Wood anatomy of CITES-listed tree species

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WOOD ANATOMY OF CITES-LISTED TREE SPECIES

Peter Gasson[1], **Pieter Baas**[2] and **Elisabeth Wheeler**[3]

SUMMARY

The wood anatomy of all currently CITES-listed angiosperm and conifer tree taxa is illustrated with low- to high-power magnification light micrographs. Their diagnostic wood features are presented in numerical codes taken from the IAWA Hardwood (1989) and Softwood (2004) Lists of microscopic features for wood identification. Features used are summarized in two appendices. These descriptions and illustrations can be used for genus identification when carefully compared with look-alike non-CITES-listed timbers illustrated and described in the InsideWood web-database or present in reference wood collections.

Key words: CITES-listed tree species, microscopic wood identification, hardwoods, softwoods.

INTRODUCTION AND EXPLANATORY NOTES

Tree species whose international trade is restricted by CITES are listed in Table 1 (excluding palms and cycads). Gasson (2011, this issue) discusses the possibilities and limitations of wood anatomy in identifying these timbers. Here we present a microscopic atlas of the CITES-listed tree species together with coded descriptions, as an aid to their identification.

Plates are in alphabetical order by family with the hardwoods before the softwoods. The scientific name is followed by one or two common names and the CITES appendix in which the species is listed. Abbreviations in the plate captions are: TS = transverse section; TLS = tangential longitudinal section; RLS = radial longitudinal section; IVP = intervessel pits; VRP = vessel-ray parenchyma pits.

The numbers are from the "IAWA List of Microscopic Features for Hardwood Identification" (IAWA Committee 1989) and the "IAWA List of Microscopic Features for Softwood Identification" (IAWA Committee 2004). Only the anatomical features present are listed. Hardwood characters not included are those for element length and other quantitative features (28, 44, 51–55, 71–74, 123). Softwoods begin at feature 40, and again quantitative features have not been coded (features 49–52, 96, 112–114). See Appendices 1 and 2 for an explanation of the feature codes. A feature followed by a "v"

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Table 1. Tree species on CITES Appendices (d.d. October 2010), listed by genus name.

Hardwoods (Angiosperms)

Aniba rosaeodora (Lauraceae)
Aquilaria spp. (Thymelaeaceae)
Balmea stormae (Rubiaceae)
Bulnesia sarmientoi (Zygophyllaceae)
Caesalpinia echinata (Leguminosae)
Caryocar costaricense (Caryocaraceae)
Cedrela fissilis, C. lilloi (= *C. angustifolia*), *C. odorata* (Meliaceae)
Dalbergia nigra, D. retusa, D. stevensonii (Leguminosae)
Dipteryx panamensis (Leguminosae)
Gonystylus spp. (Thymelaeaceae)
Guaiacum spp. (Zygophyllaceae)
Gyrinops spp. (Thymelaeaceae)
Magnolia liliifera var. *obovata* (Magnoliaceae)
Oreomunnea pterocarpa (Juglandaceae)
Pericopsis elata (Leguminosae)
Platymiscium pleiostachyum (Leguminosae)
Prunus africana (Rosaceae)
Pterocarpus santalinus (Leguminosae)
Swietenia humilis, S. macrophylla, S. mahagoni (Meliaceae)
Tetracentron sinense (Trochodendraceae)

Softwoods (Gymnosperms)

Abies guatemalensis (Pinaceae)
Araucaria araucana (Araucariaceae)
Fitzroya cupressoides (Cupressaceae)
Pilgerodendron uviferum (Cupressaceae)
Pinus koraiensis (Pinaceae)
Podocarpus neriifolius, P. parlatorei (Podocarpaceae)
Taxus chinensis (= *T. wallichiana* var. *chinensis*), *T. cuspidata, T. fuana, T. sumatrana, T. wallichiana* (Taxaceae)

is a feature that is present in some samples of a species, but absent in others, shows a tendency toward that feature, or is rare. For example, a 9v indicates that a wood sample has mostly solitary vessels, but does not meet the criterion of >90 % solitary vessels, a 7v indicates that there is a tendency towards a diagonal/radial vessel arrangement, a 14v indicates that scalariform perforation plates are rare. For all species it should be appreciated that these descriptions in IAWA codes are based on examination of but a few samples and information from the literature, so the full range of variation in the species may not be represented. For the hardwood species, the references used to create or edit the InsideWood (2004-onwards) descriptions are given; this list is not all inclusive and additional information may be found by consulting Kew's Plant Micromorphology database (http://kbd.kew.org/kbd/searchpage.do). If you find errors in these descriptions, please contact the authors, so that the descriptions on InsideWood can be corrected. In addition to our observations, the softwood descriptions incorporate information from Greguss (1955), Heinz (2004), and Phillips (1948).

ACKNOWLEDGEMENTS

We thank Gerald Koch (Hamburg) for providing a sectioning block of *Platymiscium pleiostachyum* and Luke Hailey (Kew) for sectioning at very short notice the *Platymiscium* and *Magnolia* samples.

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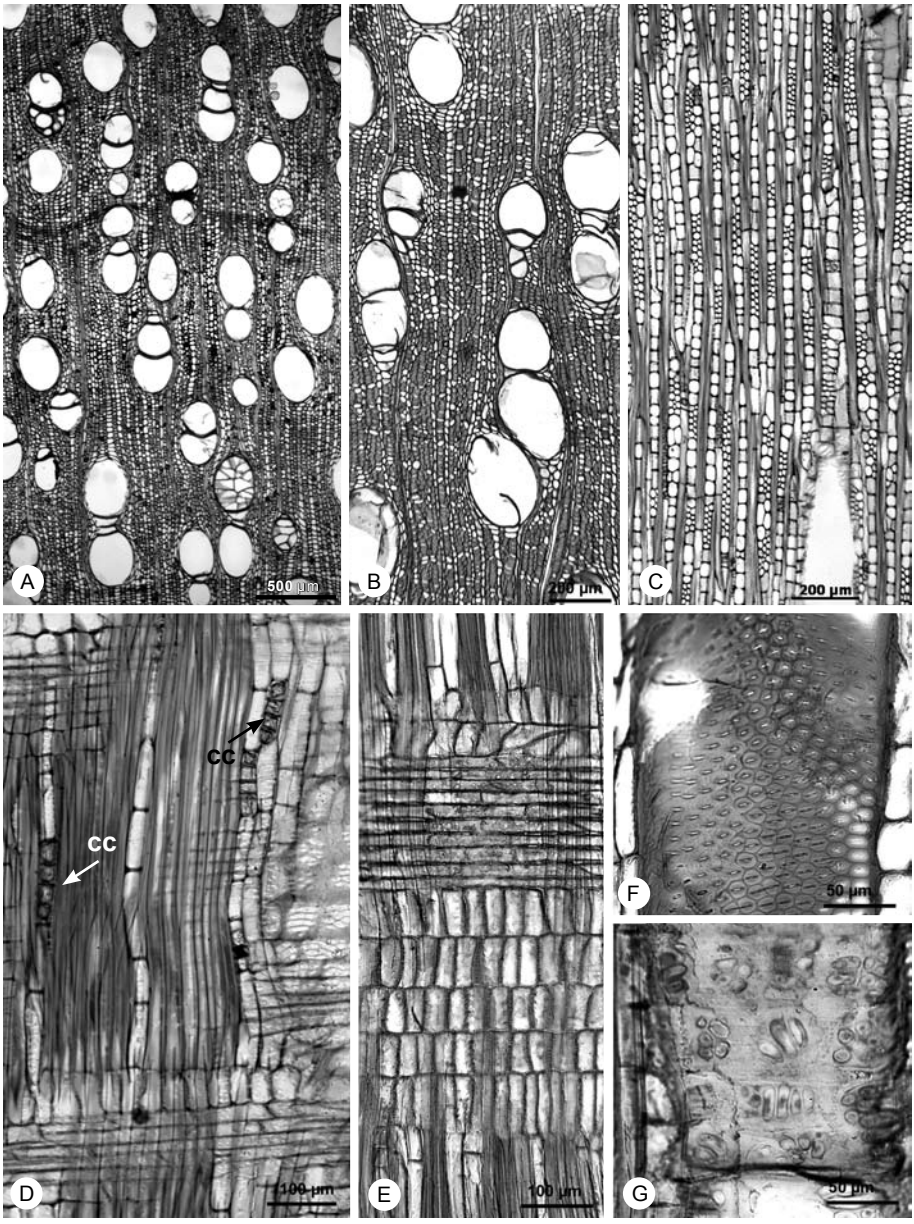

Figure 1. *Caryocar costaricense* Donn. Sm. (Caryocaraceae). Ajo, Cagui, Piquia (Kribs 1968). Appendix 2. — A, B: TS. – C: TLS. – D, E: RLS. – F: IVP. – G: VRP. — cc = chambered crystals.

IAWA Hardwood codes: 1v 2 5 13 22 23 26 27 31 32 34 43 46 56 61 66 69 70 76 77 78 79v 93 94 97 100 102 107v 108 116 136 142

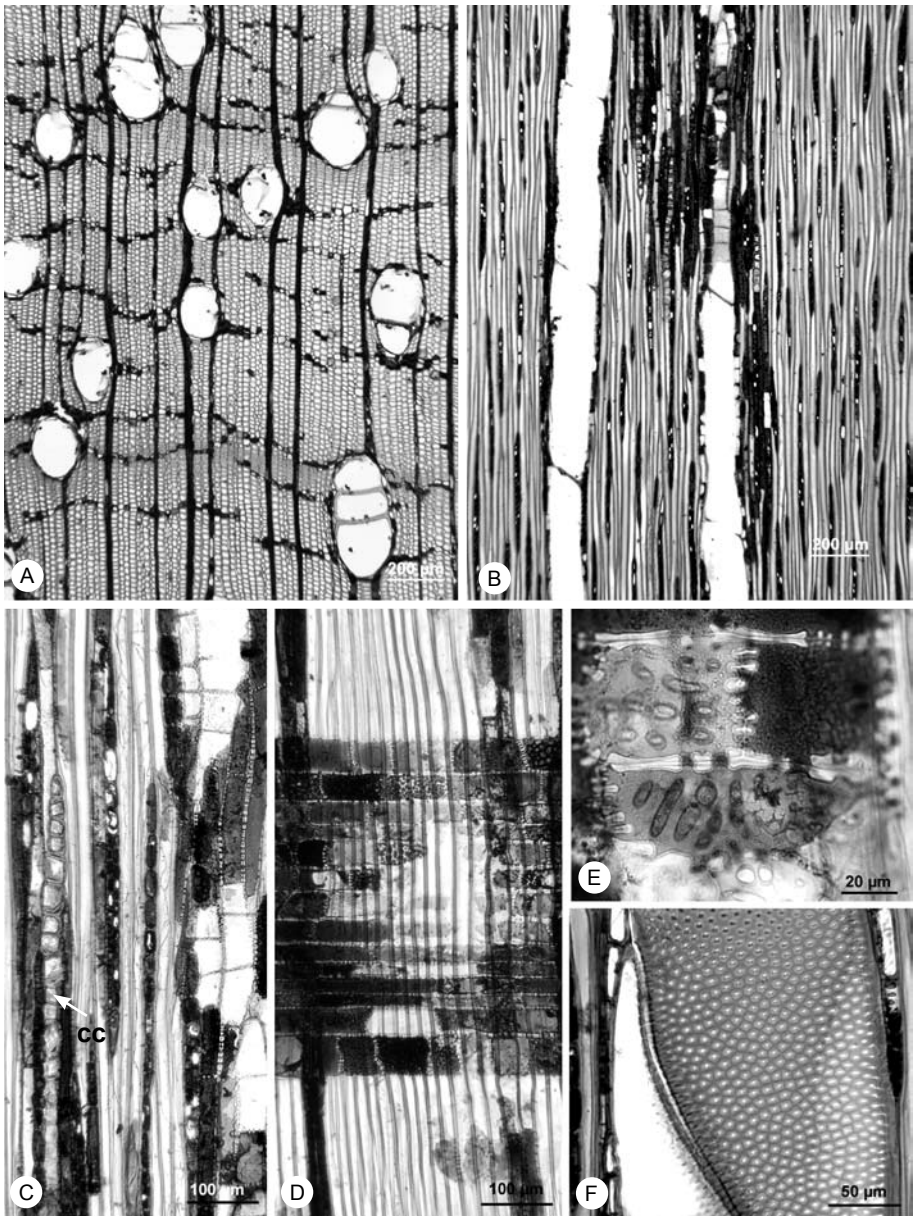

Figure 2. *Oreomunnea pterocarpa* Oerst. (Juglandaceae). Caribbean Walnut (Heimsch & Wetmore 1939; Manchester 1983). Appendix 2. — A: TS. – B, C: TLS. – D: RLS. – E: VRP. – F: IVP. — cc = chambered crystals.

IAWA Hardwood codes: 1 2 5 13 14v 15v 22 23 26 31 32v 42 47 56 61 66 69 76v 77 78v 86 87v 89 93 97 106v 107 108 115 136 142

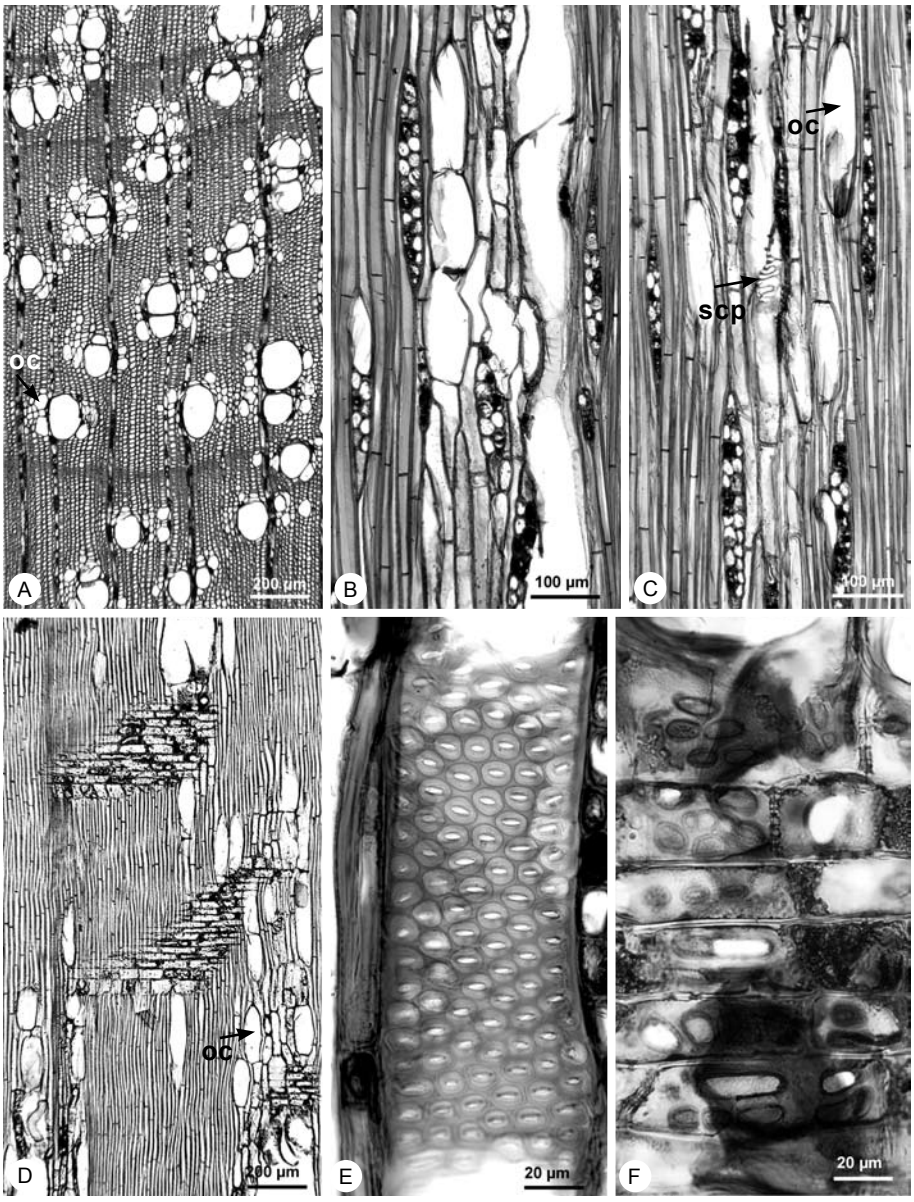

Figure 3. *Aniba rosaeodora* Ducke (Lauraceae). Bois de rose, Pau Rosa (Kribs 1968; Richter 1981). Appendix 2. — A: TS. – B, C: TLS. – D: RLS. – E: IVP. – F: VRP. — oc = oil cells; scp = scalariform perforation.

IAWA Hardwood codes: 1 2v 5 7v 13 14v 15v 16v 22 23v 27 31v 32 33v 42 47 56 61 65 69 78 79 84v 92 97 106 115 124 125 126 152

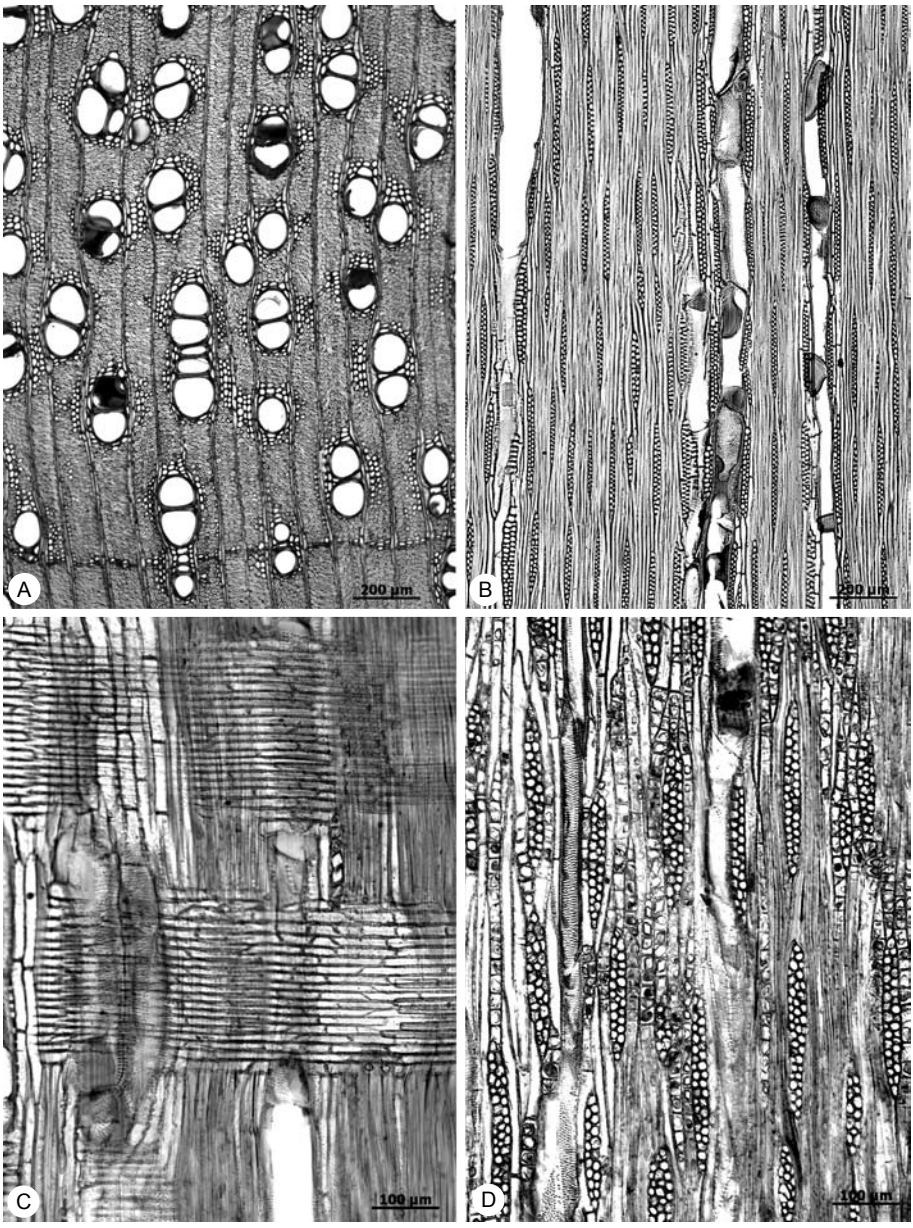

Figure 4. *Caesalpinia echinata* Lam. (Leguminosae, Caesalpinioideae). Brazilwood, Pernambuco (Brazier & Franklin 1961; Kribs 1968; Détienne & Jacquet 1983; Richter & Dallwitz 2000-onwards; Gasson *et al*. 2009). Appendix 2. — A: TS. – B: TLS. – C: RLS. – D: TLS.

IAWA Hardwood codes: 1v 2 5 13 22 23v 24 25 29 30 41 42v 48 49v 58 61 66 70 79 80 81 83 89 91 92 97 104 115 118v 120v 122v 136 138 142

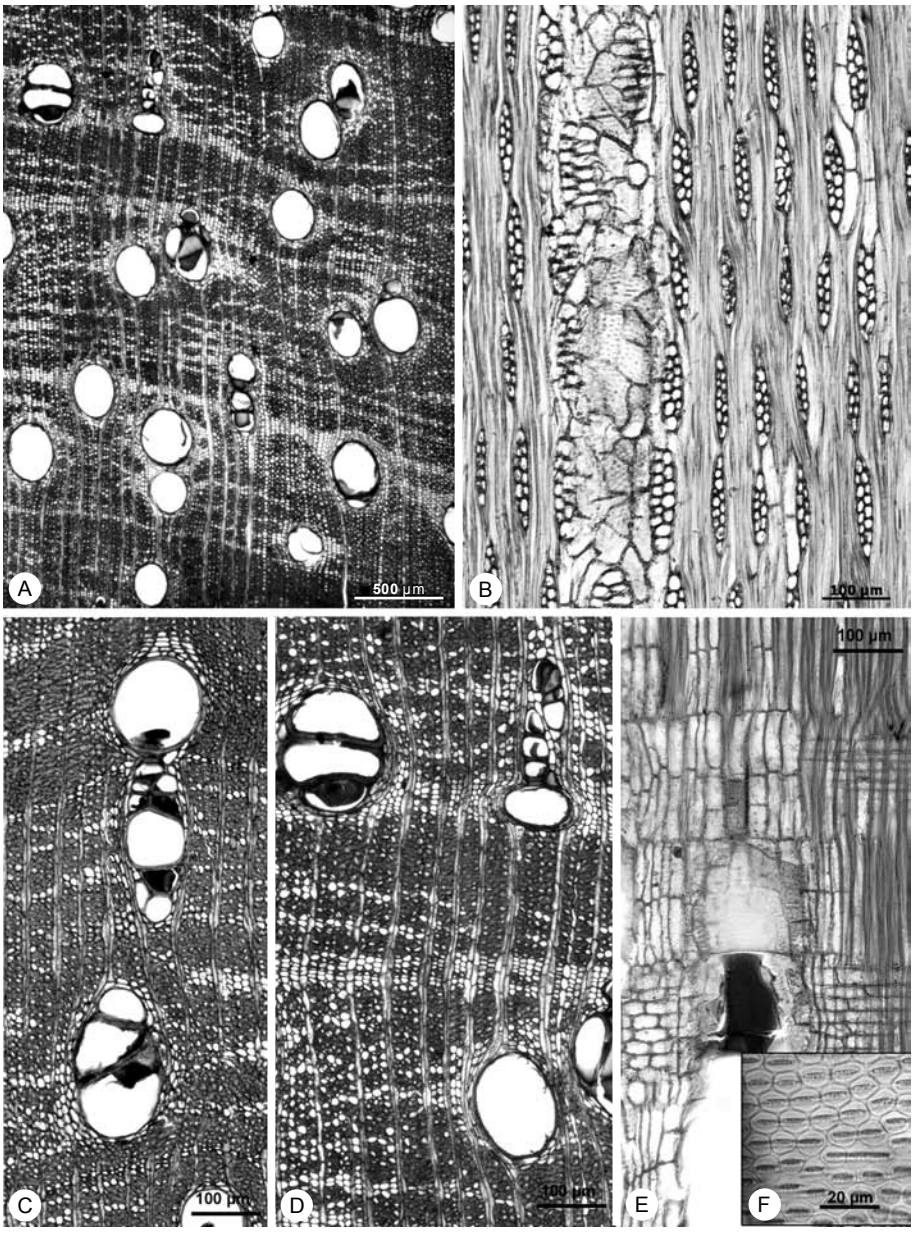

Figure 5. *Dalbergia nigra* Fr. Allem. (Leguminosae, Papilionoideae). Brazilian Rosewood (Détienne & Jacquet 1983; Richter & Dallwitz 2000-onwards; Miller & Wiemann 2006; Gasson *et al*. 2010). Appendix I. — A: TS. – B: TLS. – C, D: TS. – E: RLS. – F: IVP.

IAWA Hardwood codes: 1 2 5 13 22 23 26 27v 29 30 42 45v 46 47v 58 61 66 70 76 77 79 80 83 84v 86 89 90 91 97 104 106v 115 118 120 121 136 142

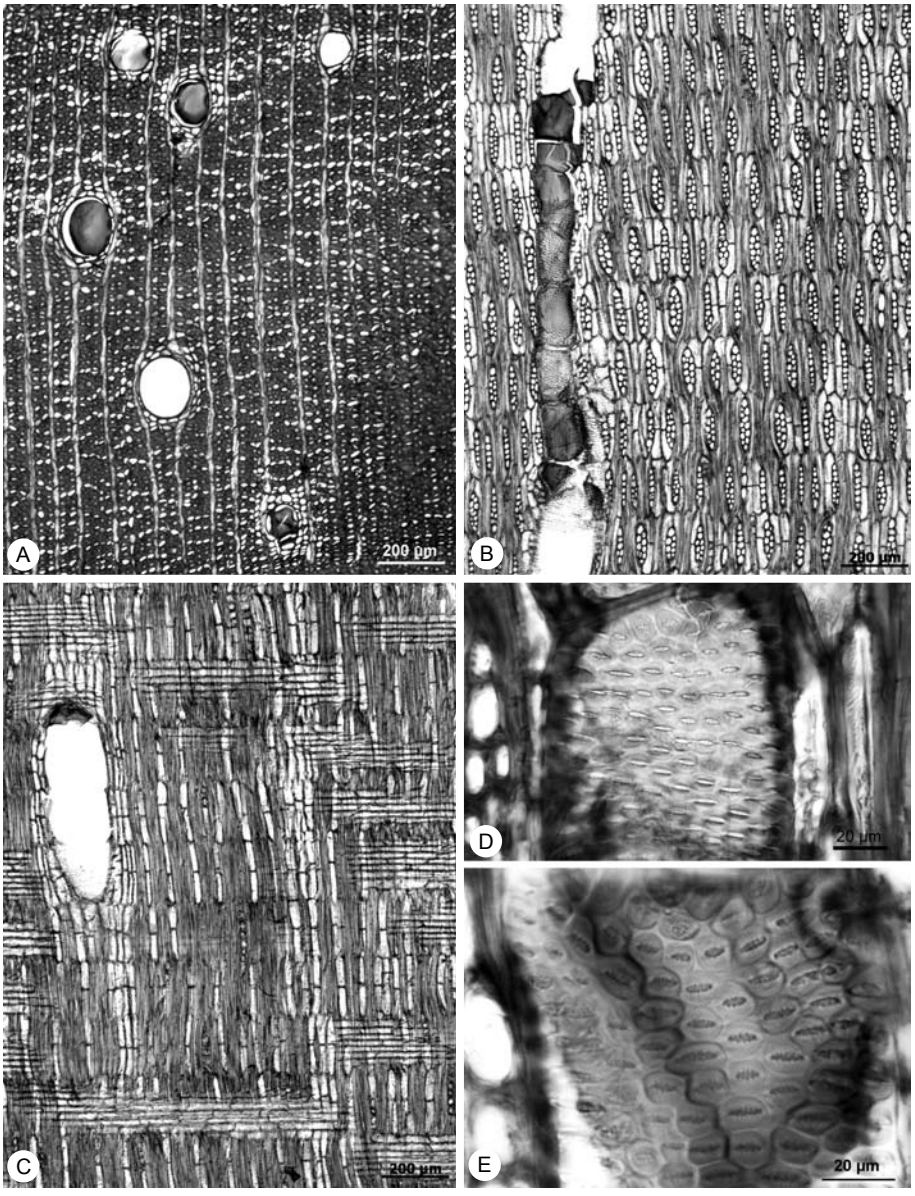

Figure 6. *Dalbergia retusa* Hemsl. (Leguminosae, Papilionoideae). Cocolobo (Kribs 1968; Richter & Dallwitz 2000-onwards). Appendix 3. — A: TS. – B: TLS. – C: RLS. – D, E: IVP.

IAWA Hardwood codes: 1 2 5 13 22 23 26 29 30 42 46 47 58 61 66 70 76 77 79 80v 83v 86v 87v 89 90v 91 92v 96v 97 104 106v 115 116 118 120 121 136 142

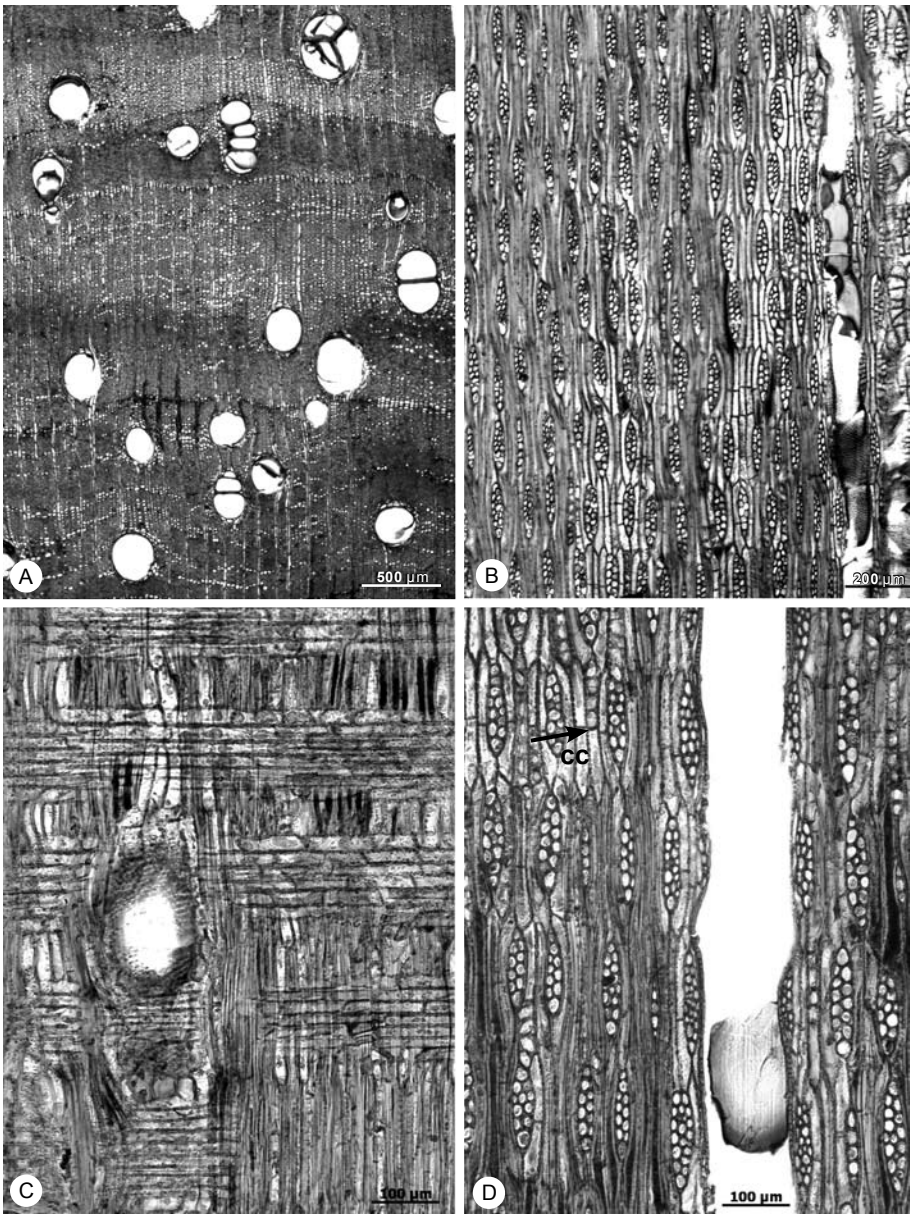

Figure 7. *Dalbergia stevensonii* Standl. (Leguminosae, Papilionoideae). Honduras Rosewood. Appendix 3. — A: TS. – B: TLS. – C: RLS. – D: TLS. – cc = chambered crystals.

IAWA Hardwood codes: 1v 2 5 13 22 23 26 29 30 42 45v 46 47 58 61 66 70 76 77 78 79 80 83 86 89v 90 91 97 104 115 116v 118 120 121 136 142

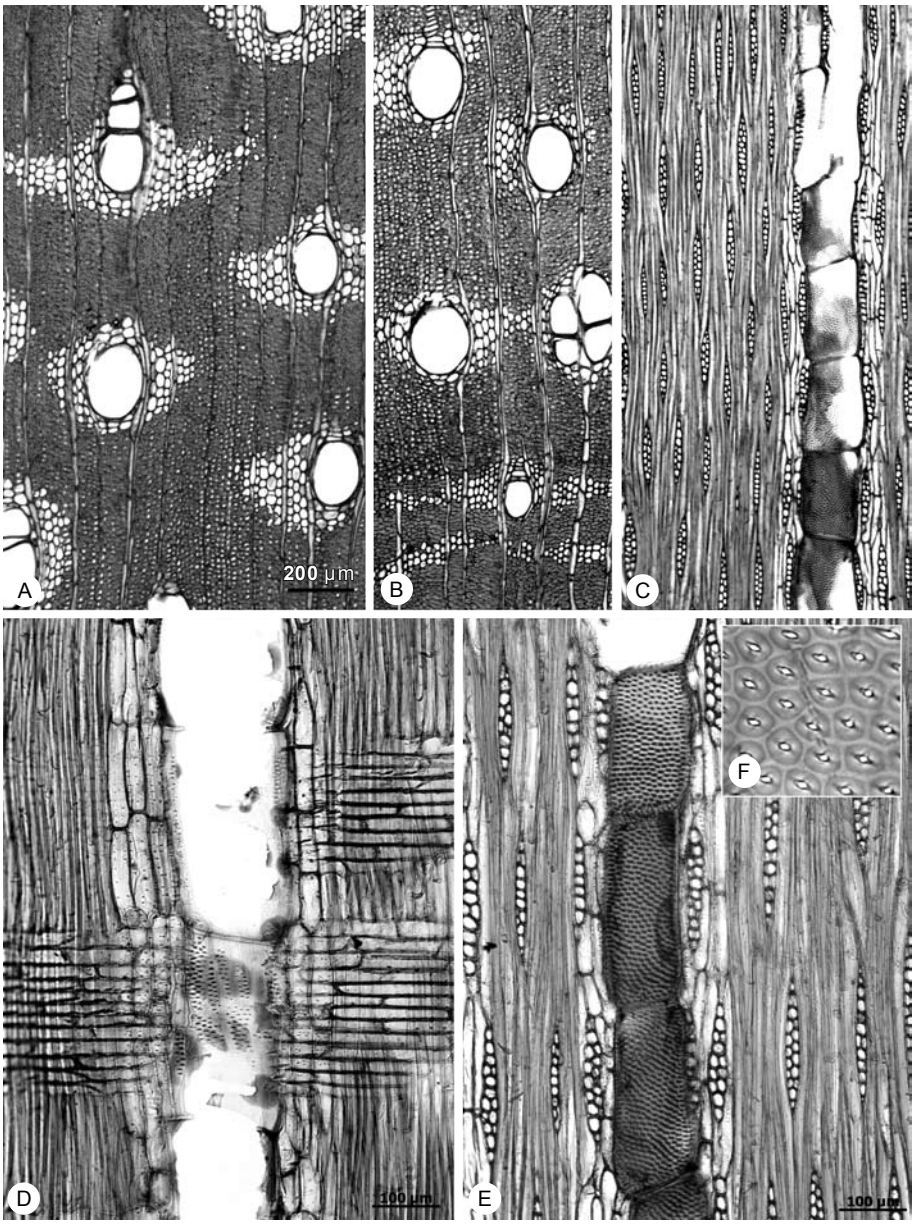

Figure 8. *Dipteryx oleifera* Benth. [*D. panamensis* (Pittier) Record & Mell.] (Leguminosae, Papilionoideae). Almendro Amarillo. Appendix 3. — A, B: TS. – C: TLS. – D: RLS. – E: TLS. – F: IVP.

IAWA Hardwood codes: 2 5 13 22 23v 26 29 30 42 46v 47 58 61 66 69 70 80 81 82 83 91 92v 97 104 115 118 120 136 142

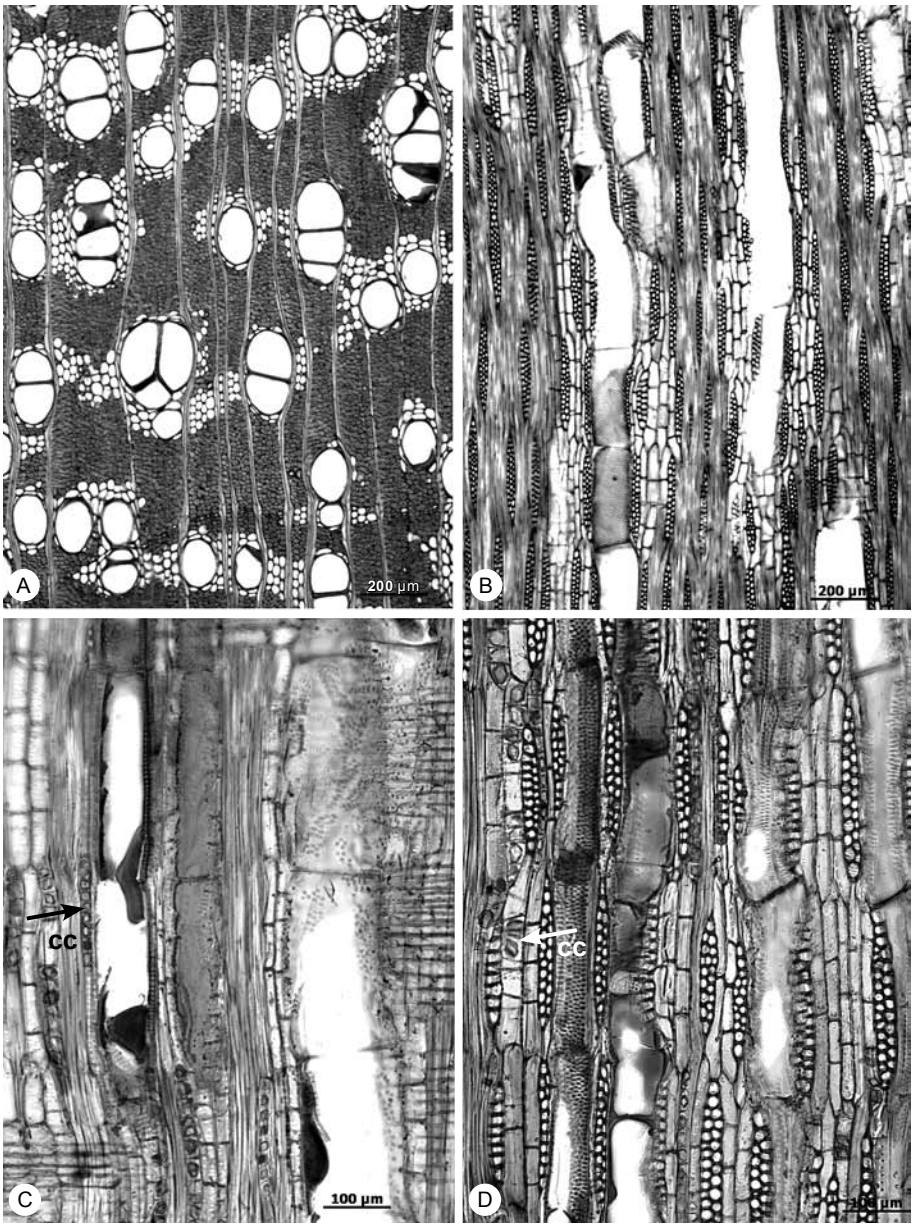

Figure 9. *Pericopsis elata* (Harms) Meeuwen [*Afrormosia elata* Harms] (Leguminosae, Papilionoideae). African Teak (Ng'adwe *et al*. 2010). Appendix 2. — A: TS. – B: TLS. – C: RLS. – D: TLS. – cc = chambered crystals.

IAWA Hardwood codes: 1v 2v 5 13 22 23v 25v 26 29 30 41v 42 47 58 61 66 70 76v 78 79 80v 81v 83 84v 89v 92 97 104 106v 115 118 119v 120 136 142

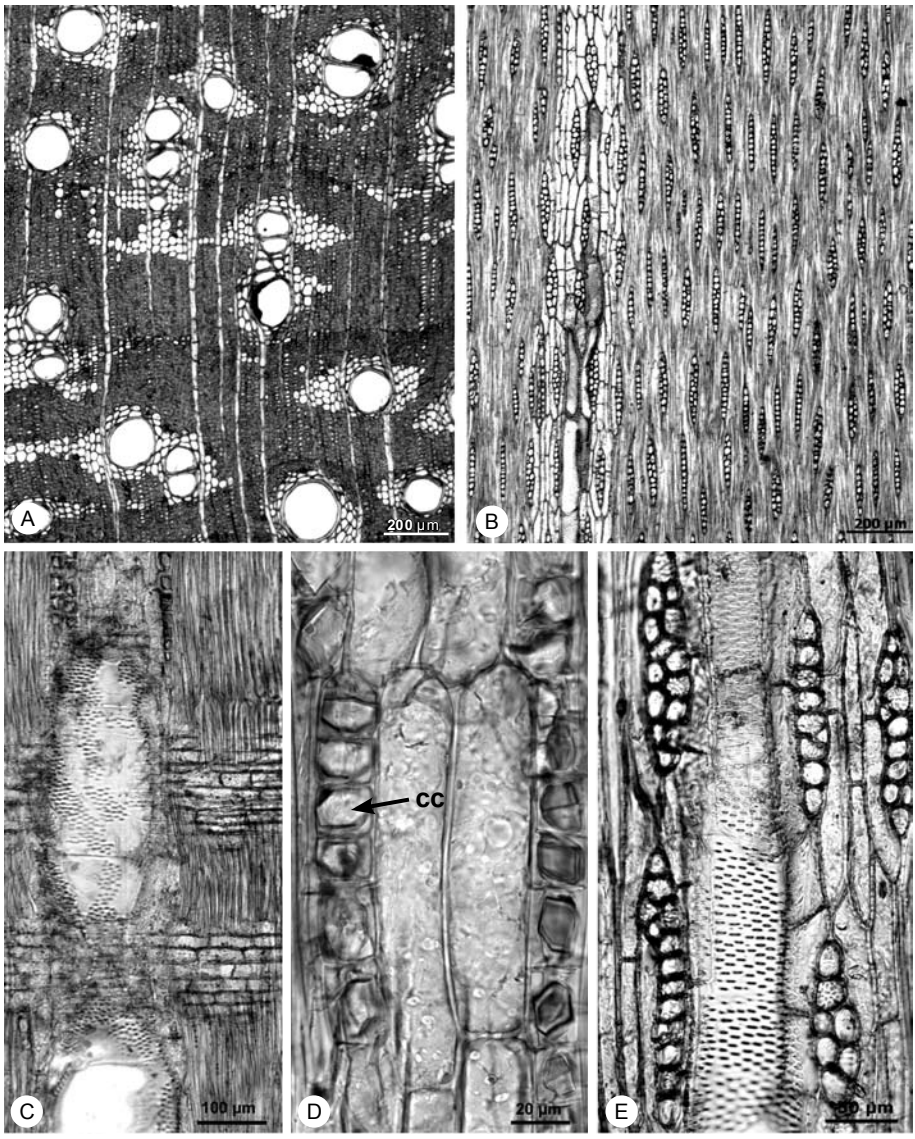

Figure 10. *Platymiscium pleiostachyum* Donn. Sm. (Leguminosae). Cristobal, Granadillo, Cachimbo. Appendix 2. — A: TS. – B: TLS. – C: RLS. – D: RLS. – E: TLS. – cc = chambered crystals.

IAWA Hardwood codes: 1v 2v 5 13 22 23 25 26 29 30 42 46 47 58 61 66 69v 70 76 80 81v 82 83 90 91 92 96v 97v 104 115 116 118 120 136 142

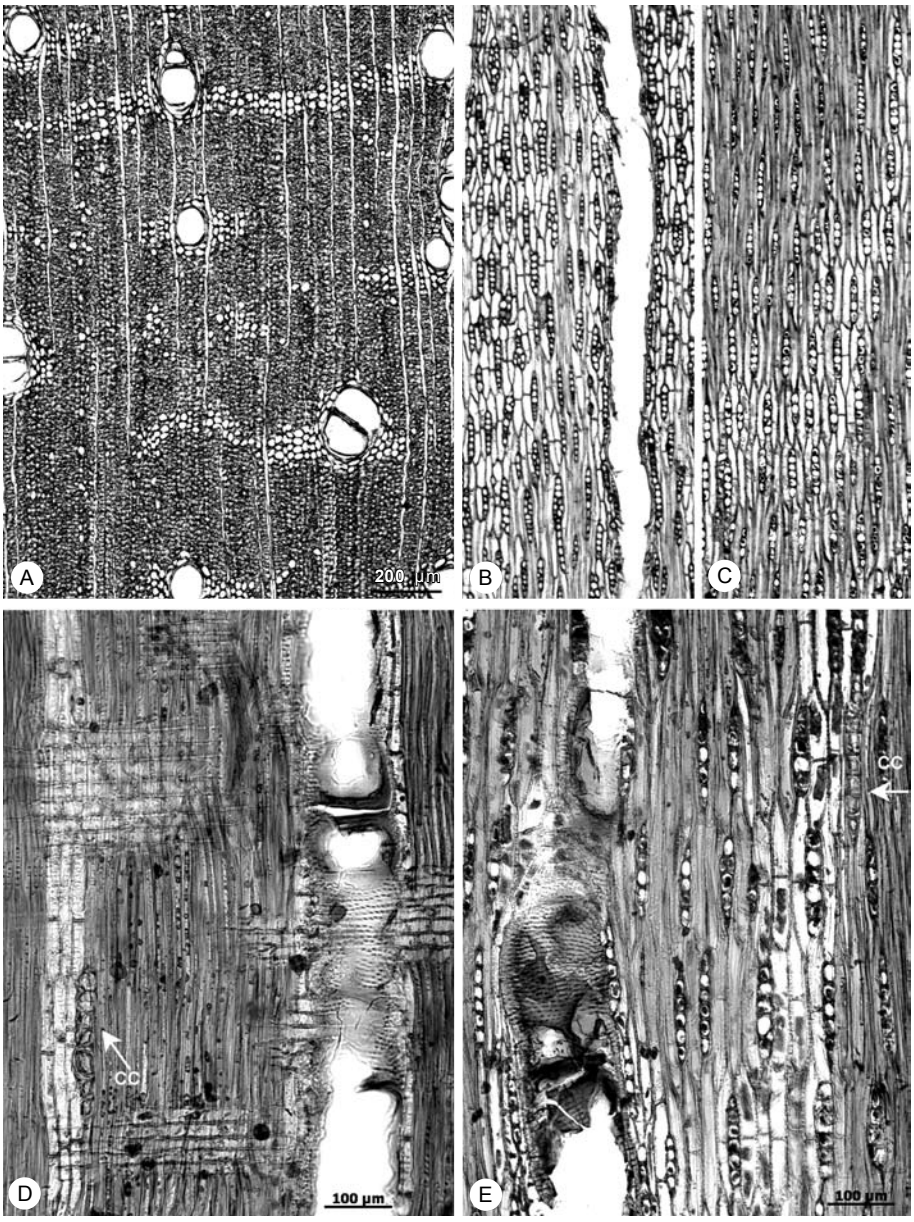

Figure 11. *Pterocarpus santalinus* L.f. (Leguminosae, Papilionoideae). Red Sandalwood, Red Sanders (Kribs 1968; Normand & Paquis 1976; Richter & Dallwitz 2000-onwards). Appendix 2. — A: TS. – B, C: TLS. – D: RLS. – E: TLS. – cc = chambered crystals.

IAWA Hardwood codes: 1v 2v 4v 5 13 22 23 26 27v 29 30 42 43 46 47v 58 61 66 69 70v 80 82 83 85v 86v 90 91 96 97v 104 115 116 118 120 136 142

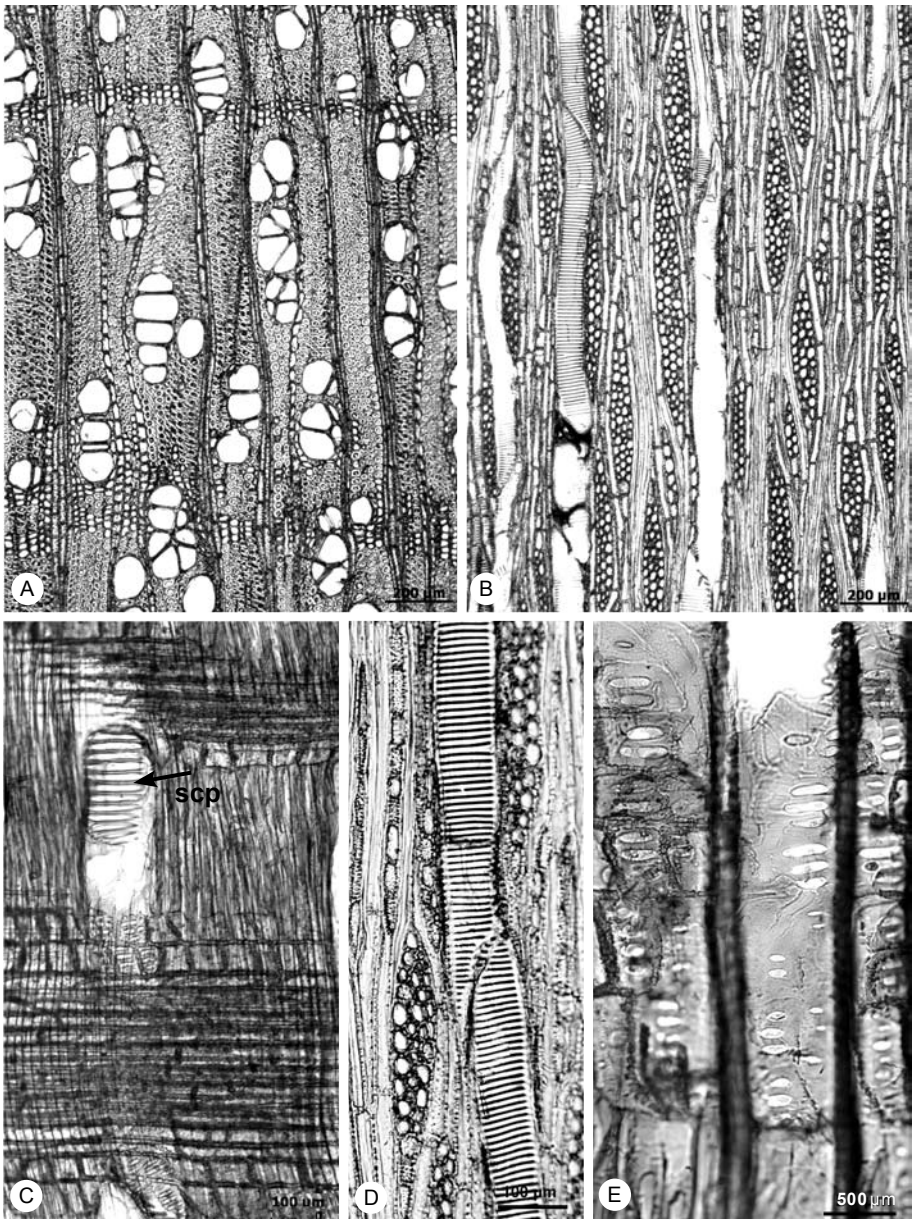

Figure 12. *Magnolia liliifera* (L.) Baill. var. *obovata* (Korth.) Govaerts (Magnoliaceae). Giogi, Champak. Appendix 3. — A: TS. – B: TLS. – C: RLS. – D: IVP. – E: VRP. – scp = scalariform perforation.

IAWA Hardwood codes: 1 5 14 15 16 20 32 34v 41 47 48 61 66 69 89 93 98 106 107 115

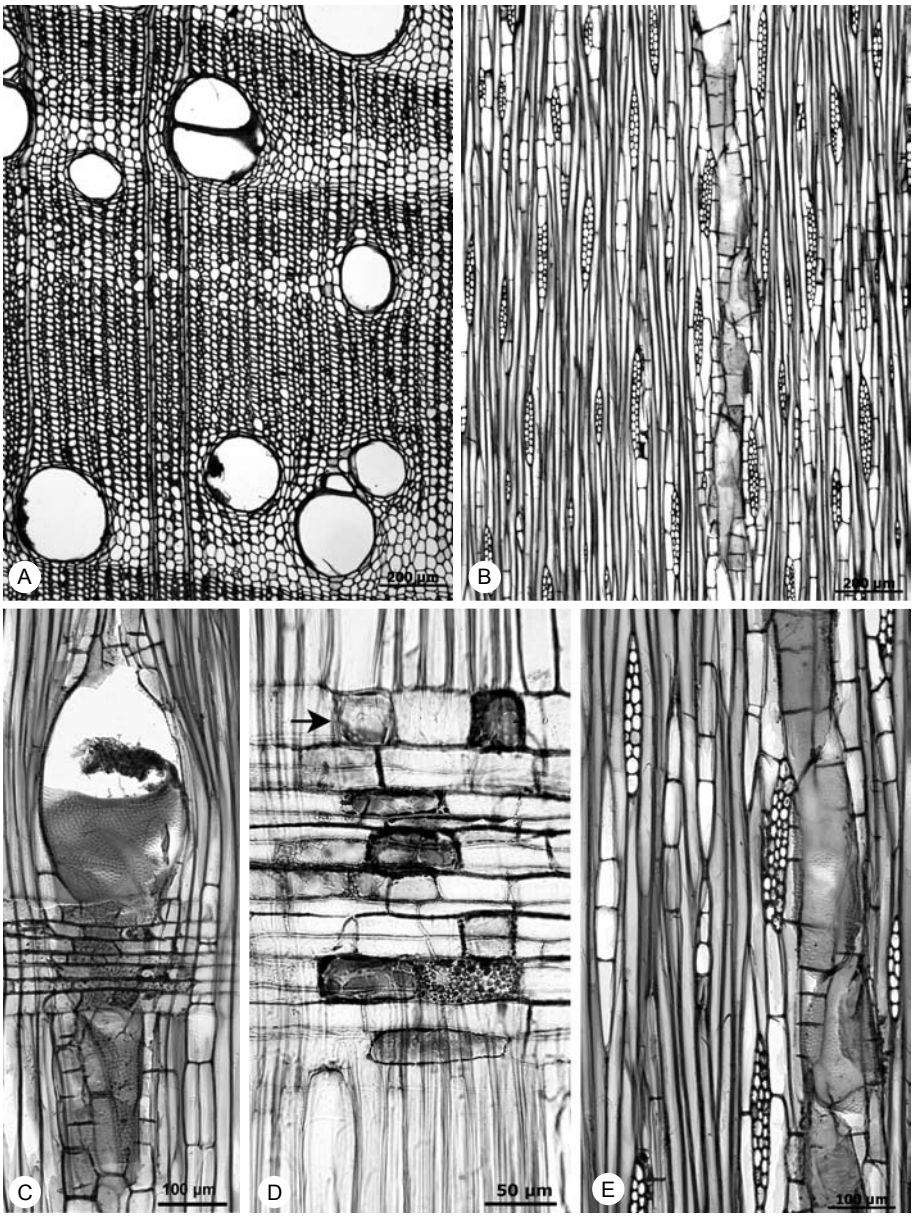

Figure 13. *Cedrela fissilis* Vell. (Meliaceae). Cedro (Brazier & Franklin 1961; Miller & Détienne 2001; White & Gasson 2008). Appendix 3. — A: TS. – B: TLS. – C, D: RLS, crystal in square ray parenchyma cell (arrow). – E: TLS.

IAWA Hardwood codes: 1 4 5v 13 22 23v 25 26v 30 42 46 47 58 61 65 66 69 76 78 79 80v 85 89 92 93 97v 98v 104 106 115 131v 136v 137v 141v 142v

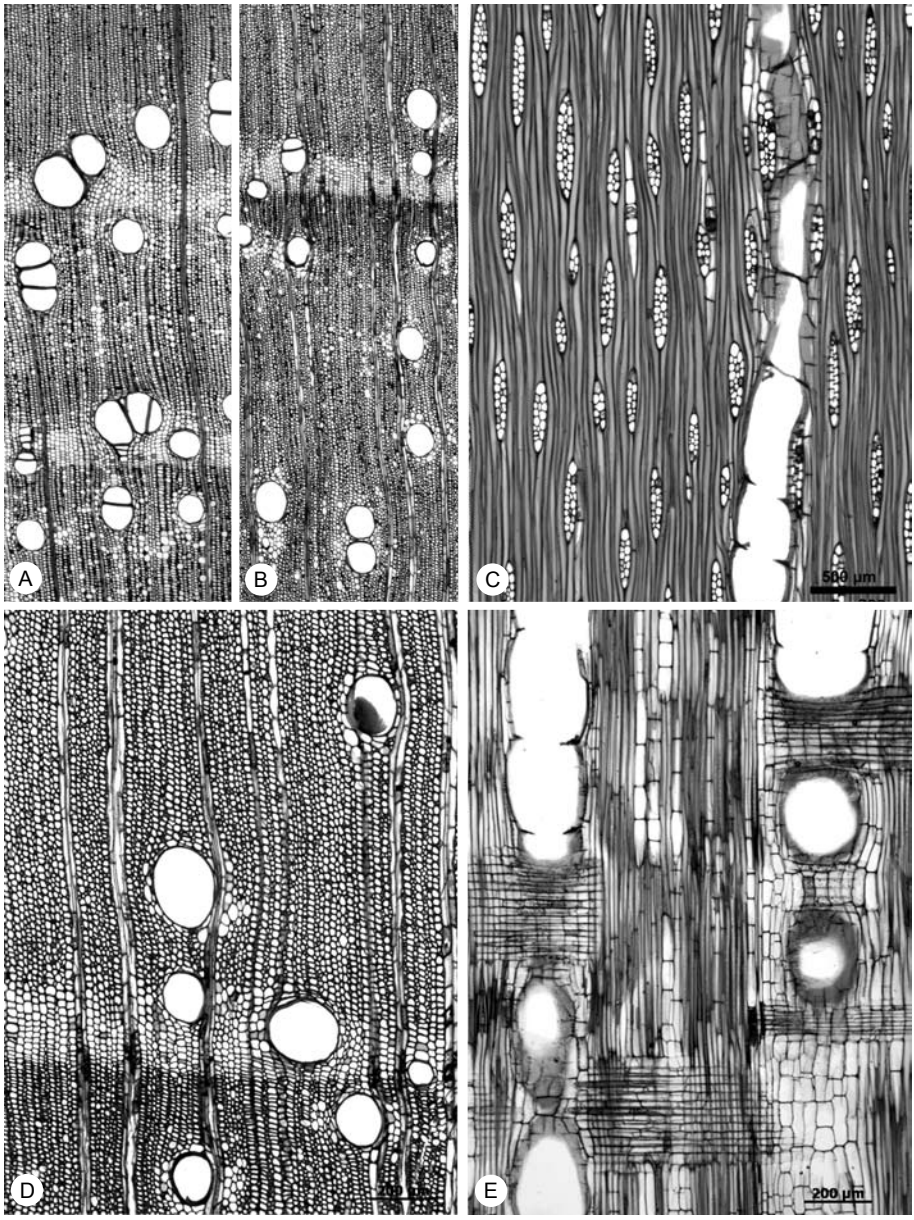

Figure 14. *Cedrela odorata* L. (Meliaceae). Cedro, Cigarbox Cedar (Brazier & Franklin 1961; Détienne & Jacquet 1983; Miller & Détienne 2001; White & Gasson 2008). Appendix 3. — A, B: TS. – C: TLS. – D: TS. – E: RLS.

IAWA Hardwood codes: 1 3v 4v 5v 13 22 23v 25 30 42 46 47 58 61 65v 66 69 76 78 79v 80v 85 89 92 93 97v 98v 106 107v 115 131v 136v 137v 141v 142v

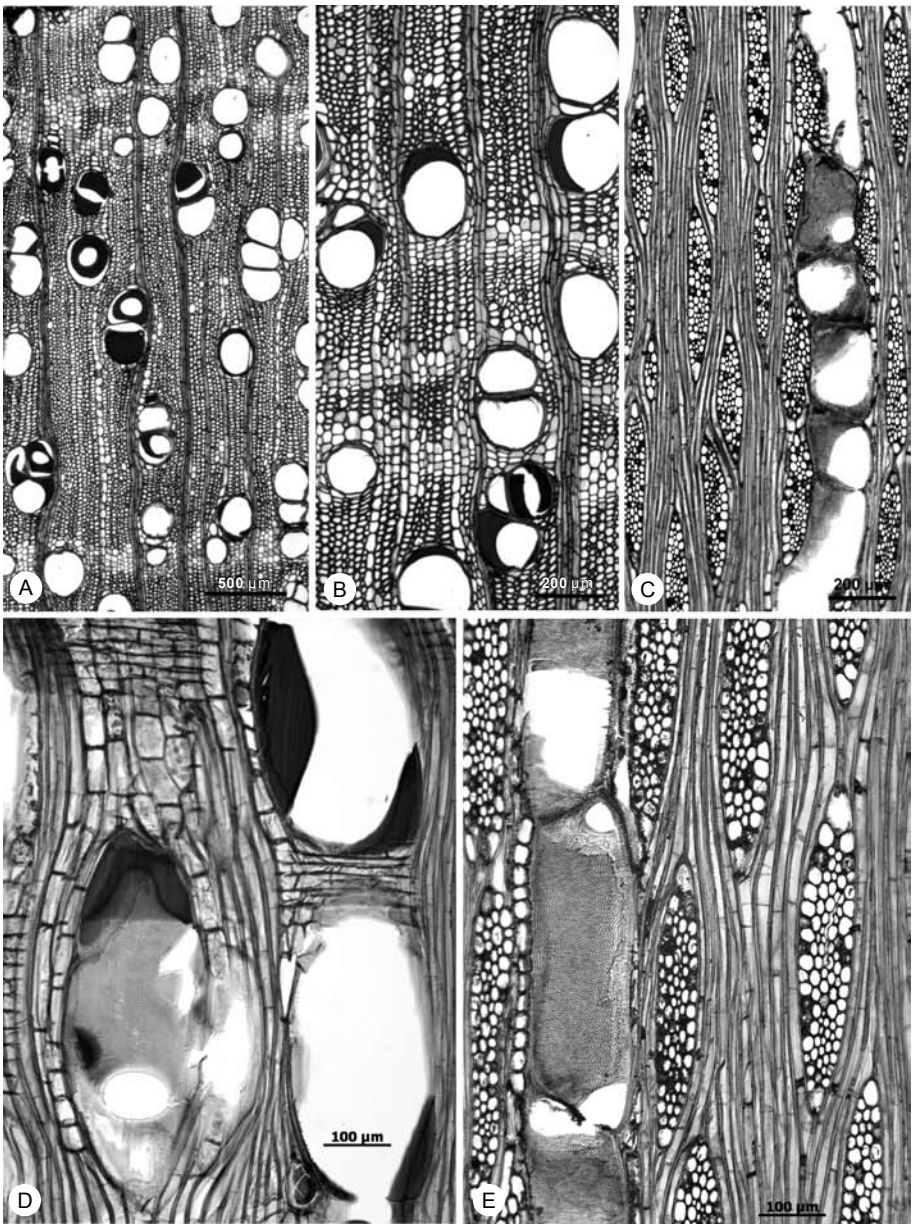

Figure 15. *Swietenia humilis* Zucc. (Meliaceae). Mexican Mahogany (White & Gasson 2008). Appendix 2. — A, B: TS. – C: TLS. – D: RLS. – E: TLS.

IAWA Hardwood codes: 1v 2v 5 13 22 23v 24 30 42 46v 47 58 61 65 66 69 76v 78 79v 85v 89 93 97v 98 106 107v 115 118v 122v 131v 136v 137v 141v 142v

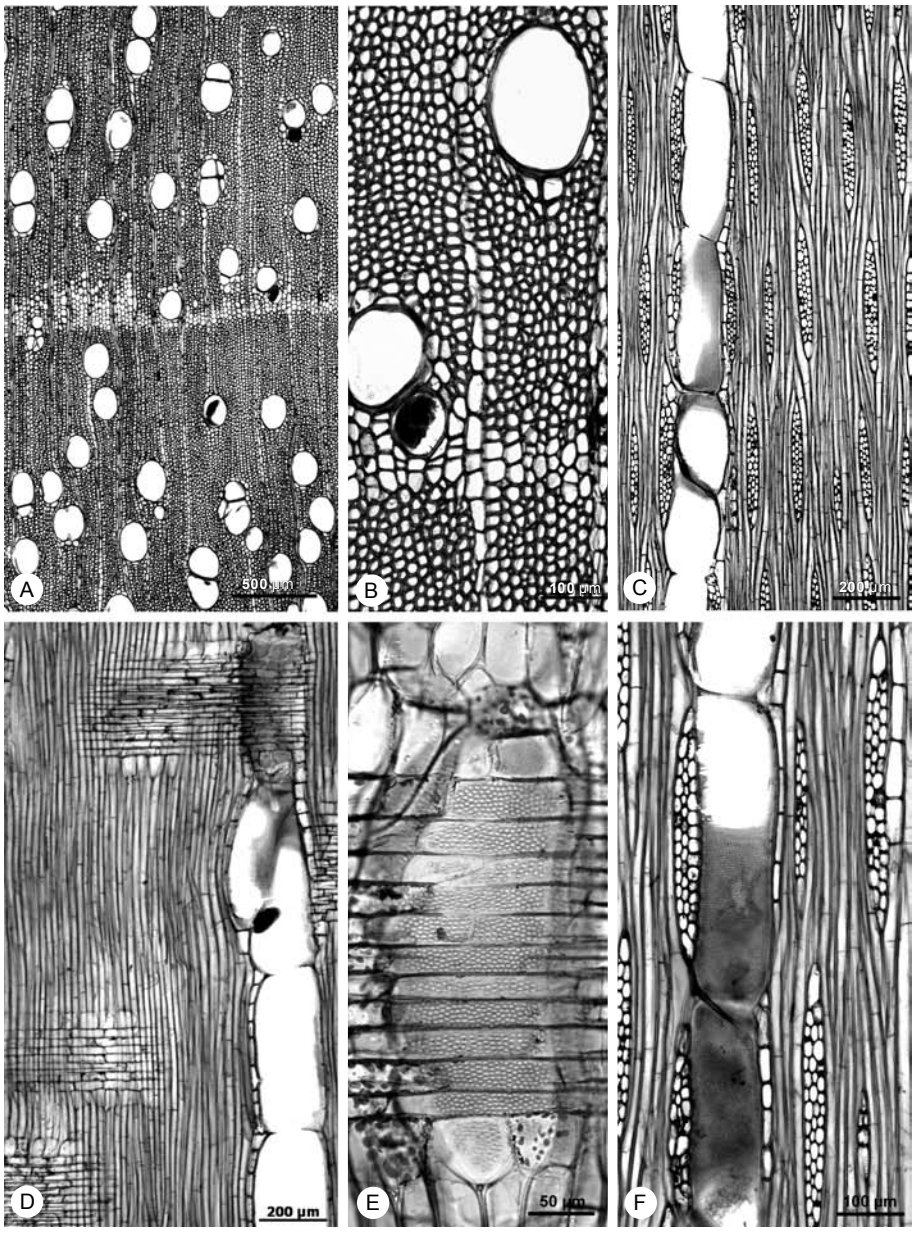

Figure 16. *Swietenia macrophylla* King (Meliaceae). Big Leaf Mahogany (White & Gasson 2008). Appendix 2. — A, B: TS. – C: TLS. – D: RLS. – E: VRP. – F: TLS.

IAWA Hardwood codes: 1v 2v 5 13 22 23v 24 30 42 46v 47 58 61 65 66 69 76v 78 79v 85v 89 93 97v 98 106 107v 115 118 122v 131v 136v 137v 138v 141v 142v

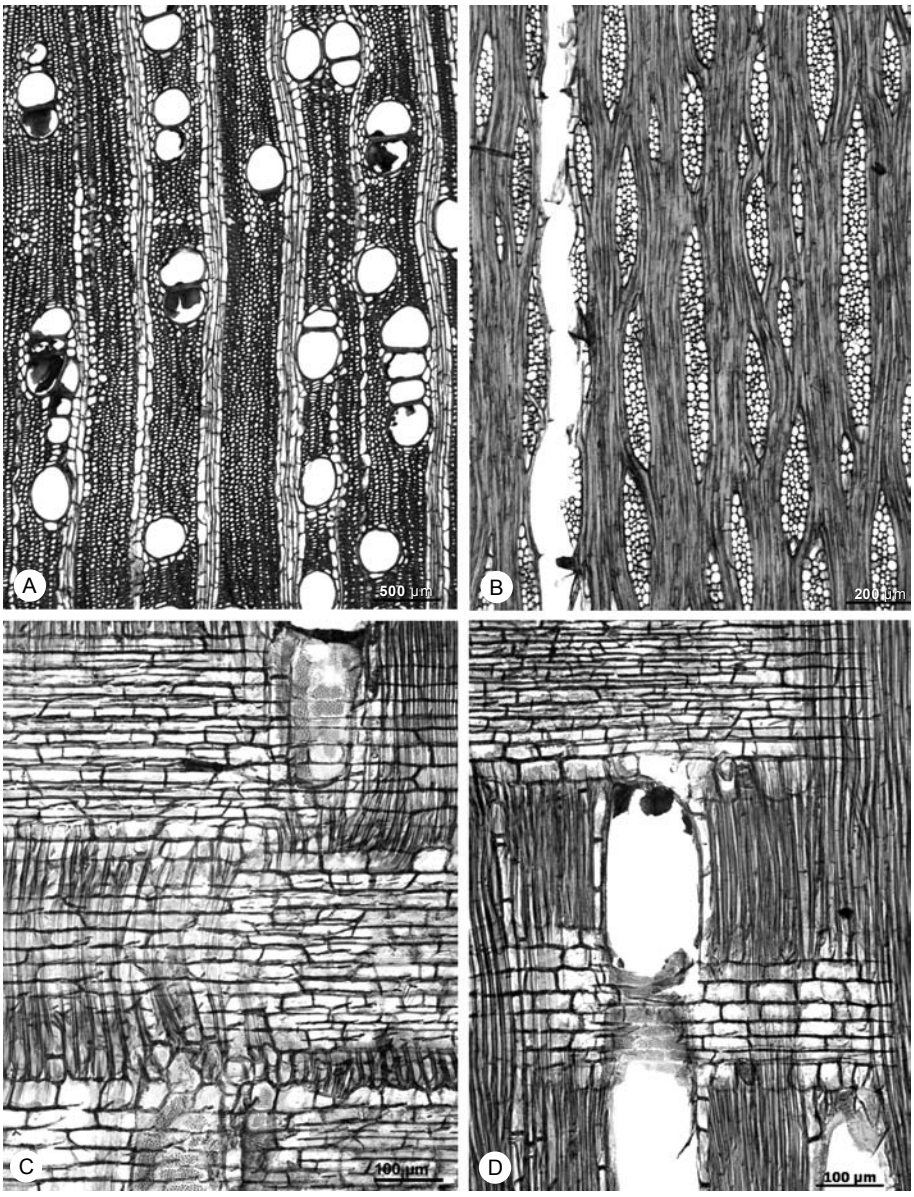

Figure 17. *Swietenia mahagoni* (L.) Jacq. (Meliaceae). American Mahogany (Soerianegara & Lemmens 1993; White & Gasson 2008). Appendix 2. — A: TS. – B: TLS. – C, D: RLS.

IAWA Hardwood codes: 1v 2v 5 13 22 23v 24 25v 30 42 46v 47 58 61 65 66 69 76v 78 79v 85v 89 93 97v 98 106 107v 115 118v 122v 131v 136v 137v 141v 142v

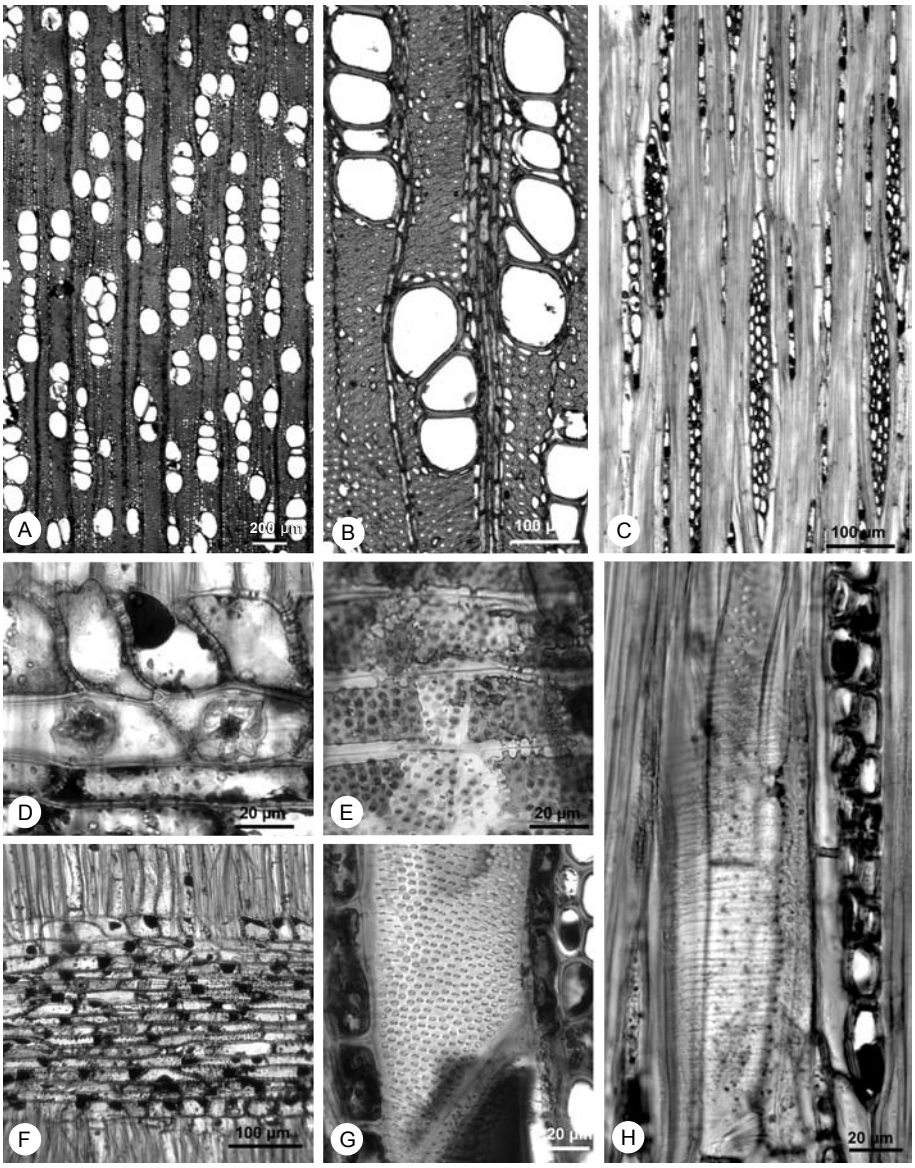

Figure 18. *Prunus africana* (Hook. f.) Kalkman (Rosaceae). African Cherry, Red Stinkwood (Kribs 1968). Appendix 2. — A, B: TS. – C: TLS. – D: RLS, druses. – E: VRP. – F: RLS. – G: IVP. – H: TLS, helical thickenings in vessel element.

IAWA Hardwood codes: 2 5 7v 10v 13 22 23v 24 25 30 36v 37v 41 42 47 48v 58 61v 62 66 69 76 78 89v 92 93 98 103v 106 107 110v 115 144v 145v

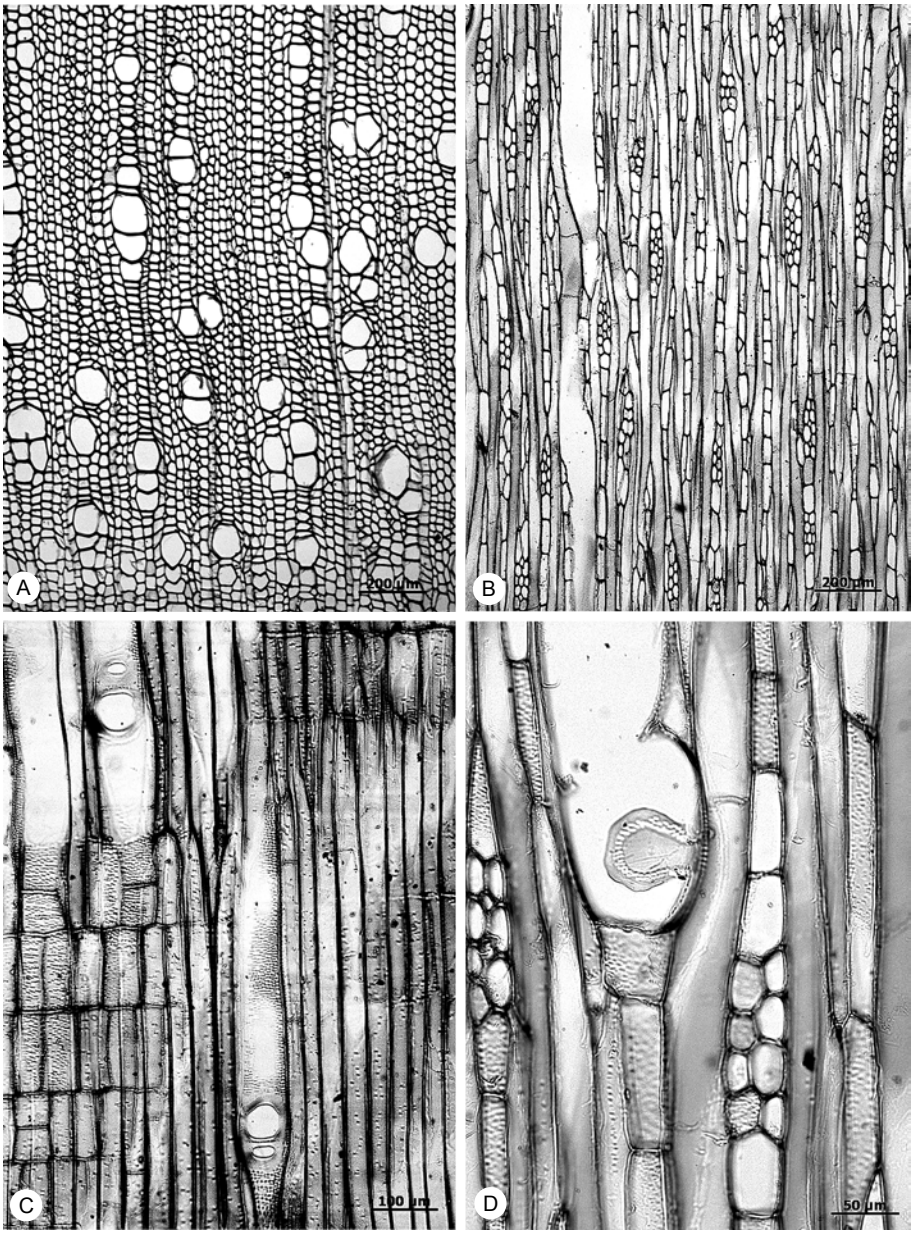

Figure 19. *Balmea stormae* Martínez (Rubiaceae). Ayugue. Appendix 1. — A: TS. – B: TLS. – C: RLS. – D: TLS.

IAWA Hardwood codes: 2 5 12 13 22 23 24 25 29 30 41 47 48 61 66 68 75 78v 97 108 112 115

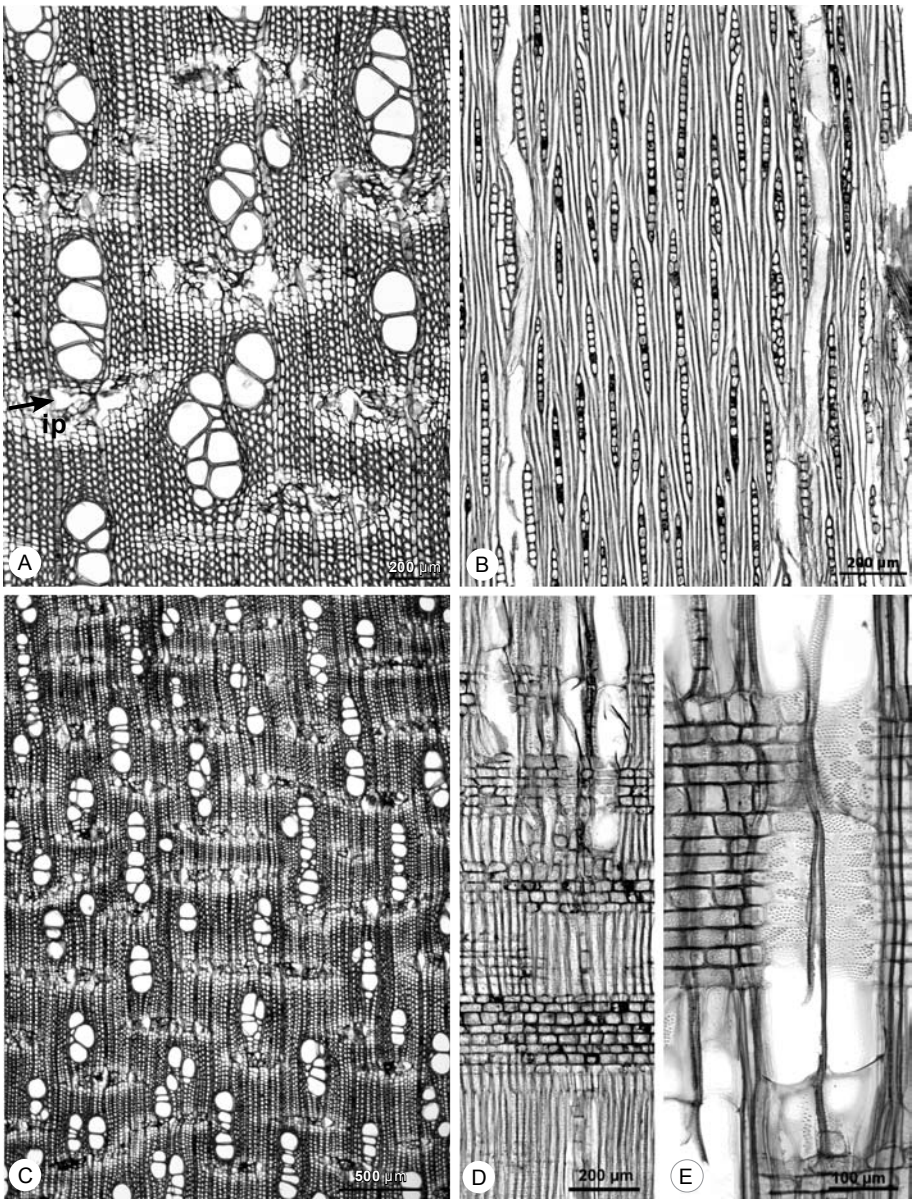

Figure 20. *Aquilaria agallocha* Roxb. (Thymelaeaceae). Agarwood (Pearson & Brown 1932). Appendix 2. — A: TS. – B: TLS. – C: TS. – D: RLS. – E: VRP. – ip = included phloem. All *Aquilaria* species are CITES-listed and wood anatomically quite similar.

IAWA Hardwood codes: 2 5 10 13 22 23v 25 29 30 42 47 58 62 66 68 69 75 78 91 92 96 97v 105v 106v 107v 108v 109v 115 133v 134

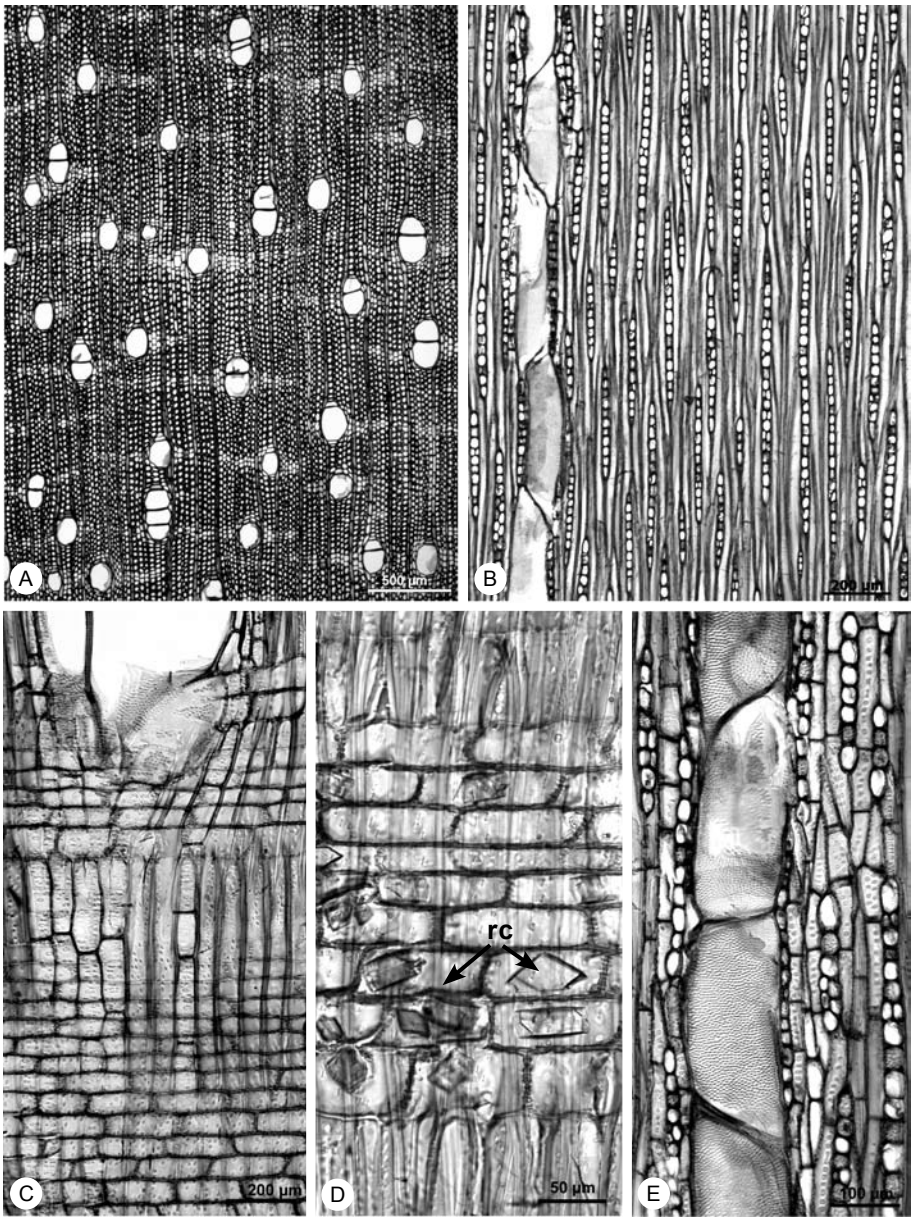

Figure 21. *Gonystylus punctatus* A.C. Sm. (Thymelaeaceae). Ramin (Soerianegara & Lemmens 1993; Richter & Dallwitz 2000-onwards). Appendix 2. — A: TS. – B: TLS. – C, D: RLS. – E: TLS. – rc = crystals in ray cells. All *Gonystylus* species are CITES-listed and wood anatomically very similar.

IAWA Hardwood codes: 2 5 12v 13 22 23 24 25v 29 30 42 47 58v 62 66 69 80 82 83 91 92 93 96 104 106v 115 136 138 141v 151 154v

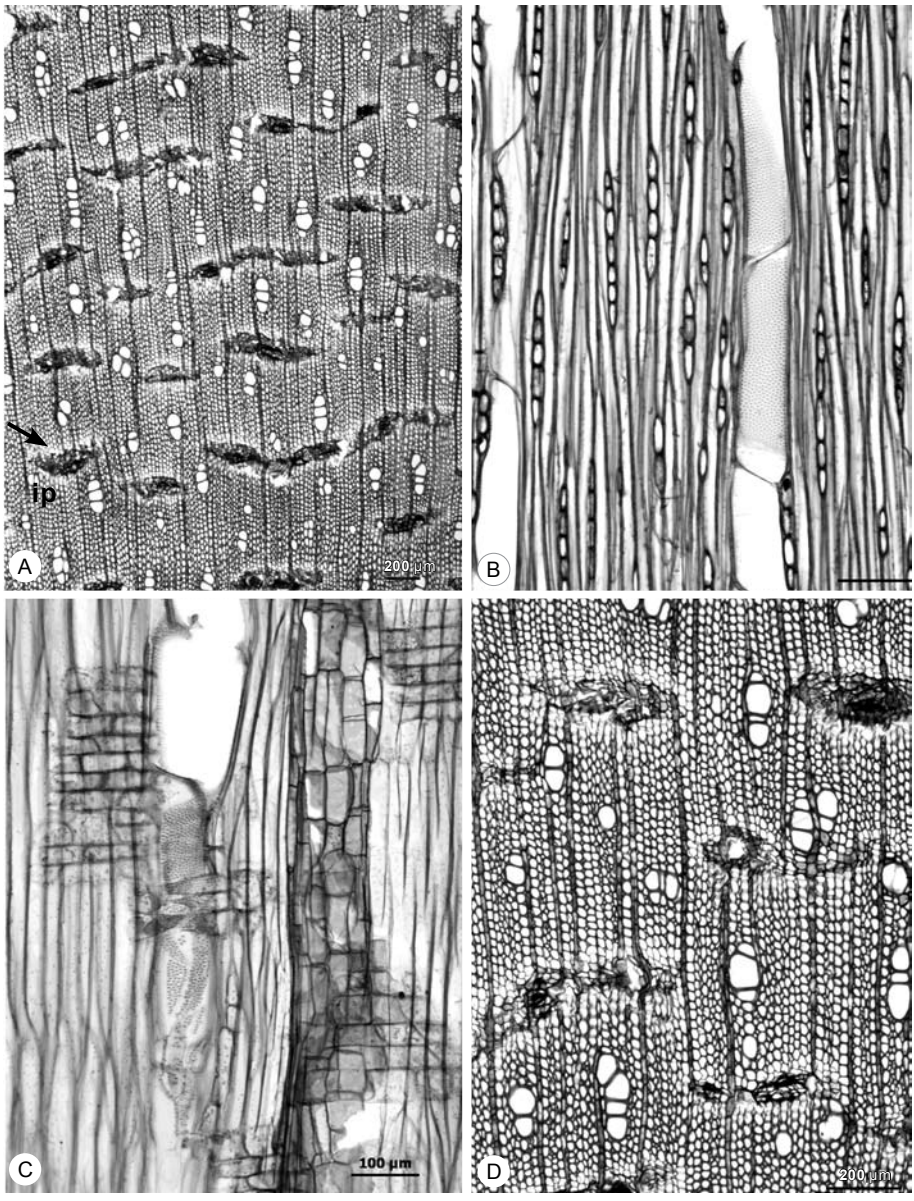

Figure 22. *Gyrinops walla* Gaertn. (Thymelaeaceae). Agarwood. Appendix 2. — A: TS. – B: TLS. – C: RLS. – D: TS. – ip = included phloem. All *Gyrinops* species are CITES-listed and wood anatomically quite similar.

IAWA Hardwood codes: 2 5 12v 13 22 23 24 25 29 30 41 47 62 66 68 75 96 97v 105v 106v 107v 108v 109v 115 134

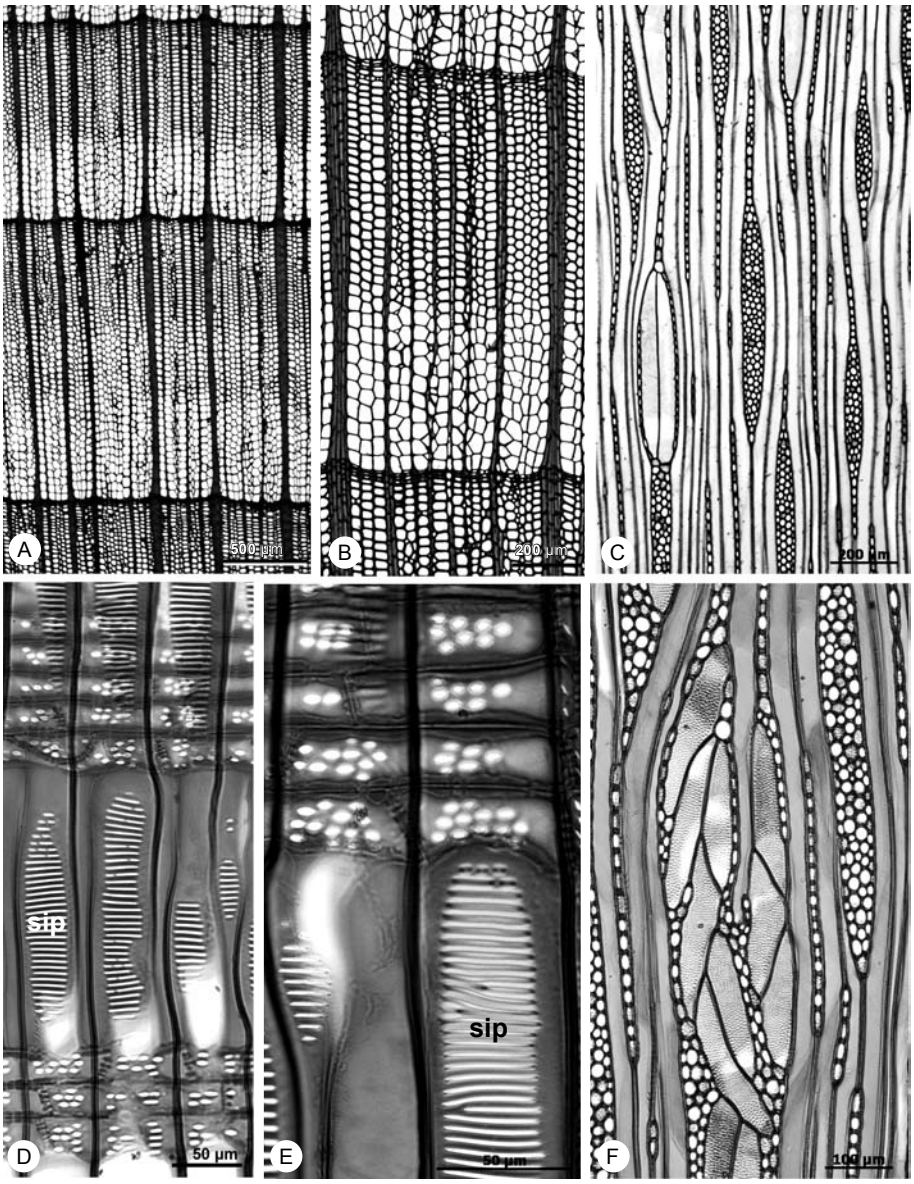

Figure 23. *Tetracentron sinense* Oliv. (Trochodendraceae). Shui qing shu (Suzuki *et al*. 1991). Appendix 3. — A, B: TS. – C: TLS. – D, E: RLS showing scalariform intertracheid pits (sip). – F: TLS.

IAWA Hardwood codes: 1 59 76 77 91 92 93 98 102 103 104 110v 115

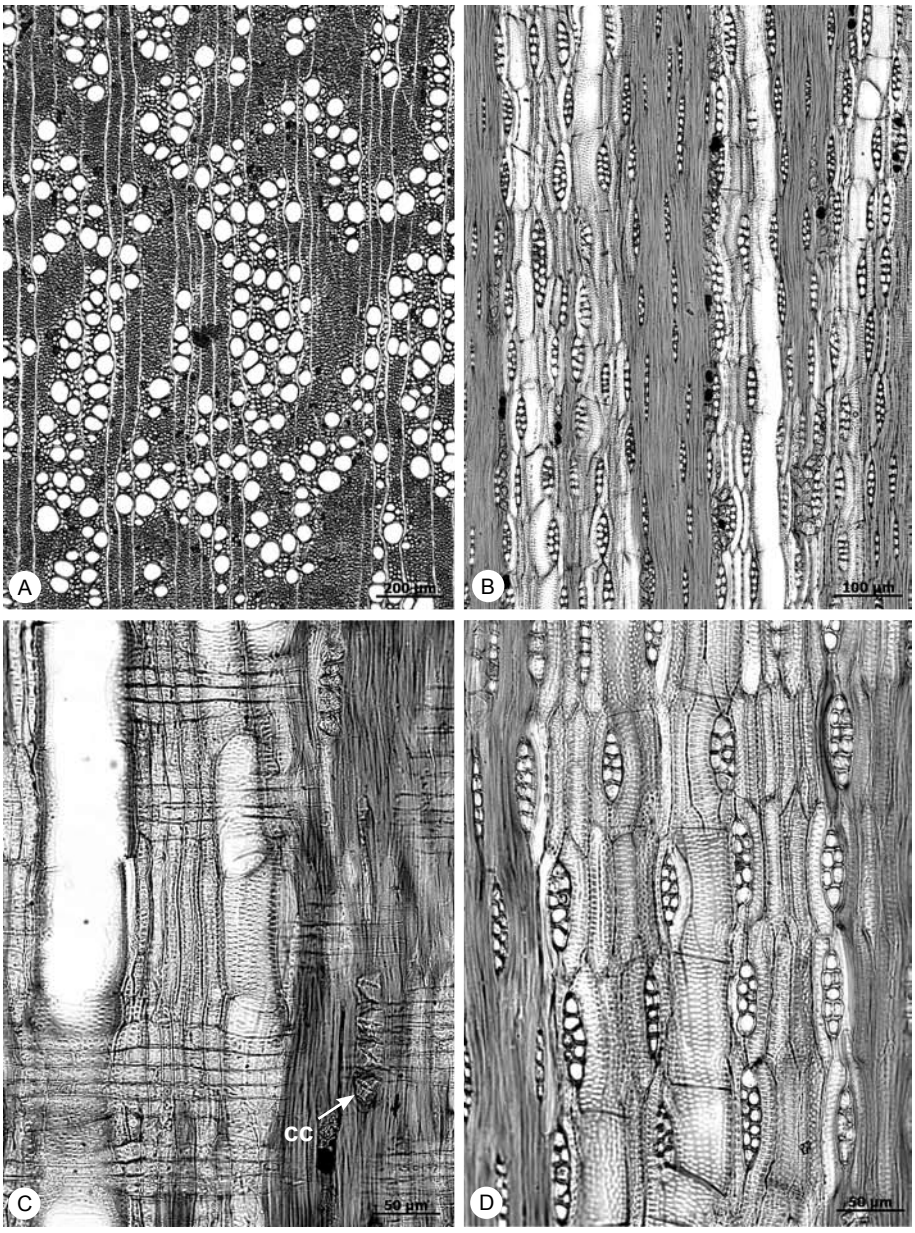

Figure 24. *Bulnesia sarmientoi* Lorentz *ex* Griseb. (Zygophyllaceae). Holywood, Palo Santo, Lignum Vitae (Tortorelli 1956; Kribs 1968). Appendix 2. — A: TS. – B: TLS. – C: RLS. – D: TLS. – cc = chambered crystals.

IAWA Hardwood codes: 2 5 7v 13 22 23v 25 30 41 45v 49 50v 58v 60 61 62 66 70 76 77v 78 79 90 91 97 104 116 118 120 136 142

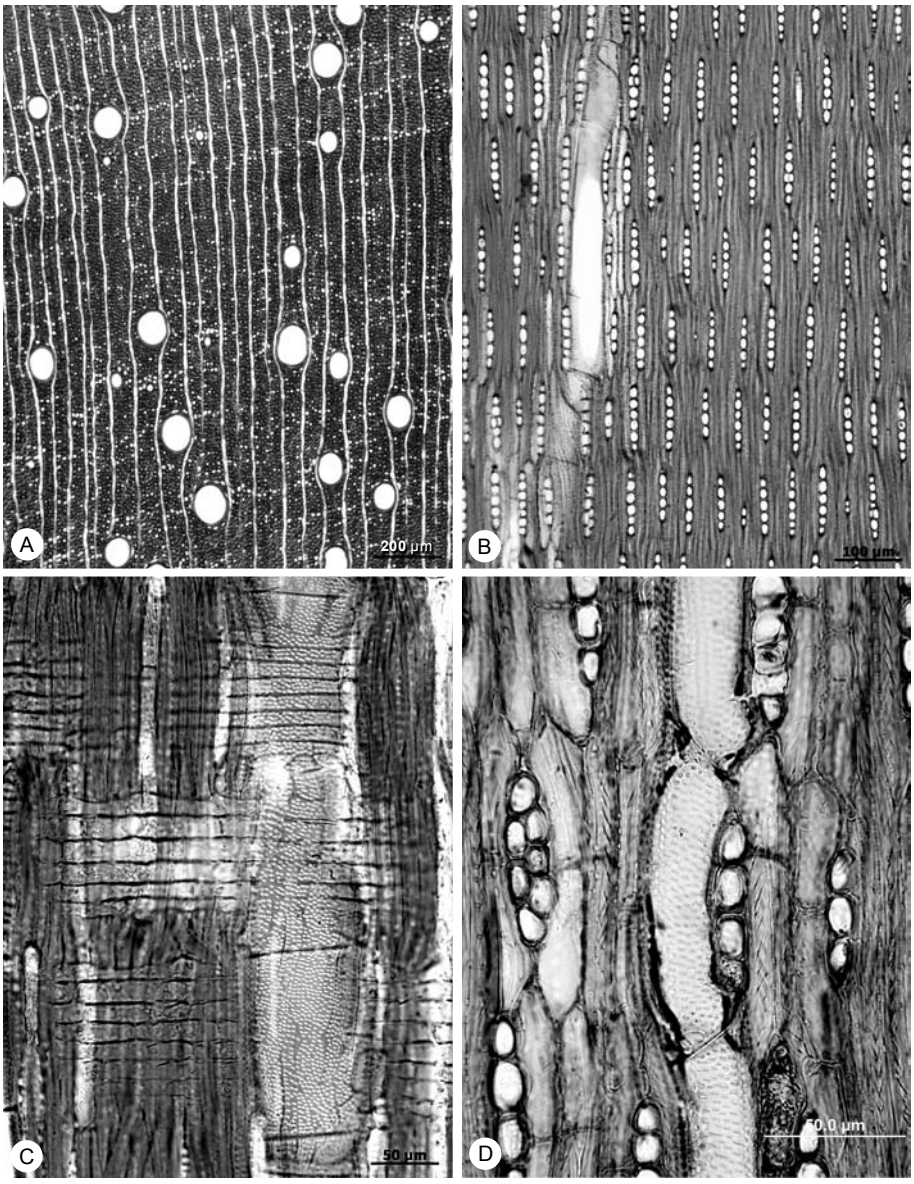

Figure 25. *Guaiacum officinale* L. (Zygophyllaceae). Lignum Vitae, Holywood (Kribs 1968; Nardi Berte & Edlmann Abbate 1992). Appendix 2. — A: TS. – B: TLS. – C: RLS. – D: TLS. All species of *Guaiacum* are CITES-listed and wood anatomically quite similar.

IAWA Hardwood codes: 2 5 9 13 22 23v 24 30 41 45v 47 58 60 61v 62v 63 66 70 76 77 78 86v 90 91 96 104 115 118 120 121 136v 142v

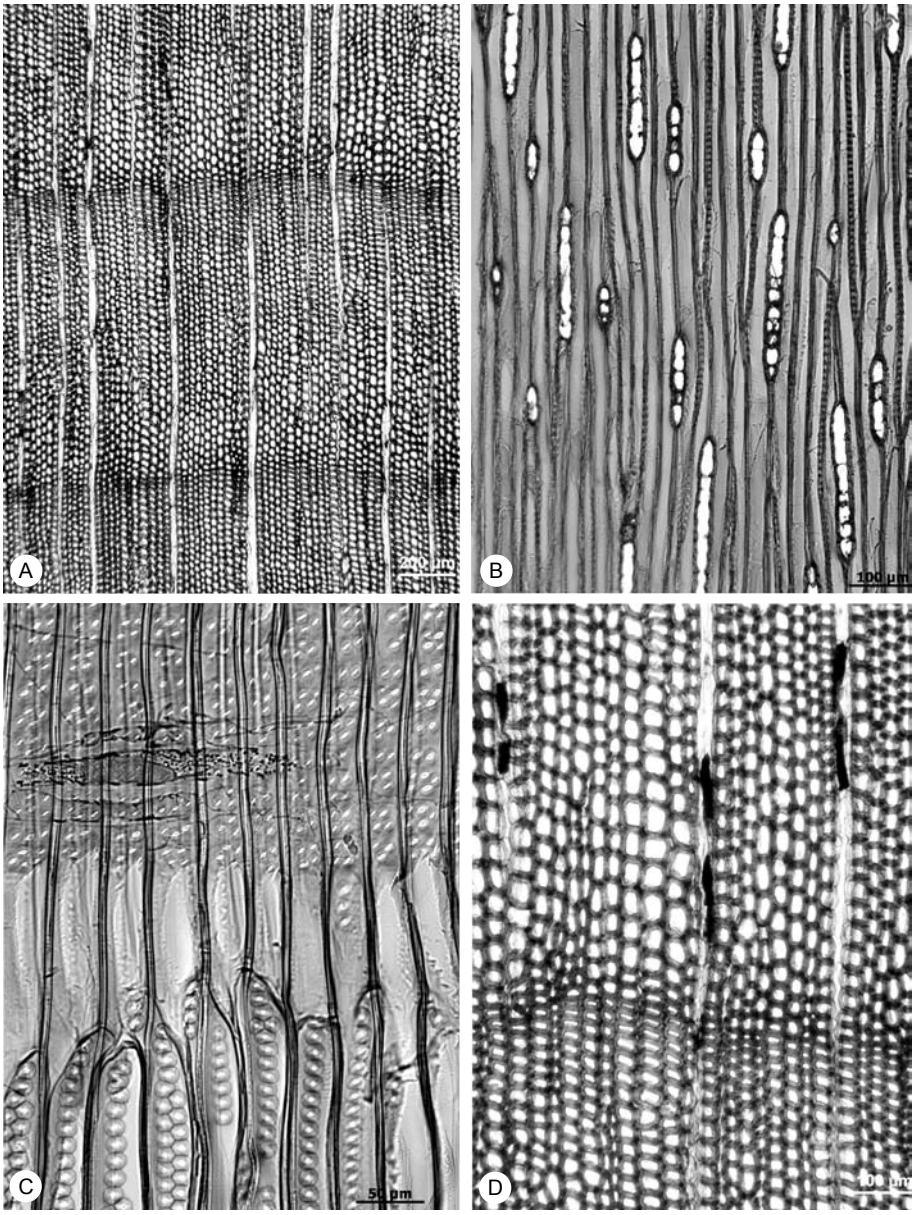

Figure 26. *Araucaria araucana* (Araucariaceae). Monkey Puzzle Tree. Appendix 1. — A: TS. – B: TLS. – C: RLS. – D: TS.

IAWA Softwood codes: 40 43 44 45 47 48 54 56 80 85 87 95 99 100v 103 107

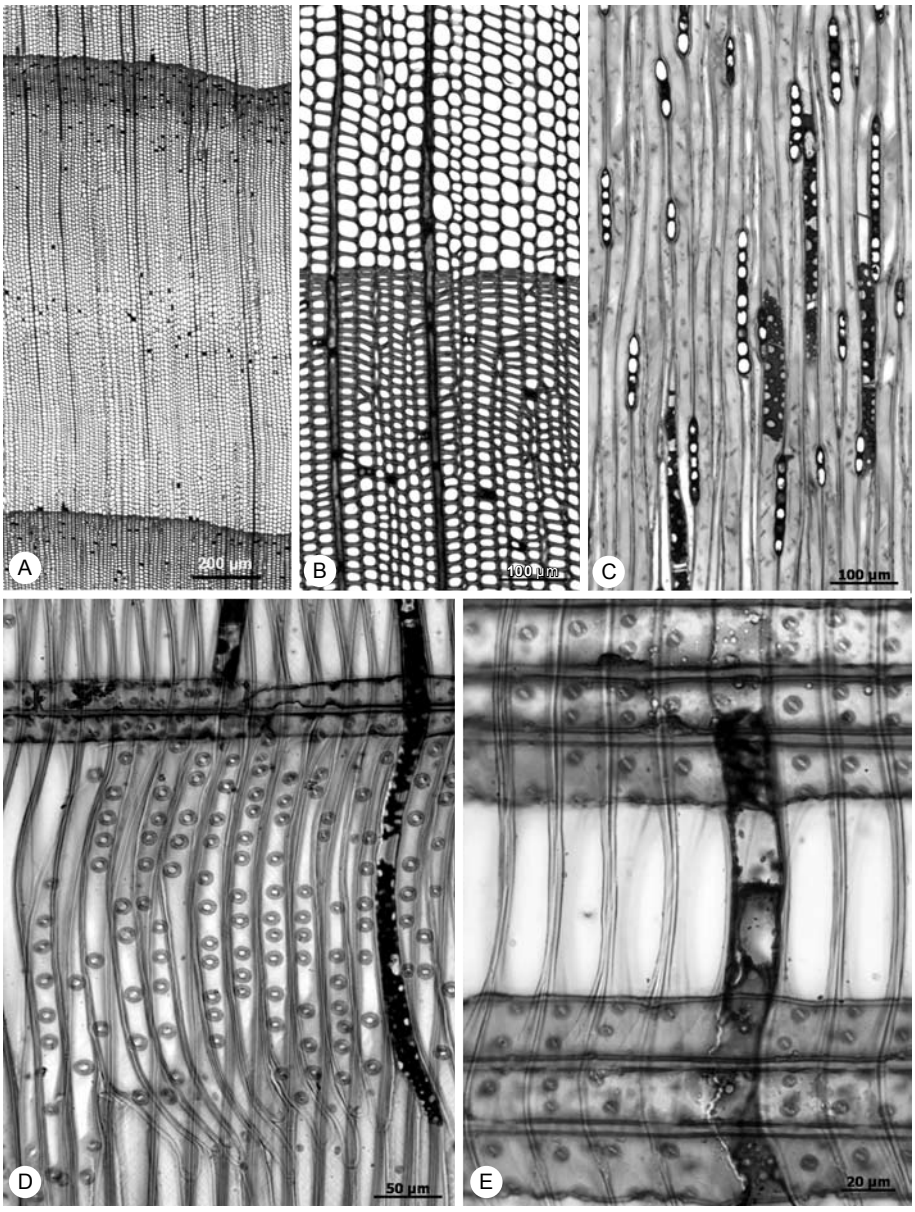

Figure 27. *Fitzroya cupressoides* (Molina) I.M. Johnst. (Cupressaceae). Patagonian Cypress. Appendix 1. — A, B: TS. – C: TLS. – D, E: RLS.

IAWA Softwood codes: 40 43 44 54 55v 56 58v 72 73 74 76v 78v 80 86 87 89v 93 94v 98 103 107

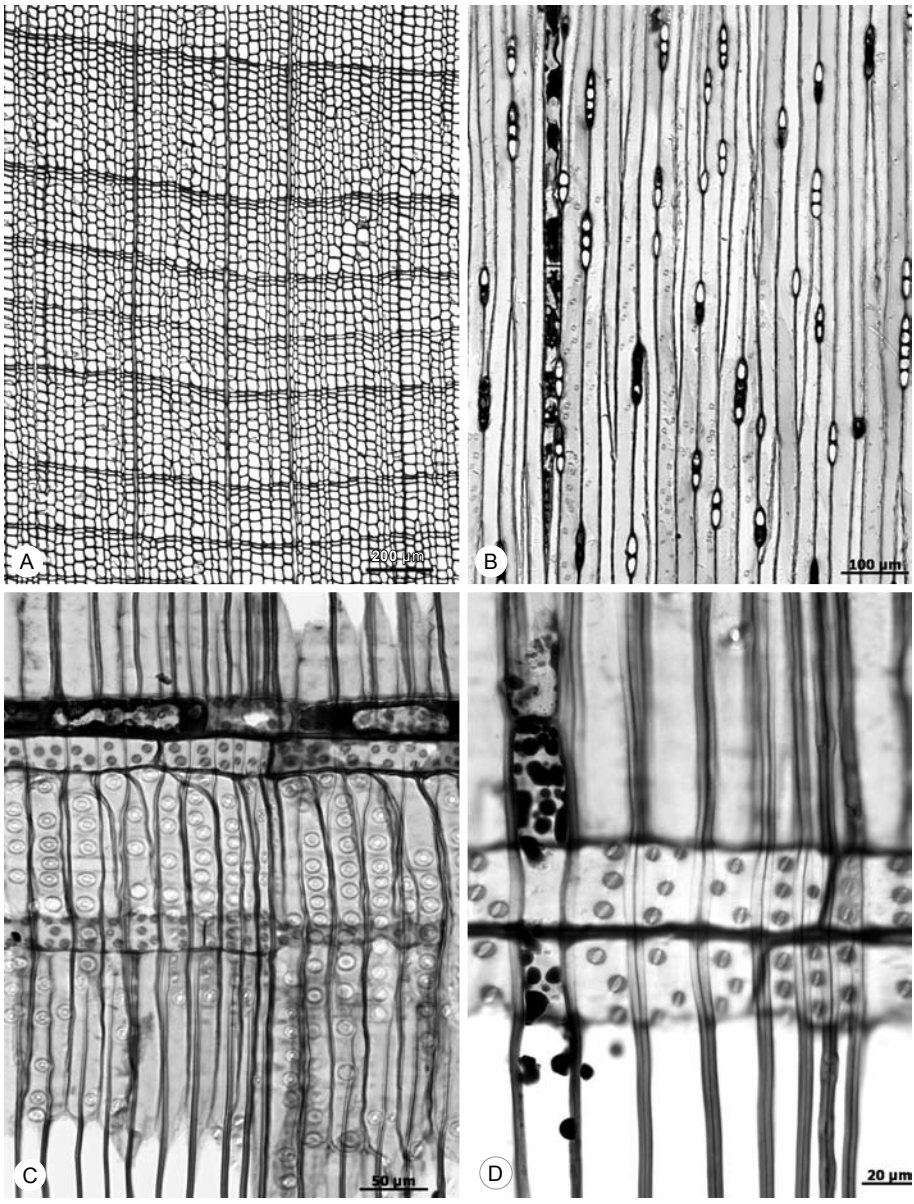

Figure 28. *Pilgerodendron uviferum* (D.Don) Florin (Cupressaceae). Ciprés de las Guaiteca. Appendix 1. — A: TS. – B: TLS. – C, D: RLS.

IAWA Softwood codes: 40 43 44 54 56 58v 72 73 74 76 80 85v 86 87 93 94v 98 99 102 107

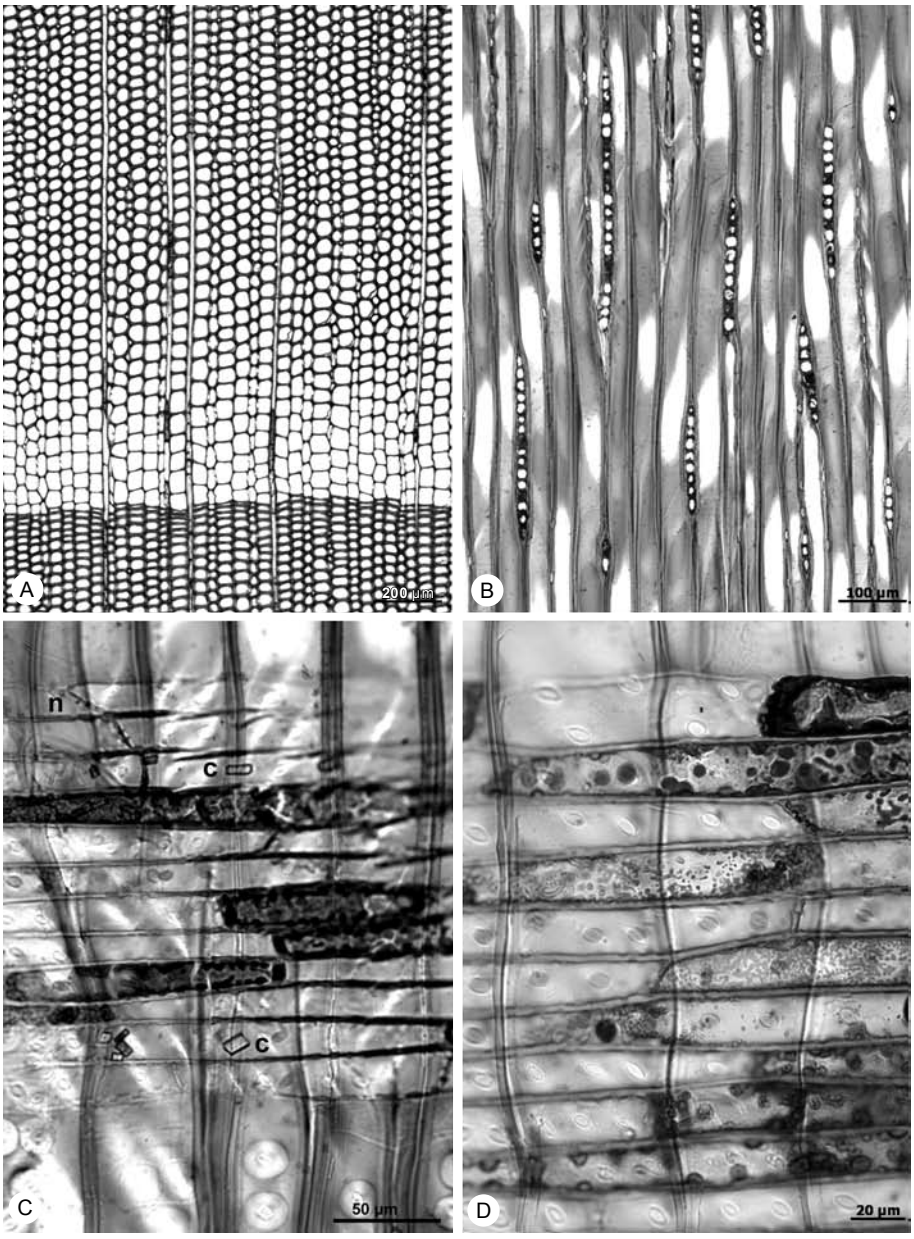

Figure 29. *Abies guatemalensis* Rehder (Pinaceae). Guatemalan Fir, Pinabete. Appendix 1. — A: TS. – B: TLS. – C, D: RLS. – c = crystal; n = nodular end wall.

IAWA Softwood codes: 40 43 44 45v 54 56 58v 80 86 88 89v 94 98 103 107 111v 118 119 122

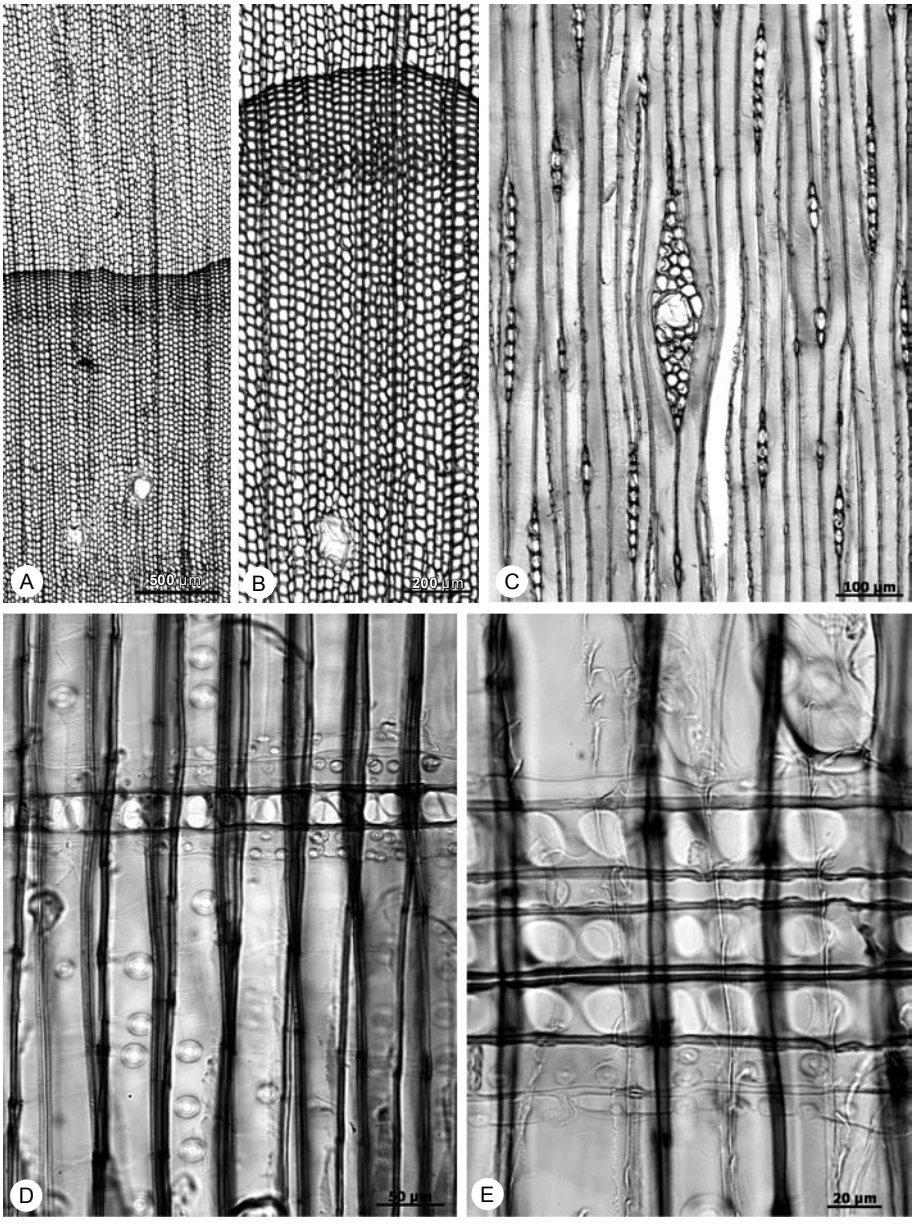

Figure 30. *Pinus koraiensis* Siebold & Zucc. (Pinaceae). Korean Pine. Appendix 3. — A, B: TS. – C: TLS. – D, E: RLS.

IAWA Softwood codes: 40 42v 43v 44 54 55v 56 79 81 85 87 90 97 103 107 109 110 111v 117

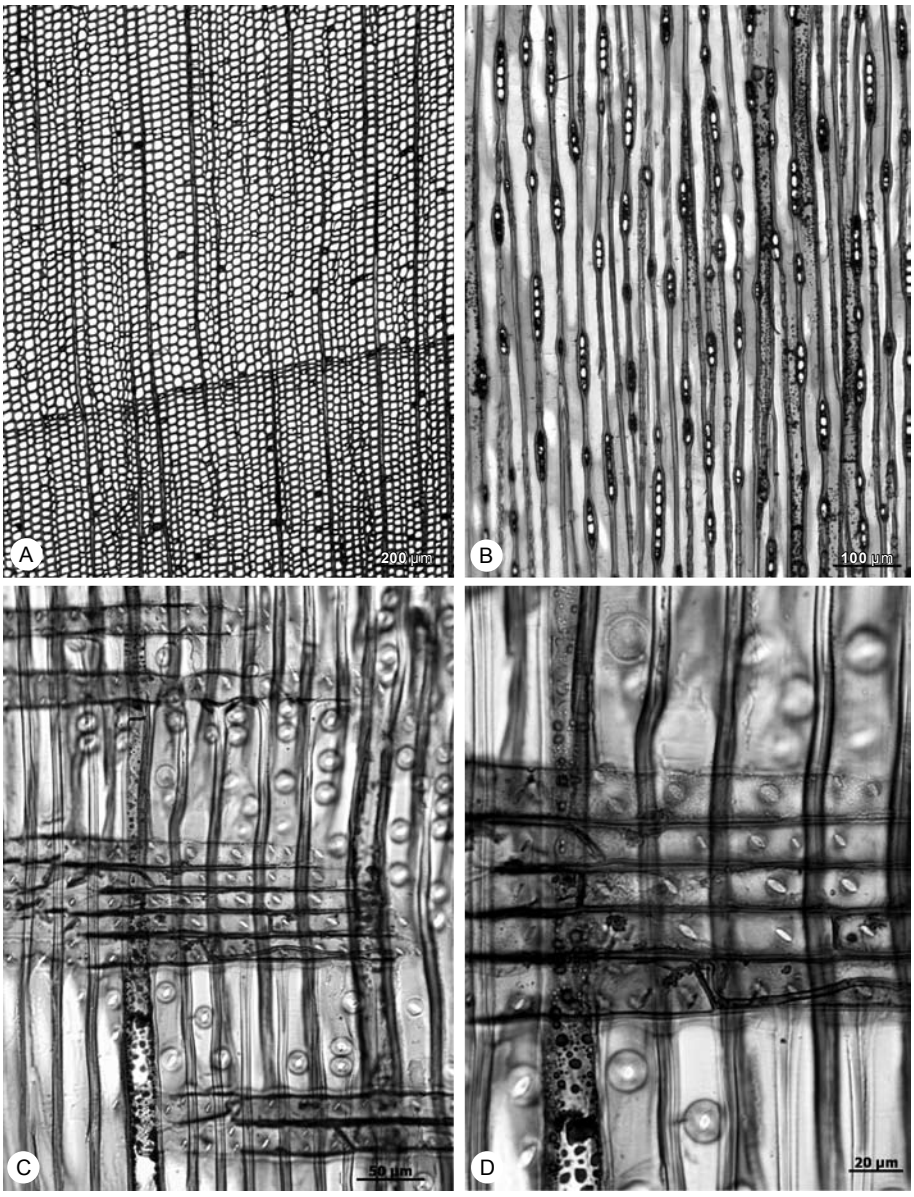

Figure 31. *Podocarpus neriifolius* D. Don (Podocarpaceae). Black Pine Podocarp. Appendix 3. — A: TS. – B: TLS. – C, D: RLS.

IAWA Softwood codes: 40 41v 43 44 54 55v 72 73 74v 76 80 85 87 93 94v 98 102 103v 107

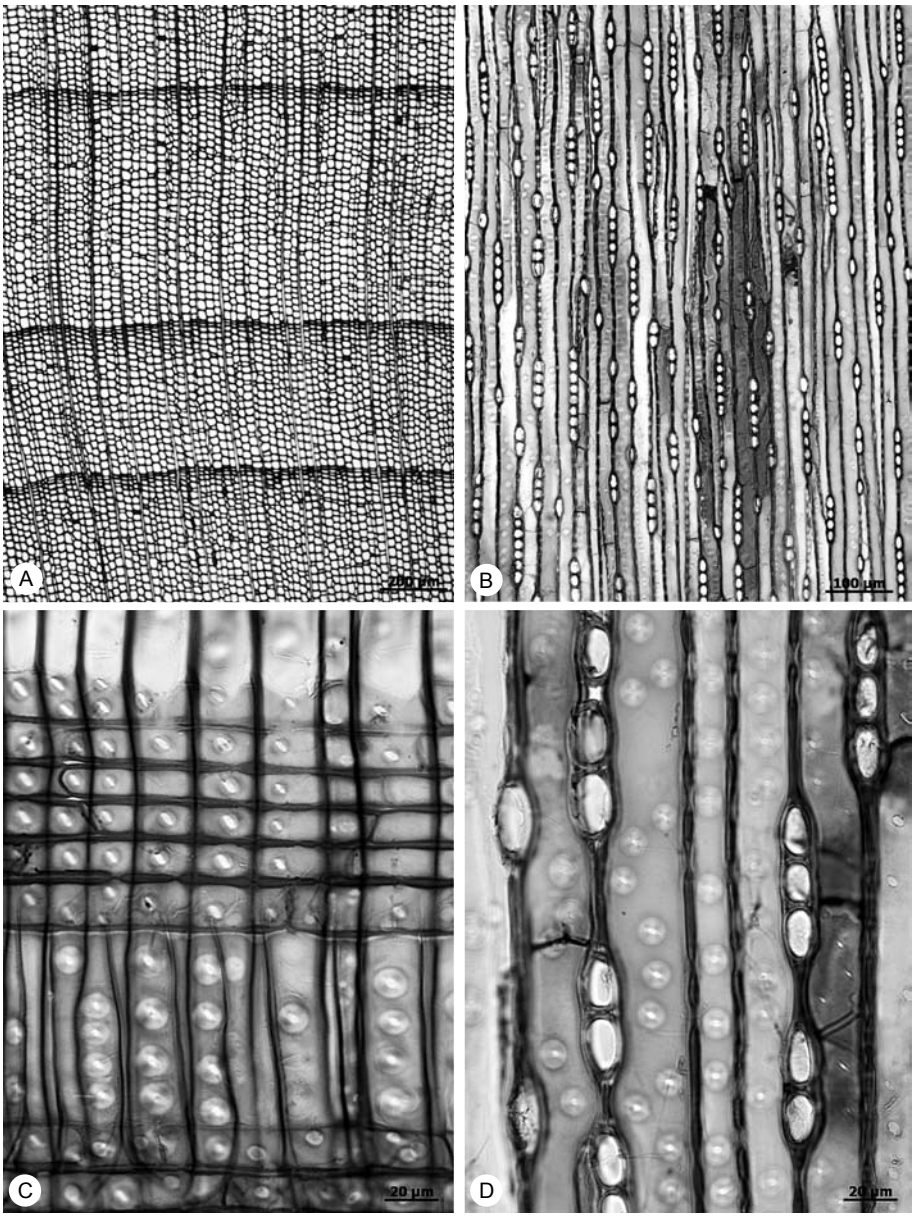

Figure 32. *Podocarpus parlatorei* Pilg. (Podocarpaceae). Parlatore's Podocarp, Moneromero. Appendix 1. — A: TS. – B: TLS. – C: RLS. – D: TLS.

IAWA Softwood codes: 40 41v 43 44 54 72 73 76 80 85 87 93 98 102 107

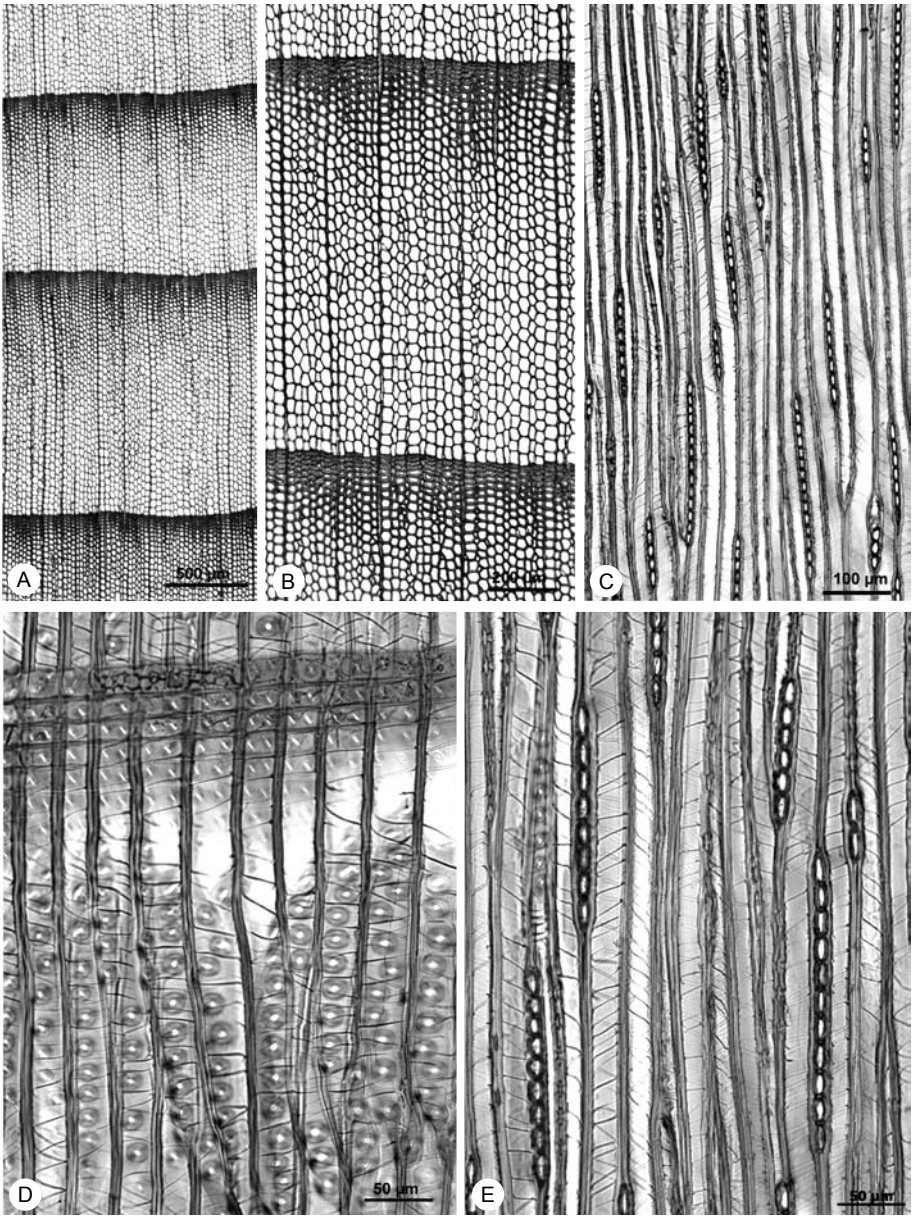

Figure 33. *Taxus cuspidata* Siebold & Zucc. (Taxaceae). Appendix 2. — A, B: TS. – C: TLS. – D: RLS. – E: TLS. – Other CITES-listed *Taxus* species (*T. chinensis, T. fuana, T. sumatrana* and *T. wallichiana*) are wood anatomically quite similar (Heinz 2004).

IAWA Softwood codes: 40 43 44 54v 55v 56 61 62 65 68 80 85 87 88v 89v 93 98 103 107

Appendix 1

Explanation of codes for microscopic hardwood features (IAWA 1989) used in the plate legends.

Anatomical Features

Growth rings

1. Growth ring boundaries distinct
2. Growth ring boundaries indistinct or absent

Vessels

Porosity

3. Wood ring-porous
4. Wood semi-ring-porous
5. Wood diffuse-porous

Vessel arrangement

6. Vessels in tangential bands
7. Vessels in diagonal and/or radial pattern
8. Vessels in dendritic pattern

Vessel groupings

9. Vessels exclusively solitary (90% or more)
10. Vessels in radial multiples of 4 or more common
11. Vessel clusters common

Solitary vessel outline

12. Solitary vessel outline angular

Perforation plates

13. Simple perforation plates
14. Scalariform perforation plates
    15. Scalariform perforation plates with ≤ 10 bars
    16. Scalariform perforation plates with 10–20 bars
    17. Scalariform perforation plates with 20–40 bars
    18. Scalariform perforation plates with ≥ 40 bars
19. Reticulate, foraminate, and/or other types of multiple perforation plates

Intervessel pits: arrangement and size

20. Intervessel pits scalariform
21. Intervessel pits opposite
22. Intervessel pits alternate
23. Shape of alternate pits polygonal
24. Minute – ≤ 4 μm
25. Small – 4–7 μm
26. Medium – 7–10 μm
27. Large – ≥ 10 μm

Vestured pits

29. Vestured pits

Vessel–ray pitting

30. Vessel–ray pits with distinct borders; similar to intervessel pits in size and shape throughout the ray cell
31. Vessel–ray pits with much reduced borders to apparently simple: pits rounded or angular
32. Vessel–ray pits with much reduced borders to apparently simple: pits horizontal (scalariform, gash-like) to vertical (palisade)
33. Vessel–ray pits of two distinct sizes or types in the same ray cell
34. Vessel–ray pits unilaterally compound and coarse (over 10 μm)
35. Vessel–ray pits restricted to marginal rows

Helical thickenings

36. Helical thickenings in vessel elements present
    37. Helical thickenings throughout body of vessel element
    38. Helical thickenings only in vessel element tails
    39. Helical thickenings only in narrower vessel elements

Tangential diameter of vessel lumina

Mean tangential diameter of vessel lumina
    40. ≤ 50 μm
    41. 50–100 μm
    42. 100–200 μm
    43. ≥ 200 μm
45. Vessels of two distinct diameter classes, wood not ring-porous

Vessels per square millimetre

46. ≤ 5 vessels per square millimetre
47. 5–20 vessels per square millimetre
48. 20–40 vessels per square millimetre
49. 40–100 vessels per square millimetre
50. ≥ 100 vessels per square millimetre

Tyloses and deposits in vessels

56. Tyloses common
57. Tyloses sclerotic
58. Gums and other deposits in heartwood vessels

Wood vesselless

59. Wood vesselless

Tracheids and fibres

60. Vascular/vasicentric tracheids present

Ground tissue fibres

61. Fibres with simple to minutely bordered pits
62. Fibres with distinctly bordered pits
63. Fibre pits common in both radial and tangential walls
64. Helical thickenings in ground tissue fibres

Septate fibres and parenchyma-like fibre bands

65. Septate fibres present
66. Non-septate fibres present
67. Parenchyma-like fibre bands alternating with ordinary fibres

Fibre wall thickness

68. Fibres very thin-walled
69. Fibres thin- to thick-walled
70. Fibres very thick-walled

Axial parenchyma

75. Axial parenchyma absent or extremely rare

Apotracheal axial parenchyma

76. Axial parenchyma diffuse
77. Axial parenchyma diffuse-in-aggregates

Paratracheal axial parenchyma

78. Axial parenchyma scanty paratracheal
79. Axial parenchyma vasicentric
80. Axial parenchyma aliform
    81. Axial parenchyma lozenge-aliform
    82. Axial parenchyma winged-aliform
83. Axial parenchyma confluent
84. Axial parenchyma unilateral paratracheal

Banded parenchyma

85. Axial parenchyma bands more than three cells wide
86. Axial parenchyma in narrow bands or lines up to three cells wide
87. Axial parenchyma reticulate
88. Axial parenchyma scalariform
89. Axial parenchyma in marginal or in seemingly marginal bands

Axial parenchyma cell type/strand length

90. Fusiform parenchyma cells
91. Two cells per parenchyma strand
92. Four (3–4) cells per parenchyma strand
93. Eight (5–8) cells per parenchyma strand
94. Over eight cells per parenchyma strand
95. Unlignified parenchyma

Rays

Ray width

96. Rays exclusively uniseriate
97. Ray width 1 to 3 cells
98. Larger rays commonly 4- to 10-seriate
99. Larger rays commonly > 10-seriate
100. Rays with multiseriate portion(s) as wide as uniseriate portions

Aggregate rays

101. Aggregate rays

Ray height

102. Ray height > 1 mm

Rays of two distinct sizes

103. Rays of two distinct sizes

Rays: cellular composition

104. All ray cells procumbent
105. All ray cells upright and/or square
106. Body ray cells procumbent with one row of upright and/or square marginal cells
107. Body ray cells procumbent with mostly 2–4 rows of upright and/or square marginal cells
108. Body ray cells procumbent with over 4 rows of upright and/or square marginal cells
109. Rays with procumbent, square and upright cells mixed throughout the ray

Sheath cells

110. Sheath cells

Tile cells

111. Tile cells

Perforated ray cells

112. Perforated ray cells

Disjunctive ray parenchyma cell walls
113. Disjunctive ray parenchyma cell walls

Rays per millimetre
114. ≤ 4/mm
115. 4–12/mm
116. ≥ 12/mm

Wood rayless
117. Wood rayless

Storied structure
118. All rays storied
119. Low rays storied, high rays non-storied.
120. Axial parenchyma and/or vessel elements storied
121. Fibres storied
122. Rays and/or axial elements irregularly storied

Secretory elements and cambial variants

Oil and mucilage cells
124. Oil and/or mucilage cells associated with ray parenchyma
125. Oil and/or mucilage cells associated with axial parenchyma
126. Oil and/or mucilage cells present among fibres

Intercellular canals
127. Axial canals in long tangential lines
128. Axial canals in short tangential lines
129. Axial canals diffuse
130. Radial canals
131. Intercellular canals of traumatic origin

Tubes / tubules
132. Laticifers or tanniniferous tubes

Cambial variants
133. Included phloem, concentric
134. Included phloem, diffuse
135. Other cambial variants

Mineral inclusions

Prismatic crystals
136. Prismatic crystals present
  137. Prismatic crystals in upright and/or square ray cells
  138. Prismatic crystals in procumbent ray cells
  139. Prismatic crystals in radial alignment in procumbent ray cells
  140. Prismatic crystals in chambered upright and/or square ray cells
  141. Prismatic crystals in non-chambered axial parenchyma cells
  142. Prismatic crystals in chambered axial parenchyma cells
  143. Prismatic crystals in fibres

Druses
144. Druses present
  145. Druses in ray parenchyma cells
  146. Druses in axial parenchyma cells
  147. Druses in fibres
  148. Druses in chambered cells

Other crystal types
149. Raphides
150. Acicular crystals
151. Styloids and/or elongate crystals
152. Crystals of other shapes (mostly small)
153. Crystal sand

Other diagnostic crystal features
154. More than one crystal of about the same size per cell or chamber
155. Two distinct sizes of crystals per cell or chamber
156. Crystals in enlarged cells
157. Crystals in tyloses
158. Cystoliths

Silica
159. Silica bodies present
  160. Silica bodies in ray cells
  161. Silica bodies in axial parenchyma cells
  162. Silica bodies in fibres
163. Vitreous silica

Appendix 2

Explanation of codes for microscopic softwood features (IAWA 1989) used in the plate legends.

Anatomical Features

Growth rings

Presence of growth ring boundaries
40. Growth ring boundaries distinct
41. Growth ring boundaries indistinct or absent

Transition from earlywood to latewood
42. Abrupt
43. Gradual

Tracheids

Tracheid pitting in radial walls (in earlywood only)
44. (predominantly) Uniseriate
45. (predominantly) Two or more seriate

Arrangement of (two or more seriate) tracheid pitting in radial walls (earlywood only)
46. Opposite
47. Alternate

Organic deposits (in heartwood tracheids)
48. Present

Intercellular spaces throughout the wood *(in transverse section)*
53. Present

Latewood tracheid wall thickness
54. Thin-walled (double wall thickness less than radial lumen diameter)
55. Thick-walled (double wall thickness larger than radial lumen diameter)

Torus *(pits in earlywood tracheids only)*
56. Present
57. Scalloped

Torus extensions
58. Present

Pits with notched borders
59. Present

Warty layer *(visible under the light microscope)*
60. Present

Helical and other wall thickenings
Helical thickenings in tracheids

Helical thickenings in longitudinal tracheids *(presence)*
61. Present

Helical thickenings *(in longitudinal tracheids - location)*
62. Present throughout the growth increment
63. Well developed only in earlywood
64. Well developed only in latewood

Helical thickenings *(in longitudinal tracheids - whether single or grouped)*
65. Single
66. Grouped (double or triple)

Helical thickenings *(in longitudinal tracheids - spacing, earlywood tracheids only)*
67. Narrowly spaced (number of coils more than 120 per mm)
68. Widely spaced (number of coils less than 120 per mm)

Helical thickenings in ray tracheids
69. Commonly present
70. (present but) Rare

Callitroid thickenings
71. Present

Axial parenchyma
Axial parenchyma *(excl. epithelial and subsidiary cells of intercellular canals)*
72. Present

Arrangement of axial parenchyma
73. Diffuse (evenly scattered throughout the entire growth increment)
74. Tangentially zonate
75. Marginal

Transverse end walls
76. Smooth
77. Irregularly thickened
78. Beaded or nodular

Ray composition
Ray tracheids
79. Commonly present
80. Absent or very rare

Cell walls of ray tracheids
81. Smooth
82. Dentate
83. Reticulate

Ray tracheid pit borders angular or with dentate thickenings *(radial section, Larix & Picea only)*
84. Present

End walls of ray parenchyma cells
85. Smooth (unpitted)
86. Distinctly pitted

Horizontal walls of ray parenchyma cells
87. Smooth (unpitted)
88. Distinctly pitted

Indentures
89. Present

Cross-field pitting
90. "Window-like" (fenestriform)
91. Pinoid
92. Piceoid
93. Cupressoid
94. Taxodioid
95. Araucarioid

Number of pits per cross-field *(earlywood only – categories)*
97. (large window-like) 1–2
98. 1–3
99. 3–5
100. 6 or more

Ray size

Average ray height *(number of cells)*
102. Very low (up to 4 cells)
103. Medium (5 to 15 cells)
104. High (from 16 to 30 cells)
105. Very high (more than 30 cells)

Ray width *(cells)*
107. Exclusively uniseriate
108. 2–3-seriate in part

Intercellular canals

Axial intercellular *(resin)* ***canals***
109. Present

Radial intercellular *(resin)* ***canals***
110. Present

Traumatic *(resin)* ***canals*** *(axial, radial)*
111. Present

Epithelial cells *(of intercellular canals)*
116. Thick-walled
117. Thin-walled

Mineral inclusions

Crystals
118. Present

Type of crystals
119. Prismatic
120. Druses
121. Other forms (specify)

Crystals located in
122. Rays
123. Axial parenchyma
124. Cells associated with intercellular canals