Introduction

Central Oregon in the west-coastal United States is home to a sequence of middle Eocene to Early Oligocene terrestrial sediments that contain abundant and diverse fossil woods, leaves, fruits and seeds, and vertebrates (Chaney 1948, Hanson 1996, Retallack et al. 2000, Dillhoff et al. 2009). The middle Eocene Clarno Nut Beds deposit includes a rich fossil fruit and seed assemblage (Scott 1954, Manchester 1994) as well as the world’s single most diverse assemblage of fossil woods (Wheeler and Manchester 2002). The fossil woods described herein are ca. 8 million years younger from a late Eocene deposit of the John Day Formation near the community of Post, Oregon. These were investigated as part of an ongoing treatment of the flora at the Post Hammer locality (UF locality 279), which includes at least ten fruit types (Manchester and McIntosh 2007). Twelve woods were introduced previously, representing the families Aceraceae, Anacardiaceae, Cercidiphyllaceae, Fagaceae, Hamamelidaceae, Juglandaceae, Malvaceae, Ulmaceae, and Cupressaceae (Wheeler et al. 2006). Woods referable to *Trochodendron beckii*, *Cercidiphyllum alalongum*, *Liriodendroxylon multiporosum* were described earlier (Scott and Wheeler 1982; see Wheeler and Manchester 2002 for locality clarification) and a more detailed treatment of the ulmaceous woods from the same flora was presented by Wheeler and Manchester (2007).

In this article we focus on woods of the Post Hammer site and discuss their significance for understanding past floristic diversity, providing data for biogeographic and phylogenetic studies, and providing insights into woody plants’ responses to changing climates. We describe the woods in alphabetical sequence by family and compare the incidence of features considered of ecological significance to the older Nut Beds wood assemblage.
Materials and methods

Locality

The Post Hammer locality (UF 279) is situated about three km east of the town of Post, Oregon, and is named informally for Michael Hammer, a devoted fossil collector who brought it to our attention. The silicified woods are found loose in eroded tuffs that are situated in the upper part of the Clarno Formation near the transition to the John Day Formation. A minimum age for these wood sites is provided by a white tuff overlying the fossiliferous tuff at UF locality 278. Sandine crystals from this white tuff give an $^{40}$Ar/$^{39}$Ar date of $36.21 \pm 0.26$ MA ($n = 26$; Manchester and McIntosh 2007). There are no datable tuffs in or immediately below the fossiliferous horizon to provide a maximum age. However, this late Eocene date may be a reasonable approximation of the age of the Post woods, contrasting with the middle Eocene age of the Clarno Nut Beds.

Sample preparation

The University of Florida (UF) collections at the Florida Museum of Natural History include more than 80 specimens of silicified wood from the Hammer locality. After examining them with a hand lens and/or dissecting microscope, we selected examples of what appeared to be different wood types for thin sectioning. This paper describes 16 wood types. Eight additional angiosperms represented by secondary xylem, a palm, and one conifer from the same collection remain undescribed.

A diamond lapidary saw was used to cut thick sections (wafers) of transverse (TS), tangential (TLS), and radial (RLS) surfaces. One side of the wafer was smoothed to remove saw marks, and then affixed to a glass side using 24-hour transparent epoxy. The sections were then ground until they were thin enough (ca. 30 \mu m) to allow seeing anatomical details with transmitted light microscopy. Initial grinding was done using a Buehler petrographic thin section grinding machine. Final thinning was done by hand, using a glass plate and a slurry of carborundum grit. Cover slips were mounted using Canada Balsam to improve clarity for light microscopy. Samples are deposited in the palaeobotanical collections of the Florida Museum of Natural History, University of Florida, Gainesville; in this paper individual samples are referred to by their UF specimen numbers.

Affinities

Possible relationships of the fossils to modern woods were determined by searching the InsideWood database (InsideWood 2004–onwards), using some of the strategies described by Wheeler (2011) and Wheeler et al. (2020). The search criteria used are given, i.e., IAWA hardwood list feature numbers (IAWA Committee 1989) followed by the codes “p” for present, “r” for required present; “a” for absent, “e” for required absent. Subsequently, descriptions and slides of the suggested matches were compared to the fossil. Samples of extant woods are referred to by their wood collection numbers, most abbreviations as given by Index Xylarianum 4.1 (Lynch and Gasson 2010).

The text-figures illustrating the features used to establish relationships show TS = transverse section, RLS = radial longitudinal section, and TLS = tangential longitudinal section.

For quantitative features, we mostly report average (standard deviation), range; if three values are given, this is minimum – average – maximum.

The minimum diameters of the samples were estimated from the growth ring curvature and/or divergence of the rays. Although our fragmentary samples do not allow for providing information on dbh (diameter breast height, a common forestry measurement), we consider this crude estimate to be useful for indicating whether the sample came from juvenile or mature wood. There can be differences between juvenile and mature wood anatomy, especially in quantitative features and ray structure (e.g., Carlquist 2001). Most of the descriptions in InsideWood are for mature wood samples, so this needs to be kept in mind when making comparisons.

We refer to images of modern wood samples by Index Xylarianum 4.1 numbers (Lynch and Gasson 2010).

Nomenclature

There is a tradition among some Indian and European palaeobotanists that fossil woods should be assigned to a genus ending in -oxylon or -iniun, even when the fossil wood has a combination of characters unique to an extant genus, e.g., Cistoxylon for a wood with features unique to Cistus (Gottwald 1992), Evodinium for woods thought to resemble Evodia (Bande and Prakash 1984). The International Code of Botanical Nomenclature does not require or recommend that fossil wood names have these endings. In our monograph on woods from the middle Eocene Nut Beds flora, our approach to naming was: “When a fossil wood has a suite of anatomical features characteristic of an extant genus, we assign it to that genus. Collinson (1986) provided rationale for this approach. This does not preclude the possibility that the wood may have belonged to a plant that had leaves and/or reproductive structures different from the specified extant genus” (Wheeler and Manchester 2002: 11). We continue this approach here as well because we think that doing so provides information on mosaic evolution and variation in how different plant parts change through time.

New names of fossil plants and other nomenclatural acts are registered in the Plant Fossil Names Registry, which is hosted and operated by the National Museum, Prague for the International Organisation of Palaeobotany, each with a unique PFN number.

Systematic palaeobotany

Family Anacardiaceae R.Bs., 1818 nom. cons.
Genus Pistacia L., 1753

Pistacia terrazasae sp. nov.

Text-fig. 1a–i

Holotype. Designated here. UF 279-24545 (Text-fig. 1b–i).

Paratype. Designated here. UF 279-85025 (Text-fig. 1a).

Plant Fossil Names Registry Number. PFN002712 (for new species).
Text-fig. 1. *Pistacia terrazasae* sp. nov., a: UF 279-85025; b–i: UF 279-24545. a: Ring-porous wood with widely spaced solitary earlywood vessels; latewood vessels in radial multiples of 4 or more and in clusters, TS. b: Growth ring boundary, fiber walls thin to thick, TS. c: Simple perforation plates, alternate intervessel pits, helical thickenings in vessels, TLS. d: Multiseriate rays to 4-seriate, tyloses in vessels, helical thickenings throughout body of vessel element, and alternate intervessel pitting, TLS. e: Vessel-ray parenchyma pitting with reduced borders, ovular outline, RLS. f: Marginal row of upright cells, one inflated and crystalliferous, procumbent body cells, RLS. g: Multiseriate rays mostly 3-seriate, occasionally 4-seriate, uniseriate rays usually <10 cells tall, TLS. h: Ray with enlarged crystalliferous marginal cell, to left of C, TLS. i: Ray with canal, TLS. Scale bars: 200 µm in a, g; 100 µm in b, d, h; 50 µm in c, i; 20 µm in e, f.

Table 1. Comparison of *Pistacioxyylon* (arranged by age, oldest to youngest) and *Pistacia terrazasae*. EW VTD = earlywood vessel tangential diameter in µm; EW row = number of rows of wide earlywood vessels; IVP = horizontal diameter of intervessel pits in µm; Cry = crystals, Ab = absent, UpR = in upright ray parenchyma cells, Tyl = in tyloses; RW = width in cell number of rays without canals; C = common, U = Uncommon; Eo = Eocene, Ol = Oligocene, Mio = Miocene, l = late, e = early.

<table>
<thead>
<tr>
<th>Taxon (Reference)</th>
<th>EW VTD</th>
<th>EW row</th>
<th>IVP</th>
<th>Cry</th>
<th>RW</th>
<th>Canals</th>
<th>Age, Location</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Pistacioxyylon muticoides</em> (1)</td>
<td>75–188</td>
<td>1</td>
<td>6–8</td>
<td>Ab</td>
<td>1–3(–4)</td>
<td>C, 1–3 per ray</td>
<td>Ol, France</td>
</tr>
<tr>
<td><em>P. hollieisii</em> (2)</td>
<td>117 (105–165)</td>
<td>4–5</td>
<td>7–10</td>
<td>Tyl</td>
<td>1–3</td>
<td>U, 1 per ray</td>
<td>l Mio, Germany</td>
</tr>
<tr>
<td><em>P. leiboensis</em> (3)</td>
<td>170 (109–265)</td>
<td>1</td>
<td>5–8</td>
<td>Ab</td>
<td>1–5*</td>
<td>U, 1 per ray</td>
<td>l Mio, China</td>
</tr>
<tr>
<td><em>P. praeeterehinitthus</em> (4)</td>
<td>80–105</td>
<td>2–3</td>
<td>6–8</td>
<td>?</td>
<td>1–5*</td>
<td>1 per ray</td>
<td>Mio?, Germany</td>
</tr>
<tr>
<td><em>P. sp.</em> (4)</td>
<td>120–150</td>
<td>2–3</td>
<td>7–19</td>
<td>?</td>
<td>1–5*</td>
<td>1–2 per ray</td>
<td>Mio?, Germany</td>
</tr>
<tr>
<td><em>P. afuki</em> (5)</td>
<td>81 (42–130)</td>
<td>1</td>
<td>5–7</td>
<td>Ab</td>
<td>1–3</td>
<td>C, 1–3 per ray</td>
<td>e Mio, Turkey</td>
</tr>
<tr>
<td><em>Pistacia terrazasae</em> sp. nov. (this paper)</td>
<td>89 (57–139)</td>
<td>1</td>
<td>7–9</td>
<td>UpR</td>
<td>1–3(–4)</td>
<td>U, 1 per ray</td>
<td>Eo, USA</td>
</tr>
</tbody>
</table>


* Ray width described as to 5 cells wide, however, it seems probable that is the width of rays with canals.
Repository. Paleobotany Collections, Florida Museum of Natural History, Gainesville, Florida, USA.

Etymology. Named for Teresa Terrazas to acknowledge her comprehensive treatment of the wood anatomy of the Anacardiaceae

Type locality. UF 279. About 3 km east of Post, Crook County, Oregon, USA.

Type stratum and age. John Day Formation, Eocene.


Description. Growth rings present, marked by radially flattened latewood fibers, and differences in vessel diameter and density between latewood and earlywood of subsequent rings. Ring-porous.

Earlywood vessels solitary and rounded to slightly oval in outline, earlywood pore zone 1–2 pores deep, not contiguous; latewood vessels mostly in radial multiples and clusters, solitary latewood vessels angular in outline (Text-fig. 1a, b); average tangential diameter of earlywood vessels 89 (22) µm, range 57–139 µm; perforations exclusively simple (Text-fig. 1c); intervessel pits alternate (not angular in outline) (Text-fig. 1c, d), 7–9 µm in horizontal width; vessel-ray parenchyma pits with reduced borders and rounded to oval in outline (Text-fig. 1e), occasionally irregular in shape, most commonly in upright/square ray cells; prominent helical thickenings along the full length of narrow vessel elements (Text-fig. 1c, d); mean vessel element length 354 (38), range 275–435 µm; tyloses abundant, bubble-like in earlywood vessels, more widely spaced in latewood vessels.

Fibers non-septate, walls medium-thick, pitting not observed.

Axial parenchyma rare, scanty paratracheal.

Rays 1–3(–4)-seriate, uniseriate low, usually less than 10 cells high (Text-fig. 1d, g, h). Multiseriate rays heterocellular, body of procumbent cells, with 1–2(–4) marginal rows of upright cells (Text-fig. 1e); total multiseriate ray height average 308 (100), range 135–555 µm; 4–5/mm. Solitary crystals occasional in upright/square marginal ray cells (Text-fig. 1f, h), some crystalliferous cells enlarged, rarely chambered. Radial canals present (Text-fig. 1i), oval in outline, canal size – width by height ranging from 40 × 70 µm to 60 × 110 µm, with thin-walled walled epithelial cells.

Comparisons with extant woods. A search of InsideWood for ring-porous wood (3p), vessels in radial multiples of four or more common (10p), simple perforation plates (13p), alternate intervessel pits (22p), vessel-ray parenchyma pits with reduced borders (31p), helical thickenings along the length of the vessel elements (36p 37p), and radial canals (130p) returned five species of Pistacia and Rhus microphylla Engel. in the Anacardiaceae. Rhus microphylla has a broad earlywood zone, while Pistacia species have narrow earlywood zones, usually with one discontinuous row (more rarely two rows) of enlarged solitary earlywood pores (Fahn et al. 1986, Terrazas 1994, Abundiz-Bonilla et al. 2004). Consequently, we assign these Post Hammer woods to Pistacia.

Pistacia is a genus of shrubs to small trees with a disjunct distribution (Mabberley 2017). Seven species occur from the Mediterranean basin to Central Asia (P. atlantica Desf., P. integerrima J.L. Stewart, P. khinjuk Stocks, P. lentiscus L., P. palaestina Boiss., P. terebinthus L., P. vera L.), two species occur in eastern Asia (P. chinensis Bunge, P. weinmannifolia J.P. ex Franch.), two species are distributed from the southwestern United States to Central America (P. mexicana Kunth, P. texana Swingle) (Yi et al. 2008). InsideWood has reference images of Pistacia chinensis (FRI 547, CAFW 8636), P. khinjuk (LW s.n.), P. lentiscus (SRW 14465), P. mexicana (FPW 27837, MADW 12256), and P. palaestina (MADW 26695). The latewood of Pistacia terrazasae does not have a pronounced diagonal or tangential arrangement and thus resembles the latewood of P. lentiscus (SRW 14465) and P. mexicana (MADW 12256) more than the other species which usually have a pronounced tangential to diagonal-dendritic arrangement. Ray widths in this new species also are similar to P. lentiscus and P. mexicana. According to Terrazas (1994), who examined wood of 10 extant Pistacia species, multiseriate rays in P. mexicana and P. lentiscus were “most commonly 2–3” cells wide, implying that in other species multiseriate rays usually are 3–5. Appendix I of her dissertation (p. 308) shows the quantitative ray and vessel element features of these two species are similar.

Pistacia lentiscus is found from the Canary Islands across southern Europe from Portugal to Greece and Turkey, across North Africa from Morocco to Egypt and the Middle East; P. mexicana is found in southern Texas, Mexico, Guatemala, and Honduras (AL-Saghir 2010). Both species are evergreen, which is unusual for ring-porous species because ring-porous species almost always are deciduous (Boura and De Franceschi 2007). Yi et al. (2008), using molecular data, placed these two species in section Lentiscus, while AL-Saghir (2010, 2012), using morphological data (almost exclusively leaf characters), placed them in section Lentiscella. Earlier phylogenetic analyses also placed these two widely separated geographically species in the same section (Parfitt and Baldenes 1997).

Comparisons with fossil woods. Dupéron (1973) created the genus Pistacioxyylon Dupéron to accommodate a late Eocene/Oligocene wood with features found in ring-porous species of Pistacia. Selected features of the Pistacioxyylon species described to date are compared with Pistacia terrazasae (Tab. 1). This Post Hammer wood type and the other species assigned to Pistacioxyylon have a combination of wood anatomical features unique to Pistacia. We suggest all could be assigned to Pistacia to indicate that their anatomy is indistinguishable from that of the extant genus.
Co-occurring fruits/seeds. Manchester and McIntosh (2007) illustrated a silica fruit cast with characters similar to those of extant *Anacardium* L., *Cyrtocarpa* Kunth, and *Pistacia* from the same locality (UF 279). It is possible that this wood and that fruit came from the same source plant, given they are the only Anacardiaceae known at locality UF 279. However, without direct attachment between them or repeated co-occurrences this cannot be established. The Nut Beds flora included a fossil fruit, *Pistachioides striata* Manchester (1994), which shares many features with pistachio nuts, but it was not assigned to the modern genus because of insufficient preservation of anatomical details. Although numerous silicified woods are preserved at the Nut Beds, including some Anacardiaceae, none of them resemble *Pistacia*.

Remarks. Xie et al. (2014) hypothesized that *Pistacia* originated near the Eocene-Oligocene boundary at 37.60 Ma. The minimum age for the Post sites is 36.21 ± 0.26 Ma (Manchester and McIntosh 2007), which places *Pistacia terrazasae* near this hypothesized time of origin. It is the oldest known occurrence of a wood with features of *Pistacia* and the only one known from the USA. Ramírez and Cevallos-Ferriz (2002) described *Pistacia marquezii* J.L. Ram. et Cev.-Ferriz, based on Oligocene leaves (Pie de Vaca Formation, Mexico) and that they thought most similar to present-day *P. chinensis*. They used this similarity to support the concept of exchange between low-latitude North America and Asia. The question remains whether this Oregon fossil wood is evidence for a migration of *Pistacia* from Asia to Mexico and the American Southwest via the Pacific Northwest.

**Text-fig. 2. Celtis popsii** sp. nov., UF 279-34460. a: Growth ring with earlywood of multiple rows of vessels solitary and in radial multiples; latewood vessels in wavy tangential bands, TS. b: Growth ring boundary, latewood vessels in multiples with axial parenchyma confluent, TS. c: Simple perforation plates, alternate intervessel pits, polygonal in outline, TLS. d: Vessel-ray parenchyma pits to right of VRP, oval in outline, with slightly reduced borders, RLS. e: Rays tending to two sizes, some multiseriate rays with distinct sheath cells, multiseriate rays usually with 1 marginal row of square to upright cells, occasionally with 4 or more; uniseriate rays less than 10 cells high, TLS. f: Detail of multiseriate ray with distinct sheath cells, vessel element end walls, TLS. Scale bars: 200 µm in a, e; 100 µm in b; 50 µm in c, f; 20 µm in d.
Family Cannabaceae Martinov, 1820 nom. cons.

Genus Celtis Tourne., ex L., 1753

Celtis popsii sp. nov.

Text-fig. 2a–f

Holotype. Designated here. UF 279-34460 (Text-fig. 2a–f). Minimum estimated axis diameter 28 cm.

Plant Fossil Names Registry Number. PFN002695 (for new species).

Repository. Paleobotany Collections, Florida Museum of Natural History, Gainesville, Florida, USA.

Etymology. Named in honor of Raymond “Pops” Shepherd, who loved and respected the natural beauty of our earth, father of Mark Shepherd, generous supporter of the J. C. Raulston Arboretum.

Type locality. UF 279. About 3 km east of Post, Crook County, Oregon, USA.

Type stratum and age. John Day Formation, Eocene.


Description. Growth rings distinct. Wood ring-porous to semi-ring-porous.

Earlywood zone 2–4(4+) rows deep with vessels solitary and in radial multiples of 2–3. Latewood vessels in radial multiples and clusters arranged diagonally and in tangential bands (Text-fig. 2a, b). Tangential diameter of earlywood vessels 126 (18), 88–166 μm; perforations exclusively simple; intervessel pits crowded alternate, mostly polygonal in outline (Text-fig. 2c), medium-large, 7–11; vessel-ray parenchyma pits oval in outline, not crowded, borders slightly reduced (Text-fig. 2d); vessel element lengths average 380 (141) μm; thin-walled bubble-shaped tyloses present.

 Fibers mostly non-septate, possibly a few septate, pits not observed, likely thick-walled.

Axial parenchyma vasicentric-confluent (Text-fig. 2a, b), strands mostly of 4 cells.

Rays 1–5(–6) cells wide; tendency to two size classes as 2–3-seriate rays are rare, sheath cells present in most of the wider rays (Text-fig. 2e, f); heterocellular with procumbent body cells and 1–2(–5) marginal rows of square and upright cells. Multiseriate ray height average 737 (169) μm; 4–6/304 mm. Possibly crystals in somewhat enlarged upright marginal ray parenchyma cells.

Comparisons with extant woods. A search of InsideWood for the combination: wood not diffuse-porous (5e), tangential bands of vessels (6p), simple perforation plates (13p), alternate intervessel pitting that is not small to minute (22p 24a 25a), non-septate fibers (66p), vasicentric parenchyma (79p), heterocellular rays of two size classes (103p 104a 105a) with sheath cells (110p) only returned species of Celtis (Cannabaceae). If vessels in a diagonal arrangement (7p) is used instead of vessels in a tangential arrangement, again only Celtis has that combination of features.

Celtis is a widespread genus with ca. 60 species, mostly trees, that occurs in temperate and tropical regions (Africa, Asia, Central and South America, North America, Southern Europe; Sattarian 2006, McBerley 2017). InsideWood includes coded descriptions of 25 species and images of 22 species.


Present-day ring-porous Celtis species usually have only 1–2 rows of earlywood vessels. However, some samples of C. occidentalis (BWCW 8272; BWCW 8456; FPAW 9598), and C. sinensis (TWtW 23448) have multiple rows of earlywood vessels. Ring-porous Celtis generally have wider rays (to 12-seriate) than diffuse-porous species (to 8-seriate, but mostly 1–5-seriate). The anatomy of this Post Hammer wood with its tendency to semi-ring-porosity and rays to 5–6-seriate suggests it grew in a seasonal environment, but one not as pronounced as North Temperate Celtis species experience today.

Comparisons with fossil woods. Apparently, the three generic names – Celtisxylon T.TriRedi (Trivedi 1971), Celtisxylon Greguss (Greguss 1943), Celtisxylon Wurzinger (Wurzing 1953) – created for fossil woods thought to resemble Celtis – were not properly diagnosed (Gregory et al. 2009). Celtisxylon was applied to a wood from Deccan Intertrappean beds of India but was only mentioned in an abstract without diagnosis or designation of holotype, Celtisxylon was never formally diagnosed, and Celtisxylon was used in a thesis, but not formally published.

Woods thought to have affinities with Celtis have been reported from the Miocene of temperate Europe and Asia. Selmeier (2018, 2015) described Celtisxylon cristalliferum A.Selm. from the lower and middle Miocene of Germany and compared it to C. palaeohungaricum Greguss and
C. campestre (E. Hofm.) Greguss from the Miocene of Hungary. These latter two species had rays up to 10–12 cells wide, while the widest rays of C. cristalliferum were 6–7-seriate. Celtixylon cristalliferum differs from Celtis popsii because it has a narrower earlywood pore zone with 1–2 (3) rows of large vessels, less well-defined sheath cells in the rays, and not as obvious a tendency to two size classes of rays. The illustration of the Celtixylon sp. (probable Miocene age) that Gottwald (2004) described also shows only 1–2 rows of large earlywood pores.

As detailed above, Celtis popsii differs from other fossil wood species thought related to Celtis and has wood anatomical features that fall within the range of and are unique to Celtis, so we assign it to the genus. To the best of our knowledge, this is the only fossil Celtis wood known from North America.

Co-occurring fruits/seeds. To date, there is no record of Celtis in the fruit/seed assemblage of locality UF 279.

Family Cercidiphyllaceae Engl., 1907 nom. cons.
Genus Cercidiphyllum Siebold et Zucc., 1846

Cercidiphyllum alalongum R.A. Scott et E.A. Wheeler, 1982

Material. A single specimen (UF 279-24543) with an estimated minimum diameter of 8.8 cm.

Description. Growth rings distinct, marked by bands of radially narrow fibers, difference in vessel diameter between latewood and earlywood vessels of successive rings (Text-fig. 3a, b). Wood diffuse-porous.
Vessels predominantly solitary (Text-fig. 3a, b), mean tangential diameter 59 (12) µm, 32–86 µm; 82–95–102/ mm²; perforations all scalariform, 28–47 fine bars (Text-fig. 3c); intervessel pits rare, opposite to scalariform (Text-fig. 3e); vessel-ray parenchyma pits scalariform; vessel element lengths 980–1,400 µm; tyloses not observed. Faint helical thickenings occasionally observed in vessel element tips (Text-fig. 3d).

Fibers non-septate, thick-walled, small (2–3 µm) bordered pits observed on radial walls of some fibers. Axial parenchyma rare.

Rays 1–2(–3)-seriate, uniseriate portions frequently alternating with multiseriate portions, occasionally width of the uniseriate and multiseriate portions similar (Text-fig. 3f, g), markedly heterocellular with upright cells often 2× the height of the procumbent cells (Text-fig. 3h), procumbent cells with relatively thick walls and richly pitted, upright and square cells with relatively thin walls; uniseriate rays exclusively of upright and square cells, usually less than 10 cells high; ~12 rays per mm.

Crystals not observed.

Comparisons with extant woods. The combination of diffuse-porous wood (5p), exclusively solitary vessels (9p), scalariform perforation plates with more than 20 bars (17p), opposite-scalariform pits (22a – alternate pits absent), narrow numerous vessels (42a 43a 46a 47a 48a – absence of both medium-wide vessels and fewer than 40 vessels per mm²), long vessel elements (54p), fibers with bordered pits (62p), axial parenchyma rare-absent (75p), rays 1–3-seriate (97p) and heterocellular rays (104a 105a) occurs in the saxifragalean families Altingiaceae (Liquidambar L.), Cercidiphyllaceae (Cercidiphyllum), and Hamamelidaceae (Corylopsis Siebold et Zucc.). Sakala and Privé-Gill (2004) discussed how to distinguish woods of these three genera and concluded that *Cercidiphyllum* consistently had more bars per perforation plate (to ~40 bars) than the other two genera. Based on their criteria this wood has affinities with the Cercidiphyllaceae. Scott and Wheeler (1982) detailed differences between the ray structure of *Cercidiphyllum* and *Corylopsis*: rays in *Cercidiphyllum* have more than two alternating 1-seriate and 2–3-seriate portions and in some rays the 1-seriate and 2–3-seriate portions are of equal width.


Pearson (1987) and Crawley (1989) suggested the Clarno Nut Beds *Cercidiphyllum alalangum* R.A.Scott et E.A.Wheeler (Scott and Wheeler 1982) should be included in *Cercidiphyloxylon spenceri* (Pearson 1987). Ray structure is notorious for its variability, especially differences between juvenile wood and mature wood. Nonetheless, we consider the Nut Beds *Cercidiphyllum* distinct from the European *Cercidiphyllum*-like woods, which do not have alternating uniseriate and multiseriate parts. The Chinese sample does, but the parts are not of equal width. Helical thickenings in vessel element tails were not reported for the European or Chinese woods. Admittedly, the preservation of those specimens does not appear to be as good as the Oregon specimens, so helical thickenings might have been difficult to observe.

Remarks. Leaves and fruits with features unique to *Cercidiphyllum* are not known prior to the Oligocene, although extinct genera attributed to the family are widespread in the Paleocene and Eocene (e.g., Crane and Stockey 1985). This was a major part of the rationale Sakala and Privé-Gill (2004) used for assigning the Nut Beds and London Clay *Cercidiphyllum*-like woods to *Cercidiphyloxylon*, i.e., these Eocene woods predate the occurrence of "real" *Cercidiphyllum*. However, the Oligocene *Cercidiphyllum*-like woods, which are of an age when there is "real" *Cercidiphyllum* also were placed in *Cercidiphyloxylon*. It is a matter of opinion, but we do not think there are significant anatomical differences between the Paleocene, Eocene, or Oligocene *Cercidiphyllum*-like woods and present-day *Cercidiphyllum* and do not think it necessary to assign the Paleogene woods to *Cercidiphyloxylon* rather than *Cercidiphyllum*. This "disconnect" between fossil woods resembling the present-day *Cercidiphyllum* and fruits that do not may be an example of mosaic evolution within the Cercidiphyllaceae.

Co-occurring fruits/seeds. By "real" *Cercidiphyllum*, we refer to occurrences of fruits with follicles borne in sessile clusters, in association with leaves closely resembling those of extant *Cercidiphyllum japonicum*. Such fossils occur only a few km from the UF 279 wood locality, but in everlasting strata considered to be lower Oligocene (Meyer and Manchester 1997). Brown (1935) used a broader concept of the genus *Cercidiphyllum*, incorporating fossil infructescences with fruits borne in racemes rather than clusters, associated with *Trochodendroides*. Today such infructescences are usually placed in the extinct genus *Jenkinsella* et al. (2014).
Repository. Paleobotany Collections, Florida Museum of Natural History, Gainesville, Florida, USA.

Etymology. Named for William W. Dodge IV, who made sure paleoxylotomy in North Carolina was alive and well during the Covid-19 pandemic.

Type locality. UF 279. About 3 km east of Post, Crook County, Oregon, USA.

Type stratum and age. John Day Formation, Eocene.


Description. Growth rings distinct, marked by radially narrow fibers, and differences between latewood and earlywood vessels of subsequent rings (latewood vessels are narrower and not as crowded as earlywood vessels) (Text-fig. 4a, b). Diffuse-porous to semi-ring-porous (Text-fig. 4a).
Vessels mostly solitary, but also occasional radial, oblique and tangential pairs; average earlywood tangential diameter 55 (11), range 39–79 µm; vessel frequency in first half of growth ring ca. 90/mm²; perforations simple and scalariform with 4-24 bars, mostly 8–12 bars (Text-fig. 4d, e); intervessel pits opposite (5–7 µm), transitional to scalariform (Text-fig. 4c); pits to ray parenchyma oval to horizontally elongate, with reduced borders (Text-fig. 4f); vessel element lengths 450–520 µm.

Non-septate fibers with distinctly bordered pits on radial walls.

Axial parenchyma apotracheal, diffuse as isolated cells and diffuse-in-aggregates as short uniseriate bands, more easily seen in latewood (Text-fig. 4a).

Rays uniseriate and multiserial, tending to be of two sizes, with rays 1–5(–6)-seriate common, and wider multiserial rays to 18–20-seriate, with few intermediate widths; wide rays irregularly spaced (Text-fig. 4g, h); average multiserial ray height 1.56 mm, range 0.74–2.69 mm; homocellular to heterocellular, body composed of procumbent cells usually with 1–4 (up to 8) marginal rows of square and upright cells.

Solitary rhomboidal crystals occasional in procumbent ray cells. Storied structure absent.

Comparisons with extant woods. The following combination of features indicates affinities with Fagus (Fagaceae): distinct growth rings (1p), simple and scalariform perforation plates (13p 14p), opposite intervessel pitting (21p), vessel-ray parenchyma pits with reduced borders (30a), narrow numerous vessels (42a 43a 46a 47a), non-septate fibers with distinctly bordered pits on radial walls (62p 66p), diffuse and diffuse-in-aggregates ray parenchyma pits with reduced borders, often vertically elongate, while Platanus; pitting. Spacing of and size of the wide rays is more easily seen in latewood (Text-fig. 4a).

There are differences between Fagus dodgei and the mid-Miocene Fagus mancosii E.A.WHEELEr et T.A.DILLHOFF from Washington State, USA (Wheeler and Dillhoff 2009), which had more scalariform intervessel pits and larger opposite intervessel pits, narrower and shorter rays (to 16-seriate and 1.7 mm high), less axial parenchyma, and lacked crystals. Thus, although there is no reliable way to distinguish between extant species of Fagus, we are choosing to recognize Fagus dodgei as a new species to emphasize that it differs from the mid-Miocene Vantage Fagus wood.

Remarks. Denk and Grimm (2009) proposed that Fagus evolved in the Northern Pacific Region. Fossil species of Fagus, based on fruits and leaves, are known from the Paleogene of the Pacific Northwest. The middle Eocene Fagus langevinii MANCHESTER et R.M.DILLHOFF from McAbee, British Columbia, and Republic, Washington, differs from the early Oligocene Fagus pacifica R.W.CHANEY from the Bridge Creek flora of Oregon (Manchester and Dillhoff 2004).

Co-occurring fruits. A single silicified Fagus nut was recovered from the same locality, UF 279 (Manchester and McIntosh 2007).


Lithocarpoxylon ashwillii sp. nov.

Text-fig. 5a–g

Holotype. Designated here. UF 279-24559 (Text-fig. 5a–g).

Plant Fossil Names Registry Number. PFN 002680 (for new species).

Repository. Paleobotany Collections, Florida Museum of Natural History, Gainesville, Florida, USA.

Type locality. UF 279. About 3 km east of Post, Crook County, Oregon, USA.

Type stratum and age. John Day Formation, Eocene.

Etymology. Named for Melvin Ashwill, who alerted S. R. Manchester to these woods.


Description. Minimum estimated diameter of 30 cm.

Growth rings distinct. Semi-ring-porous.

Vessels in diagonal to radial alignment; exclusively solitary, round to oval in outline (Text-fig. 5a, b), mean tangential diameter of the earlywood vessels (first three rows) 208 (28)–215 (39) µm, 160–260 µm. Simple perforation...
Text-fig. 5. *Lithocarpoxylon ashwillii* sp. nov., UF 279-24544. a, b: Semi-ring porous wood, exclusively solitary vessels in a radial/diagonal arrangement, diffuse axial parenchyma, TS. c: Homocellular rays composed of procumbent cells; vasicentric tracheids; vessel elements with simple perforation plates (PP), TLS. d: Vessel-ray parenchyma pits (VRP) with reduced borders, vertical, RLS. e: Crystalliferous axial parenchyma strand (C) with a single crystal per chamber; ray with procumbent cells, RLS. f: Aggregate ray (right) composed of loosely associated 1–2-seriate rays, TLS. g: Uniseriate rays, thin-walled tyloses in vessels, vasicentric tracheids (VT). *Lithocarpoxylon* sp., UF 279-84864. h, i: Semi-ring porous wood, exclusively solitary vessels in radial arrangement. j: Aggregate ray and uniseriate rays. k: Scalariform perforation plate with fewer than 10 bars. l: Vessel-ray parenchyma pits with reduced borders to simple, vertical. Scale bars: 200 μm in a, b, f, h, j; 100 μm in c, i; 50 μm in d, e; 20 μm in k, l.
plates (Text-fig. 5c, d), end walls of vessel elements usually horizontal (Text-fig. 5g). Vessel-ray parenchyma pits with reduced borders and commonly vertically elongated (Text-fig. 5d). Thin-walled tyloses common in wider vessels.

Non-septate fibers of medium wall thickness. Some with small (ca. 3 µm) bordered pits on radial walls. Vasicentric tracheids present (Text-fig. 5c, g).

Axial parenchyma apotracheal diffuse, diffuse-in-aggregates, and in 1-seriate lines (Text-fig. 5a, b), 4–8 cells per strand.

Rays uniseriate (Text-fig. 5f, g), homocellular composed of procumbent cells and heterocellular with some square and upright cells; upright and square cells more common in region of vessels. Some loosely aggregate rays composed of 1–2(-3)-seriate rays (Text-fig. 5f). Rays 2–15–47 cells high; uniseriate rays 12–15–18/mm.

Solitary prismatic crystals occasional in chambered axial parenchyma, 1 crystal per chamber, number of chambers 2–10 (Text-fig. 5e).

Comparisons with extant woods. The affinities of this wood are clearly with the Fagaceae because of the combination of semi-ring-porosity (4p), exclusively solitary vessels that are in a radial to diagonal arrangement (7p 9p), vertical vessel-ray parenchyma pits with reduced borders (32p), vasicentric tracheids (60p), and aggregate rays (7p 9p), vertical vessel-ray parenchyma pits with reduced borders and commonly vertically elongated (Text-fig. 5l). Thin-walled tyloses common.

Axial parenchyma apotracheal diffuse, diffuse-in-aggregates (Text-fig. 5h–l), 4–8 cells per strand.

Vasicentric tracheids present (Text-fig. 5j, l).

Rays uniseriate and aggregate (Text-fig. 5j), homocellular composed of procumbent cells. Aggregate rays composed of 1–8-seriate rays, loosely associated (Text-fig. 5j). Uniseriate rays 3–11–16 cells high; uniseriate rays > 12 per mm.

Crystals not observed.

Comparisons with extant woods. The rationale for assigning this sample to Lithocarpoxylon is the same as that for UF 279-24559 described above. This sample differs in having more frequent aggregate rays composed of wider individual rays and narrower vessels.

Comparisons with fossil woods. Most other species of Lithocarpoxylon, with the notable exception of Lithocarpoxylon microporosum Y.M.CHENG, Y.F.WANG, F.X.LIU, R.C.MEHROTRA, X. M.JIANG, C.S.LI et Y.G.JIN from the Pliocene of Yunnan, China (Cheng et al. 2018), have wider vessels than this Post Hammer wood; most also have rays greater than 10 cells wide or compound rays. For now, we are hesitant to assign this wood to a new species based on differences in quantitative features.

Genus Quercus L., 1753
Quercus sp. Red oak group
Text fig. 6a–g

Material. UF 279-24550.

Description. Growth rings distinct. Ring-porous to semi-ring-porous.

Vessels exclusively solitary, latewood vessels in diagonal to radial alignment (Text-fig. 6a, b), round to occasionally oval in outline, mean tangential diameter of earlywood vessels 199 (28), 124–244 µm; perforations simple (Text-fig. 6e); vessel-vasicentric pits alternate, rounded in outline (Text-fig. 6d), 9–10 µm; vessel-ray parenchyma pits with reduced borders, horizontally to vertically elongate, variable (Text-fig. 6e); vessel element lengths 275–325 µm. Thin-walled tyloses present.
Imperforate tracheary elements include vasicentric tracheids (Text-fig. 6d), and non-septate fibers with thick walls.

Axial parenchyma apotracheal, relatively abundant, diffuse, diffuse-in-aggregates, and in 1-seriate lines (Text-fig. 6a, b); strands of 4 cells.

Rays of two distinct sizes (Text-fig. 6a, b, c), uniseriate (rarely with biseriate portions) (Text-fig. 6f) and wide rays 38–62 cells wide, 0.49–1.1 mm; some wide rays with areas of cells of differing wall thicknesses and some with imperforate elements, probably beginning of ray dissection; homocellular, composed of procumbent cells (Text-fig. 6g); uniseriate rays 2–7–15 cells high; numerous 8–12–14 per mm.

Crystals occasional in chambered axial parenchyma strand, usually less than 4-chambers.

Comparisons with extant woods. This wood has features of the Castaneioideae (e.g., Wheeler et al. 2022): vessels exclusively solitary in radial/diagonal, vasicentric tracheids, vessel-ray parenchyma pits with reduced borders, homocellular rays of two distinct sizes, apotracheal parenchyma. Because the latewood vessels are rounded in outline, this wood is assigned to the Red Oak group, Quercus sect. Lobatae Loudon; latewood vessels in the White Oak group are angular in outline (e.g., Brazier and Franklin 1961, Panshin and DeZeeuw 1980). Distinguishing species in the Red Oak Group based on wood anatomy is not feasible, so we are only designating it as Quercus sp. Red Oak Group.

Comparisons with other fossil woods. This ring-porous to semi-ring-porous wood differs from the Nut Beds Quercinium crystallifera R.A.Scott et
E.A.Wheeler, which is diffuse to semi-ring-porous. Other differences are that UF 279-24550 has exceptionally wide rays, its rays are not typically aggregate, and crystals are not common. Reports of fossil oak woods are quite common in the literature, with different species reflecting differences in age and locality as much as differences in anatomy (e.g., Müller-Stoll and Mädel 1957, Suzuki and Ohba 1991).


coccurring fruits. Manchester and McIntosh (2007) illustrated an oblate nut covered in whorls of scales and preserved as a silica cast lacking internal anatomy from locality UF 279 (figs 37–39) that was interpreted as representing an acorn of Quercus with the nut fully enclosed by the cupule.

Family Hamamelidaceae R. Br., 1818 nom. cons.

Genus Hamamelidoxylon Lign., 1907

Hamamelidoxylon crystalliferum sp. nov.

Text-fig. 7a–i

Holotype. Designated here. UF 279-34464 (Text-fig. 7a–i). Minimum estimated axis diameter 15 cm.

Paratype. UF 279-24555 (minimum estimated diameter 30 cm).

Plant Fossil Names Registry Number. PFN002681 (for new species).

Repository. Paleobotany Collections, Florida Museum of Natural History, Gainesville, Florida, USA.

Type locality. UF 279. About 3 km east of Post, Crook County, Oregon, USA.

Type stratum and age. John Day Formation, Eocene.

Etymology. Named for crystals in this wood.


Description. Growth rings boundaries distinct to indistinct, marked by a few rows of radially narrow fibers, with latest latewood vessels narrower than the first earlywood vessels (Text-fig. 7a, b). Wood diffuse-porous.

Vessels predominantly solitary, angular in outline (Text-fig. 7a, b), mean tangential diameter 43 (8)–47 (6); 104–149 mm²; perforations all scalariform, 11–15 bars (Text-fig. 7e); intervessel pits scalariform (Text-fig. 7c); vessel-ray parenchyma pits horizontally elongated (Text-fig. 7f); vessel element lengths 690–950 µm.

Fibers non-septate, medium-thick to thick walled; distinctly bordered pits on radial walls and tangential walls (Text-fig. 7c, f). Axial parenchyma rare.

Rays 1–2(–3)-seriate, heterocellular, uniseriate and biseriate portions occasionally alternating, but not commonly (Text-fig. 7f, g); width of uniseriate portions usually not the same as the biseriate portions; uniseriate rays composed of upright cells, biseriate portions of rays composed of procumbent cells, with uniseriate portions of 1–4 (or more) rows of upright cells, upright cells at least 4× higher than the procumbent cells (Text-fig. 7h).

Solitary crystals occasional in chambered (2–3) upright ray cells, crystalliferous cells usually inflated (Text-fig. 7i).

Comparisons with extant woods. In InsideWood, the combination of diffuse-porous woods (5p), narrow, numerous vessels (42a 43a 47a 48a) that are predominantly solitary (9p), exclusively scalariform perforation plates (13a 14p), scalariform intervessel pits (20p), vessel-ray parenchyma pits horizontally elongate with reduced borders (32p), axial parenchyma rare (75p), fibers with distinctly bordered pits (62p), heterocellular 1–2-seriate rays (97p 104a 105a), and crystals in chambered upright ray cells (140p) is unique to the Hamamelidaceae, occurring in Corylosis, Eustigma GARDNER et CHAMP., Sinowilsonia HEMSL. (subfamily Hamamelidoidiaceae), and Mytilaria Lecomte (subfamily Mytilarioidae). Of these, Sinowilsonia is the most similar because of its lower number of bars per perforation plate (<20) compared to the three other genera.

The anatomy of extant Hamamelidaceae has been reviewed by Tang (1943), Skvortsova (1975), and Wheeler et al. (2010). The growth ring boundaries resemble those seen in evergreen Asian species of the family (e.g., Chunya H.T.CHANG, Exbucklandia R.W.BR.) more than those of deciduous species.

Comparisons with fossil woods. Lignier's (1907) diagnosis of the genus Hamamelidoxylon includes these features: rays numerous, rays uniseriate, rarely biseriate, vessels predominantly solitary, scalariform perforation plates, axial parenchyma rare. His plate XX (line drawings of H. renauldi LIGN.) shows a perforation plate with over 25 bars, horizontally elongate vessel-ray parenchyma pitting, ray cell walls with abundant pitting as seen in radial sections, and thick-walled fibers. Subsequently, woods with rays 1–2(–3) cells wide were assigned to the genus, e.g., the European species: H. castellanense GRAMBAST-FESSARD (Grambast-Fessard 1969), H. daphniphylloides H.GOTTwald (Gottwald 1992), and H. renanum BURGHI (van der Burgh 1973). The genus has been used for woods that have characteristics of the family, but not necessarily of the genus Hamamelis L.

Three species of Hamamelidoxylon have been described from the Pacific Northwest of North America: H. uniseriatum E.A.WHEELE et MANCHESTER from the middle Eocene Clarno Formation (Wheeler and Manchester 2002, 2014) whose characteristics best fit the tribe Exbucklandiidae, and H. beckii E.A.WHEELER et T.A.DILLHOFF and H. suzukii E.A.WHEELER et T.A.DILLHOFF from the middle Miocene Vantage Forests, Washington (Wheeler and Dillhoff 2009). Table 2 compares H. crystalliferum to them and to the European and Asian Hamamelidoxylon species that have reasonably complete descriptions. The data in the table show that H. crystalliferum’s combination of 15 or fewer bars per perforation plate, rays 1–2(–3) cells wide, and crystals in...
Text-fig. 7. *Hamamelidoxylon crystalliferum* sp. nov., UF 279-34464. a: Diffuse porous wood with exclusively solitary vessels, tending to be angular in outline, TS. b: Growth ring boundary, marked by radially narrowed fibers, latewood vessels narrower than earlywood vessels of the next ring, fibers thick-walled, no axial parenchyma visible, TS. c: Scalariform intervessel pits in narrow vessel (left), fibers with distinctly bordered pits, TLS. d: Scalariform perforation plate, tyloses (T) formation from marginal ray cell, TLS. e: Scalariform perforation plates with fewer than 15 bars (PP), RLS. f: Vessel-ray parenchyma pits with
chambered upright ray cells does not match any of the other species and indicates it is appropriate to create a new species.

*Liquidambaroxylon* and all Altingiaceae never possess crystals in chambered upright ray cells.

Co-occurring fruits/seeds. The fossil genus *Fortunearites* **Manchester**, known from infructescence in the middle Eocene Clarno Nut Beds, Oregon, has a combination of characters found only in *Fortunaria* and *Sinowilsonia* (Manchester 1994, Manchester et al. 2009). It is possible that these two late Eocene wood samples might be related to the plant that produced *Fortunearites*. However, present-day *Fortunaria* wood has banded axial parenchyma, so is distinct from *Sinowilsonia* and these Post Hammer woods.

### Table 2. Comparison of *Hamamelidoxylon* species. Arranged by age, oldest to youngest. GR = Growth ring boundaries, I = indistinct, D = distinct; VTD = vessel tangential diameter in µm, standard deviation in parentheses when known; V/mm² = vessels per mm²; Bars/PP = number of bars per perforation plate; RW = ray width in cell number; Cry = crystals, Rch = crystals in chambered square / upright cells, K = Cretaceous, Pal = Paleocene, Eo = Eocene, Mio = Miocene, e = early, m = middle, l = late; OR = Oregon, WA = Washington.

<table>
<thead>
<tr>
<th>Taxon (Reference)</th>
<th>GR</th>
<th>VTD (µm)</th>
<th>V/mm²</th>
<th>Bars/PP</th>
<th>RW</th>
<th>Cry</th>
<th>Age</th>
<th>Locality</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Hamamelidoxylon crystalliferum</em> sp. nov. (UF 279-24555) (this paper)</td>
<td>D/I</td>
<td>47 (6)</td>
<td>122–149</td>
<td>11–15</td>
<td>1–3</td>
<td>Rch, I</td>
<td>I Eo</td>
<td>OR, USA</td>
</tr>
<tr>
<td><em>Hamamelidoxylon crystalliferum</em> sp. nov. (UF 279-34464) (this paper)</td>
<td>D/I</td>
<td>43 (8)</td>
<td>104–131</td>
<td>11–15</td>
<td>1–2(–3)</td>
<td>Rch, I</td>
<td>I Eo</td>
<td>OR, USA</td>
</tr>
<tr>
<td><em>Hamamelidoxylon cf. suzukii</em> (UF 279-34465) (this paper)</td>
<td>D</td>
<td>58 (11)</td>
<td>85–117</td>
<td>18–32</td>
<td>1–2(–3)</td>
<td>R</td>
<td>I Eo</td>
<td>OR, USA</td>
</tr>
<tr>
<td><em>H. obirensis</em> (1)</td>
<td>D</td>
<td>52</td>
<td>83–120</td>
<td>22–56</td>
<td>1(–2)</td>
<td>no</td>
<td>I K</td>
<td>Japan</td>
</tr>
<tr>
<td><em>H. uniseriatum</em> (2)</td>
<td>D</td>
<td>58 (13)</td>
<td>72–133</td>
<td>24–40</td>
<td>1(–2)</td>
<td>no</td>
<td>m Eo</td>
<td>OR, USA</td>
</tr>
<tr>
<td>cf. <em>H. uniseriatum</em> (3)</td>
<td>D</td>
<td>55 (11)</td>
<td>50–82</td>
<td>20–36</td>
<td>1</td>
<td>no</td>
<td>m Eo</td>
<td>OR, USA</td>
</tr>
<tr>
<td><em>H. daphniphyllioides</em> (4)</td>
<td>D</td>
<td>45</td>
<td>?</td>
<td>30–58</td>
<td>1–2(–3)</td>
<td>no</td>
<td>Eo</td>
<td>Germany</td>
</tr>
<tr>
<td><em>H. renaultii</em> (5, 6)</td>
<td>D</td>
<td>36</td>
<td>119–200</td>
<td>32</td>
<td>1(–2)</td>
<td>no</td>
<td>Mio, Pal/Eo</td>
<td>France, UK</td>
</tr>
<tr>
<td><em>H. beckii</em> (7)</td>
<td>D/I</td>
<td>54 (7)</td>
<td>77–94</td>
<td>14–24</td>
<td>1(–2)</td>
<td>R</td>
<td>Mio</td>
<td>WA, USA</td>
</tr>
<tr>
<td><em>H. suzukii</em> (7)</td>
<td>D</td>
<td>53 (7)</td>
<td>60–86</td>
<td>16–27</td>
<td>1–2</td>
<td>R</td>
<td>m Mio</td>
<td>WA, USA</td>
</tr>
<tr>
<td><em>H. rhenanum</em> (8)</td>
<td>D</td>
<td>30–50 µm</td>
<td>?</td>
<td>20–25</td>
<td>1–2(–3)</td>
<td>no</td>
<td>Mio</td>
<td>Germany</td>
</tr>
<tr>
<td><em>H. castellanense</em> (9)</td>
<td>D</td>
<td>40–60</td>
<td>80–100</td>
<td>ca. 16–20</td>
<td>1–2(–3)</td>
<td>Rch, I</td>
<td>Mio</td>
<td>France</td>
</tr>
</tbody>
</table>


Fibers non-septate, thick walled; distinctly bordered pits on radial walls and tangential walls (Text-fig. 7k, m, n).

Axial parenchyma rare, diffuse (Text-fig. 7k).

Rays 1–2(–3)-seriate (Text-fig. 7m), heterocellular (Text-fig. 7n); ray body composed of procumbent cells, with marginal rows of square cells, (Text-fig. 7n).

Solitary crystals occasional in upright/square ray cells (Text-fig. 7n).

Comparisons with extant woods. The combination of features used to search InsideWood for this sample’s affinities was similar to that used for the sample designated *Hamamelidoxylon crystalliferum*, except that we used crystals in upright/square ray parenchyma cells (137p) as a search criterion, not crystals in chambered upright ray parenchyma cells (140p). Results of this search returned Hamamelidaceae (*Corylopsis, Mytilaria, Sinowilsonia*), Altingiaceae (*Liquidambar*), and Cercidiphyllaceae. As we did for *Cercidiphyllum*, we used the work of Sakala and Privé-Gill (2004) on distinguishing between these families, and, in this case, conclude that this wood has affinities with the Hamamelidaceae.

Comparisons with fossil woods. Table 2 compares features of the *Hamamelidoxylon* species with relatively complete descriptions. Although there are differences in quantitative features (higher vessel frequency, rays more frequently 3-seriate), we suggest this late Eocene wood is similar to *Hamamelidoxylon suzukii* (Wheeler and Dillhoff 2009) from the middle Miocene, Ginkgo Petrified Forest State Park, Washington, USA.

Reduced borders and horizontally elongate, RLS: g: Rays 1–2-seriate, TLS: h: Upright cells approximately 4× higher than procumbent cells, RLS: i: Inflated chambered crystalliferous ray cell, RLS: *Hamamelidoxylon cf. suzukii*, UF 279-34465, j, l: Diffuse-porous wood with exclusively solitary vessels, angular in outline, thick-walled fibers, axial parenchyma not common, apotracheal diffuse, TS: l: Scalariform perforation plate with >20 bars, RLS: m: Rays mostly 2–3-seriate, TLS: n: Rays with procumbent body cells and square marginal cells. Scale bars: 200 µm in a, j; 100 µm in g, m, n; 50 µm in b, c, d, e, g, h, I, k, l; 20 µm in f.
Family Juglandaceae DC. ex Perleb, 1818 nom. cons.

Genus *Pterocaryoxylon* sensu Müller-Stoll and Mädel (1960)

*Pterocaryoxylon* sp.

Text-fig. 8a–f

Material. UF 279-24551 (minimum estimated diameter 11.8 cm), UF 279-24557 (minimum estimated diameter 13 cm), UF-85024.

Description. Growth rings present, marked by radially flattened fibers and differences in latewood and earlywood vessel diameters of successive growth rings (Text-fig. 8a, b). Semi-ring-porous.

Vessels solitary and in radial multiples of 2, average tangential diameter of earlywood 206 (28) µm, range 124–294 µm; perforations simple, intervessel pits alternate (Text-fig. 8c), ca. 7 µm; vessel-axial parenchyma pits similar to intervessel pits (Text-fig. 8d); vessel element lengths averages 460 (73)–486 (88) µm; thin-walled tyloses occasional.

Fibers non-septate, thin-walled, pits not observed.

Axial parenchyma scanty paratracheal to vasicentric, marginal, and in narrow lines through the growth ring, lines more closely spaced in the latewood than in the earlywood (Text-fig. 8a, b); strands usually of eight cells.

Rays 1–3(4)-seriate (Text-fig. 8e). Multiseriate rays heterocellular, with procumbent body cells and usually with 1–2 marginal rows of square to upright cells; uniseriate rays composed of mostly upright cells (Text-fig. 8f), total multiseriate ray height averages 382 (91) µm, range 225–625 µm. 10–12/mm.

Text-fig. 8. *Pterocaryoxylon* sp., a–c, e: UF 279-85024; d, f: UF 279-24551. a, b: Wood semi-ring-porous, vessels solitary and in short radial multiples, axial parenchyma scanty vasicentric, marginal, and in narrow lines, TS. c: Crowded alternate intervessel pitting, simple perforation plate (PP), TLS. d: Vessel-axial parenchyma pitting similar to intervessel pitting, RLS. e: Rays mostly 1–3 cells wide, occasionally 4 cells, uniseriate rays probably mostly square to upright cells, TLS. f: Rays heterocellular, body cells procumbent. Scale bars: 200 µm in a, b; 100 µm in e, f; 50 µm in c; 20 µm in d.
Crystals not observed. Storied structure absent.

Remarks. These Juglandaceae woods were compressed and contorted, especially their earlywood. For measuring vessel diameters, we selected vessels that were oval to circular in outline and that we considered to be close to their original outline in the living tree.

Comparisons with extant woods. Affinities with Juglandaceae are indicated by the combination of semi-ring-porosity, vessels solitary and in short radial multiples, narrow continuous lines of axial parenchyma, medium-sized alternate intervessel pits, vessel-ray parenchyma pits similar in size to intervessel pits. Because these woods have exclusively simple perforations and lack crystals, they are most similar to *Pterocarya Kunth* and the butternut group of *Juglans* L. (Asian species of Section Cardiocaryon, and the American *J. cinerea L.*, traditionally placed in section *Trachycaryon*). Phylogenetic analyses confirm a close relationship between *Pterocarya* and *Juglans* (Stanford et al. 2000, Manos et al. 2007). Sometimes *Pterocarya* woods can be distinguished from the butternuts because latewood vessels in *Pterocarya* can be in a pronounced diagonal pattern (Müller-Stoll and Mädel 1960, Miller 1976, Wheeler et al. 1978). A difference between these Post Hammer woods and woods of extant *Pterocarya* and the *Juglans* butternut group is that rays in the recent woods typically are homocellular with all procumbent cells. However, some extant juglandaceous species have heterocellular rays. These western North America *Pterocarya* are the oldest known species of the genus. *Pterocarya* and *Pterocarya* have been reported from the Miocene-Pliocene of central and eastern Asia (e.g., Rajput and Khan 1982, Choi et al. 2010, Cheng et al. 2018), and Europe (e.g., Müller-Stoll and Mädel 1960, Privé 1974, Dupérón 1988). Müller-Stoll and Mädel (1960) cited another character of the type species *Pterocarya* not strictly a wood character, but useful to confirm affinity with the *Pterocarya*-Juglans-Cyclocarya group and distinguishing it from all other extant genera of the Juglandaceae: septate pith. The center of the stem is not known for these Eocene species.

The two juglandaceous woods of the nearby older middle Eocene Nut Beds, Oregon, differ: *Clarnoxylon blandichardi* Manchester et E.A. Wheeler (which has solid pith rather than septate) has prismatic crystals commonly occurring in enlarged ray parenchyma cells; *Engelhardioxylon nutbedensis* Manchester has both simple and scalariform perforation plates and prismatic crystals in ray parenchyma (Wheeler and Manchester 2002).

Co-occurring fruits/ seeds. The bi-winged fruits of *Pterocarya* have not been confirmed prior to the Oligocene. However, the extinct 4-winged genus *Cruciptera* known from the middle to late Eocene of Oregon (Manchester 1991), the early middle Eocene of Yellowstone (pers. obs.), and middle Eocene of Germany (Manchester et al. 1994), seems to have been rather common. We speculate that *Cruciptera* may have been produced on trees with wood similar to that of *Pterocarya*, and it may have corresponded to *Pterocarya*.

**Family Malvaceae Juss., 1789 nom. cons.**

*Genus Wataria K.Terada et Mits.Suzuki, 1998*

*Wataria kvacekii* sp. nov.

Text-fig. 9a–h

Holotype. Here designated. UF 279-24546 (Text-fig. 9a–h).

*Plant Fossil Names Registry Number. PPFN002682* (for new species).

Repository. Paleobotany Collections, Florida Museum of Natural History, Gainesville, Florida, USA.

Etymology. Species name to honor Zlatko Kvaček, a kind man, who was and will continue to be an inspiration for those who study Tertiary floras.

Type locality. UF 279. About 3 km east of Post, Crook County, Oregon, USA.

---

Table 3. Comparison of *Pterocaryoxylon knowltonii* and UF 279 *Pterocaryoxylon* sp. EW VTD = earlywood vessel tangential diameter in µm; LW = latewood; IV = intervessel; VE = vessel element length.

<table>
<thead>
<tr>
<th>Feature</th>
<th><em>Pterocaryoxylon knowltonii</em></th>
<th>UF 279 <em>Pterocaryoxylon</em> sp.</th>
</tr>
</thead>
<tbody>
<tr>
<td>EW VTD (µm)</td>
<td>160-215-310</td>
<td>124-206-294</td>
</tr>
<tr>
<td>LW vessel arrangement</td>
<td>Diagonal</td>
<td>Tending to diagonal</td>
</tr>
<tr>
<td>IV pit size (µm)</td>
<td>10–12</td>
<td>ca. 7</td>
</tr>
<tr>
<td>VE length (µm)</td>
<td>460–850 (range)</td>
<td>460 (73) – 486 (88)</td>
</tr>
<tr>
<td>Ray width (cell number)</td>
<td>1–3</td>
<td>1–3(–4)</td>
</tr>
<tr>
<td>Ray height (µm)</td>
<td>155–315 (range)</td>
<td>222-382-625</td>
</tr>
</tbody>
</table>
Type stratum and age. John Day Formation, Eocene.

Diagnosis. Wood ring-porous. Earlywood zone with more than 1 row of earlywood vessels. Vessels solitary and in short radial multiples. Perforation plates exclusively simple. Intervessel pits alternate, small; vessel-ray parenchyma pits similar to intervessel pits. Vessel elements and imperforate elements regularly or irregularly storied. Axial parenchyma scanty paratracheal to vasicentric and diffuse-in-aggregates. Rays typically less than 10-seriate; heterocellular; commonly >1 mm high. Tile cells present, Pterospermum-type.

Description. Growth rings present, marked by radially flattened fibers, and differences in diameters of latewood and earlywood vessels of subsequent rings (Text-fig. 9a). Wood distinctly ring-porous, earlywood pore zone usually 3 vessels deep.

Vessels predominantly solitary and in occasional radial multiples of 2 in both earlywood and latewood (Text-fig. 9a); average tangential diameter of earlywood vessels 143 (33) µm; perforations simple (Text-fig. 9b); intervessel pits alternate (Text-fig. 9c), 3–5 µm in horizontal diameter; vessel-parenchyma pits similar to intervessel pits (Text-fig. 9d); vessel element length averages 346 (26), range 310–410 µm; widely spaced thin-walled tyloses present; helical thickenings not observed. Fibers thin to medium-thick-walled, storied, without distinctly bordered pits; non-septate, tending to be storied structure (Text-fig. 9e, h).

Axial parenchyma scanty paratracheal to vasicentric, (diffuse-) diffuse-in-aggregates, strands of 4–8 (Text-fig. 9a).
Table 4. Comparison of Wataria species and Triplochitioxylon. EW VTD = earlywood vessel tangential diameter in µm; EW row = number of rows of wide earlywood vessels; IVP = horizontal diameter of intervessel pits in µm; VEL = vessel element lengths in µm; RW = width in cell number; R Ht = ray height in µm; Cry = Crystal location, APc = chambered axial parenchyma, R = ray parenchyma; Eo = Eocene, Ol = Oligocene, Mio = Miocene, e = early, m = middle, l = late; OR = Oregon.

<table>
<thead>
<tr>
<th>Taxon (Reference)</th>
<th>EW VTD</th>
<th>EW row</th>
<th>IVP</th>
<th>VEL (µm)</th>
<th>RW</th>
<th>R Ht (µm)</th>
<th>Cry</th>
<th>Age, Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wataria kvacekii sp. nov. (this paper)</td>
<td>143</td>
<td>(1–)2–3</td>
<td>3–5</td>
<td>310-346-410</td>
<td>1–6</td>
<td>320-1075-2600</td>
<td>APc</td>
<td>Eo, OR, USA</td>
</tr>
<tr>
<td>Wataria miocenica (1, 2)</td>
<td>257–294</td>
<td>(1–)2–3</td>
<td>2–4</td>
<td>70-234-350</td>
<td>1–10–12</td>
<td>621-870, 1280*</td>
<td>APc, R</td>
<td>Mio, Japan</td>
</tr>
<tr>
<td>Wataria miocenica (3)</td>
<td>252</td>
<td>1–3</td>
<td>?</td>
<td>200-257-345</td>
<td>est. to 8</td>
<td>140-985-1900</td>
<td>Mio, Korea</td>
<td></td>
</tr>
<tr>
<td>Wataria oligocenica (2)</td>
<td>210</td>
<td>3–5</td>
<td>ca. 3</td>
<td>75-219-325</td>
<td>1–10+</td>
<td>200-688-1000</td>
<td>APc, Ol, Japan</td>
<td></td>
</tr>
<tr>
<td>Wataria parvipora (2)</td>
<td>150–181</td>
<td>1–2(–3)</td>
<td>ca. 5</td>
<td>65-185-290</td>
<td>(1–)5–5(–7)</td>
<td>550-803-1200</td>
<td>R</td>
<td>Mio, Japan</td>
</tr>
<tr>
<td>Wataria parvipora (3)</td>
<td>181</td>
<td>1–2(–3)</td>
<td>?</td>
<td>125-178-250</td>
<td>1–7</td>
<td>120-558-900</td>
<td>R</td>
<td>Mio, Korea</td>
</tr>
<tr>
<td>Wataria yunnanica (4)</td>
<td>270</td>
<td>1 (–2–3)</td>
<td>ca. 3</td>
<td>144-280-569</td>
<td>1–12</td>
<td>193-873-2037</td>
<td>APc, R</td>
<td>Mio, China</td>
</tr>
<tr>
<td>Triplochitioxylon oregonense (5)</td>
<td>185</td>
<td>n/a</td>
<td>3–5</td>
<td>400-440-600</td>
<td>(1–)4–6(–10)</td>
<td>?-1267-2100</td>
<td>R</td>
<td>Mio, OR, USA</td>
</tr>
</tbody>
</table>


* mean ray heights

fig. 9a, b), also chambered with solitary prismatic crystals (Text-fig. 9e, f). Rays 1–6-seriate (Text-fig. 9e).

Multiseriate rays heterocellular with uniseriate rows of 1–3 cells; Pterospermum-type tile cells present; (Text-fig. 9f, g) some rays the same height as the vessel elements and axial parenchyma strands, most rays extending over multiple tiers of the storied parenchyma. Total multiseriate ray height averages 1.075 (634) µm, 320–2,600 µm. 5–8 mm.

Axial parenchyma and vessel elements storied (Text-fig. 9e).

Comparisons with extant woods. Tile cells are unique to the Malvales. A search of the InsideWood database for the combination of tile cells (111p) and ring-porosity (3p) only returned species of the present-day genera Grewia L. (Malvaceae/Grewioideae) and Reevesia Lindl. (Malvaceae/Helicteroideae), and the fossil wood genus Wataria from the Oligocene – Miocene of Asia, whose species were originally assigned to Reevesia (Terada and Suzuki 1998).

Ring-porous species of Grewia and Reevesia differ from Wataria kvacekii because their latewood vessels are in clusters.

Comparisons with fossil woods. Rodriguez-Reyes et al. (2014) reviewed the characteristics of fossil malvaceous woods and noted only two genera with distinctly ring-porous species: Reevesia and Wataria. Selmeier (2000b) described semi-ring-porous Grewioxylon with a transition from earlywood to latewood that is gradual. This Post Hammer wood generally conforms to the genus Wataria Terada et Mits.Suzuki (Terada and Suzuki 1998), diagnosed as having distinctly ring-porous woods, earlywood vessels mostly solitary with latewood vessels mostly solitary, not in clusters; perforation plates simple; alternate intervessel pitting; helical thickenings absent; storied axial parenchyma, heterocellular multiseriate rays with tile cells. To date, four species of Wataria have been described W. miocenica K. Terada et Mits.Suzuki, W. oligocenica K. Terada et Mits.Suzuki, W. parvipora K. Terada et Mits.Suzuki, and W. yunnanica Yan-Jie Li et Osoks (Tab. 4). Species have been distinguished based on number of rows of wide earlywood vessels, latewood vessel grouping, and crystal occurrence (e.g., Li et al. 2015). There also are differences in quantitative features (earlywood vessel diameter, vessel element length, axial parenchyma strand length, ray width and height). Table 4 indicates that this Wataria kvacekii’s combination of the aforementioned features differs from previously described Wataria species and so consider it a new species. Axial parenchyma is not as easy to see in the Post Wataria wood as it is in the Asian species, but as best we can determine its distribution is similar to other species.

Two types of malvaceous woods were reported from the nearby middle Eocene Nut Beds flora, Clarno Formation, Oregon, both are semi-ring-porous to diffuse-porous, without a well-defined earlywood pore zone (Manchester and Miller 1978, Manchester 1979, 1980, Wheeler and Manchester 2002). Chattawaya palliforme Manchester also differs because it lacks storied structure and its rays are wider (to 14-seriate). Although not distinctly ring-porous, Triplochitioxylon oregonensis Manchester shares many features with this Post Hammer wood: storied structure, intervessel pit size, vessel-ray parenchyma pit type, ray heights, crystals in chambered axial parenchyma. Terada and Suzuki (1998) commented on the similarities between Triplochitioxylon Manchester and Wataria. Triplochitioxylon has longer vessel elements; averages of 440–487 µm vs. average of 346 µm with a maximum of 410 µm for Wataria kvacekii. This difference likely is related to most measurements for the Post Wataria being of the barrel-shaped earlywood vessel elements. Wide earlywood vessel elements are shorter than the narrow latewood vessels (e.g., Süss 1967, Kitin et al. 1999); it’s been suggested that the widening of earlywood vessel elements in ring-porous woods results in their shortening (Chalk and Chattaway 1935). It is tempting to hypothesize that Wataria kvacekii belongs to the same lineage as Triplochitioxylon and that the differences in porosity between them are associated with the increasing seasonality in the transition from the middle Eocene to the late Eocene.

Co-occurring fruits/seeds. Malvaceae recognized from fruits from the Teater Road locality include Craigia W.W. Sm. et W.E. Evans and the extinct genus Florissantia Knowlt. (Manchester 1992: figs 34, 318
Text-fig. 10. *Platanoxylon cf. haydenii*, a, e, h: UF 279-34470; b, c, d, f, g: UF 279-34469. a, b: Diffuse porous wood with vessels solitary and in small multiples, which are mostly tangential or oblique, diffuse and diffuse-in-aggregates axial parenchyma, TS. c–e: Scalariform perforation plates. f, g: Opposite intervessel pits, TLS. h: Two size classes of rays, TLS. *Platanus* sp., UF 279-24552. i: Predominantly solitary vessels, diffuse and diffuse-in-aggregates parenchyma, growth ring boundary distinct, noded rays, TS. j: Simple perforation plates (PP), RLS. k: Body of ray with procumbent ray cells, RLS. l: Scalariform perforation plate, RLS. m: Rays of two sizes, wide rays >10-seriate, TLS. Scale bars: 200 µm in a, b, h, i, m; 100 µm in j, k: 50 µm in c, d, f, l.
35, 37–40). Extant Craigia wood is distinguished from the fossil wood treated here by its helically thickened vessel elements, wider rays (>10-seriate), and lack of storied structure (Manchester et al. 2006). Fossils of flowers and fruits with the distinctive persistent calyx of Florissantia occur in eastern Asia (Manchester 1999: fig. 7B) as well as at various localities in North America. Pollen from the anthers of Florissantia flowers is similar to that of Tilia L. and Craigia (Manchester 1992, Kvaček et al. 2005). Based on circumstantial evidence of co-occurrence, it is possible that Wataria/Triplochitoxylon trees may have borne flowers corresponding to the genus Florissantia.

**Family Platanaceae T. Lestib., 1826 nom. cons.**

**Genus Platanoxylon ANDR., 1952 emend. by Süss and Müller-Stoll (1977)**

*Platanoxylon* cf. *haydenii* (FELIX) SÜSS et MÜLL.-STOLL, 1977
Text-fig. 10a–h

**Material.** UF 279-34469; UF 279-34470, minimum estimated axis diameter 30 cm.

**Description.** Growth rings present, marked by slightly noded rays and 1–2 rows of radially narrow fibers. Wood diffuse-porous.

Vessels solitary and in short multiples, some tangentially arranged (Text-fig. 10a, b); average tangential diameter 76 (11) \( \mu \text{m} \), range 59–96 \( \mu \text{m} \); average 45/\( \text{mm}^2 \). Perforation plates exclusively scalariform, generally with fewer than 20 bars (Text-fig. 10c, d); intervessel pits opposite (Text-fig. 10f, g), vessel-ray parenchyma pits not observed.

Fibers non-septate, thick-walled.

Axial parenchyma diffuse-in-aggregates, in interrupted short uniseriate lines (Text-fig. 10a, b, f).

Rays of two distinct sizes, larger rays often >20 cells wide (Text-fig. 10a, b, h), composed of procumbent cells, sometimes with 1–2 marginal rows of square cells; multiseriate ray height averages 3.05 mm, range 1.1–5.53 mm.

**Remarks.** Although vessel-ray parenchyma pits were not observed in these samples, their other characteristics indicate they are Platanoxylon (narrow numerous vessels, some in tangential multiples (Text-fig. 10a, b); scalariform perforation plates (Text-fig. 10c, d, e); opposite intervessel pits (Text-fig. 10f, g); diffuse-in-aggregates parenchyma; tall and wide rays composed mostly of procumbent cells (Text-fig. 10h). The characteristics that distinguish them from other woods with wide rays (e.g., Fagus and Euptelea) were detailed by Scott and Wheeler (1982) and discussed earlier with reference to Fagus *dodgei*. Platanoid woods are common in the Paleogene of western North America. Woods similar to *Platanoxylon haydenii* are common in the older Clarno Formation, with multiple samples occurring at both the Nut Beds (Wheeler and Manchester 2002) and Hancock Canyon (Wheeler and Manchester 2014). These Post Hammer woods with their exclusively scalariform perforation plates are similar to other Eocene platanoid woods and differ from present-day *Platanus* woods that have both simple and scalariform perforation plates.

**Genus Platanus L., 1753**

*Platanus* sp.
Text-fig. 10i–m

**Material.** UF 279-24552, minimum estimated axis diameter 30 cm.

**Description.** Growth rings present, marked by noded rays, rows of radially narrow latewood fibers, and differences between vessel diameters between latest latewood and earliest earlywood. Wood diffuse-porous (Text-fig. 10i).

Vessels predominantly solitary, occasionally in oblique or tangential multiples; average tangential diameter 58 (9) \( \mu \text{m} \), range 42–77 \( \mu \text{m} \); 82–102 vessels/\( \text{mm}^2 \). Perforation plates predominantly simple (Text-fig. 10j), rare scalariform perforation plates with fewer than 15 bars (Text-fig. 10f, i); scalariform intervessel pits observed at ends of vessel elements, vessel-ray parenchyma pits horizontally elongated. Vessel element lengths average 499 (100) \( \mu \text{m} \), range 260–740 \( \mu \text{m} \).

Fibers non-septate, thick-walled.

Axial parenchyma diffuse, diffuse-in-aggregates, and in interrupted short uniseriate lines (Text-fig. 10i).

Rays of two distinct sizes, narrow rays 1–3-seriate (Text-fig. 10m), larger rays to 24 cells wide and 6.6 mm high; heterocellular, body of procumbent cells with 1–4 marginal rows of square to upright cells. In radial section, some ray cells appear enlarged and possibly crystalliferous (Text-fig. 10k).

**Remarks.** We place this wood in *Platanus*, rather than Platanoxylon, because it has predominantly simple perforation plates like the extant genus, in contrast with woods of Platanoxylon/Plataninium, which have exclusively or predominantly scalariform perforation plates. The horizontally elongate vessel-ray parenchyma pits are not typical of extant *Platanus* but occasionally occur in the Vietnamese species *P. kerrii* GAGNER. The occurrence of multiple types of Platanaceae woods agrees with the leaf and fruit record.

Coeval megafossils of Platanaceae from the late Eocene of Oregon include dispersed fruits with the distinctive basal tuff of hairs diagnostic of extant *Platanus* from the Teater Road locality (Manchester and Lott, pers. obs.). Also present in the region during the late Eocene are leaves of the extinct genera *Macginiteca* J.A. WOLFE et WEHR (and associated fruits of *Macginicarpa* which lack dispersal hairs, late Eocene of Gray Butte and middle Eocene Clarno Formation sites), *Platameliphyllum* N. MASLOVA (Clarno Formation sites; Hugelge et al. 2022) *Platanites* E. FORBES (John Day Gulch locality of the Clarno Formation) as well as extant *Platanus* leaves (Clarno Formation sites).

**Family Sapindaceae Juss., 1789 nom. cons.**

**Genus Acer L., 1753**

*Acer* Post Hammer sp. 1
Text-fig. 11a–e

**Material.** UF 279-34456 (minimum estimated diameter 12.5 cm).
Text-fig. 11. *Acer* Post Hammer species 1, UF 279-34456. a, b: Diffuse-porous wood with distinct growth rings, marked by marginal parenchyma, vessels solitary and in short radial multiples, TS. c: Crowded alternate intervessel pits, TLS. d: Simple perforation plates, helical thickenings in vessel elements, TLS. e: Rays 2–3-seriate, gum deposit in vessel element, TLS. *Acer* Post Hammer species 2. UF 279-34466. f: Diffuse-porous wood with distinct growth rings, marked by marginal parenchyma, vessels solitary and in short radial multiples, TS. g: Alternate intervessel pits, helical thickenings in vessel elements, TLS. h: Rays 1–4(–5)-seriate, TLS. i: Crystalliferous strand, multiseriate ray, TLS. *Trochodendron beckii*, UF 279-24558. j, k: Distinct growth rings, abrupt transition from earlywood to latewood, vesselless, wide rays noded at growth ring boundaries, TS. l: Rays of two distinct sizes, uniseriate and multiseriates >10-seriate, TLS. m. Scalariform intertracheary pits. RLS. Scale bars: 500 µm in j; 200 µm in a, f, k, l; 100 µm in b, h; 50 µm in c, d, e, g, i, m.
Description. Growth rings distinct, marked by radially flattened fibers. Diffuse-porous (Text-fig. 11a, b). Vessels solitary (57% and in radial multiples of 2–3); average tangential diameters 40 (SD = 10), range 24–63 µm; vessel frequency 50–56/mm²; perforations exclusively simple (Text-fig. 11d); gum deposits appear accumulated at ends of vessel elements (Text-fig. 11e); intervessel pits crowded alternate, mostly polygonal in outline with included apertures (Text-fig. 11c), small to medium; vessel-ray parenchyma pits similar in size and shape to intervessel pits; helical thickenings present along entire length of the vessel element (Text-fig. 11d).

Fibers non-septate, walls thin to medium, pitting not observed.

Axial parenchyma marginal. (Text-fig. 11a, b).
Rays 1–3(–4)-seriate (Text-fig. 11e). Homocellular, composed of procumbent cells; multisieriate ray height averages 238 (69) µm; 8–10/mm.

Storied structure absent; crystals not observed.

Acer Post Hammer sp. 2
Text-fig. 11f–i

Material. UF 279-34466.

Description. Growth rings distinct, marked by radially flattened fibers. Diffuse-porous (Text-fig. 11f). Vessels solitary (48%) and in radial multiples of 2–4; average tangential diameter 55 (11), range 39–73 µm; vessel frequency 64–78/mm²; perforations simple; intervessel pits crowded alternate (Text-fig. 11g), rounded to polygonal in outline with included apertures, 8–10 µm; vessel-ray parenchyma pits similar in size and shape to intervessel pits; helical thickenings present along entire length of the vessel element; (Text-fig. 11g) vessel element lengths 275–495 µm; mean 390 µm (n = 12); tyloses absent. Fibers non-septate, walls of thin to medium thickness, pitting not observed. Axial parenchyma marginal (Text-fig. 11f), apparently diffuse; strands of chambered crystalliferous cells with more than 16 chambers per strand (Text-fig. 11i); oneystal per chamber. Rays 1–4(–5)-seriate (Text-fig. 11h). Multiseriate rays homocellular, composed of procumbent cells; multisieriate ray height averages 512 (206) µm, range 175–850 µm; 5–7/mm. Chambered crystalliferous cells, occasional, more than 16 chambers per strand; one crystal per chamber. Storied structure absent.

Comparisons with extant woods. Woods of Acer are relatively easy to identify to genus because of their distinctive combination of features: diffuse-porosity (5p), vessels solitary and in short radial multiples (6a 7a 8a 9a 10a 11a), exclusively simple perforation plates (13p 14a), alternate intervessel pits that are neither minute nor large (22p 24a 27a), vessel-ray parenchyma pits similar in size and shape to the intervessel pits (30p), spiral thickenings throughout the vessel elements (36p 37p), vessels not wide or few (42a 43a 46a), non-septate fibers with simple to minutely bordered pits (61p 65a 66p), non-storied homocellular rays that are not exclusively uniseriate or >10-seriate (96a 99a 104p 118a), axial parenchyma not abundant and marginal parenchyma present (77a 79a 80a 83a 86a 89p) and in some species crystals in chambered axial parenchyma cells (e.g., Brazier and Franklin 1961, Panshin and DeZeeuw 1980).
Table 5. Comparison of Acer species. Arranged by age, oldest to youngest. VTD = vessel tangential diameter in µm, mean (standard deviation) or minimum-average-maximum; V/mm² = vessels per mm², range or average as a single number; RW = ray width in cell number; MsRH = multisierate ray height in µm, mean (standard deviation) or minimum-average-maximum; Cry = crystals present in long chambered strands; Eo = Eocene, Mio = Miocene, e = early, m = middle, l = late; OR = Oregon, WA = Washington.

<table>
<thead>
<tr>
<th>Taxon (reference)</th>
<th>VTD (µm)</th>
<th>V/mm²</th>
<th>RW</th>
<th>MsRH (µm)</th>
<th>Cry</th>
<th>Age</th>
<th>Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acer integrifoliolum (3)</td>
<td>48 (5–50) (7)</td>
<td>88–97</td>
<td>1–3(–4)</td>
<td>297 (137–546) (159)</td>
<td>Yes</td>
<td>m Eo</td>
<td>USA, OR</td>
</tr>
<tr>
<td>Acer Post Hammer sp. 1 (this paper)</td>
<td>24–40–63</td>
<td>50–56</td>
<td>1–3(–4)</td>
<td>238 (69)</td>
<td>No</td>
<td>1 Eo</td>
<td>OR, USA</td>
</tr>
<tr>
<td>Acer Post Hammer sp. 2 (this paper)</td>
<td>39–55–73</td>
<td>64–78</td>
<td>1–4(–5)</td>
<td>512 (206)</td>
<td>Yes</td>
<td>1 Eo</td>
<td>OR, USA</td>
</tr>
<tr>
<td>A. momijiyamense (2, 5)</td>
<td>20–75 (range)</td>
<td>20–70</td>
<td>1–4(–5)</td>
<td>50–600–7–50*</td>
<td>Rare</td>
<td>Ol</td>
<td>Japan</td>
</tr>
<tr>
<td>A. cf. amoenum (1)</td>
<td>up to 75 µm</td>
<td>?</td>
<td>1–6(–9)</td>
<td>up to 1200</td>
<td>Yes</td>
<td>e Mio</td>
<td>Japan</td>
</tr>
<tr>
<td>Acer spp. (7)</td>
<td>37</td>
<td>132</td>
<td>1–5</td>
<td>214</td>
<td>No</td>
<td>e Mio</td>
<td>Turkey</td>
</tr>
<tr>
<td>Acer spp (6)</td>
<td>55</td>
<td>206</td>
<td>1–5</td>
<td>220</td>
<td>No</td>
<td>e Mio</td>
<td>Turkey</td>
</tr>
<tr>
<td>A. minokamoensis (5)</td>
<td>24–43–55</td>
<td>numerous</td>
<td>1–3</td>
<td>79–90–505</td>
<td>No</td>
<td>e Mio</td>
<td>Korea</td>
</tr>
<tr>
<td>A. pohangensis (5)</td>
<td>24–39–55</td>
<td>numerous</td>
<td>1–4</td>
<td>32–600–1185</td>
<td>No</td>
<td>e Mio</td>
<td>Korea</td>
</tr>
<tr>
<td>A. watarianum (2)</td>
<td>30–90 (range)</td>
<td>15–35</td>
<td>1–5(–6)</td>
<td>70–460 (range)</td>
<td>Yes</td>
<td>e Mio</td>
<td>Japan</td>
</tr>
<tr>
<td>A. beckianum (4)</td>
<td>31–60–82</td>
<td>23–35</td>
<td>1–3</td>
<td>237 (65)</td>
<td>Yes</td>
<td>m Mio</td>
<td>USA, WA</td>
</tr>
<tr>
<td>A. berkholphi (4)</td>
<td>35–65–90</td>
<td>17–24</td>
<td>1–3</td>
<td>365 (135)</td>
<td>No</td>
<td>m Mio</td>
<td>WA, USA</td>
</tr>
<tr>
<td>A. olearvii (4)</td>
<td>30–59–80</td>
<td>52–71</td>
<td>1–7</td>
<td>437 (239)</td>
<td>No</td>
<td>Mio</td>
<td>WA, USA</td>
</tr>
<tr>
<td>A. paratrunanum (4)</td>
<td>30–53–72</td>
<td>18–26</td>
<td>1–4(–5)</td>
<td>230 (60)</td>
<td>Yes</td>
<td>Mio</td>
<td>WA, USA</td>
</tr>
</tbody>
</table>


* 50–600 reported as range, with 750 µm given as outlier.

Exclusively of upright cells; central cells of multisierate rays procumbent, with up to 10 marginal rows of upright cells, heights of multisierate portions of the rays 0.7–1.56 mm.

Note: We did not measure total ray height including the uniseriate margins because it was difficult to be sure of where the uniseriate margins ended.

Remarks. Vesselless woods are rare among angiosperms, and this specimen with its wide heterocellular rays and scalariform bordered pits has features of Trochodendraceae (Bailey and Nast 1945, Herget and Phinney 1954). This specimen from the Post Hammer locality (UF 279) further documents the occurrence of Trochodendron wood in the Eocene of Oregon (Scott and Wheeler 1982). This species was previously recognized from the Miocene of Oregon (Hergert and Phinney 1954) from the same formation where fossil trochodendraceous infructescences and leaves have been recognized (Manchester et al. 2018). There are differences in the quantitative features (tracheid diameters, ray width) between the woods from these separate occurrences, but we don’t consider them to be great enough to treat them as different species. Although the two extant genera of this family, Trochodendron and Tetracentron, are confined to eastern Asia, the family is well represented in the Cenozoic of western North America and known from leaves and fruits of both modern and extinct genera ranging from Paleocene to Miocene (Manchester et al. 2018, Manchester et al. 2021).

Conclusions

The wood assemblage from the late Eocene Post Hammer locality is smaller and less diverse than the middle Eocene Clarno Nut Beds wood assemblage. It includes woods with anatomy similar to extant genera: Pistacia (Anacardiaceae); Celtis (Cannabaceae), Cercidiphyllum (Cercidiphyllaceae), Fagus, Quercus of the red oak group (Fagaceae), Acer (Sapindaceae), Ulmus (Ulmaceae; Wheeler and Manchester 2007), and Trochodendron (Trochodendraceae).

To the best of our knowledge, the Pistacia, Celtis, and Trochodendron woods are the oldest occurrences of woods with characteristics unique to these genera. There is also a permineralized palm stem (UF 279-24547) from the same site. Angiosperm woods that can be identified to family but have a combination of features found in more than one extant genus of that family are Lithocarpon, resembling Lithocarpus, and Nolothaphysiellus, and the evergreen Quercus species (Fagaceae); Hamamelidoxylon (Hamamelidaceae); and Pterocaryoxylon, with features shared with Juglans (butternut group) and Pterocarya (Juglandaceae). Two genera are likely extinct because they can be identified to family but have a combination of features that does not conform to a modern genus: Wataria (Malvaceae), which also occurs in Japan, and Platanoxylon (Platanaceae), one of the most commonly occurring fossil woods in the Paleocene of the Northern Hemisphere. Study of this wood assemblage is an example of how studying coeval fruit and seed assemblages, leaf compressions, and woods provides a better understanding of the vegetation (Tab. 6).

These taxa are consistent with warm temperate possibly to subtropical vegetation. Differences between the Post Hammer assemblage and the Clarno Nut Bed assemblage document changes in vegetation and functional traits as would be expected as a result of the middle to late Eocene climatic change, increased seasonality and decreased mean annual temperature. All Post Hammer woods have distinct growth ring boundaries, whereas one-third of the Nut Beds have indistinct growth ring boundaries (Wheeler and
Manchester 2002). Moreover, two of the Post Hammer woods are distinctly ring-porous, a trait not seen in any of the Nut Beds woods; ring-porosity is correlated with the deciduous habit and distinct seasonality.

As research continues, we will compare this assemblage with other wood localities in the region. The Dietz locality (UF 278), situated a few km east of the Hammer locality, has also yielded well preserved woods in association with silicified fruits and seeds. Although we have encountered some of the same woods at UF 278 (Platanaceae, Ulmaceae), there are differences, including the presence of Magnoliaceae, Araliaceae, and more conifers.

**Acknowledgments**

We thank the N.C. State Libraries, Raleigh, N.C., for their continued support of the InsideWood web site, especially Carolyn Argentati, Adam Constabularis, and Shirley Rodgers; and Terry Lott, University of Florida, Gainesville, for helping with formatting and checking references, and help with fossil names registration; Pieter Baas and Jakub Sakala for their tactful and constructive reviews of the manuscript. Dewey Dietz provided guidance in the field. Dr. Jim Wood (Post, Oregon) kindly provided access to collect fossil plants from his Aspen Valley Ranch.

**References**

Abundiz-Bonilla, L. A. M., Baraja-Morales, J., Teno-


<table>
<thead>
<tr>
<th>Family</th>
<th>Wood taxa</th>
<th>Reproductive structures²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taxaceae</td>
<td></td>
<td>Diploporus torreyoides</td>
</tr>
<tr>
<td>Conifer</td>
<td>Indet. wood</td>
<td>Sabal seed</td>
</tr>
<tr>
<td>Palmae</td>
<td>Indet. stem</td>
<td></td>
</tr>
<tr>
<td>Trochodendraceae</td>
<td><em>Trochodendron beckii</em> (HERGERT et H.K.PHINNEY) R.A.S.COTT et E.A.WHEELEER</td>
<td></td>
</tr>
<tr>
<td>Platanaceae</td>
<td><em>Platanoxylon haydenii</em> (FELIX) SÜSS et MÜLL.-STOLL</td>
<td>Platanus sp.</td>
</tr>
<tr>
<td>Cercidiphyllaceae</td>
<td><em>Cercidiphyllum alalongum</em> R.A.S.COTT et E.A.WHEELEER</td>
<td></td>
</tr>
<tr>
<td>Hamamelidaceae</td>
<td><em>Hamamelidoxylon crystalliferum</em> sp. nov.</td>
<td>H. suzukii E.A.WHEELEER et T.A.DILLHOFF</td>
</tr>
<tr>
<td>Betulaceae</td>
<td></td>
<td><em>Alnus</em> sp. infructescence</td>
</tr>
<tr>
<td>Fagaceae</td>
<td><em>Fagus dodgii</em> sp. nov.</td>
<td><em>Fagus</em> sp. nut</td>
</tr>
<tr>
<td></td>
<td><em>Lithocarpoxylon ashwillii</em> sp. nov.</td>
<td><em>Quercus</em> sp.</td>
</tr>
<tr>
<td></td>
<td><em>Lithocarpoxylon</em> sp.</td>
<td></td>
</tr>
<tr>
<td>Juglandaceae</td>
<td><em>Pterocarya</em> sp.</td>
<td><em>Carya</em> sp. nut</td>
</tr>
<tr>
<td>Malvaceae</td>
<td><em>Wataria kvacekii</em> sp. nov.</td>
<td></td>
</tr>
<tr>
<td>Anacardiaceae</td>
<td><em>Pistacia</em> terrazasae* sp. nov.</td>
<td><em>Indet. fruit similar to Pistacia</em></td>
</tr>
<tr>
<td>Cannabaceae</td>
<td><em>Celtis populi</em> sp. nov.</td>
<td></td>
</tr>
<tr>
<td>Ulmaceae</td>
<td><em>Ulmus danielli</em> E.A.WHEELEER et MANCHESTER¹</td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Ulmus woodii</em> E.A.WHEELEER et MANCHESTER</td>
<td></td>
</tr>
<tr>
<td>Sapindaceae</td>
<td><em>Acer</em>, 2 spp.</td>
<td><em>Aralia</em> sp. fruit</td>
</tr>
<tr>
<td>Alangiaceae</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Davidiaceae</td>
<td></td>
<td><em>Davidia</em> fruit</td>
</tr>
<tr>
<td>Mastixiaceae</td>
<td></td>
<td><em>Tectocarya</em> sp. (misidentified as <em>Mastixicarpum</em> by Manchester 2006) fruit</td>
</tr>
</tbody>
</table>

¹presented by Wheeler and Manchester 2007
²presented in Manchester and McIntosh 2006

| Table 6. Taxonomic composition of the Post Hammer locality. |

