WOOD ANATOMY OF FIVE EXOTIC HARDWOODS GROWN IN WESTERN SAMOA

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ABSTRACT

The wood anatomy of five hardwood species grown as exotics in Western Samoa has been examined. The species are **Anthocephalus chinensis** (Lamk) Rich. ex Walp., **Cedrela odorata** L., **Eucalyptus deglupta** Blume., **Swietenia macrophylla** King, and **Tectona grandis** L.

There should be no difficulty in distinguishing between the timbers described, and between these timbers and the indigenous timbers of Western Samoa. However, when the origin of the specimen is unknown, identification of **C. odorata** may be difficult because of its similarity to other species of **Cedrela** and, because of limited information, it is not certain whether **A. chinensis** can be separated from the other two species of **Anthocephalus**.

INTRODUCTION

The wood properties of five hardwood timber species, which have been grown in exotic plantations in Western Samoa, have been investigated at FRI as part of a foreign aid programme.

Anthocephalus is a small genus of three species distributed in the Indo-Malaysian region including New Guinea (Willis 1966). The main commercial species is *A. cadamba* (Roxb.) Miq. which produces soft yellow-white wood used locally in India as a source of matchwood, plywood, and paper (Bor 1953). It has also been used for cases, furniture, and interior finishings (CSIRO 1958). Information on the wood anatomy of *Anthocephalus* is sparse, with only brief mention by Metcalfe & Chalk (1950). More detailed information has been given by CSIRO (1958) based on material grown in New Guinea. The identification of *Anthocephalus* pulp fibres has been examined by Parham & Gray (1982).

Cedrela odorata (Spanish cedar) is indigenous to India (Brandis 1971), but is grown as an exotic species in Central and South America where the wood is used for cigar boxes, boat building, general construction, exterior use, furniture and cabinets, millwork, patterns, lining for chests, musical instruments, veneer, and plywood (Kribs 1968). The anatomy and identification of this species have been discussed by Brazier & Franklin (1961) and Kribs (1968). Photomicrographs of related species have been published by Forest Products Research Laboratory (1953), Hayashi *et al.* (1973), and Miles (1978).

Eucalyptus deglupta is indigenous to Papua New Guinea and the Philippines. It is a fast-growing species particularly suited to growth in plantations (Paijmans 1976). The wood is used for heavy and light construction, boat decking and planking, furniture, and interior finishing (CSIRO 1958). Some information on the wood anatomy of this species has been provided by CSIRO (1958) and Dadswell (1972).

Swietenia macrophylla (mahogany) is indigenous to Central and South America. The wood is used widely in boat building (decking and planking), and for furniture and cabinets, piano cases, interior finishing, millwork, patterns, exterior use, musical instruments, turnery, sculpture, veneer, plywood, and gun stocks (Kribs 1968). The wood anatomy and identification of this species have been examined by Brazier & Franklin (1961) Kribs (1968), Jane (1970), and Miles (1978).

Tectona grandis (teak) is a large deciduous tree, indigenous throughout India and Burma (Bor 1953). The wood is used widely for boat building (decking and planking, frames, keels), exterior use, furniture and cabinets, interior finishing, millwork, general construction, flooring, carving, and turnery (Kribs 1968). The wood anatomy and identification of this species have been examined by Brazier & Franklin (1961), Kribs (1968), Jane (1970), Miles (1978), and Gottwald & Parameswaran (1980).

This report provides detailed information on the anatomy of all five species to allow identification of timber imported into New Zealand. The amount of detail is considered adequate to allow identification even when the origin of the timber is not known.

MATERIALS AND METHODS

The species examined were *Anthocephalus chinensis, Cedrela odorata, Eucalyptus deglupta, Swietenia macrophylla,* and *Tectona grandis.* For *C. odorata, E. deglupta,* and *T. grandis* 10 samples, representing individual trees, were examined. For *S. macrophylla* seven samples were examined, and for *A. chinensis* six samples were examined. All samples were taken from dry timber from commercially utilisable trees – the *A. chinensis* were 14 years old, *C. odorata* were 27 years, *E. deglupta* were 13 years, *S. macrophylla* were 29 years, and the *T. grandis* were 80 years.

Blocks approximately 1.5 × 2.0 cm were cut from each sample and boiled in water until saturated. The blocks were then placed in FAA solution for 4 days before microtoming with a sledge microtome to produce transverse, tangential longitudinal, and radial longitudinal sections 20–25 μm in thickness. Tangential longitudinal and radial longitudinal sections were treated with sodium hypochlorite to remove gum deposits. Sections were washed before staining in 1% safranin. Sections were mounted in 10% glycerol or dehydrated in ethanol and mounted in Eukitt. After sectioning, slices 1–2 mm thick were removed from the tangential and radial faces of each block for examination on the scanning electron microscope (SEM). The slices were trimmed, cleaned in sodium hypochlorite, and washed in distilled water. They were then dehydrated in acetone, and vacuum dried before being mounted on aluminium stubs and coated with gold/palladium. Matchstick-sized pieces were removed from the remainder of each block for maceration in 50 : 50 glacial acetic acid and hydrogen peroxide. The macerated material was washed before mounting in 10% glycerol.

Measurements of cell and anatomical proportions were made using standard techniques (Harris 1966; Patel 1973). The percentage volume of vessels was estimated by comparing the weights of tracings of vessels in transverse view using a projection microscope. An area of 25 mm^2 was examined for each tracing. The numbers of measurements or counts made for each feature were as follows:

Vessel length	10
Vessel diameter	30
Vessels/mm^2	10
Percentage volume vessels	1
Fibre length	30
Fibre lumen diameter (tangential)	30
Fibre lumen diameter (radial)	30
Fibre wall thickness	30
Ray height	30
Rays/mm	10

All anatomical terms are those defined by the International Association of Wood Anatomists (1964), Jane (1970), Committee of the IAWA (1981), and Ohtani *et al.* (1984).

RESULTS

Anthocephalus chinensis (cadamba wood)

Macroscopic: Wood pale yellow-white or straw coloured, medium to coarse in texture, soft, low to medium density, a distinct unpleasant odour. Growth rings inconspicuous.

Areas of grey sapstain were common in the samples examined.

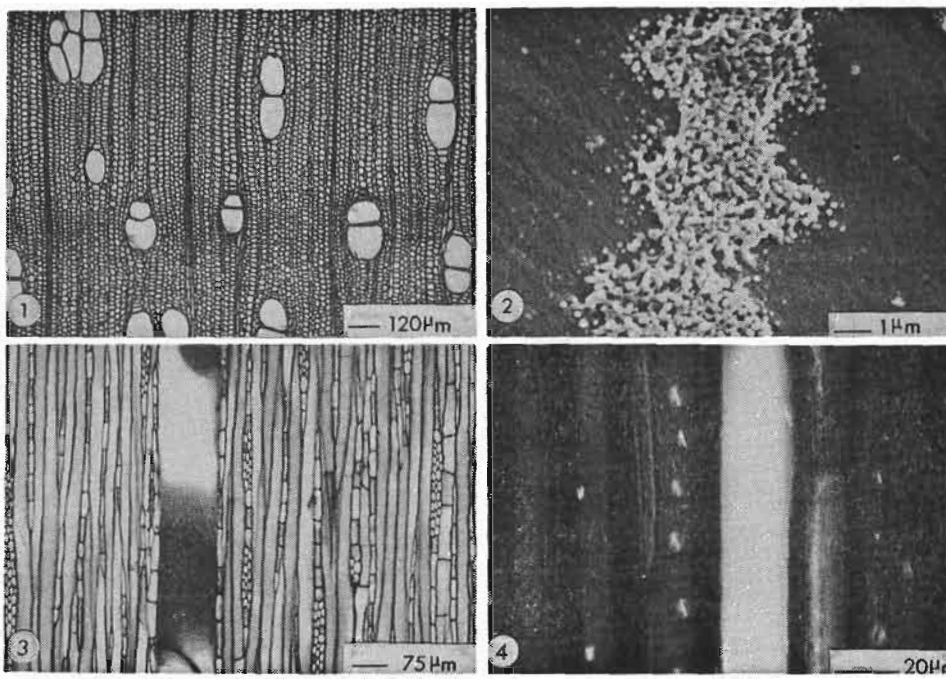
Microscopic: Indistinct growth rings present (Fig. 1), marked by an increase in fibre wall thickness.

Vessels solitary or in radial multiples of up to four but predominantly in radial pairs. Clusters of up to six vessels occasionally present. Vessels distinctly oval in transverse view (Fig. 1), contain occasional yellow gum deposits. Perforations simple. Intervascular pits minute, alternate or randomly arranged, with mainly round borders. Occasional coalescent apertures present, pits heavily vestured (Fig. 2). Vessel to ray pits similar to the intervascular pits. Vessels average 0.8 mm in length (range 0.1–1.4 mm); 147 μm in tangential diameter (range 57–229 μm), 3 vessels/mm^2 (range 1–8 vessels/mm^2), and occupy 8–11% of the total volume.

Axial parenchyma sparse to moderately abundant. Paratracheal parenchyma scanty. Apotracheal parenchyma diffuse and diffuse in aggregate forming short uniseriate tangential lines. Three to 10 but mainly seven or eight cells per strand.

Rays heterocellular consisting of procumbent cells with many rows of marginal upright and square cells. Multiseriate portion of the ray often exceeds 10 cells in height. Uniseriate margins often longer at one end than at the other and axially united rays common (Fig. 3). Uniseriate rays consist of upright or upright and square cells. Majority of multiseriate rays two to three cells wide but rays up to five cells wide occasionally present. Rays average 0.7 mm in height (range 0.1–2.5 mm) and 9 rays/mm (range 5–12 rays/mm).

Fibres thin-walled with moderately abundant bordered pits confined to the radial walls (Fig. 4). Fibres average 1.7 mm in length (range 1.0–2.6 mm), 24 μm in tangential lumen diameter (range 9–39 μm), 22 μm in radial lumen diameter (range 10–36 μm), and 3 μm in wall thickness (range 1–6 μm).



Anthocephalus chinensis

FIG. 1—Transverse view of the wood showing an indistinct growth ring. Note the oval shape of the vessels and the predominance of radial pairs.

FIG. 2—Vestured intervascular pits.

FIG. 3—Tangential longitudinal view of the wood. Note the axially united ray just to the right of the vessel.

FIG. 4—Prominent bordered pits on the radial walls of the fibres.

Cedrela odorata (Spanish cedar)

Macroscopic: Wood pinkish to reddish brown in colour, with high lustre. Medium to coarse in texture, medium density, pleasant cedar-like odour. Growth rings inconspicuous.

Microscopic: Distinct growth rings present, marked by a radial flattening of the fibres and an increase in wall thickness followed by a band of marginal parenchyma. Most samples either semi ring porous or ring porous (Fig. 5).

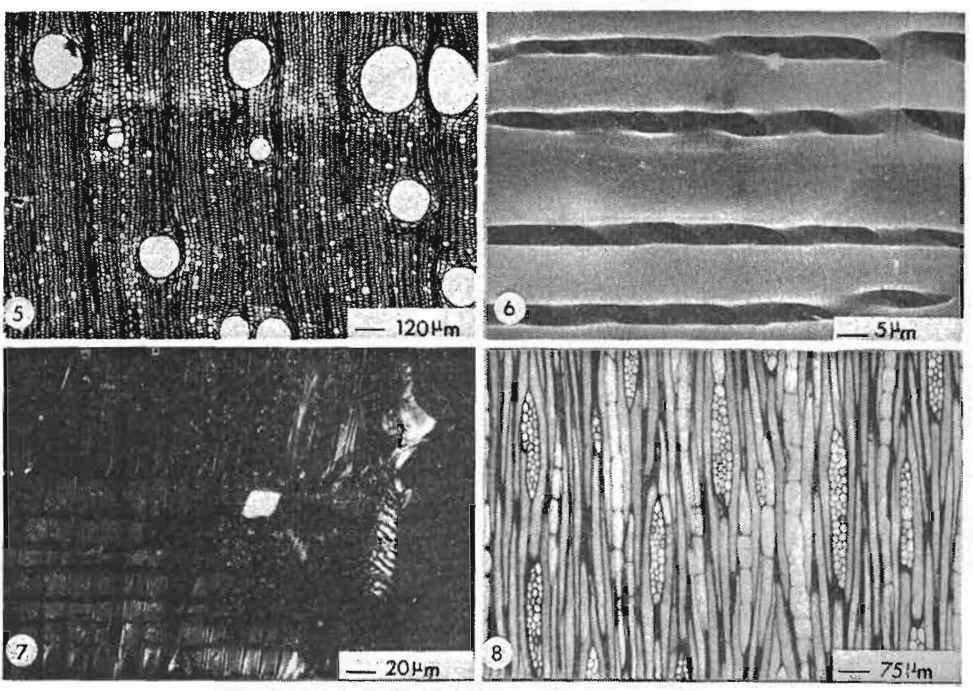
Vessels predominantly solitary but also in radial multiples of up to four. Vessels round in transverse view (Fig. 5). Perforations simple and often occluded with brown gum. Intervascular pits small to minute, alternate or randomly arranged, with round or angular borders. Coalescent apertures sometimes present (Fig. 6). Vessel to ray pits similar to the intervascular pits. Vessels average 0.3 mm in length (range 0.1–0.6 mm),

177 μm in tangential diameter (range 40–330 μm), 3 vessels/mm² (range 1–7 vessels/mm²), and occupy 5–10% of the total volume.

Axial parenchyma moderately abundant to abundant and prominent (Fig. 5) because of the large size of individual cells compared with adjacent fibres. Paratracheal parenchyma vasicentric. Apotracheal parenchyma diffuse to diffuse in aggregate and in marginal bands 5–17 cells wide. Four to eight cells per strand. Rare rhomboidal crystals present (Fig. 7).

Rays slightly heterocellular, consisting mainly of procumbent cells. Marginal cells either square or upright and confined to one or two rows. Uniseriate rays absent (Fig. 8). Multiseriate rays generally two to four cells wide but may reach up to six cells wide. Marginal cells rarely contain crystals. Rays average 0.3 mm in height (range 0.1–0.7 mm) and 4 rays/mm (range 2–6 rays/mm).

Fibres thin- to moderately thick-walled, with minute inconspicuous pits confined to the radial walls. Tips of the fibres contain brown gum deposits (Fig. 8). Fibres rarely septate with one septa per fibre. Fibres average 1.3 mm in length (range 0.8–1.8 mm), 18 μm in tangential lumen diameter (range 5–32 μm), 13 μm in radial lumen diameter (range 2–29 μm), and 3 μm in wall thickness (range 1–5 μm).



Cedrela odorata

FIG. 5—Transverse view of the wood of a semi ring porous specimen. Note the prominent axial parenchyma.

FIG. 6—Coalescent intervascular pit apertures.

FIG. 7—A crystal in the marginal ray parenchyma under polarised light.

FIG. 8—Tangential longitudinal view of the wood. Note the gum deposits in the tips of the fibres.

Eucalyptus deglupta

Macroscopic: Wood pale-pinkish-brown to brown in colour, coarse to very coarse in texture, variable in density, no distinctive odour. Growth rings inconspicuous.

Microscopic: Indistinct growth rings present marked by radial flattening of the fibres, an increase in wall thickness, and a slight reduction in the size and number of vessels.

Vessels mostly solitary with occasional radial, tangential, or oblique multiples of up to four. Vessels often exhibit a dendritic or tangential arrangement (Fig. 9). Vessels round or oval in transverse view and contain occasional tyloses. Perforations simple. Intervascular pits minute, alternate or randomly arranged, with round borders and vestures (Fig. 10). Vessel to ray pits large (Fig. 11), round to oval, simple or with a slight border, and sometimes vestured (Fig. 10). Vessels average 0.7 mm in length (range 0.4–1.2 mm), 190 μm in tangential diameter (range 30–330 μm), 8 vessels/mm^2 (range 4–15 vesels/mm^2), and occupy 19–35% of the total volume.

Axial parenchyma sparse to abundant (Fig. 9). Paratracheal parenchyma scanty and can be distinguished from adjacent vasicentric tracheids in transverse view by a coating of brown gum on the cell wall adjacent to the lumen. Apotracheal parenchyma diffuse to diffuse in aggregate. Parenchyma cells chambered with one crystal per chamber and 3–10 chambers per cell (Fig. 12). Two to seven cells per strand.

Rays homocellular consisting entirely of procumbent cells, or (rarely) slightly heterocellular with one marginal row of square cells. Majority of rays uniseriate (Fig. 13) or part biseriate but may (rarely) reach up to five cells wide. Rays average 0.3 mm in height (range 0.1–0.8 mm) and 10 rays/mm (range 5–14 rays/mm).

Fibres thin- to moderately thick-walled, with small inconspicuous bordered pits mainly on the radial walls. Fibres average 1.2 mm in length (range 0.7–1.9 mm), 11 μm in tangential lumen diameter (range 4–21 μm), 10 μm in radial lumen diameter (range 2–22 μm), and 2 μm in wall thickness (range 1–5 μm).

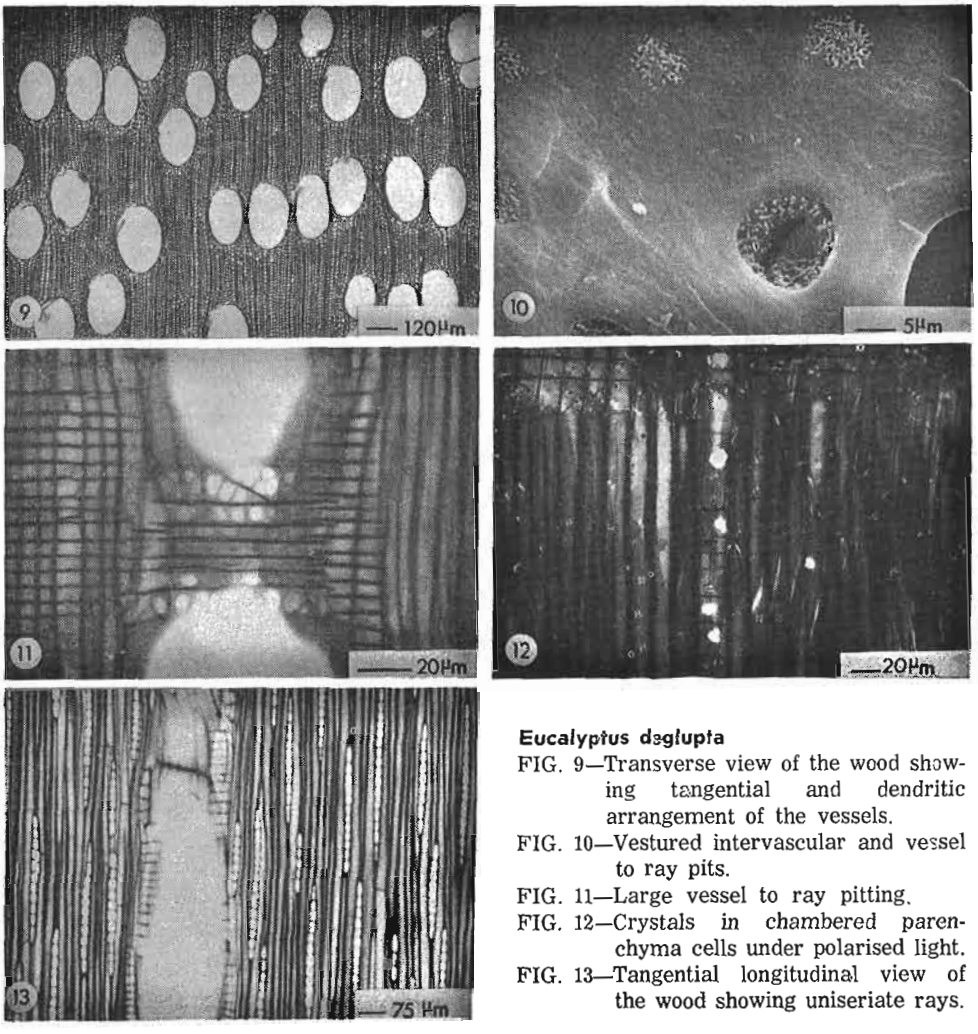
Vasicentric tracheids abundant, with prominent bordered vestured pits similar to the intervascular pits.

Swietenia macrophylla (mahogany)

Macroscopic: Wood medium to dark reddish brown in colour, or pale pinkish or golden brown when freshly cut. Texture fine, medium density, no distinctive odour. Interlocked grain present. Growth rings inconspicuous.

Microscopic: Distinct growth rings marked by an increase in fibre wall thickness, a decrease in vessel diameter, and a band of marginal parenchyma. Indistinct growth rings marked by an increase in fibre wall thickness.

Vessels solitary and in radial multiples of up to five (usually twos and threes), tangential multiples of up to three, and clusters of up to 10. Some samples show slight tendency to semi ring porosity. Vessels round or slightly oval in transverse view and often contain red gum desposits (Fig. 14). Perforations simple and usually occluded with dark brown gum deposits (Fig. 15). Intervascular pits minute, alternate or randomly arranged, with round or angular borders, and often with gash-like coalescent



Eucalyptus deglupta

FIG. 9—Transverse view of the wood showing tangential and dendritic arrangement of the vessels.

FIG. 10—Vestured intervascular and vessel to ray pits.

FIG. 11—Large vessel to ray pitting.

FIG. 12—Crystals in chambered parenchyma cells under polarised light.

FIG. 13—Tangential longitudinal view of the wood showing uniseriate rays.

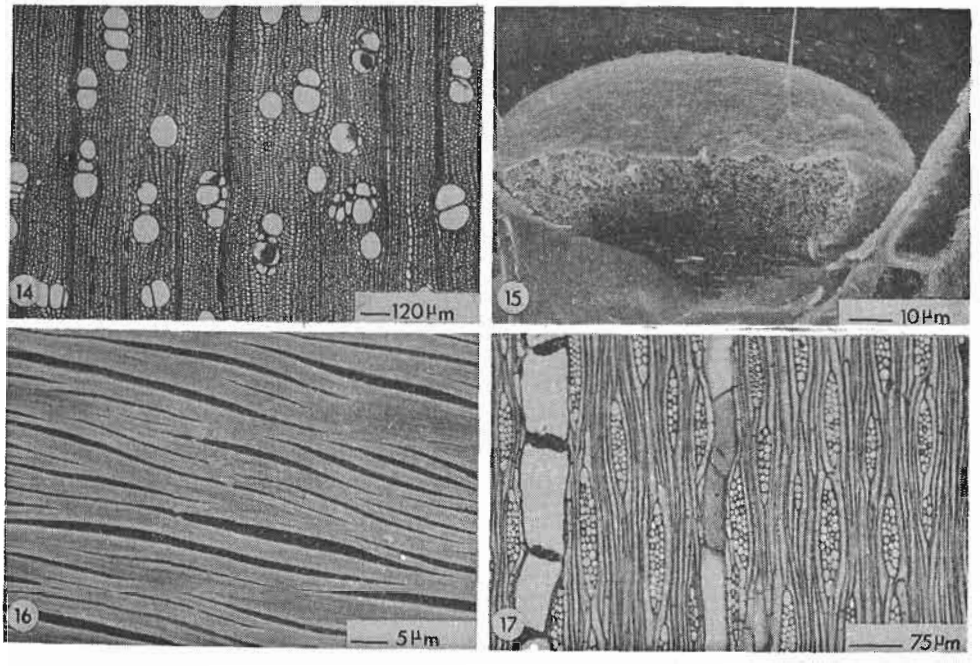
apertures (Fig. 16). Vessel to ray pits similar to the intervascular pits. Vessels average 0.3 mm in length (range 0.1–0.6 mm), 73 μm in tangential diameter (range 29–126 μm), 8 vessels/mm^2 (range 3–16 vessels/mm^2), and occupy 7–13% of the total volume.

Axial parenchyma sparse to moderately abundant (Fig. 14). Paratracheal parenchyma scanty, unilateral or vasicentric. Apotracheal parenchyma rare, diffuse, diffuse in aggregate, or in marginal bands three to six cells wide. Three to eight cells per strand.

Rays heterocellular consisting of procumbent cells with one or (rarely) two rows of marginal square or upright cells. Uniseriate rays sparse, consisting of procumbent cells or a mixture of procumbent, square, and upright cells (Fig. 17). Uniseriate rays generally only three to four cells in height. Multiseriate rays two to six cells wide. Rays average 0.3 mm in height (range 0.1–0.6 mm), and 5 rays/mm (range 2–9 rays/mm).

Fibres thin- to thick-walled, with minute inconspicuous pits confined to the radial walls. Most fibres septate with one or rarely two septa per fibre. Fibres average 1.2 mm in length (range 0.7–1.9 mm), 14μm in tangential lumen diameter (range 7–25 μm), 13 μm in radial lumen diameter (range 5–21 μm), and 3 μm in wall thickness (range 1–4 μm).

All elements show some tendency towards the storeyed arrangement but this is not a prominent feature.



Swietenia macrophylla

FIG. 14—Transverse view of the wood of a diffuse porous specimen.
FIG. 15—A gum plug in a perforation plate.
FIG. 16—Gash-like intervascular pits.
FIG. 17—Tangential longitudinal view of the wood. Note the gum plugs in the perforation plates and the partially storeyed rays.

Tectona grandis (teak)

Macroscopic: Heartwood yellow-brown, green-brown, or golden-brown in colour, and sapwood straw coloured. Wood medium to coarse in texture, hard, dense, straight to wavy grain. Distinctive odour, and growth rings conspicuous.

Microscopic: Wood semi ring porous or ring porous (Fig. 18) with a marked reduction in vessel diameter from earlywood to latewood. Growth ring boundaries indicated by an increase in fibre wall thickness followed by a band of marginal parenchyma. Growth rings usually distinct.

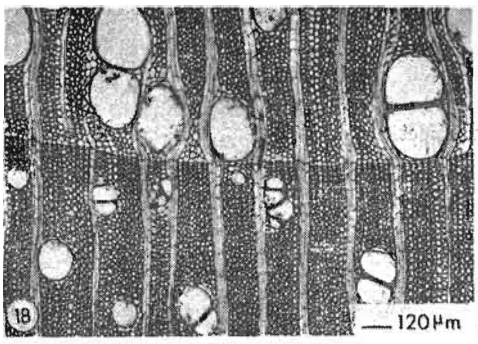
Vessels mostly solitary or in radial pairs, but occasionally in radial multiples of up to four or (rarely) in tangential multiples of up to three. Vessels round to oval in transverse view with abundant thick-walled tyloses (Fig. 19) and brown gum deposits. Perforations simple. Intervascular pits minute (Fig. 20), alternate or randomly arranged, with round or angular borders and occasional coalescent apertures. Vessel to ray pits similar to intervascular pits. Vessel wall adjacent to the lumen vestured (Fig. 20). Vessels average 0.2 mm in length (range 0.1–0.5 mm), 147 μm in tangential diameter (range 49–303 μm), 5 vessels/mm^2 (range 2–12 vessels/m^2), and occupy 4–21% of the total volume.

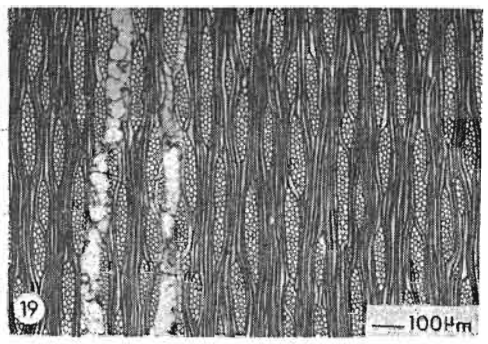
Axial parenchyma sparse to moderately abundant. Paratracheal parenchyma scanty, unilateral or vasicentric. Apotracheal parenchyma marginal in bands two to eight cells wide. Mainly two to four but rarely up to eight cells per strand.

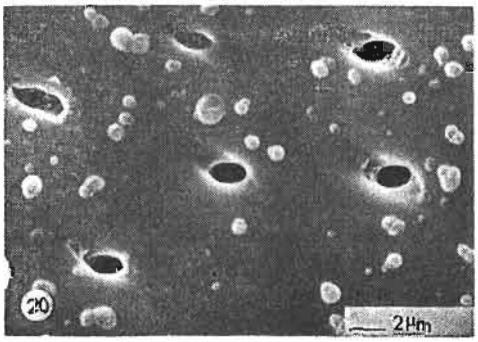
Rays homocellular consisting of procumbent cells, and two to six cells wide. Uniseriate rays absent. Rays average 0.4 mm in height (range 0.1–1.1 mm) and 5 rays/mm (range 3–7 rays/mm). Some tendency for the rays to be storeyed (Fig. 19).

Fibres thick- to very thick-walled, with minute inconspicuous simple pits confined to the radial walls. Most fibres septate with one to three septa per cell. Fibres average 1.3 mm in length (range 0.6–2.0 mm), 12 μm in tangential lumen diameter (range 4–26 μm), 14 μm in radial lumen diameter (range 4–28 μm), and 4 μm in wall thickness (range 2–6 μm).

Macroscopic and microscopic features for all species are summarised in Table 1.







Tectona grandis

FIG. 18—Transverse view of the wood of a ring porous specimen.

FIG. 19—Tangential longitudinal view of the wood. Note the partially storeyed rays and the heavily tylosed vessel.

FIG. 20—Globular vestures on the vessel wall. Note the minute intervascular pits.

TABLE 1—Summary of macroscopic and microscopic features

		A. chinensis	C. odorata	E. deglupta	S. macrophylla	T. grandis
Macroscopic						
Colour:	Brown		+	+	+	+
	Red		+		+	
	Yellow	+				
	White	+				
	Grey					
Texture:	Fine				+	
	Medium	+	+		+	+
	Coarse	+	+	+		+
Odour present		+	+			+
Density:	Low	+		—	+	
	Medium	+	+	+		
	High			—		+
	Hard					+
	Soft	+				
Lustre high			+			
Grain:	Straight	+	+	+		+
	Wavy					+
	Interlocked				+	
Microscopic						
Growth rings		Indistinct	Distinct or indistinct	Indistinct	Distinct or indistinct	Distinct
Vessels:	Arrangement		Semi ring porous	Dendritic	Semi ring porous	Ring porous
	Large			—		—
	Medium	+	+	+	—	+
	Small				+	
	Tyloses			+		+
	Gum	+	+		+	+
	Intervascular pits	Minute	Minute	Minute	Minute	Minute
	Vessel to ray pits	Minute	Minute	Large	Minute	Minute
	Vestures	+		+		
Axial parenchyma:						
	Absent					
	Sparse	+		+	+	+
	Abundant	+	+	+	+	+
	Apotracheal	+	+	+	—	+
	Paratracheal	—	+	+	+	+
	Banded		+		+	+
	Crystals		—	+		

TABLE 1 (Cont.)

		A. chinensis	C. odorata	E. deglupta	S. macrophylla	T. grandis
Rays:	Homocellular		+	+		+
	Heterocellular	+	+	—	+	
	Procumbent	+	+	+	+	+
	Square	+	+	+	+	
	Upright	+	+		+	
	Long tails	+				
	Uniseriate	+		+	—	
	2-5 cells wide	+	+	—	+	+
	5-10 cells wide		—		—	—
	>10 cells wide					
	>1 mm height	—				
	Crystals		—			
Fibres:	Thin walled	+	+	+	+	
	Thick walled		+	+	+	+
	Very thick walled					+
	Septate		—		+	+
	Conspicuous pits	+				
	Pits on tangential walls			—		
	Pits on radial walls	+	+	+	+	+
	Libriform		+	+	+	+
	Fibre tracheids	+				
	Vasicentric tracheids			+		

+ Present
— Uncommon or rare

DISCUSSION

Little information is available on the wood anatomy of *Anthocephalus*. Metcalfe & Chalk (1950) give the following specific information: vessels medium-sized (100–200 μm), less than 5 vessels/mm^2, rays with upright cells filled with crystal sand in some species. Average vessel size (tangential diameter) in the material described in this report was 147 μm and on average there were 3.1 vessels/mm^2. These figures agree with those of Metcalfe & Chalk (1950), although there are more vessels per square millimetre in some specimens and crystal sand was not observed. Amongst the indigenous timbers of Western Samoa, *Neonauclea forsteri* (Seem.) Merr. (afa) is the only species related to *A. chinensis*. Both trees are members of the Rubiaceae. Because they are both yellowish in colour the two species may appear superficially similar; however, there are a number of differences which separate these two timbers. Vessels are more abundant in *N. forsteri* (average 18 vessels/mm^2), and are smaller (average 107 μm). The multiseriate portions of the rays are generally less than 10 cells high in *N. forsteri* (unpubl. data). Other rubiaceous woods of commercial importance include *Adina cordifolia* Hook. (haldu), *Calycophyllum candidissimum* (Vahl.) DC (degame), *Corynanthe pachyceras* K. Schum. (anikiba), *Genipa americana* L. (jagua), *Mitragyna stipulosa* (DC) O. Ktze. (abura), *Neonauclea calycina* (Bart.) Merr. (kalamansani), *Pausinystalia lane-poolei*

Hutch. (idagbon), and *Sarcocephalus* sp. (bilinga or opepe). Of these only abura, bilinga, degame, haldu, and kalamansani are yellow or have yellow tints. Abura, haldu. and degame all have abundant small vessels. Kalamansani is hard and heavy, and bilinga has larger vessels (average 200 μm) which are solitary and often arranged in echelon (Kribs 1968).

The wood anatomy of *Cedrela odorata* has been studied in some detail by Kribs (1968). The description presented here is in agreement apart from the absence of traumatic gum ducts. *Cedrela odorata* is a member of the Meliaceae family, a large family containing many timber species including *Swietenia macrophylla* which was also studied. The two timbers are readily separated. *Swietenia macrophylla* is darker in colour and finer grained than *C. odorata*, and lacks a distinctive odour; *S. macrophylla* has small vessels and the large axial parenchyma cells are less conspicuous than those of *C. odorata; S. macrophylla* also has septate fibres which are rare in *C. odorata.* Amongst the indigenous Western Samoan timbers, a'amatia (*Amoora* sp.) and mamala (*Dysoxylum* sp.) are members of the Meliaceae. Both of these species have abundant banded and confluent axial parenchyma and contain abundant crystals in chambered parenchyma cells and fibres. The fibres are septate compared with only rare septa in *C. odorata.* Other meliaceous timbers include *Azadirachta integrifolia* Merrill (maranggo), *Cabralea cangerana* Sald. (cancharana), *Carapa guianensis* Aubl. (andiroba or crabwood), *Cedrela* sp., *Chukrasia tabularis* A. Juss and other species (chikrassi). *Dysoxylum fraseranum* Benth. (rosewood or rose mahogany), *Ekebergia capensis* Sparrm. (Cape ash), *Entandrophragma* sp. (sapele), *Gaurea* sp. (gaura), *Khaya* sp. (African mahogany), *Lovoa* sp. (tiger wood), *Melia azedarach* L. (Persian lilac), *Toona australis* (F. Muell.) Harms, and *Turraeanthus africana* (Welw.) Pell. (avodire) (Kribs 1968). Only certain species of *Cedrela, Entandrophragma, Toona.* and *Gaurea* have a cedar-like odour similar to that of *C. odorata.* Both *Entandrophragma* and *Gaurea* have prominent parenchyma bands and septate fibres. *Gaurea* has uniseriate or biseriate rays, but *C. odorata* has rays up to six cells wide. Neither *Entandrophragma* nor *Gaurea* exhibit ring porosity (Kribs 1968). Other species of *Cedrela,* and *Toona australis,* are very similar to *C. odorata* and there may be some difficulty when the origin of the specimen is not known. However, the detailed anatomical measurements given in this report may allow confirmation of *C. odorata.* Brazier & Franklin (1961) suggested that *T. australis* can be separated from *Cedrela* spp. by the greater abundance of small druses in chambered cells, but that separation of *Cedrela* spp. by wood anatomy is not practical. The identification of the commercial mahoganies was examined by Jane (1970). Hess (1950) compared the woods of *Carapa* and *Swietenia* and concluded that these timbers can be separated only by examining several features together. Brazier & Franklin (1961) indicated that these two genera are separated by the more common occurrence of storeyed rays in *Swietenia* but other features must also be examined.

There are about 500 species of *Eucalyptus,* many of which provide commercial timbers (Dadswell 1972). Identification of *Eucalyptus* wood is generally made by grouping species with similar characteristics together. Identification of individual species is difficult (R. K. Bamber, pers. comm.). The main subdivision involves separation into coloured and non-coloured (pale-coloured) groups (Dadswell *et al.* 1934). *Eucalyptus deglupta* is generally straw coloured or pinkish-brown and can be

classified as non-coloured. Within the non-coloured division there are a further nine groups – ashes, stringybarks, peppermints. gums, bloodwoods, mahoganies, tallow woods, blackbutts, and boxes (Dadswell *et al.* 1934). *Eucalyptus deglupta* has two features which separate it from all of the above groups of species, predominantly uniseriate rays and abundant crystals in chambered axial parenchyma cells. Large rays, assumed to be traumatic in origin, have been reported in one specimen of this species (Donaldson 1982).

Tectona grandis is a member of the Verbenaceae family. Other commercial timbers of this family include *Gmelina arborea* L. (gumhar), *Petitia domingensis* Jacq. (capa wood), and various species of *Vitex* (Kribs 1968). *Tectona grandis* can be separated from the other genera by its distinctive odour and by its often prominent ring porosity. The identification of the commercial teaks has been examined by Jane (1970), and the anatomy of the wood and bark of *Tectona* in relation to taxonomy has been examined by Gottwald & Parameswaran (1980). The occurrence of warts and vestures in the Verbenaceae has been examined by Mathew & Shah (1983). They indicated that pit vestures are absent in *Tectona* but reported the occurrence of globular warts on the vessel wall, as was found in the present study (Fig. 20).

The results of this study indicate that, in general, there should be no difficulty in distinguishing between the timbers described, and between these timbers and the indigenous timbers of Western Samoa. However, when the origin of the specimen is unknown, identification of *C. odorata* may be difficult because of its similarity to other species of *Cedrela* and, because of limited information, it is not certain whether *A. chinensis* can be separated from the other two species of *Anthocephalus*.

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REFERENCES

BOR, N. 1953: "Manual of Indian Forest Botany". Oxford University Press, London.

BRANDIS, D. 1971: "Indian Trees", 5th edition. Bishen Singh Mahendra Pal Singh, Dehra Dun.

BRAZIER, J. D.; FRANKLIN, G. L. 1961: "Identification of Hardwoods". **DSIR, Forest Products Research Bulletin No. 46.**

COMMITTEE OF THE IAWA 1981: Standard list of characters suitable for computerised hardwood identification. **IAWA Bulletin (NS) 2(2 & 3):** 99-145.

CSIRO 1958: "Card Sorting Key for the Timbers of New Guinea and Neighbouring Islands". Division of Forest Products, Melbourne.

DADSWELL, H. E. 1972: "The Anatomy of Eucalypt Woods". **CSIRO Forest Products Laboratory, Division of Applied Chemistry, Technological Paper No. 66.**

DADSWELL, H. E.; BURNELL, M.; ECKERSLEY, A. M. 1934: "Identification of the Light-coloured Woods of the Genus **Eucalyptus". CSIRO Division of Forest Products Technical Paper No. 12.**

DONALDSON, L. A. 1982: Abnormal rays in the wood of eucalypts. **IAWA Bulletin (NS) (3 & 4):** 214–5.

FOREST PRODUCTS RESEARCH LABORATORY 1953: "An Atlas of End Grain Photomicrographs for the Identification of Hardwoods". **DSIR, Forest Products Research Bulletin No. 26.**

GOTTWALD, H.; PARAMESWARAN, N. 1980: Anatomy of the wood and bark of **Tectona** (Verbenaceae) in relation to taxonomy. **Botanisch Jahrbücher für Systematik, Pflanzengeschichte und Pflanzengeographie 101:** 363–84.

HARRIS, J. M. 1966: A method of minimising observer bias in measuring tracheid length. **Journal of the Royal Microscopical Society 86:** 81–3.

HAYASHI, S.; KISHIMA, T.; LAU, L. C.; WONG, T. M.; BALAN MENON, P. K. 1973: "Micrographic Atlas of South East Asian Timber". Division of Wood Biology, Wood Research Institute, Kyoto University, Kyoto, Japan.

HESS, R. W. 1950: Identification of **Swietenia** and **Carapa**. **Tropical Woods No. 96:** 47–51.

INTERNATIONAL ASSOCIATION OF WOOD ANATOMISTS 1964: "Multilingual Glossary of Terms used in Wood Anatomy". Konkordia Winterthur, Zurich.

JANE, F. W. 1970: "The Structure of Wood". A. & C. Black, London.

KRIBS, D. A. 1968: "Commercial Foreign Woods on the American Market". Dover Publications Inc., New York.

MATHEW, L.; SHAH, G. L. 1983: Vestured pits and warts in Verbenaceae. **IAWA Bulletin (NS) 4(1):** 39–40.

METCALFE, C. R.; CHALK, L. 1950: "Anatomy of the Dicotyledons", Vol. 2. Clarendon Press, Oxford.

MILES, A. 1978: "Photomicrographs of World Woods". Building Research Establishment, London.

OHTANI, J.; MEYLAN, B. A.; BUTTERFIELD, B. G. 1984: Vestures or warts – proposed terminology. **IAWA Bulletin (NS) 5(1):** 9–11.

PAIJMANS, K. 1976: "New Guinea Vegetation". Elsevier Scientific Publishing Co., Amsterdam/Oxford/New York.

PARHAM, R. A.; GRAY, R. L. 1982: "The Practical Identification of Wood Pulp Fibres". Tappi Press, Atlanta, United States.

PATEL, R. N. 1973: Wood anatomy of the dicotyledons indigenous to New Zealand. 1. Cornaceae. **New Zealand Journal of Botany 11:** 3–22.

WILLIS, J. C. 1966: "A Dictionary of Flowering Plants and Ferns". Cambridge University Press, London.