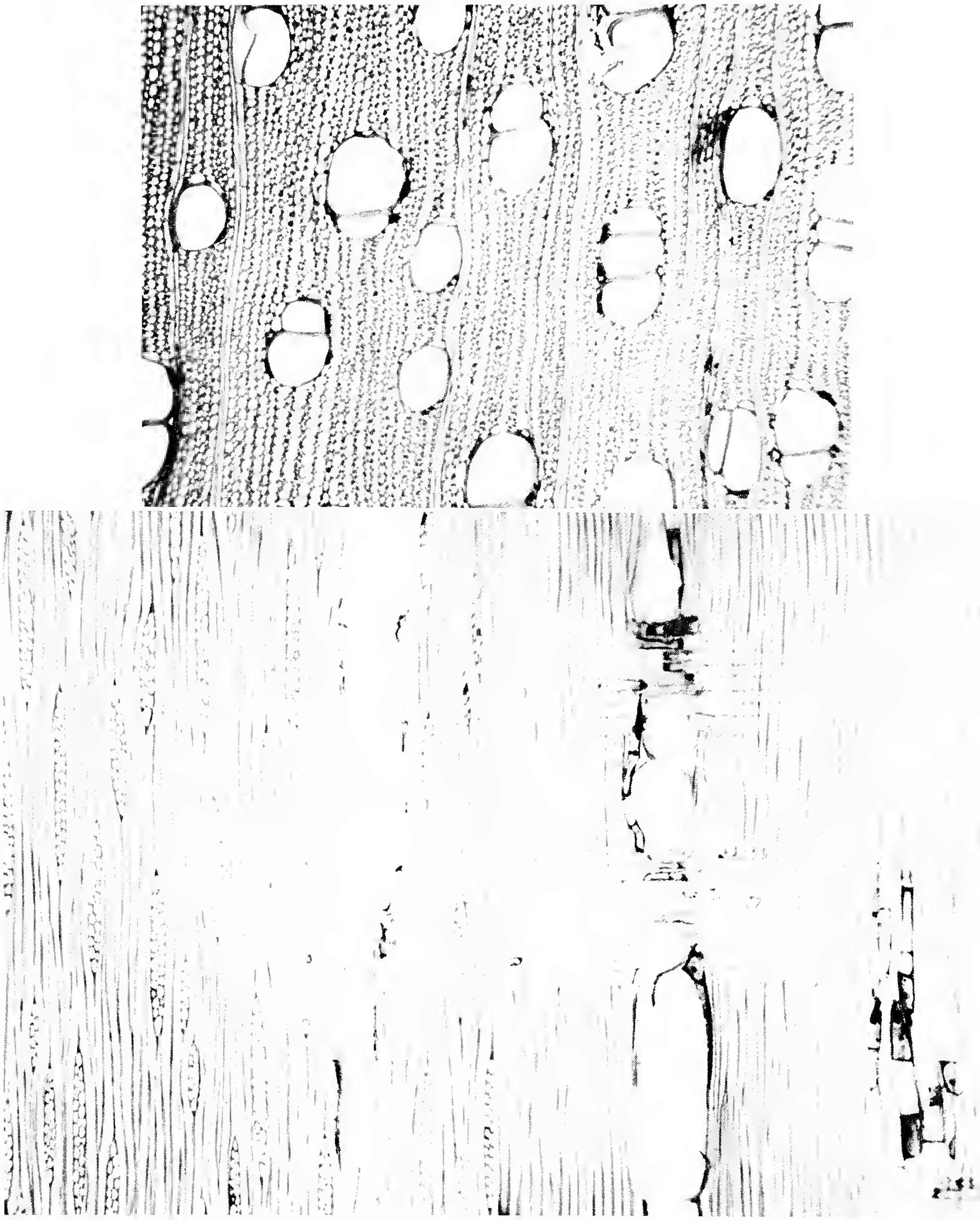


PLATE 18

MORACEAE

Antiaris africana Engler

Standard trade name: Antiaris
Local names: Oro orgiovu (Nigeria), Kyenkyen (pronounced Chenchen—Ghana)

A large, deciduous tree of the drier types of forest, to 130 ft high; with gray bark, the slash exuding a watery latex which soon darkens to the color of milky tea; ripe fruits red or orange. Plants in the family Moraceae are recognized by the milky juice, the prominent stipules which leave a scar on falling, and the minute, unisexual flowers often arranged on variously shaped receptacles.

General Description.—The wood is light and medium soft with a recorded air-dry weight varying from 23 to 33 lb/ft ^{3}, the average being 27 lb/ft ^{3}. Green weight is about 42 lb/ft ^{3}. The general appearance of the timber is similar to obeche (*Triplochiton scleroxylon*); it is light yellow-brown in color with no clear distinction between sapwood and heartwood. The texture is medium to coarse, and the grain interlocked.

Seasoning.—Antiaris seasons fairly rapidly, but with a tendency to distort. British Forest Products Laboratory kiln schedule A is recommended (FPRL, 1956).

Durability.—It is a perishable wood. Logs are susceptible to damage by ambrosia and longhorn beetles. Sapwood of lumber is also susceptible to powder-post beetles. It is permeable to preservatives.

Working Qualities.—Antiaris has similar working properties of obeche (*Triplochiton scleroxylon*). It finishes cleanly in most operations if sharp cutters are used. It nails and glues well, stains and polishes satisfactorily.

Uses.—Used locally in Ghana for cutlass handles and boxes, doors, benches, and canoes. It has been used for plywood core. Suitable for furniture, interiors, and also for light joinery. Antiaris has a thick inner bark, which yields a strong and durable cloth, providing satisfactory wrapping material for baled rubber and other products.

Xylem Anatomy.—Growth rings present. Wood diffuse-porous. Vessels: solitary but with a few radial multiples of 2 to 4 pores; circular in outline; average diameter 168μm, range 125μm–200μm; average vessel element length 453μm, range 350μm–650μm; vessel wall thickness averages 3.75μm; perforation plates scalariform (?); vessel element end wall inclination very slightly oblique to transverse; intervascular pitting alternate, large pits. Imperforate tracheary elements: septate fiber tracheids; average length 1260μm, range 1038μm–1500μm. Vascular rays: heterogeneous, mainly multiseriate, generally 3 or 4 cells wide, varying considerably in height, 6 to 35 cells; biseriate and uniseriate rays also present; fusiform rays with numerous circular pits. Axial parenchyma: paratracheal, vasicentric, occasionally aliform, moderately abundant.

PLATE 18

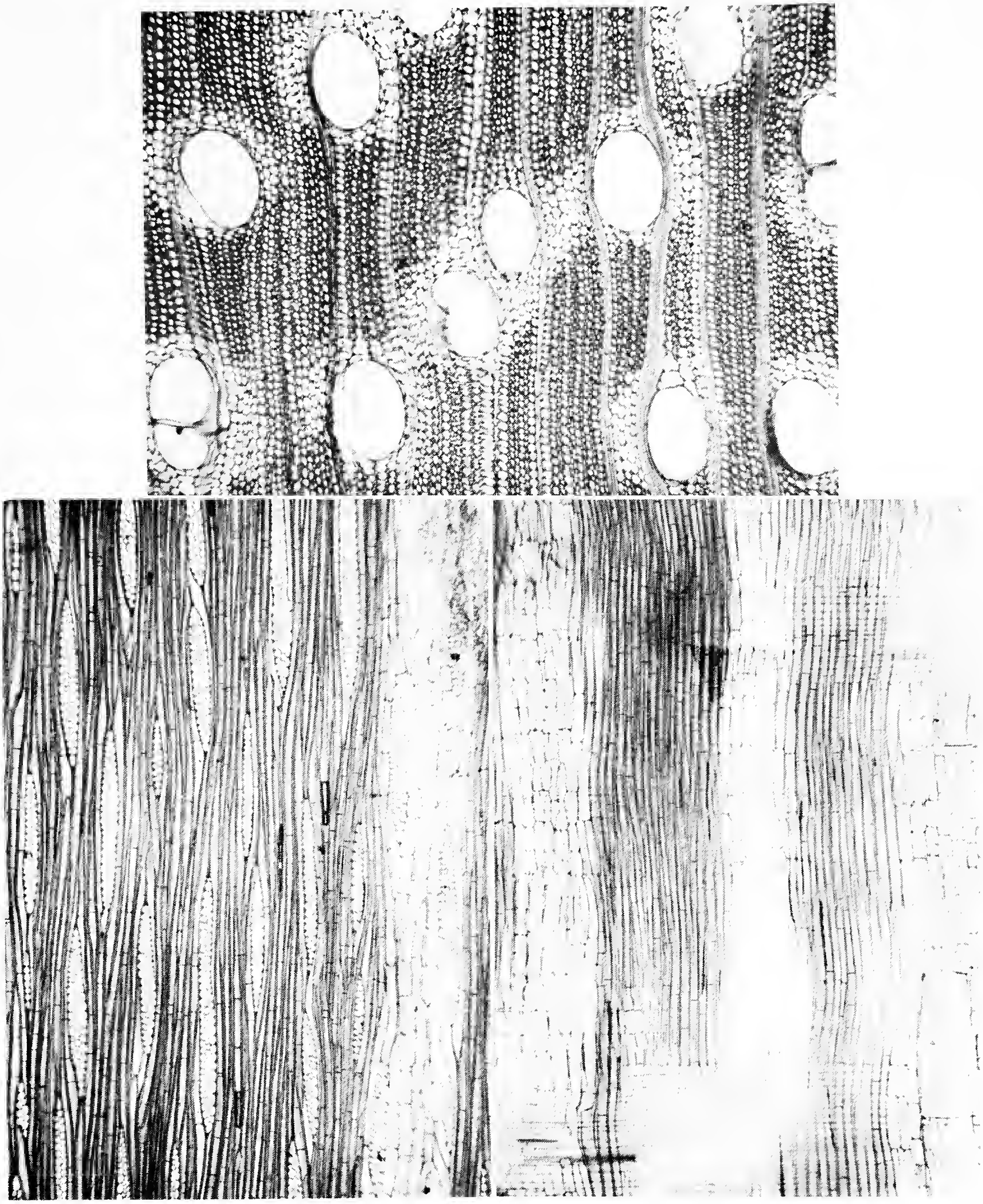


PLATE 19

MORACEAE

Chlorophora excelsa (Welwitsch) Bentham & J.D. Hooker

Standard trade name: Iroko

Local names: Odum (Ghana), Iroko (Nigeria), Kambala (French-speaking West Africa)

A large tree of deciduous and evergreen forests reaching 160 ft and up to 30 ft in girth. Unbuttressed and unbranched for 80 ft. The bark is smooth but becomes brown and scaly. The leaves of young trees of both sexes are 9 × 4 in, acuminate and serrulate; on the mature tree they are entire. The trees are dioecious; female flowers are on compact spikes 2 in long, male flowers are in dense spikes reaching 8 in long.

General Description.—Sapwood, pale in color, is clearly distinguishable from the pale yellowish brown or dark chocolate-brown heartwood. It is a medium weight, averaging about 40 lb/ft ^{3} seasoned and about 65 lb/ft ^{3} green. The grain is typically interlocked. The texture is coarse.

Seasoning.—Iroko seasons well without much degrade. The British Forest Products Laboratory kiln schedule E has proved satisfactory (FPRL, 1956).

Durability.—Very durable. The timber is resistant to, but not immune from, termite attack. It is extremely resistant to preservative treatment. The sapwood is permeable.

Working Qualities.—Iroko is hard to work with hand and machine tools, and dulls cutting edges very rapidly. Due to its interlocked grain, care must be taken in planing quarter-sawn material to avoid pick-up; a reduction of cutting angle to about 15° may be necessary. It takes nails and screws well, stains and polishes well, although it requires grain filler. It glues satisfactorily.

Uses.—It is extensively used locally for all kinds of construction work and carpentry. It is used for railroad cross-ties, bridges, fencing, carriage and wagon construction, and for bearers and flooring. Iroko is also used for tight cooperage and also for containers for radioactive materials.

Xylem Anatomy.—Growth rings present. Wood diffuse-porous. Vessels: solitary or in pairs, rarely 3's; circular to oval in cross-section; average pore diameter 260μm, range 100μm–390μm; average vessel element length 430μm, range 250μm–625μm; vessel wall thickness 4μm–6μm; perforation plates probably simple; vessel element end wall inclination is transverse; intervascular pitting transitional, between alternate and opposite, slitlike and small. Imperforate tracheary elements: nonseptate fiber tracheids, average length 1780μm, range 1563μm–2275μm; simple pits few on the radial walls. Vascular rays: heterocellular (upright and procumbent cells—the upright cells confined to the top and bottom of the ray), multiseriate, mostly 3 or 4 cells wide, 10 to 25 cells high, biseriate rays rare, uniseriate absent. Rays almost storied (transitional). Axial parenchyma: paratracheal, aliform confluent. Crystals: none observed, although generally noted for its profuse crystals of calcium oxalate, which sometimes coagulate to form big lumps. Special note: Tyloses present in vessels.

Using Tippo's 1946 concept of phylogeny, with special reference to xylem anatomy, this wood appears to be generally more advanced due to the simple transverse perforation plate, shorter circular vessels, transitional pitting of vessel wall between opposite and alternate types, paratracheal axial parenchyma and the almost storied nature of the rays and fibers.

PLATE 19

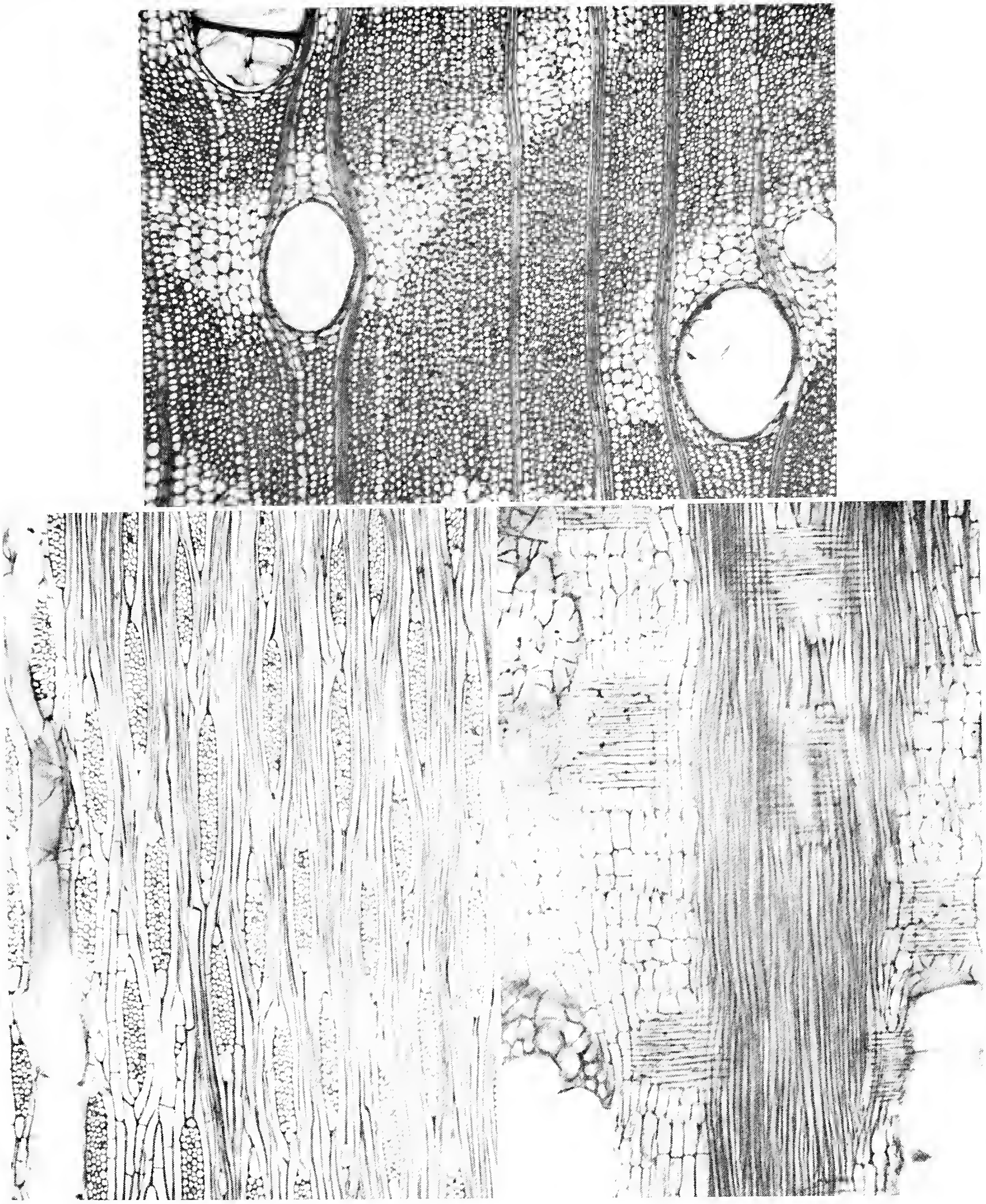


PLATE 20

MORACEAE

Musanga cecropioides R. Brown

(Syn. *M. smithii* R. Brown)
Local name: Odwuma (Ghana), also known as umbrella tree or corkwood

A small- to medium-sized, erect tree up to about 90 ft high. Girth over 6 ft above roots. Common on old farms in closed forest. Natural regeneration is prolific, often gregarious. Odwuma is of rapid growth and has stilt or prop roots. Branches are spreading, the crown umbrella-like. Buds are enclosed in large, red, hairy, and deciduous stipular sheaths up to 8 in long. Leaves are alternate, 18 × 4 in, grayish and hairy below, deeply digitately lobed, acuminate at tip, with the base cuneate. Petiole up to about 24 in long, brown, tomentose, with numerous lateral nerves. Flowers inconspicuous. Fruits succulent, green.

General Description.—The timber is very light. There is no distinction between sapwood and heartwood, the color being pinkish white throughout. Information on seasoning and other qualities is lacking. It is perishable.

Uses.—It is used instead of cork to serve as rafts or floats. It is used for temporary walls, isothermic ceilings, and inferior roofing shingles. Charcoal made from this tree is used as a floor polish (Irvine, 1961). *Musanga* species have very long fibers with thin walls and are, therefore, considered suitable for papermaking.

Xylem Anatomy.—Growth rings are absent. This wood is diffuse-porous. Vessels are usually solitary, occasionally in pairs, circular in outline. Average pore diameter 28μm, range 9μm–34μm; vessel wall thickness averages 4μm; average vessel element length 535μm, range 388μm–688μm. Fiber tracheids, average length 535μm, range 350μm–1225μm. The wood is storied. Pits of tracheids are very tiny and without pattern of distribution. Perforation plates of vessels are simple and transverse. Pits on vessel walls are bordered and arranged both oppositely and alternately. Vascular rays are heterogeneous, mainly multiseriate, although some are uniseriate. Rays are 250μm–850μm tall and 15μm–50μm wide. Axial parenchyma is scanty and anatracheid-vasicentric. Crystals are rhomboidal and found in rays.

PLATE 20

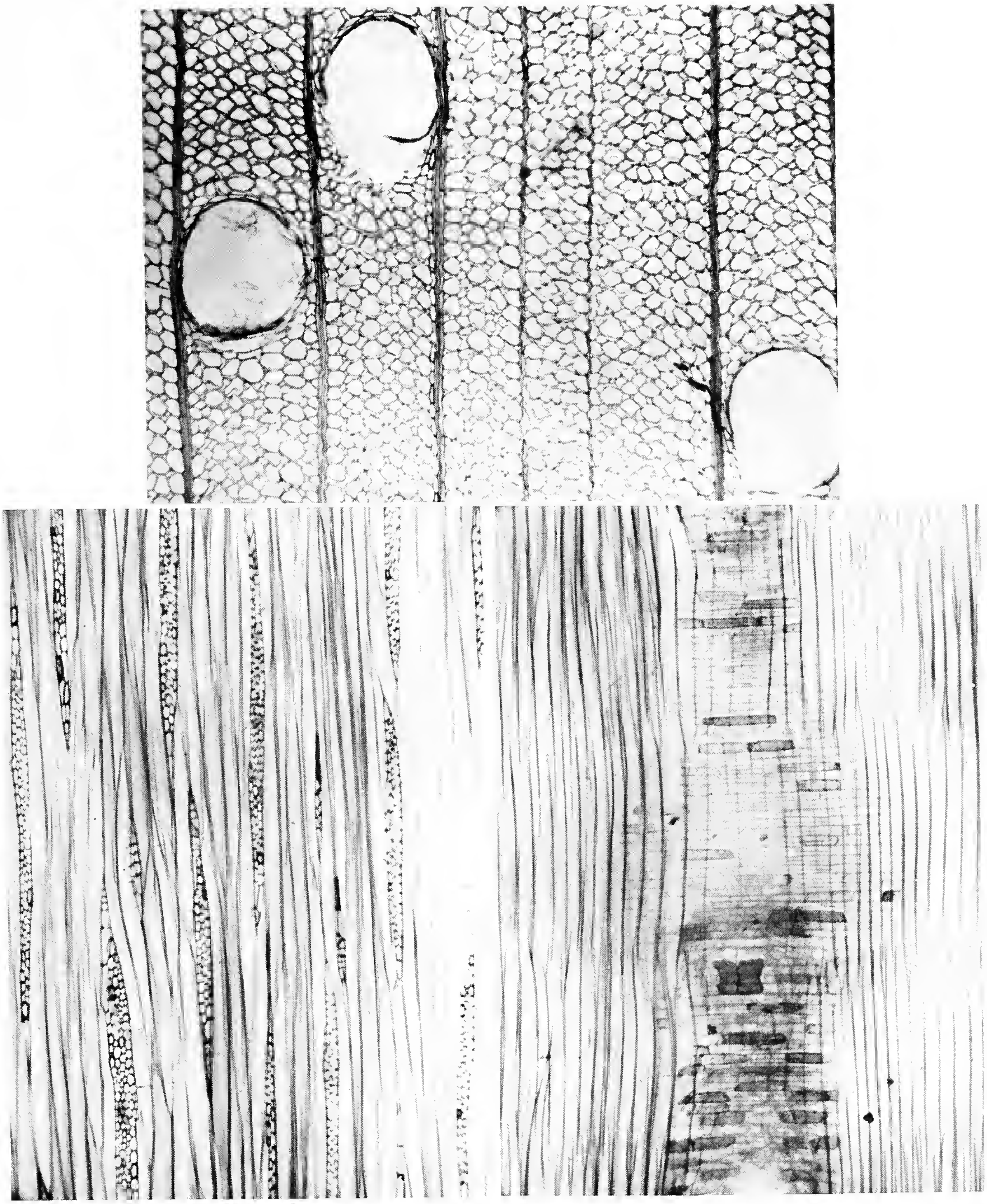


PLATE 21

OCHNACEAE

Lophira alata Banks ex C. F. Gaertner

Standard trade name: Ekki
Local names: Kaku (Ghana), Eba (Nigeria), Azobe (France and French-speaking West Africa)

Ekki may reach a height of 160 ft to 180 ft and a diameter of more than 6 ft at breast height. The bole has no buttresses but the basal swelling may extend for some 12 ft up the trunk. The bole is often free of branches for 80 to 100 ft. Crown triangular, bark reddish brown, peeling in loose flakes, slash red, leaves shorter, broader, and more obovate than those of savanna form (Irvine, 1961), petioles also shorter. Flowers white or golden yellow. Fruits over one inch long, pointed, nearly ½ in wide, broader than those of *L. lanceolata*, wing also much shorter, about ½ in long (Irvine, 1961:91).

General Description.—Ekki is outstanding for its hardness and weight, weighing from 56 to 71 lb/ft ^{3} at 12% mc. The green weight is about 77 lb/ft ^{3} at 45% mc. The specific gravity ranges from 0.74 to 0.97 based on volume when green and oven-dry weight. Heartwood is red or deep chocolate brown with a mottled appearance due to conspicuous white deposits in the pores. The sapwood is paler in color and about 2 in in width. The grain is usually interlocked; the texture coarse and uneven.

Seasoning.—It is an extremely refractory species. Not only does it dry very slowly, but severe splitting and some distortion are likely to occur during seasoning. It needs to be stacked with special care. British Forest Products Laboratory kiln schedule B is recommended for this species (fprl, 1956).

Durability.—Damage by ambrosia (pinhole borer) beetles is occasionally present. It is resistant to, though not immune from, attack by termites. Ekki is rated the most durable timber on the west coast of Africa. Maritime structures in France, Belgium, and Holland have remained intact after more than 20 years of service. Piers were found in excellent condition after 12 years of standing in brackish water infested with teredos (Forest Products Laboratory, 1965). In temperate climates the wood is almost rot-proof. It is extremely resistant to preservative treatment.

Working Qualities.—The timber is difficult to work with hand and machine tools. Dry material blunts cutting edges fairly quickly but the blunting effect of green material is not so severe. Some tearing occurs in planing with the normal cutting angle of 30°, but the finish is usually satisfactory. The timber tends to char in boring. It cannot be nailed without preboring. It has variable but generally good gluing properties.

Uses.—The high durability and hardness of ekki make it particularly suitable for pilings. It is regarded as superior to reinforced concrete for all hydraulic works or structures, such as landing stages, piling, wharves, dams, or locks. In Africa it is used untreated for sleepers and for construction work, such as bridges. It is a good heavy-duty flooring timber for warehouses and factories where a very smooth surface is not essential.

Xylem Anatomy.—Growth rings absent. Wood diffuse-porous. Vessels: mostly solitary, others in multiples of 2 or 3, oval; average pore diameter 196μm, range 98μm–244μm; average vessel length 308μm, range 210μm–560μm; vessel wall thickness 4μm; perforation plates simple; vessel element end wall inclination slightly oblique to transverse; intervascular pitting alternate. Imperforate tracheary elements: average length 1250μm, range 1150μm–2300μm. Vascular rays: homogeneous mostly multiseriate, 2 to 4 cells wide, 8 to 26 cells high; uniseriate and biseriate also present but few. Axial parenchyma: paratracheal, tendency towards aliform. Tanniferous material present in some vessels.

PLATE 21

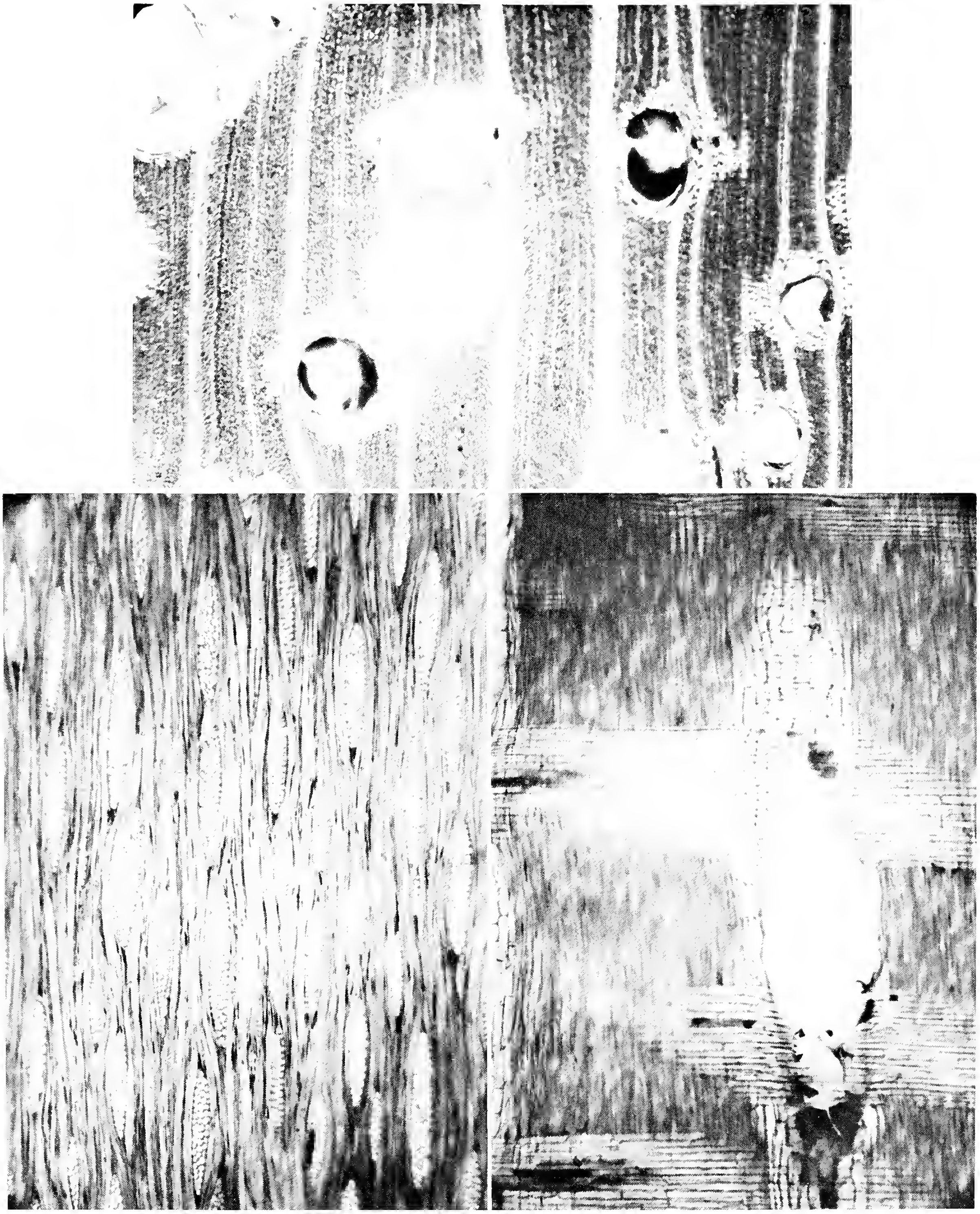


PLATE 22

RUBIACEAE (NAUCLEACEAE)

Mitragyna stipulosa (DeCandolle) O. Kuntze

Standard trade name: Abura
Local name: Subaha

A swamp forest tree up to 100 ft tall, sometimes of vast size; leaves simple, opposite with interpetiolar stipules; flowers small, scented; sapwood white, heartwood pinkish yellow, moderately hard and straight-grained.

General Description.—It is a light-weight wood, average weight being about 35 lb/ft ^{3} seasoned. Its green weight averages about 55 lb/ft ^{3}. The color of the wood is light yellowish brown or pinkish brown. It has moderately straight or interlocked grain and even texture.

Seasoning.—Abura seasons rapidly and well without any degrade. British Forest Products Laboratory kiln schedule K is strongly recommended (FPRL, 1956).

Durability.—It is not durable. It is moderately resistant to preservative treatment; the sapwood, however, is permeable.

Working Qualities.—This timber usually works well with hand and machine tools but has a variable dulling effect on cutting edges. For a good finish, then, sharp cutting edges should be employed. It stains and polishes well and takes light nails satisfactorily.

Uses.—Abura is used for light construction work. Since it is acid resistant, it is used for battery boxes as well as laboratory fittings, brick backs, and some classes of pattern making.

Xylem Anatomy.—Growth rings absent. Wood diffuse-porous. Vessels: mostly paired but also solitary and in radially oriented (occasionally tangential) groups of 3 to 5; mostly oval pore openings but sometimes circular or somewhat angular; average radial pore diameter 60μm, range 40μm–70μm; average tangential pore diameter 80μm, range 55μm–105μm; average vessel element length 608μm, range 275μm–913μm; vessel wall thickness 3μm; perforation plates not seen; vessel element end wall inclination 15° to 45° from horizontal; intervascular pitting alternate. Imperforate tracheary elements: nonseptate fiber tracheids, average length 1701μm, range 963μm–2313μm; fiber tracheids with slitlike pits on radial and tangential walls, slits slightly inclined from the horizontal. Vascular rays: heterogeneous; largely multiseriate, only a few uniseriate rays seen; mostly 2 (sometimes 3) cells wide, 9 to 49 cells high excluding uniseriate and biseriate tails; tails 2 to 6 cells high, occasional multiseriate rays divided near middle by uniseriate row of ray cells; ray cells in part occluded with dark amorphous material. Axial parenchyma: apotracheal, diffuse, isolated or in small groups of radially oriented cells.

PLATE 22

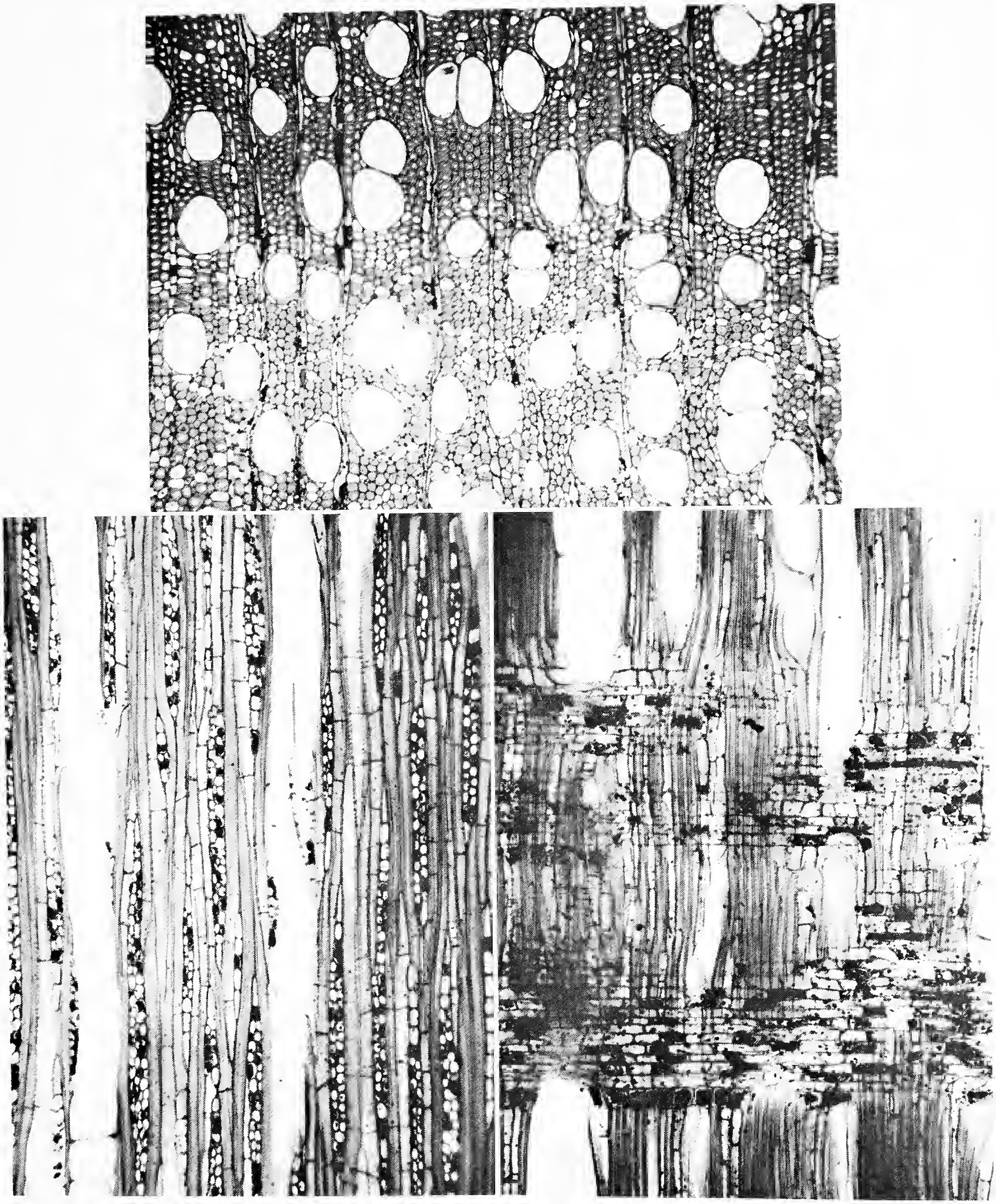


PLATE 23

RUBIACEAE (NAUCLEACEAE)

Nauclea diderichii (DeWildeman & Durand) Merrill

Standard trade name: Opepe
Local names: Jusia (Ghana and Ivory Coast), Bilinga (Cameroons)

Large trees abundant in wet places in evergreen and deciduous forests in Liberia, Ivory Coast, Ghana, South Nigeria, British Cameroons, Vbdngi-Shari, Gabon, Congo, Uganda, and Mozambique. The unbuttressed trunks attain a height of 120 ft and a girth of 9 ft, with yellowish rough bark having loose, papery scales; slash exudes a yellowish to brown sap that becomes sticky. Twigs are black, speckled.

The large (9–12 × 5–7 in), shining leaves are elliptic, acute at the ends, keeled towards the base, and stipulate. They are mostly deciduous except at the ends of shoots, and the nodes are often occupied by ants (Kennedy, 1936:216).

The small, white flowers are hairy inside and appear from February to June in small, globose, terminal heads. The fruit is yellow, fleshy, in a globose head deeply pitted between the deeply fused calyx lobes. The fruit dries hard, with embedded seeds, and is eaten in times of scarcity.

General Description.—The sapwood is white, the heartwood golden yellow, darkening later. It is hard, moderately heavy, average weight being about 46 lb/ft^3 seasoned, and about 70 lb/ft^3 when green. The grain is usually interlocked or irregular. The texture is fairly open, owing to rather large pores.

Seasoning.—With quarter-sawn material, seasoning appears to be fairly quick with little degrade, but flat-sawn timber is apt to prove refractory (FPRL, 1956). British Forest Products Laboratory kiln schedule E is recommended.

Durability.—Opepe is very durable. It is moderately resistant to preservative treatment. The sapwood is, however, permeable.

Working Qualities.—The wood works well, has a lustrous surface, and takes a good polish; it has a tendency to split when nailed but takes screws fairly well. The timber can be glued satisfactorily.

Uses.—It is eminently suitable for harbor work such as piles, fenders, and wallings because of its resistance to marine borers. It is used for heavy structural work, planking, railway wagon bottoms, railway cross-ties, and also as telegraph cross-arms. Opepe is also used for *fufu* mortars (in Ghana), canoes, and for making charcoal. In French Equatorial Africa the boiled, steeped bark is used to treat gonorrhea and stomach complaints. Leaves are used for fevers and diarrhea. Workers with the wood have suffered, sometimes fatally, from a wood alkaloid said to be a cumulative cardiac poison (Henry, 1949:665).

Xylem Anatomy.—No annual rings. Wood diffuse-porous. Vessels solitary, oval, none angular; average pore diameter 100μm, range 150μm–210μm; average vessel element length 711μm, range 375μm–1000μm; vessel wall thickness ca. 6.25μm; perforation plates mostly inclined about 10° to 20°, some transverse, simple perforations; intervascular pits very small, bordered with slitted apertures, alternate. Imperforate tracheary elements: no septate fibers evident; many fibers with few or no pits, others with numerous bordered pits in a single rank. Vascular rays: mostly heterogeneous and heterocellular; 1 to 3 seriate cells, 3 to 37 cells high; many with long "tails"; no fusiform rays. Axial parenchyma: apotracheal, scanty, in short or broken tangential chains.

Only in the lack of angular vessels and in the simple, mostly transverse perforation plates does this wood show advanced characters. In other respects it is primitive.

PLATE 23

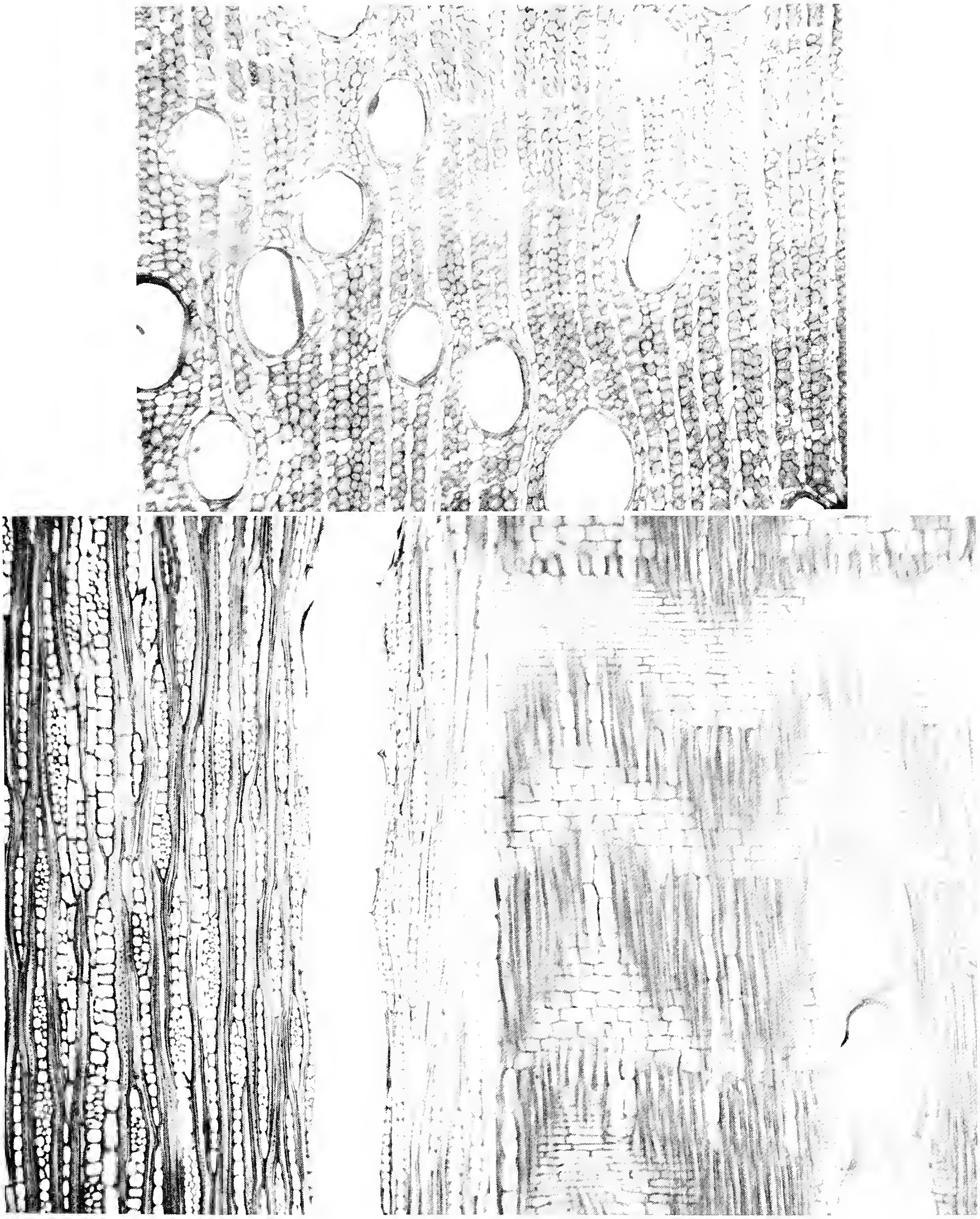


PLATE 24

SAPOTACEAE

Tieghemella heckelii Pierre ex. A. Chevalier

(Syn. *Mimusops heckelii* Hutchison & Dalziel)
Standard trade name: Makore
Local name: Baku (Ghana)

A large evergreen and deciduous forest tree growing up to 200 ft high and 30 ft in girth. The leaves are dark green and shining with numerous faint lateral nerves, obovate, and measure 6 × 2.5 in. The flowers are white, glabrous outside, axillary with pedicels 0.75 in long, and are crowded at tips of branchlets.

General Description.—Makore is moderately hard and of medium weight, seasoned weight averaging about 39 lb/ft^3 and green weight about 53 lb/ft^3. The 2–3-in wide sapwood is lighter in color. The heartwood varies in color from pinkish brown to reddish brown or dark blood-red. The generally interlocked grain is sometimes straight. The luster is high, texture uniform and fine.

Seasoning.—Makore has a moderate rate of seasoning often with little degrade. British Forest Products Laboratory kiln schedule H is recommended (FPRL, 1956).

Durability.—Makore is one of the most durable timbers of West Africa. It is very resistant, though occasionally attacked by pinhole borers and powder-post beetles. In preservative treatment it is extremely resistant, the sapwood being moderately resistant.

Working Qualities.—The timber works readily with machine and hand tools; it does, however, cause rapid blunting of cutting edges. A good finish is usually obtained with standard machining conditions. It stains and polishes well, giving excellent results. Nailing tends to split it. It glues satisfactorily.

Uses.—It compares favorably with African mahogany and can therefore be used for all purposes which African mahogany is used. It is used for furniture and fine decorative work, for veneer and plywood.

Xylem Anatomy.—Growth rings absent. Wood diffuse porous. Vessels: generally in radial multiples of 3 to 6 pores but solitary pores and vertical pairs present; oval in outline; average pore diameter 66μm, range 40μm–85μm; average vessel element length 585μm, range 388μm–900μm; vessel wall thickness 3.5μm; perforation plates simple; vessel element end wall inclination slightly oblique to strongly oblique; intervascular pitting alternate, relatively large. Imperforate tracheary elements: nonseptate fibers, average length 1268μm; range 1000μm–1650μm; fibers with a few scattered simple pits on tangential walls. Vascular rays: heterogeneous, mainly multiseriate, generally 3 cells wide, 8 to 18 cells high, but biseriate cells also present. Axial parenchyma: apotracheal, banded, cells with gummy deposits within. Crystals absent.

PLATE 24

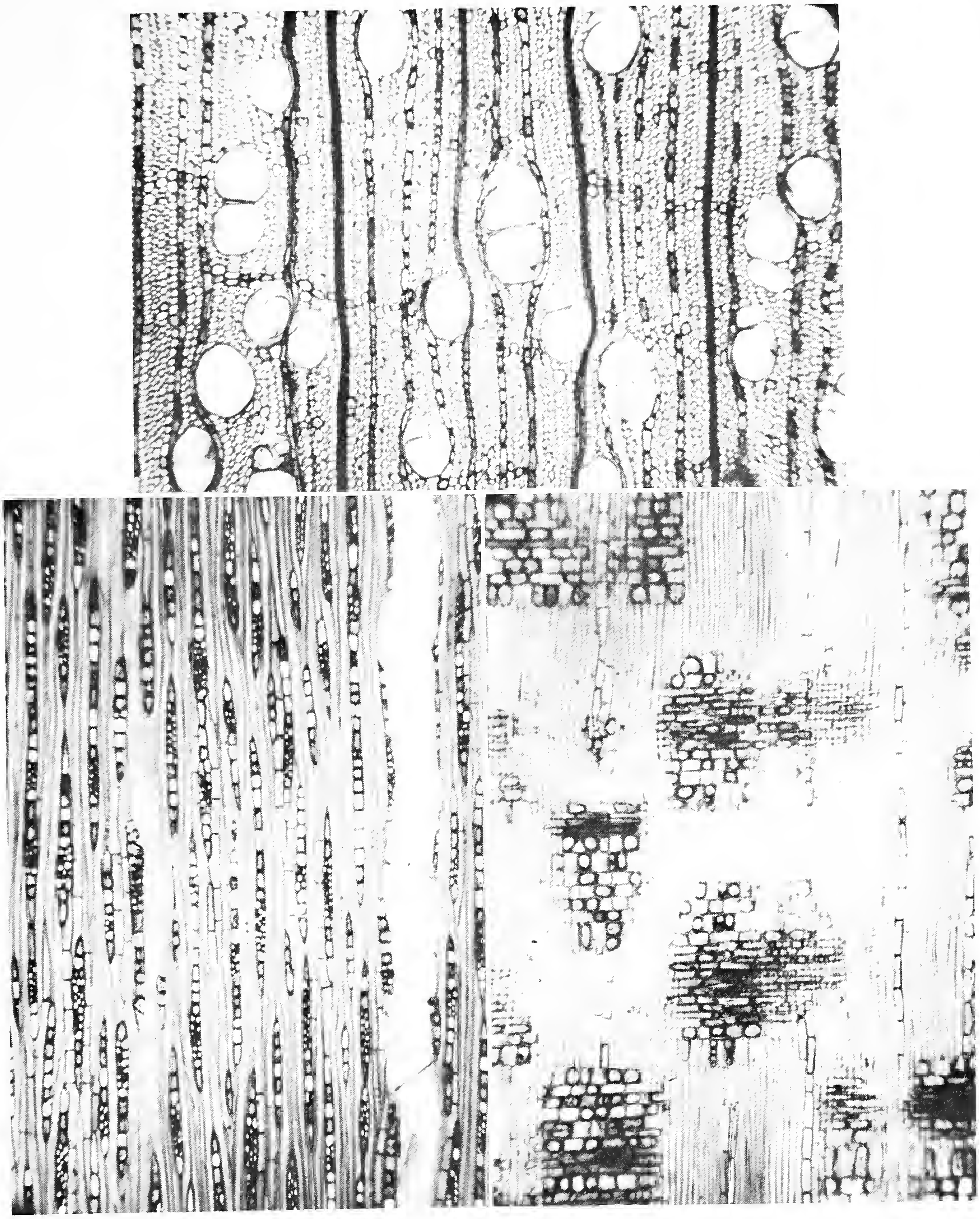


PLATE 25

STERCULIACEAE

Nesogordonia papaverifera (A. Chevalier) R. Capuron

Standard trade name: Danta
Local name: Danta (Ghana)

A deciduous forest tree up to 110 ft in height and 9 ft in diameter. Leaves alternate, up to 5 × 2.25 in, ovate-elliptic, apex acuminate, base cuneate, margins entire, minutely stellate-puberulous below, becoming glabrous. The flowers are yellowish white, few, about 0.5 in long and in slender, axillary cymes.

General Description.—Danta has an average weight of 46 lb/ft ^{3} seasoned and about 63 lb/ft ^{3} green. It has a fine, even texture. The reddish brown heartwood is distinct from the light-colored sapwood, which is usually about 2 in or more wide. Danta has a narrowly interlocking grain producing, when quarter-sawn, a striped appearance somewhat similar to that of sapele.

Seasoning.—Danta seasons rather slowly, but well, with comparatively little degrade. Knots have the tendency to split. British Forest Products Laboratory kiln schedule E is recommended (FPRL, 1956).

Durability.—It is moderately durable. The heartwood is resistant to preservative treatment, whereas the sapwood is moderately resistant.

Working Qualities.—The timber works fairly easily with both hand and machine tools. The grain has a tendency to pick-up, especially when the quarter-sawn material is planed. This can be eliminated with the reduction of the cutting angle to about 15°. It tends to split on nailing but glues and finishes satisfactorily.

Uses.—Danta is suitable for veneer and plywood, used for carriage and wagon work, and for general construction. It is also used for telephone poles and cross-arms and for tool handles. Because of its smooth wear and high resistance to abrasion, it is recommended for most forms of flooring, particularly where a decorative effect is desirable.

Xylem Anatomy.—Growth rings absent. Wood diffuse-porous. Vessels: solitary or in chains of 2 to 4; circular to wide elliptic in outline, occasionally angular, tyloses present; average pore diameter 75μm, rather uniform; average vessel element length 326μm, range 275μm–413μm; vessel wall thickness about 3μm; perforation plates generally simple; vessel element end wall inclination transverse to slightly oblique, intervascular pitting alternate, average in size. Nonseptate fibers with scanty, simple pitting scattered on radial walls. Vascular rays: storied, homogeneous, homocellular, mostly biseriate, occasionally multiseriate, 15 to 25 cells high. Axial parenchyma: paratracheal, abundant, with stained deposits in most; in uniseriate, tangential bands. The wood is a relatively advanced one. Special note: axial parenchyma in uniseriate, tangential chains.

PLATE 25

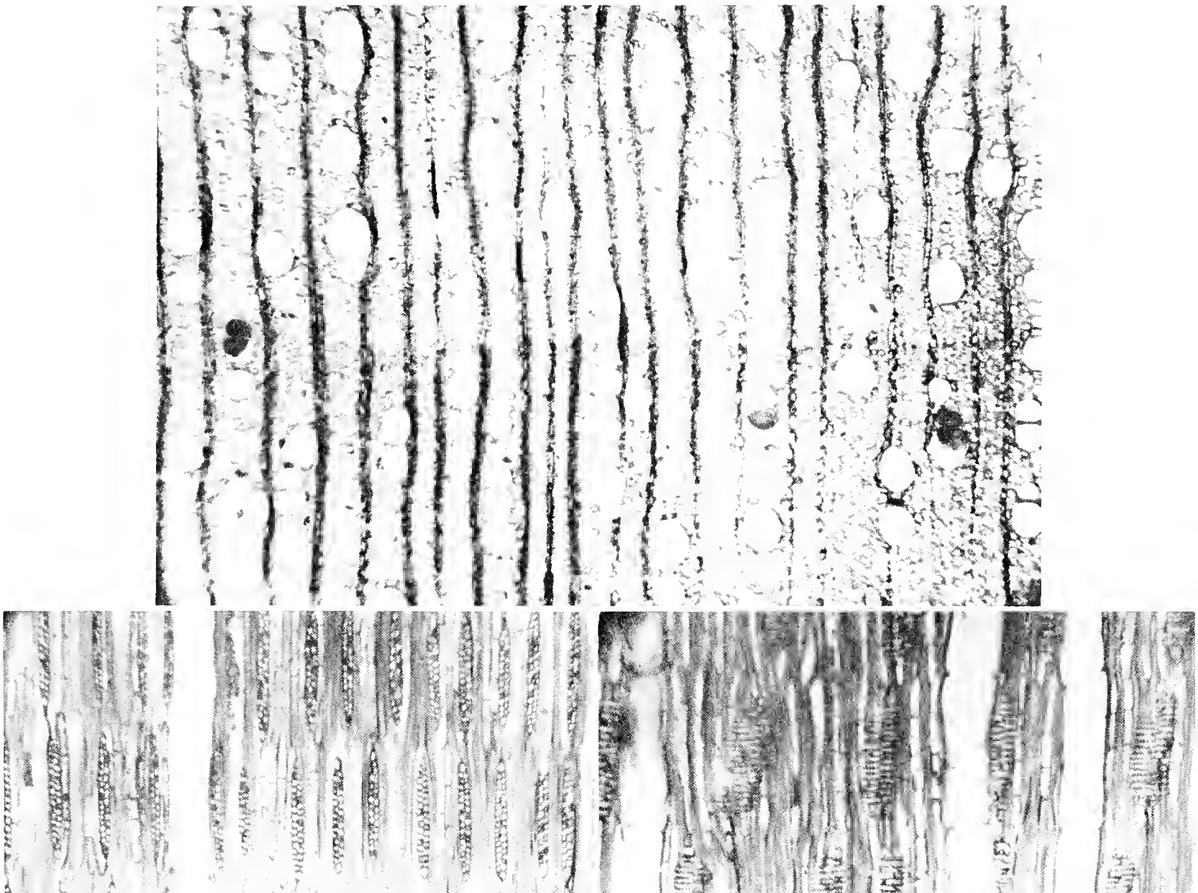


PLATE 26

STERCULIACEAE

Tarrietia utilis Sprague

Standard trade name: Niangon
Local name: Nyankom (Ghana)

A tree with a height of over 100 ft and a girth of up to 9 ft; bole cylindrical, up to 60 ft, with arched buttress and stilt roots. Leaves brown and densely scaly below, quite variable in shape, simple and entire on fertile branches and seedlings, digitate with 5 to 7 leaflets otherwise. Flowers are small, white, in racemes, axillary clusters.

General Description.—The heartwood is rather variable from pale pink to reddish brown and is not clearly demarcated from the grayish sapwood. The timber is medium hard and has wide range in weight from about 32 to 45 lb/ft^3; the average weight about 39 lb/ft^3. Niangon resembles African mahogany superficially, but its greasy feel and conspicuous rays readily distinguish it from African mahogany.

Seasoning.—Seasons rapidly and well, with little or no distortions. British Forest Products Laboratory kiln schedule E is recommended (FPRL, 1956).

Durability.—It is moderately durable and extremely resistant to preservative treatment.

Working Qualities.—Niangon works easily and readily with machine and hand tools. Its dulling effect on cutting edges is very little. The wood cuts and bores cleanly; it nails, screws, glues, polishes and stains satisfactorily, though a grain filler may be required during polishing.

Uses.—Suitable for furniture, building, both interior and exterior, joinery, and cabinet work. It is also used for boat building.

Xylem Anatomy.—Growth rings absent. Wood diffuse-porous. Vessels: solitary with a few multiples of 2 or 3 pores (rarely more), or occasionally a close association of 2 or 3 full-sized vessels; circular to ellipsoidal in shape; average pore diameter 242μm, range 160μm–310μm; average vessel element length 382μm, range 325μm–450μm. Vessel wall thickness ca. 10μm–12μm; perforation plates appear scalariform (but this is not clear), vessel end wall inclination very slightly oblique to transverse; intervascular pits numerous and alternate, generally small. Imperforate tracheary elements: average length 1903μm, range 1375μm–2375μm; walls with scattered pits. Vascular rays: mainly homogeneous and uniseriate, at times biseriate, and then a tendency towards heterogeneity; fusiform rays up to 10 cells wide and 50 cells high, frequently with dark deposits. Axial parenchyma: apotracheal, diffuse and plentiful, cells with dark deposits.

Appears somewhat primitive in xylem anatomy when applying Tippo's principles.

PLATE 26

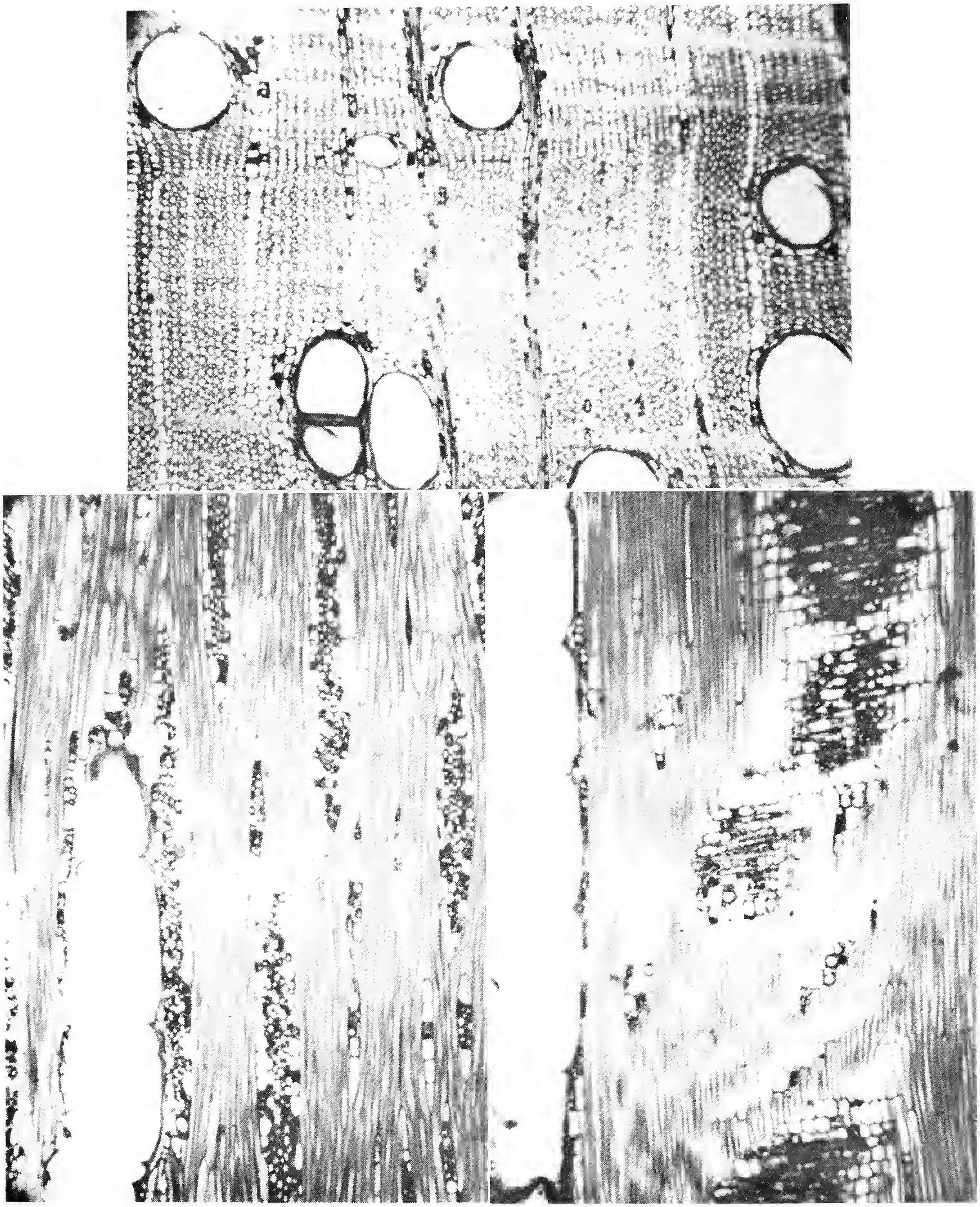


PLATE 27

STERCULIACEAE

Triplochiton scleroxylon K. M. Schumann

Standard trade name: Obeche, African whitewood
Local name: Wawa (Ghana)

A large tree up to 160 ft high and 10 ft or more in girth, bole straight and unbranched, up to 80 ft. Extensive, sharp buttresses extend as far as 25 ft up. The leaves are eaten by the African silkworm, *Anaphe venata*.

General Description.—Obeche, soft and light, has an average weight of about 24 lb/ft ^{3} when seasoned and about 35 lb/ft ^{3} green. Its color is nearly white or pale straw. There is no clear distinction between sapwood and heartwood, the sapwood being about 3–4 in wide. The grain is typically interlocked and the texture moderately coarse.

Seasoning.—Obeche seasons very rapidly and well, with very little or no defects. British Forest Products Laboratory kiln schedule L is recommended (FPRL, 1956).

Durability.—The timber is susceptible to attack by ambrosia and powder-post beetles. It is not durable. In preservative treatment the sapwood is permeable but the heartwood is resistant.

Working Qualities.—The wood works very easily with all hand and machine tools with little dulling effect on the cutting edges. The timber finishes well in most operations, taking nails and screws readily, although they do not hold well under certain circumstances. It requires grain filler in polishing.

Uses.—Used for interior core of plywood, for crating and packing cases. It is also used for interiors of drawers and cupboards.

Xylem Anatomy.—Slight evidence of growth rings. Wood diffuse-porous, but looks slightly ring-porous in distribution. Vessels: solitary but with a few radial multiples of 2 or 3 pores; circular in outline, slightly angular, average pore diameter 126μm, range 110μm–150μm; average vessel element length 300μm, range 212μm–375μm; perforation plates exclusively simple; vessel element end wall inclination slightly oblique to transverse; intervascular pitting opposite, rather large. Imperforate tracheary elements: septate fiber tracheids, average length 1690μm, range 1225μm–2075μm; fibers with few simple pits on tangential walls. Vascular rays: heterogeneous, mainly multiseriate, generally 7 cells wide, 34 cells high, but biseriate and uniseriate cells also present; fusiform rays up to 4 cells wide. Axial parenchyma: apotracheal, abundant. Biseriate and uniseriate also present; fusiform rays up to 5 cells wide.

PLATE 27

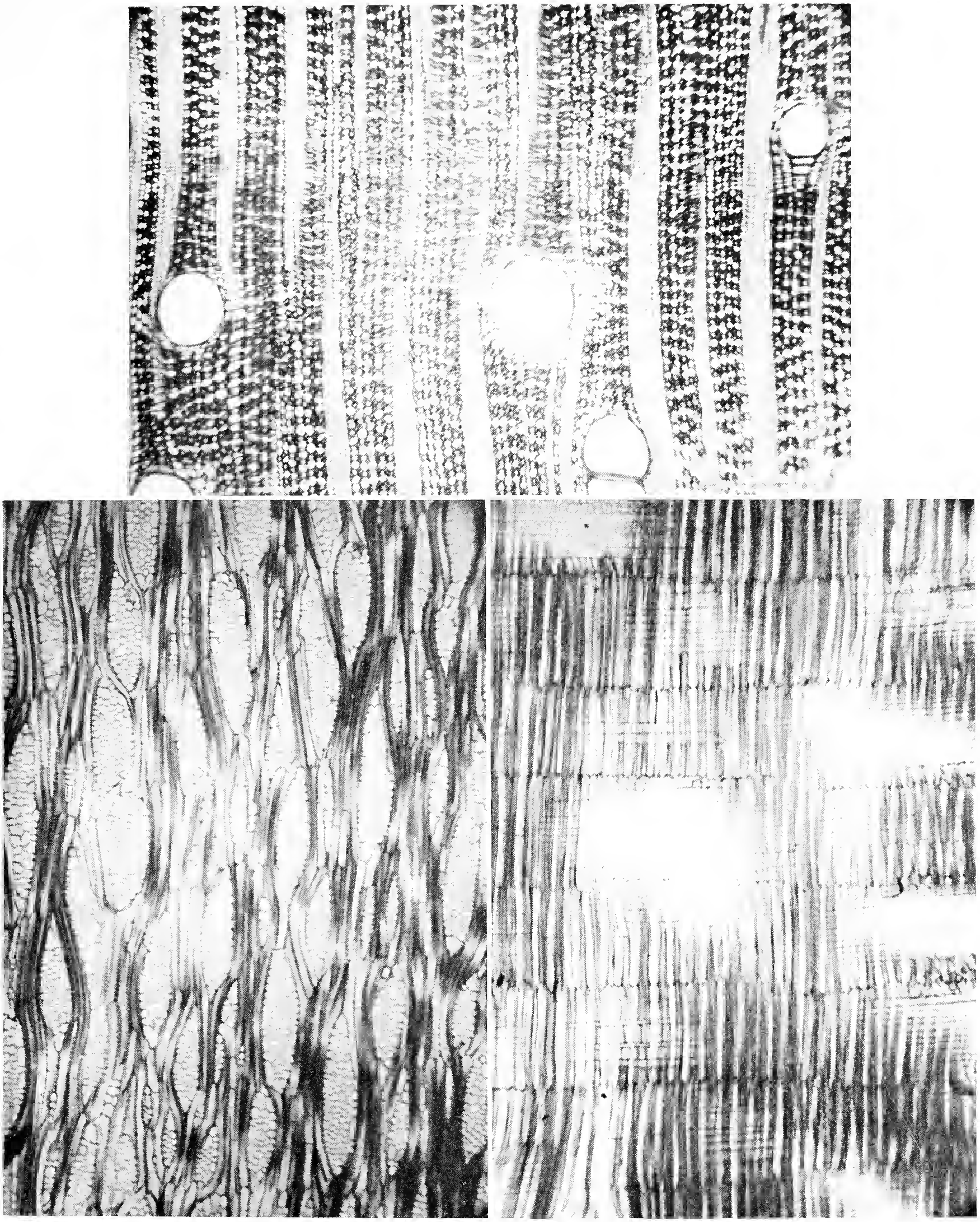


PLATE 28

ULMACEAE

Celtis mildbraedii Engler

(Syn. *C. soyansii* Engler)
Standard trade name: Celtis
Local name: Esa-fufuo

A common mixed deciduous forest tree growing up to 120 ft high and up to 10 ft in girth. The leaves are up to 7 × 3 in long, acuminate, elliptic obovate, stipulate, coarsely toothed, especially towards the apex, rarely entire. The flowers are minute, axillary, greenish white, rusty pubescent.

General Descriptions.—The wood weighs 45–50 lb/ft ^{3} seasoned and averages about 49 lb/ft ^{3}; it is hard and medium heavy. High luster, fine texture and interlocked grain, although sometimes straight. *Celtis* species have whitish or light yellow color when green, becoming grayish white later.

Seasoning.—Celtis can be kiln seasoned fairly rapidly from the green condition with little degrade.

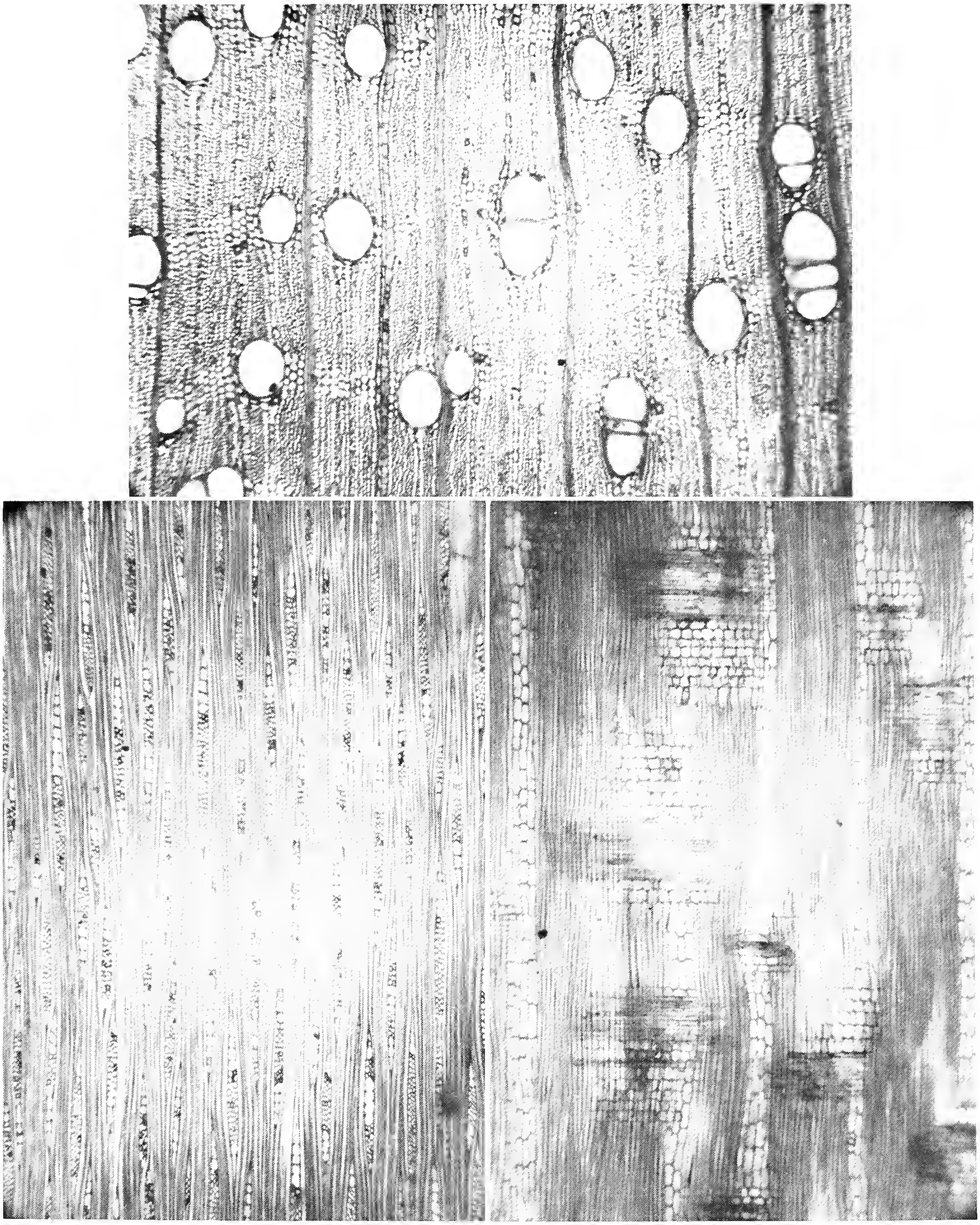
Durability.—Celtis is not durable. It is susceptible to severe damage by ambrosia and powder-post beetles. In preservative treatment the sapwood is said to be permeable while the heartwood is moderately resistant.

Working Qualities.—With machine tools celtis works well, but it is hard to work with hand tools as it dulls the cutting edges moderately. It finishes well without requiring special treatment. It peels satisfactorily and glues well, but nailing may split it. Preboring may be necessary.

Uses.—Celtis can be used for flooring and telegraph poles (treated). It is used for house posts, sports gear, and also locally (in Ghana) for *fufu* pestles. It has good strength properties and should be a useful substitute for ash. It is a good substitute for maple for dance floors (FPRL, 1956). It is used for furniture framing, commercial plywood, and light colored veneer.

Xylem Anatomy.—Growth rings variable (?). Wood diffuse-porous. Vessels: in 2's and 3's, but range from 1 to 7; generally circular; average pore diameter 59μm, range 50μm–70μm; average vessel element length 399μm, range 288μm–538μm; vessel wall thickness undetermined; perforation plates simple; vessel element end wall inclination oblique to transverse; intervascular pitting alternate. Imperforate tracheary elements: nonseptate fiber tracheids, average length 1346μm, range 1063μm–1563μm; fibers with no pits. Vascular rays: homogeneous, multiseriate (triseriate), generally 3 cells wide, 6 to 25 cells high, but uniseriate and biseriate present; no fusiform rays; no intercellular canals. Axial parenchyma: paratracheal, scanty with no amorphous deposits, apotracheal, abundant. Crystals: not present.

PLATE 28



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Glossary

In this glossary are the principal terms used in describing the anatomical features of timbers. Although most of the terms apply to the secondary xylem, there are many that are applicable to the primary xylem as well. For the most part, this glossary is based on the definitions of descriptive terms by Kribs (1935, 1937), Tippo (1941), Metcalfe and Chalk (1950), the Committee on Nomenclature of the International Association of Wood Anatomists (1957), and Esau (1960).

AXIAL PARENCHYMA CELLS. Parenchyma cells derived from fusiform cambial initials. Cells of the same length as the parent fusiform cambial initials are designated *fusiform parenchyma*. When further cell divisions take place, the original fusiform cell divides to form an axial series of shorter cells; this series of cells is termed *strand parenchyma*, as in *Parkia* (Leguminosae). Axial parenchyma are present in most species, ranging from abundant to sparse, and sometimes absent. Simple pits, sometimes bordered or half-bordered, occur between xylem parenchyma cells.

Classification of axial parenchyma is ordinarily based on the relationship of the parenchyma to vessels in the same species. There are a number of systems, each more or less complex.

Apotracheal parenchyma: Axial parenchyma that is typically independent of the vessels.

Banded apotracheal axial parenchyma form concentric lines or bands typically independently of the vessels. Bands may be one or more cells wide.

Diffuse: Single apotracheal parenchyma strands or cells which are distributed irregularly among fibers.

Diffuse-in-aggregates: Axial apotracheal parenchyma grouped in short tangential lines from ray to ray. This type is often called reticulate parenchyma when regularly formed.

Marginal apotracheal parenchyma cells are formed either singly or in a more or less continuous layer of variable width at the edge of a growth ring and may be either *terminal* (appearing at the close of a growth period) or *initial* (appearing at the beginning of a growth period).

Paratracheal parenchyma: Axial parenchyma associated with the vessels or vascular tracheids.

Aliform paratracheal parenchyma have wing-like lateral extensions.

Banded paratracheal axial parenchyma form concentric lines or bands that are associated with the vessels.

Confluent parenchyma are coalesced aliform types which form irregular tangential or diagonal bands.

Scanty paratracheal parenchyma are incomplete sheaths or occasional parenchyma cells around the vessels.

CRYSTALS. Crystals are of very common occurrence and are sometimes valuable features in identification. Frequently crystals are found in axial parenchyma and ray cells, and less frequently in septate fibers and in tyloses. In some genera there are modifications of the crystal-containing cells, which are sufficiently consistent and infrequent to form useful guides to families and sometimes to genera. These are (1) presence of crystals in enlarged cells or idioblasts, (2) changes in the cell wall, causing the crystalliferous cells to become sclerosed, and (3) the presence of a number of crystals of variable size and shape in one cell. There are several types of crystals.

Acicular crystals are needle-shaped, often small, free in the cells, and not filling them.

Crystal sand is a granular mass of very fine small crystals.

Druse: Spherical crystal clusters either attached to the cell wall by a peg or lying free in the cells.

Elongated crystals are about four times as long as broad with pointed or square ends.

Raphides: Bundles of long needle-shaped crystals, tending to fill the whole cell.

Rhomboidal, square, or diamond-shaped crystals are the most common of all types. They may occur singly or as two or more per cell.

Rod-like crystals are similar to elongated crystals in shape, but only about twice as long as broad, and they usually have square ends.

DISJUNCTIVE PARENCHYMA. Axial or radial parenchyma cells partially disjoined during the process of differentiation; contact is maintained by means of tubular processes.

FIBRIFORM VESSEL ELEMENTS or perforated fiber-tracheids. Fiber-like vessel elements, fusiform in shape and with bordered pits, usually with very small, nonterminal perforation, which occur only in short axial series and are completely dissociated from the ordinary vessel elements in the same wood. These peculiar cells are extremely rare in woody plants and are seen in the vines of Passifloraceae.

GROWTH RING. Increments of growth that result from the discontinuous action of the vascular cambium. When present, they may be sharply defined and distinct, or weakly defined and indistinct.

IMPERFORATED TRACHEARY ELEMENTS consist of tracheids and fibers.

Tracheids: Imperforate wood cells with bordered pits to congeneric elements of the same magnitude as those in vessels of the same wood. Tracheids in hardwoods are short fibrous cells and are as long as the vessel elements with which they are associated. *Vasicentric tracheids* are short, irregularly formed tracheids with conspicuous bordered pits, in the immediate proximity of vessel elements that do not form part of a definite axial row. *Vascular tracheids* are specialized cells in certain hardwoods, similar in shape, size, and arrangement to small vessel elements, but differing from them in being imperforate at the ends. The lateral walls of vascular tracheids are copiously pitted and frequently possess spiral thickening as well.

Fibers. A term of convenience for elongated cells with pointed ends and thick or not infrequently thin walls. This term is used often to include tracheids but it is limited here to fiber-tracheids and libriform wood fibers. *Fiber-tracheids* is a typically fibrous cell with a relatively thick wall, tapering pointed ends, and small bordered pits. *Libriform wood fibers* are elongated, commonly thick-walled cells with simple pits; usually distinctly longer than the cambial initial as inferred from the length of the vessel elements and axial parenchyma strands.

Fibers are classified by length as follows: extremely short (< 0.5 mm = 500μm), short, very short (0.5–0.7 mm = 500μm–700μm), moderately short (0.7–0.9 mm = 700μm–900μm), medium-sized (0.9–1.6 mm = 900μm–1600μm), moderately long (1.6–2.2 mm = 1600μm–2200μm), long, very long (2.2–3.0 mm = 2200μm–3000μm), and extremely long (over 3.0 mm = over 3000μm).

INCLUDED (OR INTRAXYLARY) PHLOEM. Phloem strands or layers that are included in, and surrounded by, the secondary xylem in certain dicotyledonous woods.

INTERVASCULAR PITTING. Strictly speaking, intervascular pitting refers to the pits in the walls of adjacent vessel elements. The term is sometimes applied to pitting between any tracheary cells (prosenchyma) in wood. Pit-pairs between vessel elements and other prosenchymatous cells are usually bordered. Where they lead to parenchymatous elements, pits may be bordered, simple or half-bordered. Intervascular pits appear to best advantage on the tangential faces of vessel elements. Variation in the arrangement, size, and shape of these pits forms a useful and important diagnostic and descriptive feature. Pitting types are classified according to average size, as follows: very small to minute (up to 4μm), small (4μm–7μm), medium-sized (7μm–10μm), large (10μm–15μm), or very large (over 15μm). Pitting arrangements are as follows:

Alternate: Multiseriate pitting in which the pits are in diagonal rows. Pits are circular or oval if they are uncrowded; if crowded they are polygonal and frequently hexagonal.

Opposite: Multiseriate pitting in which the pits are in horizontal series, pits in each series being directly above and below pits in adjacent series. Crowding here may cause individual pits to be rectangular.

Scalariform: Pitting in which elongated or linear pits are arranged in a ladder-like series.

Transitional: Pitting intermediate between scalariform and opposite, which possesses some of the characteristics of each.

PERFORATION PLATE. That portion of the wall involved in the coalescence of two vessel elements, which bears the perforation through which the vessel elements are interconnected. Perforation plates show to the best advantage in radial sections that are fairly thick, sometimes 25μm or more.

Ephedroid: The ephedroid perforation plates is a special type found in *Ephedra,* and is characterized by a small group of rather large circular openings.

Multiple perforation: The perforated end wall in a vessel element consisting of two or more openings.

Reticulate: A perforation plate with many openings presenting a net-like appearance. This type of plate is often produced by the more or less profuse branching of the bars in a scalariform perforation plate, and the two types often occur together in the same wood. If the openings are small, circular, or polygonal, the plate can be described as *foraminate.*

Scalariform: A plate bearing multiple perforations that are elongated and parallel. In the formation of scalariform plates, the remnants of the cell wall that are left between the perforations are called *bars.* The number and width of bars vary considerably and are of diagnostic significance. They may be classified according to average number of bars, as follows: few (5 or less), intermediate (5 to 15), or many (over 15); and by the width of perforations. The range and most frequent range should be determined and reported.

Simple perforation: The perforation end wall in a vessel element consisting of only one usually large and more or less round opening.

PROSENCHYMA.—A general term of elongated cells with tapering ends. Note: Used in the past as a collective term for the fibers and tracheids, and sometimes the vessel members, as opposed to the parenchyma.

SECRETORY STRUCTURES. Secretions within the secondary xylem may be intracellular or extracellular; that is, secretions may remain within the producing cells, or be secreted from them. Gums and resins may be produced in intercellular spaces and are extracellular in nature, being secreted from the producing cells. Latices and oils, on the other hand, are generally produced within cells and are intracellular.

Intercellular secretory spaces consist of cavities or canals, which secrete either gum or resin. *Intercellular cavities* are sacs or pouches surrounded by a secretory epithelium. *Intercellular canals* are more or less elongated spaces, surrounded by a secretory epithelium and being axial or vertical, radial or horizontal in disposition. Canals may be normal or natural or pathologic or traumatic. The latter is of more frequent occurrence and often results from breakdown or degeneration of cells (gummosis).

Intracellular secretory structures consist of laticifers and secretory cells. *Laticifers* are structures containing and producing latices (latexes): an *articulated laticiferous tube* is a chain of cells in which the walls separating the cells remain intact, are perforated, or completely dissolved. These structures are often called latex vessels because of the resemblance to prosenchymatous vessels. A *nonarticulated laticiferous tube* consists of enlarged tubular cells ramifying throughout the plant axis. These are single cells which are also called latex cells, except when they pass through a vascular ray and are then called latex tubes. *Secretory cells* are those cells of nearly normal size, or somewhat enlarged, that contain oil, resin, or mucilage.

SHAPE. Pores vary in shape and may be angular or rounded in cross-section.

SILICA. The presence or absence of silica, readily recognizable because of its characteristic optical properties, is a very promising criterion for separating closely allied genera and species.

Silica occurs in timbers in many forms as inclusions, aggregates, concretions, corpuscles, bodies, etc. *Silica inclusions* (refractive index 1.434) refer to the more common occurrences of silica in which the granules are smaller than the lumina of the cells in which they occur, and have a wrinkled or uneven surface. *Vitreous silica* (refractive index 1.5) refers to silica that is deposited as a lining on cell walls or completely fills the lumen of the containing cell.

SPIRAL THICKENING. Helical ridges on the inner face of and part of the secondary wall. This should not be confused with microscopic checks. When spiral thickening is present, the angle of the spiral is usually less than 45° from the horizontal; that of spiral checking is steeper.

STORIED STRUCTURES. An arrangement of the vascular cambium and its derivatives whereby horizontal series of cells or tissues are produced. This highly specialized condition occurs where there is little or no apical growth in the cambial derivatives subsequent to formation, and where the cambial initials are typically short. This arrangement produces the so-called parks in wood, which are visible to the unaided eye.

Topographic characteristics are classified into three structural types.

Diffuse-porous: Wood in which the pores are fairly uniform or only gradually changing size and distribution throughout a growth ring.

Ring-porous: Wood in which the pores formed at the beginning of the growth period are much larger and more numerous than those farther out in the ring.

Semi-ring-porous: Wood which is intermediate between the diffuse-porous and ring-porous.

Tylosis. Outgrowths of the cytoplast of ray or axial parenchyma cells, which penetrate through the pits of adjacent vessel elements and expand into these cells. Tyloses may be small and restricted in size, or they may swell to occlude the vessel lumen; they may be thin-walled or thick-walled and sclerotic, pitted or unpitted. A tylosoid is a swelling or proliferation of an epithelial cell into an intercellular canal or cavity. Tylosoids may occlude intercellular spaces. These differ from tyloses in that they do not pass through pits.

Vascular rays. Ribbon-like aggregates of cells formed by the vascular cambium (ray initials) that extend radially into the xylem and phloem. In hardwoods, vascular rays are entirely parencyhmatous and carry on vital functions in the sapwood. A ray that is two or more cells wide is said to be *multiseriate*. Uniseriate parts of a multiseriate ray are as wide as biseriate or triseriate portions. This unique condition can be observed in some species of the Sapotaceae and Rubiaceae. In tangential section the uniseriate margins of rays (or uniseriate parts), which separate superimposed multiseriate parts, are of almost the same width as the multiseriate parts.

Abundance of vascular rays may be expressed by counting the rays along a 1–mm line at right angles to the axis of the wood, preferably on the tangential section. Results are expressed as the average number of rays per mm, as follows: very few (up to 2), few (2–4), moderately numerous (4–7), numerous (7–10), or very numerous (over 10).

Ray width may be expressed either in numbers of cells or in actual dimension. When two or more definite size classes are present, separate measurements should be expressed in microns, while the width of multiseriate rays should be given both in microns and in numbers of cells. Classification of ray width in millimicrons is as follows: extremely fine (up to 15μm), fine, very fine (15μm–25μm), moderately fine (25μm–50μm), medium-sized (50μm–100μm), moderately broad (100μm–200μm), broad, very broad (200μm–400μm), and extremely broad (over 400μm).

Ray height may be expressed in terms of cells when the average height is not more than 15 cells; when this amount is exceeded, it is more convenient to record the ray height in meters. (Separate measurements should be made on uniseriate and multiseriate rays.) Classification of ray height is as follows: extremely low (up to 0.5 mm), very low (0.5–1 mm), low (1–2 mm), rather low (2–5 mm), moderately high (5 mm–1 cm), high (1–2 cm), very high (2–5 cm), and extremely high (over 5 cm).

Classification of vascular rays of dicotyledons as determined by structure constitute two classes: homocellular and heterocellular. A *homocellular ray* is a xylem ray composed of cells of the same morphological type, e.g., all procumbent or all upright. A *heterocellular ray* is a xylem ray composed of cells of different morphological types, e.g., procumbent, square, or upright cells.

Aggregate rays: A group of closely placed, small, narrow xylem rays that appear to the unaided eye or at low magnification as a single large ray.

Perforated ray cells occur when a vessel passes tangentially through a vascular ray. This is a fairly uncommon phenomenon, but occurs in Passifloraceae, as well as in a number of other plant families.

Procumbent ray cell is oriented with its main axis perpendicular to the axis (grain) or prosencyhmatous elements when viewed in radial section.

Ray-vessel pitting occurs between ray cells and vessel members and is classified by diameter measurements, as follows: fine ($< 7\mu m$), medium ($7\mu m$–$10\mu m$), or coarse ($> 10\mu m$).

Sheath cells are a series of upright cells that form a sheath around the procumbent cells of multiseriate rays.

Square ray cells in radial section have more or less equidimensional sides.

Tile cells are a special type of apparently empty upright ray cells, which may be approximately the same height as the procumbent ray cells (*Durio* type) or considerably higher than the procumbent ray cells (*Pterospermum* type). They occur in indeterminate horizontal series usually interspersed among the procumbent cells. Cells of this type are known to occur in certain genera of the Malvales.

Upright ray cell is oriented with its main axis parallel to the axis (grain) of prosencyhmatous elements when viewed in radial section.

Vertically fused rays: Two or more rays united along the margins.

VESSEL (Pore). An axial series of cells that have coalesced to form an articulated, tube-like structure of indeterminate length; the pits to congeneric elements are bordered. The cellular components of a vessel are known as vessel elements, vessel members, or vessel segments. The variation in the pattern of the vessels is one of the most important criteria for describing woods.

Pore is a term of convenience for the cross-section of a vessel or vascular tracheid. Pores are classified by the average number per square mm, as follows: very few (up to 2), few (2–5), moderately few (5–10), moderately numerous (10–20), numerous (20–40), and very numerous (over 40).

Counts of pores should be made from more than 10 fields. The percentage of pore groupings in any one of the four classes (defined below) may be computed as follows: (1) record the frequency of each class of pore grouping (count solitary pores as a class) in each of 10 randomly placed microscopic fields; (2) total the frequencies for all classes.

Solitary: A single pore completely surrounded by other elements.

Pore multiple: A group of two or more pores, crowded together and flattened along the lines of contact so as to appear as subdivisions of a single pore. The most common type is the *radial pore multiple* in which pores are in radial files with flattened tangential walls between them. In the *pore cluster,* pore grouping is irregular.

Pore chain: A radial series or line of adjacent solitary pores. This type differs from the radial pore multiple in having no tangential flattening or adjacent pores.

VESSEL ELEMENTS vary considerably in shape and size in different hardwoods, and these characters can often be studied to best advantage in macerated wood. There are three bases for measuring the length of vessel members: (1) main body length, (2) extreme body length, and (3) total length. Total length, that is, from tip to tip, is most significant, for this distance is a direct reflection of the length of the fusiform cambial initial from which the vessel element was derived.

The end walls of vessel elements are the continuous areas of superposed vessel elements. These form various angles with the grain of the wood which are more or less characteristic for certain plant groups. Generally, oblique end wall angles are associated with primitive plant families whereas horizontal end walls are indicative of the advanced specialized condition.

Vessel element lengths are classified as follows: extremely short (less than 175μm), short, very short (175μm–250μm), moderately short (250μm–350μm), medium-sized (350μm–800μm), moderately long (800μm–1100μm), long, very long (1100μm–1900μm), and extremely long (over 1900μm).

Although both radial and tangential diameters of pores are frequently used in descriptions, either dimension may be employed; however, the tangential diameter is less variable and is preferable. Diameters are classified as follows: extremely small (average tangential diameter up to 25μm), small or very small (25μm–50μm), moderately small (50μm–100μm), medium-sized (100μm–200μm), large or moderately large (200μm–300μm), very large (300μm–400μm), and extremely large (over 400μm).

VESTURED PIT. A bordered pit with the pit cavity wholly or partially lined with projections from the secondary wall.

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