Original article

Shuichi Noshiro[1]: Wooden artifacts and natural woods recovered from the Ireibaru C Site, Okinawa, of the Early Jomon Period and their implication on overseas transport

能城修一[1]：沖縄本島伊礼原Ｃ遺跡から出土した縄文時代前期の木製品および自然木の樹種とそれから類推される海上輸送

Abstract Thirty four wooden artifacts and fifty three natural woods of the Early Jomon Period recovered from the Ireibaru C Site at Chatan Village of Okinawa Island were identified. They included twenty seven taxa. Among artifacts flat grain boards of *Machilus* and *Melia azedarach* were conspicuous. Natural woods included no typical taxa of mangrove. Common stemwood taxa were *Castanopsis sieboldii*, *Ficus* cf. *erecta*, *Euonymus*, *Hibiscus tiliaceus*, *Fraxinus griffithii*, and *Ehretia* cf. *ovalifolia*. They were accompanied by rootwoods or stem-rootwoods of *Machilus, Ilex, Heritiera littoralis, Barringtonia racemosa,* and *Fraxinus griffithii*. These taxa probably formed a seaside or back mangal forest and a lower upland forest around this area. Besides these taxa indigenous to present Okinawa Island, artifacts included three coniferous taxa not growing in the present Ryukyu Islands: *Cunninghamia, Chamaecyparis obtusa*, and *Calocedrus macrolepis*. These three taxa grow together only in Taiwan at present, and two species of *Cunninghamia* and *Calocedrus macrolepis* also grow in China and *Chamaecyparis obtusa* in mainland Japan. Transport of these wooden artifacts to Okinawa Island from Taiwan or China during the Early Jomon Period is discussed in relation to ocean and human transport.
Key words: Early Jomon Period, natural woods, Okinawa Island, overseas transport, wooden artifacts

要　旨　沖縄本島北谷町の伊礼原Ｃ遺跡から発掘された縄文時代前期の木製品や加工木，および自然木の樹種を同定した。計87点中には27分類群が見いだされた。木製品ではタブノキ属およびセンダンの板目板が比較的多く見いだされた。自然木にはマングローブの主要構成要素となる樹種は見いだされなかった。幹材としてはスダジイや，イヌビワ近似種，ニシキギ属，オオハマボウ，シマトネリコ，チシャノキ類が多く，これにタブノキ属や，モチノキ属，サキシマスホウノキ，サガリバナ，シマトネリコの根材や根株材が伴っていた。自然木の樹種から考えると，当遺跡周辺には海岸林あるいはマングローブの後背林と台地下部の森林とが広がっていたと想定された。自然木の樹種はすべて沖縄本島に自生していたものと思われるが，木製品あるいは加工木には現在の琉球諸島には生育しない針葉樹3分類群，すなわちコウヨウザン属，ヒノキ，ショウナンボクが認められた。これらが現在ともに生育しているのは台湾であり，コウヨウザン属とショウナンボクは中国にも，ヒノキは日本にも生育している。海流あるいは人類による輸送によってこれらの樹種が台湾から沖縄本島にもたらされた可能性について考察した。
キーワード：沖縄本島，海上輸送，自然木，縄文時代前期，木製品

Introduction

The Nansei Shotou (literally the Southwest Islands) is a 1200 km archipelago extending from Kyushu to Taiwan and consists of the Satsunan Islands in the north and the Ryukyu Islands in the south. The Ryukyu Islands consist of the Okinawa Islands in the north and the Sakishima Islands in the south separated by a 200 km oceanic span. Vegetation history of the Nansei Shotou is poorly known, and for late Quaternary, only one or two (more on Yakushima) pollen analytical studies of limited geological length have been carried out on islands of Yakushima, Tanegashima, Nakanoshima, and Izenajima (Miyai, 1938; Nakamura, 1957: Takeoka, 1971; Hatanaka, 1985; Tsukada *et al.*,1989; Matsushita, 1992; Kimura *et al.*, 1996; Kuroda & Ozawa, 1996; Kuroda, 1998). Fossil woods or wooden artifacts recovered from archaeological excavations are also few, and Yamada (1993) listed only four sites on Okinawa Island that yielded up to seven wooden artifacts or natural woods. This is probably because deposition of sediments suitable for the study of vegetation history is limited on these islands.

Recently a lowland site of the early Kaizuka Period (Late Jomon Period) was discovered beside the sea at Ginoza Village on Okinawa Island (Ginoza-son Board

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of Education, 1999). This Mehbaru Site yielded fruits and seeds mostly deposited in store holes lined with a bamboo basket (Tsuji, 2000) and wooden artifacts including a dugout and a construction pole. The taxonomic composition of plant macrofossils and fossil woods indicated establishment of an evergreen subtropical forest on the upland and a maritime vegetation on the seashore. The results at this site clearly showed the possibility of vegetation historical studies in the Nansei Shotou similar to those carried out in mainland Japan.

During preliminary excavations of the Kuwae U. S. Marine Corps Camp at Chatan Village on Okinawa Island, archaeological remains of the Early Jomon Period were recovered in an alluvial plain bordering a hill of Ryukyu limestone (Tohmon, 2000). This was the first site of the Early Jomon Period on Okinawa Island, and the central area of preliminary excavations was named Ireibaru C Site. Recovered remains included Sobata type pottery, stone tools, bone tools, and wooden artifacts, and were accompanied by naturals woods and seeds and fruits. All wooden artifacts were in fragments, but included fragments of well manufactured articles. These wooden artifacts and natural woods of the Ireibaru C Site could be the first evidence of species selection for wooden artifacts during the Early Jomon Period on Okinawa Island and could give further basis of wood identification of trees and shrubs in the Okinawa Islands second to the Mehbaru Site.

Materials and methods

The Ireibaru C Site is located at Chatan Cho, Nakagami Gun, Okinawa Prefecture (26°19′15″N 127°45′40″E)(Fig. 1). This site is at the northeastern edge of a narrow alluvial plain on an abrasion terrace of an old beach rock, 360 m inland from the sea at present, and is at the foot of a ridge extending from a 50 m high hill of Ryukyu limestone to the east (Tohmon, 2000). A stream from a spring in a crevice of this limestone hill flows through this site and meets two other streams from the north to its west, flowing down to the sea. Wooden artifacts and natural woods of the Early Jomon Period were recovered from the

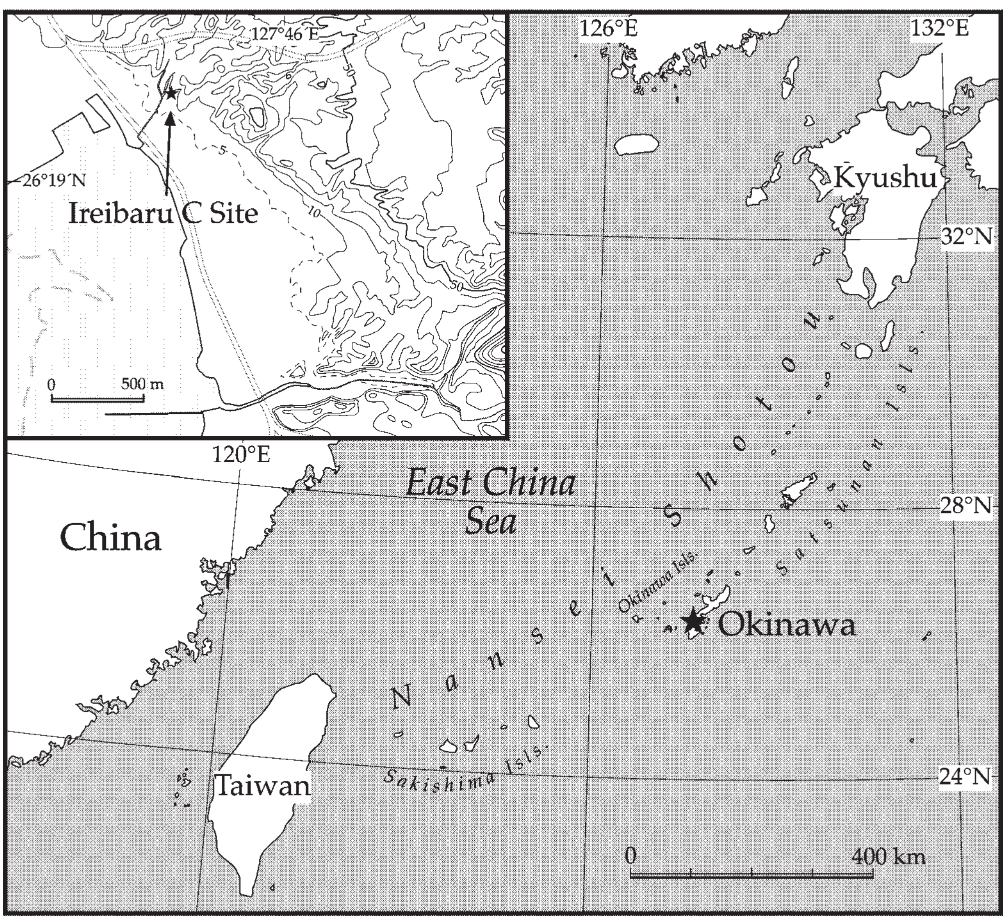


Fig. 1 Location of Okinawa Island and the geomorphology around the Ireibaru C Site.

Table 1 Radiocarbon ages obtained at the Ireibaru C Site (Omatsu & Tsuji, unpublished)

Sample No.	Horizon	Material	Method	Conventional age (yr B.P.)	Calibrated results*	Lab. no.
RH-43	midden	*Pandanus* fruit	AMS	5280 ± 60	cal BC 4070 cal BC 4220-3995	Beta-111788
RH-44	XI	tree stump	radiometric	1140 ± 60	cal AD 895 cal AD 865-985	Beta-111789
RH-224	midden	*Castanopsis* fruit	AMS	5010 ± 40	cal BC 3785 cal BC 3915-3880 cal BC 3800-3720	Beta-142452
RH-225	midden	*Castanopsis* fruit	AMS	5120 ± 60	cal BC 3955 cal BC 3975-3925 cal BC 3870-3805	Beta-142666
RH-229	XI	tree stump	radiometric	1080 ± 60	cal AD 980 cal AD 895-1010	Beta-142667

*calibrated with Calibration-1993 (RH-43, 44) and INTCAL98 (RH-224, 225, 229).
Upper row: intercept, lower row(s): 1 sigma result(s).

bottom part of layer XIV among scattered gravel (Fig. 2). In this layer, Sobata type pots abounded, accompanied by thick pots of unknown type and Todoroki D pots. Broken shells of fruits and sea shells were found as scattered middens often in depressions of layer XV, and fragments of wooden artifacts and natural woods including buttressed roots occasionally mingled among the gravel. Conventional ^{14}C ages of fruit fossils in sea shell and fruit middens were 5280 ± 60 yr B.P. (Beta-111788, RH-43), 5010 ± 40 yr B.P. (Beta-142452, RH-224), and 5120 ± 60 yr B.P. (Beta-142666, RH-225) (Table 1; Omatsu & Tsuji, unpublished).

Identification was done for 34 wooden artifacts and 53 natural woods recovered from grids 142 and 143. Wooden artifacts included fragments of flat or edge grain boards, split woods, and a basket. Natural woods were mostly round woods up to 6 cm thick. Specimens were sectioned manually and were mounted with Gumchloral (a mixture of Chloral Hydrate 50 g, Arabic Gum 40 g, Glycerin 20 ml, and pure water 50 ml). These specimens are deposited in the Xylarium of the Forestry and Forest Products Research Institute, Tsukuba, Japan (TWTw). Specimens were identified referring to the wood specimens in TWTw and to Phillips (1948), Yang & Huang Yang (1987), and Cheng *et al.* (1992).

Results

Twenty seven taxa were recognized among the 87 specimens (Table 2). Four taxa included both stem- and rootwoods, and two taxa did only rootwoods. Here all the taxa will be briefly described to show the basis of identification.

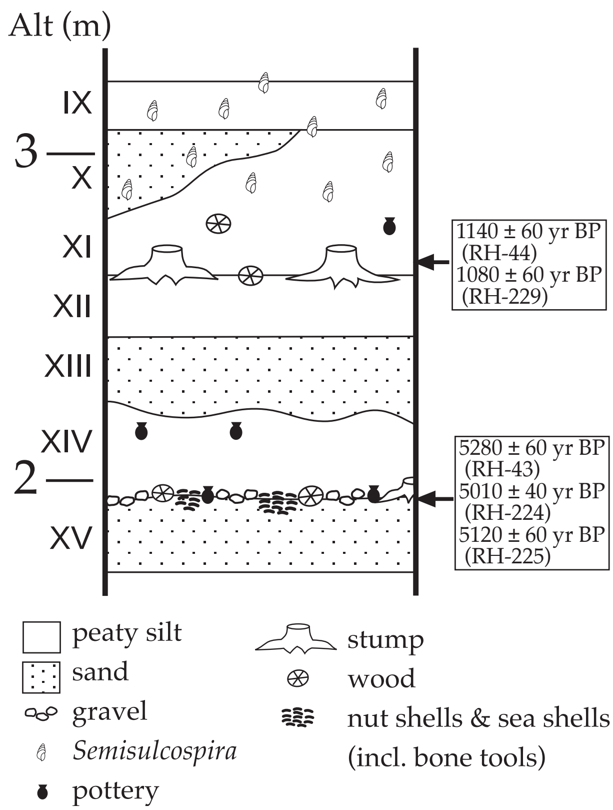
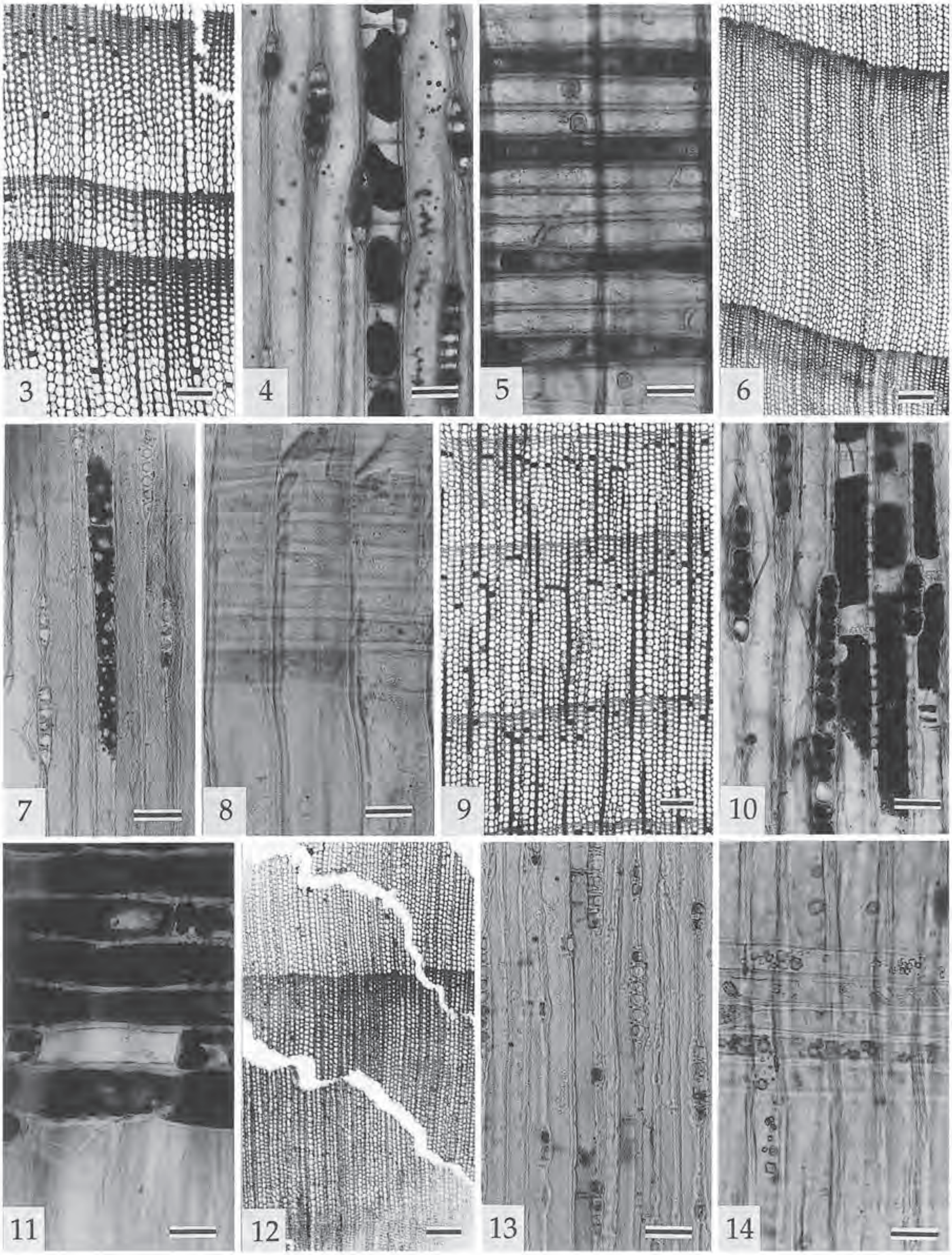


Fig. 2 Stratigraphy of the grid No. 143 of the Ireibaru C Site (modified from Tohmon (2000)). Romon numbers show layer numbers in Tohmon (2000).



Figs. 3–14 Fossil woods recovered from the Ireibaru C Site (1). — 3–5: *Cunninghamia* (stemwood), TS (3, OKI-121), TLS (4, OKI-121), RLS (5, OKI-120). — 6–8: *Chamaecyparis obtusa* (stemwood), TS (6), TLS (7), RLS (8) (OKI-166). — 9–11: *Calocedrus macrolepis* (stemwood), TS (9, OKI-143), TLS (10, OKI-143), RLS (11, OKI-142). — 12–14: *Podocarpus*

Cunninghamia Taxodiaceae (Figs. 3–5, stemwood)

Coniferous wood made of tracheids, resin cells, and ray parenchyma. Growth ring boundaries distinct. Earlywood tracheids thin-walled, large. Latewood ample, conspicuous, consisting of thick-walled rectangular tracheids with a conspicuous lumen. Transition from early- to latewood gradual. Resin cells scattered mostly in latewood or occasionally throughout earlywood; horizontal walls thick, minutely nodular. Black resin conspicuous in resin cells and ray parenchyma cells. Rays up to 24 cells high, rarely biseriate. Cross-field pits large taxodioid, 10 μm in diameter, with a nearly horizontal aperture; two per cross-field.

Note: *Cunninghamia* differs from *Cryptomeria* in having wider tracheids, radially less flattened latewood tracheids usually with a conspicuous lumen, and conspicuous black resin in ray parenchyma cells. *Taiwania* tends to have cupressoid cross-field pits, and *Gylptostrobus* and *Metasequoia* often have more than two pits per cross-field.

Chamaecyparis obtusa **(Siebold et Zucc.) Endl.** Cupressaceae (Figs. 6–8, stemwood)

Coniferous wood made of tracheids, resin cells, and ray parenchyma. Growth ring boundaries distinct. Earlywood tracheids comparatively thick-walled, medium-sized. Latewood conspicuous, 10–20 or less cells wide. Transition from early- to latewood gradual. Resin cells scattered mostly in latewood and occasionally in earlywood; horizontal walls thick, weakly nodular. Black resin conspicuous in resin cells. Rays up to 24 cells high, rarely biseriate. Cross-field pits medium-sized piceioid, 7 μm in diameter, with an oblique aperture; two per cross-field.

Note: Compared with *Chamaecyparis obtusa*, *Platycladus* (*Biota*) and *Cupressus* have narrower earlywood tracheids with thicker walls and less marked transition from early- to latewood. *Fokienia* usually has more resin cells in the earlywood than in the latewood. *Chamaecyparis formosensis* Matsum. has cupressoid cross-field pits similar to *C. pisifera* (Siebold et Zucc.) Endl.

Calocedrus macrolepis **Kurz** Cupressaceae (Figs. 9–11, stemwood)

Coniferous wood made of tracheids, resin cells, ray parenchyma, and rare ray tracheids. Growth ring boundaries moderately distinct. Earlywood tracheids comparatively thick-walled, large. Latewood conspicuous, but less than 10 cells wide; consisting of thick-walled rectangular tracheids with a conspicuous lumen. Transition from early- to latewood gradual. Resin cells scattered in the latter half of earlywood and in latewood; horizontal walls thick, conspicuously nodular. Black resin conspicuous in resin cells and ray parenchyma cells. Rays up to 19 cells high, occasionally biseriate. Ray parenchyma cells with nodular end-walls and well-pitted horizontal walls. Cross-field pits medium-sized cupressoid, 7 μm in diameter, with an oblique aperture; two per cross-field. Ray tracheids rare, occurring as a solitary or two consecutive cells.

Note: Abundant resin cells with nodular end walls and ray parenchyma cells with nodular end walls characterize this species. Several species of *Juniperus* have similar wood structure, but have narrower tracheids with more distinct growth ring boundaries and less resin in ray parenchyma cells than this species.

Podocarpus Podocarpaceae (Figs. 12–14, stemwood)

Coniferous wood made of tracheids, resin cells, and ray parenchyma. Growth ring boundaries distinct. Earlywood tracheids comparatively thick-walled, small. Latewood conspicuous and ample. Transition from early- to latewood gradual. Resin cells scattered throughout growth rings. Horizontal walls of resin cell thin. Black resin occasional in resin cells. Rays uniseriate, up to 17 cells high. Cross-field pits medium-sized cupressoid, 7 μm in diameter, with an oblique aperture; one or two per cross-field.

Note: Abundant resin cells with smooth horizontal walls and without conspicuous resin are scattered throughout growth rings and characterize this taxon.

Castanopsis sieboldii **(Makino) Hatusima ex Yamazaki et Mashiba** Fagaceae (Figs. 15–16, stemwood)

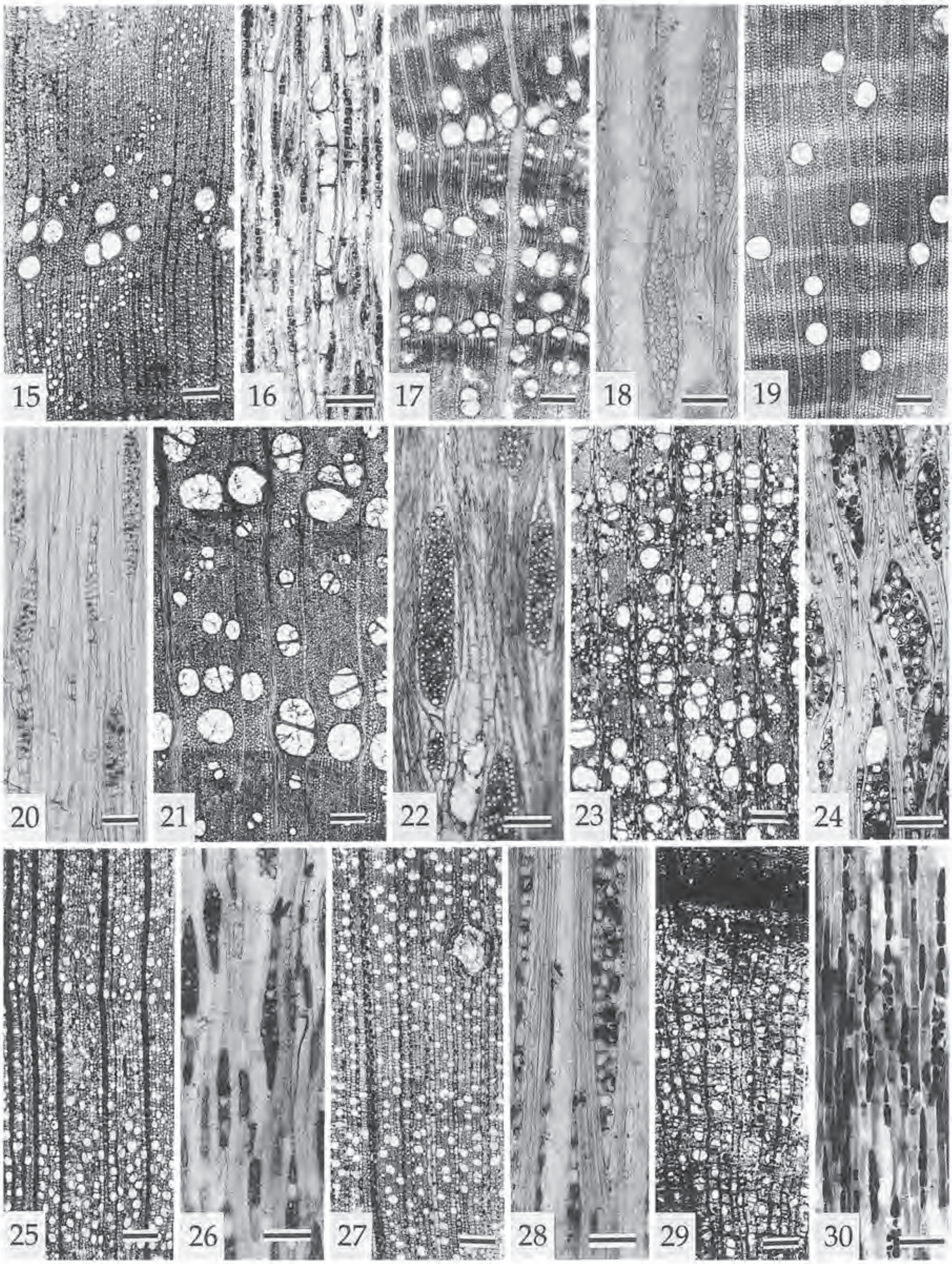
Ring-porous wood. Earlywood vessels round, solitary, 70–200 μm in tangential diameter (TD); in groups of several vessels scattered along growth ring boundaries. Latewood vessels thin-walled, small, 25–40 μm in TD; in dendritic pattern with vascular tracheids. Wood parenchyma in irregular lines. Perforations simple. Rays homocellular, usually uniseriate and rarely in aggregate rays. Vessel-ray pits horizontal to vertical.

Note: Inconspicuous occurrence of aggregate rays distinguishes this species from *Castanopsis cuspidata* (Thunb. ex Murray) Schottky.

Celtis Ulmaceae (Figs. 17–18, stemwood)

Ring-porous wood. Earlywood vessels comparatively thick-walled, round, 70–150 μm in TD; lined

(stemwood), TS (12), TLS (13), RLS (14) (OKI-172). TS = transverse section, scale bar = 200 μm; TLS = tangential section, scale bar = 100 μm; RLS = radial section, scale bar = 25 μm.



Figs. 15–30 Fossil woods recovered from the Ireibaru C Site (2). — 15–16: *Castanopsis sieboldii* (stemwood), TS (15), TLS (16) (OKI-161). — 17–18: *Celtis* (stemwood), TS (17), TLS (18) (OKI-134). — 19–20: *Ficus* cf. *erecta* (stemwood), TS (19), TLS (20) (OKI-136). — 21–22: *Morus* (stemwood), TS (21), TLS (22) (OKI-174). — 23–24: *Machilus* (stemwood),

along growth ring boundaries. Latewood vessels small, 25–50 μm in TD; scattered solitarily or in clusters of 2–3. Wood parenchyma aliform to confluent in latewood. Perforations simple. Rays heterocellular, 1-6 cells wide, with sheath cells.

Note: Ring-porous wood and heterocellular multiseriate rays with marked sheath cells characterize this taxon.

***Ficus* cf. *erecta* Thunb.** Moraceae (Figs. 19–20, stemwood)

Diffuse-porous wood without growth ring boundaries. Vessels round, solitary or in multiples of 2–3, sparse, 80–150 μm in TD. Wood parenchyma vasicentric and in bands with prismatic crystals. Perforations simple. Rays heterocellular, 1–6 cells wide; multiseriate rays usually with a single row of marginal upright cells.

Note: Regularly alternating bands of axial parenchyma and thin-walled fibers and short multiseriate rays distinguish this taxon as a tree species of *Ficus*. Distinction among the tree species of *Ficus* is not feasible at present.

Morus Moraceae (Figs. 21–22, stemwood)

Semi-ring-porous wood with sparse vessels. Vessels round, solitary or in multiples of 2–5, sparse; TD decreasing gradually from 100–200 to ca. 30 μm through growth rings. Wood parenchyma vasicentric, aliform to confluent in latewood, and marginal. Perforations simple. Helical thickenings distinct in narrow vessels. Rays heterocellular, 1–6 cells wide, with a single row of marginal upright cells.

Note: Semi-ring-porous wood with sparse round vessels or oblique vessel clusters and heterocellular rays with short wings characterize this taxon.

Machilus Lauraceae (Figs. 23–24, stemwood)

Diffuse-porous wood with indistinct growth ring boundaries. Vessels thick-walled, slightly angular, 40–140 μm in TD, unevenly scattered. Wood parenchyma vasicentric and marginal, often with large oil cells. Perforations simple. Rays heterocellular, 1–4 cells wide; 1–3 rows of marginal upright cells often including large oil cells.

Note: Thick-walled angular vessels and numerous medium-sized oil cells characterize this taxon.

Camellia Theaceae (Figs. 25–26, stemwood)

Diffuse-porous wood with distinct growth ring boundaries. Vessels exclusively solitary, polygonal, evenly scattered; TD gradually decreasing from ca. 40 to 20 μm through growth rings. Wood parenchyma diffuse-in-aggregates. Perforations scalariform with 10–20 bars. Rays heterocellular, 1–3 cells wide; multiseriate bodies short; marginal rows with large round cells having a prismatic crystal.

Note: Slightly larger earlywood vessels and enlarged cells with a crystal in ray wings characterize this taxon.

***Ternstroemia gymnanthera* (Wright et Arn.) Beddome** Theaceae (Figs. 27–28, stemwood)

Diffuse-porous wood with indistinct growth ring boundaries. Vessels exclusively solitary, polygonal, evenly scattered, 25–50 μm in TD. Wood parenchyma diffuse-in-aggregates. Perforations scalariform with 30–50 bars. Rays heterocellular, 1–3 cells wide; multiseriate rays often over 1 mm tall.

Note: Evenly scattered small vessels, abundant diffuse-in-aggregates parenchyma, and three cells wide multiseriate rays distinguish this species from other taxa in Theaceae.

***Distylium racemosum* Siebold et Zucc.** Hamamelidaceae (Figs. 29–30, stemwood)

Diffuse-porous wood with barely distinct growth ring boundaries. Vessels polygonal, solitary or in multiples of 2–4, evenly scattered, 30–75 μm in TD. Wood parenchyma diffuse-in-aggregates or in lines. Perforations scalariform with 8–11 bars. Rays heterocellular, 1–3 cells wide; multiseriate bodies short.

Note: Numerous bands of axial parenchyma, perforation plates with few bars, and short narrow rays characterize this species.

***Pongamia pinnata* (L.) Pierre** Leguminosae (Figs. 31–32, stemwood)

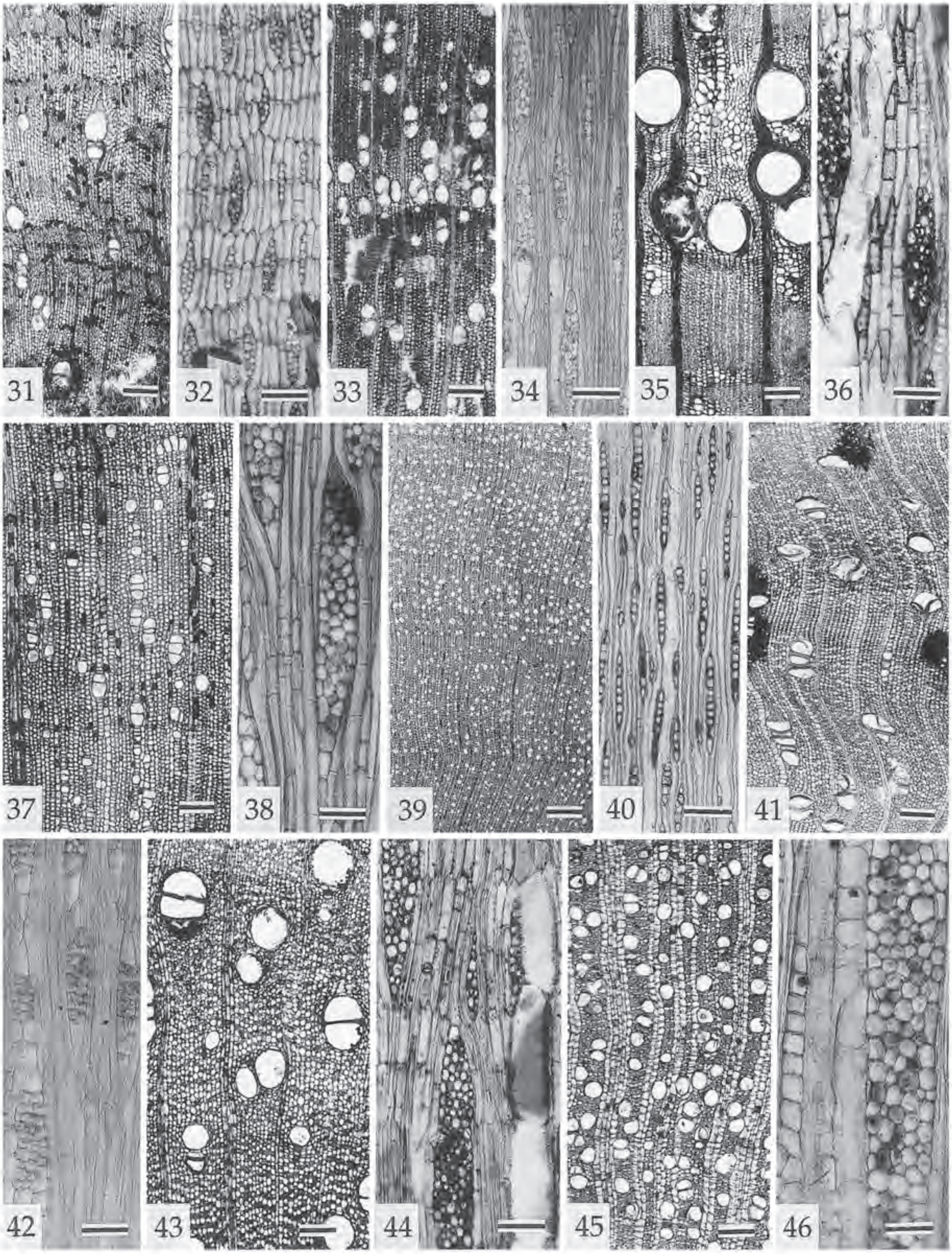
Diffuse-porous wood with indistinct growth ring boundaries. Vessels thick-walled, round, solitary or in multiples or clusters of 2–6, sparse. Wood parenchyma vasicentric and in thick bands. Perforations simple. Rays homocellular, 1–4 cells wide, short. Rays, parenchyma strands, and vessel elements storied.

Note: Alternating bands of abundant axial parenchyma and fibers and the storied structure of short vessel elements, homocellular rays, and parenchyma strands characterize this species.

Zanthoxylum Rutaceae (Figs. 33–34, stemwood)

Semi-ring-porous wood. Vessels round, solitary or in multiples of 2–3. Earlywood vessels 60–90 μm in TD, in initial bands of 2–3 rows; latewood vessels sparse, decreasing to 30 μm in TD gradually. Wood parenchyma vasicentric. Perforations simple. Rays

TS (23), TLS (24) (OKI-101). — 25–26: *Camellia* (stemwood), TS (25), TLS (26) (OKI-106). — 27–28: *Ternstroemia gymnanthera* (stemwood), TS (27), TLS (28) (OKI-125). — 29–30: *Distylium racemosum* (stemwood), TS (29), TLS (30) (OKI-163). TS = transverse section, scale bar = 200 μm; TLS = tangential section, scale bar = 100 μm.



Figs. 31–46 Fossil woods recovered from the Ireibaru C Site (3). — 31–32: *Pongamia pinnata* (stemwood), TS (31), TLS (32) (OKI-149). — 33–34: *Zanthoxylum* (stemwood), TS (33), TLS (34) (OKI-140). — 35–36: *Melia azedarach* (stemwood), TS (35), TLS (36) (OKI-154). — 37–38: *Ilex* (rootwood), TS (37), TLS (38) (OKI-185). — 39–40: *Euonymus* (stemwood),

heterocellular, 1–3 cells wide, with 1–3 rows of marginal upright cells.

Note: Sparse thick-walled vessels with simple perforations and small rays characterize this taxon.

***Melia azedarach* L.** Meliaceae (Figs. 35–36, stemwood)

Ring-porous wood. Earlywood vessels round, 180–330 µm in TD, gathering intermittently along growth ring boundaries; thin-walled vessels of 30–50 µm in TD in variously oriented clusters occurring between earlywood vessels and in latewood. Wood parenchyma vasicentric, diffuse, and aliform in latewood; prismatic crystals in long chains. Perforations simple. Helical thickenings distinct in narrow vessels. Rays homocellular, 1–5 cells wide.

Note: Radial clusters of small vessels intermingled with large solitary vessels in the earlywood and crystals in long chains characterize this species.

Ilex Aquifoliaceae (Figs. 37–38, rootwood)

Diffuse-porous wood with indistinct growth ring boundaries. Vessels angular, 30–80 µm in TD, solitary or in multiples of 2–5, sparse. Wood parenchyma diffuse-in-aggregates, often with prismatic crystals in long chains. Perforations scalariform with 7–14 bars. Rays heterocellular, 1–4 cells wide.

Note: Thin-walled vessels often in radial multiples and large rays consisting of large cells characterize this taxon.

Euonymus Celastraceae (Figs. 39–40, stemwood)

Diffuse-porous wood with distinct growth ring boundaries. Vessels exclusively solitary, angular, evenly scattered; TD decreasing from ca. 30 to 10 µm through growth rings. Perforations simple. Fibers septate. Rays uniseriate, heterocellular occasionally with marginal square to upright cells; often with prismatic crystals.

Note: Distinctly small solitary vessels, simple perforation plates, and short uniseriate rays characterize this taxon.

***Hibiscus tiliaceus* L.** Malvaceae (Figs. 41–42, stemwood)

Diffuse-porous wood usually with indistinct growth ring boundaries. Vessels thick-walled, round, 30–50 µm in TD, solitary or in multiples or clusters of 2–9, sparse. Wood parenchyma vasicentric and in dense irregular lines. Perforations simple. Rays heterocellular with a single row of marginal upright cells, 2 cells wide, short. Rays, parenchyma stands, and vessel elements storied.

Note: Thick-walled sparse vessels often in multiples, conspicuous axial parenchyma, the storied arrangement of short heterocellular rays, and the mixture of procumbent and upright cells in the ray body distinguish this species from other species of *Hibiscus*.

***Heritiera littoralis* Dryand.** Sterculiaceae (Figs. 43–44, rootwood)

Diffuse-porous wood with indistinct or barely distinct growth ring boundaries. Vessels thick-walled, round, 80–250 µm in TD, solitary or in multiples of 2–4, sparse; intervessel pits dense, ca. 4 µm in diameter. Wood parenchyma vasicentric and in dense irregular lines. Perforations simple; intervessel pits dense, ca. 5 µm in diameter. Rays heterocellular with a single row of marginal upright cells, 1–5 cells wide. Short rays, parenchyma strands, and vessel elements storied.

Note: Round vessels, abundant parenchyma in lines, the storied structure, and small dense intervessel pits characterize this species. Large vessels and obscure growth rings distinguish the rootwood from the stemwood.

***Barringtonia racemosa* (L.) Spreng.** Lecythidaceae (Figs. 45–46, stemwood; 47–48, rootwood)

Stemwood. Diffuse-porous wood with indistinct growth ring boundaries. Vessels comparatively thick-walled, angular, 40–100 µm in TD, mostly solitary or occasionally in multiples of 2–3, evenly scattered. Wood parenchyma scanty paratracheal and diffuse-in-aggregates. Perforations simple. Rays heterocellular, 1–6 cells wide, often over 5 mm tall.

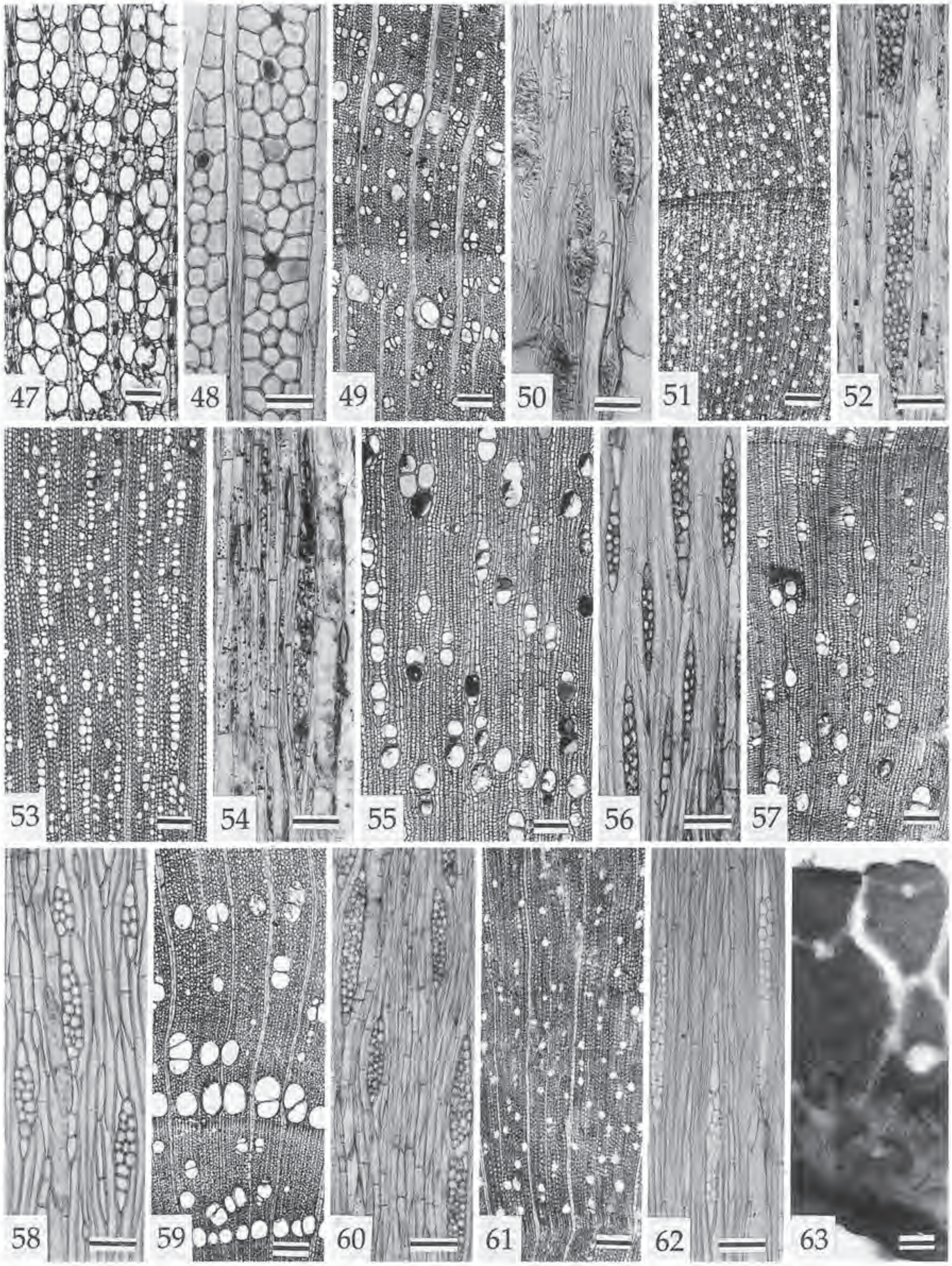
Rootwood. Diffuse-porous wood with distinct, irregular growth ring boundaries. Vessels are angular, 40–120 µm in TD; dense, touching with each other. Wood parenchyma scanty paratracheal. Perforations simple and scalariform with ca. 10 bars. Rays similar to stemwood, often with perorated ray cells with scalariform perforations.

Note: Angular thick-walled vessels with simple and scalariform perforation plates, abundant parenchyma in lines, and tall rays consisting of the mixture of procumbent, square, and upright cells of considerable size characterize this species. Rootwood has quite dense vessels compared with stemwood.

***Kalopanax pictus* (Thunb.) Nakai** Araliaceae (Figs. 49–50, stemwood)

Ring-porous wood. Earlywood vessels round, thick-walled, 50–160 µm in TD; lined along growth ring

TS (39), TLS (40) (OKI-111). — 41–42: *Hibiscus tiliaceus* (stemwood), TS (41), TLS (42) (OKI-135). — 43–44: *Heritiera littoralis* (rootwood), TS (43), TLS (44) (OKI-151). — 45–46: *Barringtonia racemosa* (stemwood), TS (45), TLS (46) (OKI-138). TS = transverse section, scale bar = 200 µm; TLS = tangential section, scale bar = 100 µm.



Figs. 47–63 Fossil woods recovered from the Ireibaru C Site (4). — 47–48: *Barringtonia racemosa* (rootwood), TS (47), TLS (48) (OKI-133). — 49–50: *Kalopanax pictus* (stemwood), TS (49), TLS (50) (OKI-112). — 51–52: *Vaccinium* sect. *Bracteata* (stemwood), TS (51), TLS (52) (OKI-137). — 53–54: *Maesa* (stemwood), TS (53), TLS (54) (OKI-118). — 55–

boundaries. Latewood vessels 20–60 μm in TD, solitary or in multiples or clusters of 2–6; often in intermittent tangential bands. Perforations simple. Fibers septate. Rays heterocellular with a single row of marginal upright cells, 1–4 cells wide.

Note: Earlywood vessels in a line at the beginning of growth rings, angular latewood vessels often in tangential bands, and heterocellular rays with one cell tall wings characterize this species.

Vaccinium* sect. *Bracteata Ericaceae (Figs. 51–52, stemwood)

Diffuse-porous wood with distinct growth ring boundaries. Vessels angular, exclusively solitary, 25–50 μm in TD, evenly scattered; helical thickenings throughout vessel elements. Wood parenchyma diffuse. Perforations simple and scalariform with 6–10 bars. Rays heterocellular, 1–4 cells wide; multiseriate rays with 1–5 rows of marginal upright cells and occasional sheath cells.

Note: Small solitary vessels, mixed perforation plates with less than a few bars, and rays tending to be of two distinct sizes distinguish this taxon from other taxa of Ericaceae.

Maesa Myrsinaceae (Figs. 53–54, stemwood)

Diffuse-porous wood with indistinct growth ring boundaries. Vessels angular, 20–50 μm in TD, solitary or in radial multiples of 2–7, evenly scattered. Perforations simple; intervessel pits dense, ca. 4 μm in diameter. Fibers septate. Rays heterocellular, 1–4 cells wide; multiseriate rays slender fusiform and often with sheath cells.

Note: Small vessels in radial multiples, simple perforation plates, and slender heterocellular rays characterize this taxon.

***Fraxinus griffithii* C. B. Clarke** Oleaceae (Figs. 55–56, stemwood; 57–58, rootwood)

Stemwood. Diffuse-porous wood with distinct or occasionally indistinct growth ring boundaries. Vessels thick-walled, angular, solitary or in radial multiples of 2–3; TD decreasing gradually from 100–120 to ca. 40 μm through growth rings. Wood parenchyma vasicentric and initial, and occasionally in scattered short lines. Perforations simple; intervessel pits dense, ca. 4 μm in diameter. Rays heterocellular with 1–3 rows of marginal upright cells, 1–2 cells wide.

Rootwood. Diffuse-porous to semi-ring-porous wood similar to stemwood with indistinct growth ring boundaries. Vessels smaller, 30–100 μm in TD, and sparser.

Note: Diffuse-porous wood with thick-walled angular vessels often in multiples, initial parenchyma, and short heterocellular rays characterize this species. *Fraxinus floribunda* Wall. has semi-ring-porous wood and homocellular rays. Rootwood tends to have smaller and sparser vessels than stemwood.

***Ehretia* cf. *ovalifolia* Hassk.** Boraginaceae (Figs. 59–60, stemwood)

Stemwood. Ring-porous wood. Earlywood vessels round, 70–130 μm in TD, in initial bands of 1–2 rows. Latewood vessels 20–100 μm in TD, in multiples or clusters of 2–3, sparse. Wood parenchyma vasicentric and in conspicuous irregular lines. Perforations simple. Rays heterocellular with occasional 1–2 rows of upright marginal cells, 1–3 cells wide.

Rootwood. Semi-ring-porous wood similar to stemwood. Vessels smaller, 50–130 μm in TD, evenly scattered.

Note: Ring-porous wood with round vessels, abundant parenchyma in lines, and almost homogeneous rays characterize this taxon. Rootwood has barely distinct growth ring boundaries with irregular growth ring width.

Callicarpa Verbenaceae (Figs. 61–62, stemwood)

Diffuse-porous wood with distinct growth ring boundaries. Vessels round, thick-walled, 20–40 μm in TD, solitary or in radial multiples of 2–3, evenly and sparsely scattered. Wood parenchyma scanty paratracheal. Perforations simple. Fibers septate. Rays heterocellular, 1–3 cells wide; multiseriate rays slender with 1–5 rows of marginal upright cells.

Note: Small thick-walled vessels occasionally in multiples, simple perforation plates, and narrow heterocellular rays characterize this taxon.

Subfam. Bambusoideae Gramineae (Fig. 63)

Vascular bundles dense. Inner structure of vascular bundles not preserved. Vascular bundles with a bundle sheath of sclerenchymatous fibres developing in an inward and an outward rhomboid extensions.

Note: Conspicuous bundle sheaths are characteristic, but the taxonomic distinction within subfamily Bambusoideae was not feasible due to the lack of comparative specimens.

The twenty seven identified taxa included three co-

56: *Fraxinus griffithii* (stemwood), TS (55), TLS (56) (OKI-181). — 57–58: *Fraxinus griffithii* (rootwood), TS (57), TLS (58) (OKI-177). — 59–60: *Ehretia* cf. *ovalifolia* (stemwood), TS (59), TLS (60) (OKI-132). — 61–62: *Callicarpa* (stemwood), TS (61), TLS (62) (OKI-122). — 63: Subfam. Bambusoideae, TS (OKI-107). TS = transverse section, scale bar = 200 μm; TLS = tangential section, scale bar = 100 μm.

Table 2 Taxa of wooden artifacts and natural woods recovered from the Ireibaru C Site

Taxon	SR	Artifacts board	Artifacts others	Natural woods
Cunninghamia	S	2		
Chamaecyparis obtusa	S	1	1	
Calocedrus macrolepis	S		2	
Podocarpus	S		1	
Castanopsis sieboldii	S		1	2
Celtis	S			1
Ficus cf. *erecta*	S			4
Morus	S	1		
Machilus	S	6	1	
Machilus	R			2
Camellia	S	1		
Ternstroemia gymnanthera	S	2		
Distylium racemosum	S			1
Pongamia pinnata	S			1
Zanthoxylum	S			1
Melia azedarach	S	5	1	
Ilex	R			2
Euonymus	S		1	2
Hibiscus tiliaceus	S			5
Heritiera littoralis	R			6
Barringtonia racemosa	S			1
Barringtonia racemosa	SR		1	1
Barringtonia racemosa	R		2	8
Kalopanax pictus	S			1
Vaccinium sect. *Bracteata*	S			1
Maesa	S			1
Fraxinus griffithii	S	1	1	4
Fraxinus griffithii	SR			1
Fraxinus griffithii	R			2
Fraxinus griffithii	–		1	
Ehretia cf. *ovalifolia*	S			5
Ehretia cf. *ovalifolia*	R		1	
Callicarpa	S			1
Subfam. Bambusoideae	–		1	
Total		19	15	53

S = stemwood, R = rootwood, SR = stem-rootwood, – = unknown.

niferous taxa not indigenous in the present Ryukyu Islands: *Cunninghamia, Chamaecyparis obtusa*, and *Calocedrus macrolepis* (Hatusima, 1975; Shimabuku, 1997)(Table 2). *Cunninghamia* and *Chamaecyparis obtusa* were found as flat grain boards and a split wood, and *Calocedrus macrolepis* was found only in fragments of unknown processing. All the other taxa are indigenous to present Okinawa Island. Wooden artifacts included 15 taxa, and rootwood artifacts of two taxa had clear marks of processing. Among wooden artifacts, flat grain boards of *Machilus* and *Melia azedarach* were conspicuous. Natural woods consisted of 18 taxa of dicotyledons and included rootwoods of *Machilus, Ilex, Heritiera littoralis, Barringtonia racemosa,* and *Fraxinus griffithii*. Among stemwoods, *Castanopsis sieboldii*, *Ficus* cf. *erecta*, *Euonymus*, *Hibiscus tiliaceus*, *Fraxinus griffithii,* and *Ehretia* cf. *ovalifolia* were comparatively dominant.

Discussion

Wooden artifacts and natural woods of the Ireibaru C Site included no typical taxa of mangrove. Common occurrence of rootwoods of *Heritiera littoralis, Barringtonia racemosa,* and *Fraxinus griffithii* and stemwoods of *Hibiscus tiliaceus* indicated existence of a seaside or back mangal forest in this area. Other taxa occurring only as stemwoods probably grew on the lower end of a ridge beside this site. The present results show that fossil wood assemblages can be preserved on abrasion terraces of islands of the Nansei Shotou when quick burial by alluvial sediments occurs. Compared with the fossil woods recovered at the Mehbaru Site (Noshiro, 1999), the lack of *Pinus* subg. *Diploxylon* and *Quercus* subg. *Cyclobalanopsis* and the occurrence of *Melia azedarach* at the Ireibaru C Site are conspicuous. This may reflect floristic difference between these two sites, but the limited number of specimens does not allow further comparison.

Among the three coniferous taxa not indigenous in the present Ryukyu Islands, *Chamaecyparis obtusa* grows in mainland Japan, south to Yakushima Island, and Taiwan, and two species of *Cunninghamia* and *Calocedrus macrolepis* grow in Taiwan and mainland China (Cheng & Fu, 1978; Wu & Raven, 1999). Thus the three taxa grow together only in Taiwan at present. In Taiwan *Cunninghamia konishii* Hayata and *Chamaecyparis obtusa* Siebold et Zucc. var. *formosana* (Hayata) Hayata grow in the temperate to subalpine zones between 1300 and 2000 m and 1300 and 2800 m respectively, and *Calocedrus macrolepis* Kurz var. *formosana* (Florin) Cheng et L. K. Fu in the subtropical to temperate zones between 300 and 1900 m (Li & Keng, 1994). These species become a large tree over 20 m tall and up to 3 m thick. Outside Taiwan, *Cunninghamia lanceolata* (Lamb.) Hook. grows widely in central and southern China between 200 and 2800 m and becomes a large tree up to 50 m tall and 3 m thick (Cheng & Fu, 1978; Wu & Raven, 1999). *Cunninghamia konishii* has a restricted distribution only in Fujian, and *Calocedrus macrolepis* grows in southern China around Yunnan. In mainland Japan *Chamaecyparis obtusa* grows on Yakushima Island between 600 and 1800 m and

Kyushu between 300 and 1600 m (Hayashi, 1960). Thus all these artifacts could have originated in Taiwan, or *Chamaecyparis obtusa* could have come from mainland Japan together with the Jomon pottery and *Cunninghamia* and *Calocedrus macrolepis* from Taiwan or mainland China.

There are two possibilities for the wooden artifact of these coniferous taxa to arrive at Okinawa Island, ocean current and human transport. The ocean transport of wooden artifacts however does not seem plausible. The Kuroshio Current at present crosses the Nansei Shotou at the Yonaguni Depression into East China Sea, flows along the Okinawa Trough, and comes out into the Pacific Ocean through the Tokara Structural Channel in the middle of the Satsunan Islands (Koba, 1992). This current flowed along this course at least from early Holocene to ca. 4500 yr B.P. (Ujiié, 1998; Ujiié & Ujiié, 1999). Thus transport of wooden artifacts by the Kuroshio Current from Taiwan or mainland China to Okinawa Island seems improbable, never from Kyushu southwards, even if we consider haphazard transport by typhoons. Besides, the wooden artifacts of these coniferous taxa did not show any clear marks of weathering caused by ocean transport.

Human transport, therefore, seems more plausible in spite of the 200 km span of ocean between Miyako Island and Okinawa Island if they come from Taiwan or mainland China. The present knowledge of archaeology, however, indicates a cultural discrepancy between the Okinawa Islands and the Sakishima Islands during the Jomon Period (Oda, 1992). Besides, the occurrence of Sobata type pottery at the Ireibaru C Site clearly shows strong cultural influence of Kyushu in the Early Jomon Period at this site. With further finds of lowland archaeological sites in the Nansei Shotou, I hope that the actual means and direction of oversea transport and cultural communication in and around the Nansei Shotou during the Early Jomon Period will be clarified.

Acknowledgement

I am grateful to the staff of the Board of Education of Chatan Village, Okinawa and Dr. Sei-ichiro Tsuji for their support during the field work and sampling of materials at the site, to Profs. Tseng-Chieng Huang and Su-Hwa Chen for information on vegetation historical studies in Taiwan, and to Dr. Tadashi Kajita for information on oceanic transport of fruits and seeds.

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（2000年10月17日受理）

書　評：Dickison, W. C. 2000. Integrative Plant Anatomy. xvii + 533 pp. Academic Press, San Diego. ISBN 0-12-215170-4. US$69.95.

本書は昨年の暮れに58才で亡くなったWilliam C. Dickisonの遺作である。彼はビワモドキ科やリョウブ科，クノニア科，ミツバウツギ科，マメモドキ科を中心として植物の解剖学的な形態を解明し，その生態との関係を探求してきた研究者であった。本書は，植物の解剖学的な形態を詳細に記述するというこれまでの植物解剖学の教科書とは大いに異なって，書名のごとく応用植物解剖学といった趣の書物となっている。これは著者がしばしば人から尋ねられた，植物解剖学にはどんな意味があって，他の分野とどのように関連しているのかという疑問に答えたものである。したがって本書では，植物解剖学の概要には最初の4章で触れるのみで，後の章はすべて多方面の分野と植物解剖学との関わりを記述している。

全体は3部に分けられている。第1部の第1章から第4章は植物解剖学の概論で，植物の生長および細胞の形態からはじまって，一次組織の起源と構造，茎・葉・根の組織学，二次組織の起源と構造を記述していく。第2部の第5章から第8章では，植物学の他の分野と植物解剖学との関連を論じており，進化系統学と比較形態学における位置づけや，植物の構造と生理的機能あるいは生態との関連，公害が植物の構造におよぼす影響と話を進めていく。第3部の第9章から第16章ではより異なった領域と植物解剖学との関連を述べており，遺伝育種や，植物病理，植物の防御機構，香辛料や薬草における分泌機構，生薬学，繊維の構造と利用，法医学に対する貢献，年輪気候学，木材の材質，そして芸術品の修復や同定などにおける役割と，さまざまな分野における植物解剖学の役わりを探っていく。

遺伝学や植物病理学，年輪気候学，林産学など，それぞれの分野では，これまでにも教科書が出版されているが，植物解剖学の立場にたって，これだけ広い分野との関わりを包括的に記述した書物はおそらく初めてであろう。これまで植生史研究ではまったく対象とされていなかった研究分野を見出したり，これまでの研究手法を見直すうえで，参考となる書物である。

（能城修一）