LATE CRETACEOUS CONIFER WOODS OF TERLINGUA RANCH, BREWSTER COUNTY, TEXAS

by

Alaa Ibrahim, B.S.

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Committee Members:

David E. Lemke, Chair

Michael A. Huston

Garland R. Upchurch, Jr.

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ABSTRACT

Terlingua Ranch, in southern Brewster County, Texas, is a nearly 100,000 hectare property located between Big Bend National Park on the east, Big Bend Ranch State Park on the west, and the entrance to the Christmas Mountains. The southeastern portion of the ranch contains an abundance of fossilized conifer wood specimens occurring as logs ranging from 1.6 m in diameter and 15 m in length to much smaller logs and pieces of float. Most of these fossils occur in strata belonging to the Upper Cretaceous (Campanian) Aguja Formation (83–72 mya). Anatomical details of the fossil conifer specimens from Terlingua Ranch were analyzed by comparing wood anatomical features of the fossil specimens with a database compiled by examining the structure of extant conifer woods and through the use of published keys for fossil conifer wood identification. Three different fossil wood types were identified from Terlingua Ranch: a cupressoid/ podocarpoid wood type, a *Cupressinoxylon* wood type, and the first definitive report of a *Taxodioxylon* wood type from the southern portion of the western interior. These results are compared to other studies of fossilized woods from the Upper Cretaceous of the Western Interior of North America.

I. INTRODUCTION

The Late Cretaceous is considered one of the most important periods in the history of the Earth's vegetation (Upchurch and Wolfe, 1993). Plant megafossils of this period have been shown to be valuable tools for increasing our knowledge and understanding of vegetation and climate during this period, especially for the Western Interior of North America. Megafossils are significantly larger than pollen and spores and they have less potential for long distance transport. Therefore, they can provide direct evidence for vegetation history. Megafossil assemblages have allowed researchers to gain knowledge of localized plant communities of the Cretaceous (Upchurch and Wolfe, 1993).

The Cretaceous of North America can be divided into three intervals, each characterized by its own dominant group of plants (Upchurch and Wolfe, 1993). These intervals are characterized by an increase in the dominance of flowering plants over gymnosperms and other vegetation types (Crane, 1987; Lidgard and Crane, 1988). The first period extended from the Neocomian to the early Albian (146 to 125 mya). This time period was dominated by both gymnosperms and non-woody groups, such as ferns and other spore-bearing plants. Megafossil assemblages of this period, such as the lower Potomac group flora (Fontaine, 1889; Ward, 1905; Berry, 1911), are known from the northern Western Interior and the Atlantic and Gulf coastal plains. Conifers were the dominant plants among the woody species (Hughes, 1976; Taylor, 1981; Stewart, 1983) and included the extant family Cupressaceae (cypress family), which occurs in North America today; Araucariaceae (araucaria family), which today is restricted to the Southern Hemisphere; Podocarpaceae, which today is absent from North America (Airy

Shaw, 1966); and the extinct family Cheirolepidiaceae. During this time period, flowering plants were rare (Upchurch and Wolfe, 1993).

The second interval ranged from early Albian to middle Cenomanian (125 to 93 mya). During this interval, angiosperms began to increase in diversity and abundance as compared to gymnosperms (Crane, 1987; Lidgard and Crane, 1988). A transition from forests in which gymnosperms were the dominant vegetation to assemblages in which flowering plants took over, occurred during this interval (Upchurch and Wolfe, 1993). Abundant pollen and leaves of flowering plants have been found and characterized from this interval (Upchurch and Wolfe, 1993).

The third interval ranged from late Cenomanian to late Maastrichtian from (93 to 66 mya). Much of the megafossil flora of this interval is represented by sequences of fossil from the eastern United States (Upchurch and Wolfe, 1993). Conifers were abundant and diverse during this interval, being represented by probable evergreen forms similar to extant *Sequoia* (Parker, 1976; Wolfe and Upchurch, 1987) and various deciduous forms. Araucariaceae was another family of the late Cenomanian to late Maastrichtian, being represented by forms similar to the extant *Agathis* (Berry, 1911), as was the extinct family Cheirolepidiaceae (Penny, 1947).

Angiosperms were abundant during the late Cenomanian to late Maastrichtian, with many new genera and species being found and characterized. Dicotyledons were the most diverse plants during this interval and were represented primarily by leaf megafossils. (Upchurch and Wolfe, 1993). Angiosperm fossil wood assemblages are known from many localities including the Gulf and Atlantic Coastal Plain (Cahoon, 1972; Wheeler and Gensel, 1988), the Mississippi Embayment (Wheeler et al., 1987),

Big Bend National Park, Texas (Wheeler and Lehman, 2001), south-central New Mexico (Estrada-Ruiz et al., 2012), and California (Page, 1970, 1979, 1980, 1981).

Although well-preserved angiosperm woods are known from the western interior (Wolfe and Upchurch, 1987), only a few works specifically describe coniferous woods of this area from the Late Cretaceous. The studies of Ramanujam (1972), Roberts and Hendrix (2000), Falcon-Lang (2003), Wheeler and Lehman (2005), and Davies-Vollum et al. (2011) provide our only detailed look at Late Cretaceous (Campanian) conifers from the Western Interior. The present study, which examines a collection of petrified conifer wood samples from a locality in the southern portion of the Western Interior of North America, will add to our understanding of conifer diversity during this time period.

II. MATERIALS AND METHODS

Terlingua Ranch, in southern Brewster County, Texas, is a nearly 100,000 hectare area situated northwest of Big Bend National Park that almost completely encircles the Texas State University System Christmas Mountains property. During the course of fieldwork associated with a vegetation survey of the region, numerous petrified logs and fragments of petrified wood ("float") were encountered on private property in two small areas along the eastern margin of Terlingua Ranch. The first site, centered at approximately N 29° 26.527', W 103° 21.314', covers an area of about 8.1 hectares, while the second site, centered at approximately N 29° 28.421', W 103° 20.003', covers about 8.75 hectares. Both sites are situated along the eastern margin of Terlingua Ranch near its boundary with the Sombrero Peak Ranch.

Geologic setting

Geologically, this portion of Terlingua Ranch is characterized primarily by surface exposures of rocks of Cretaceous age that have been intruded by younger igneous rocks. Quaternary fluvial deposits are also widespread in the area. Surface exposures in the general area of the study site are primarily rocks belonging to the Upper Cretaceous Gulfian Series, comprising the Boquillas, Pen, Aguja, and Javelina formations. In general, these strata are dominated by flaggy or marly limestones, shales, and sandstones that record a transition from a marine to a continental depositional environment (Henry et al., 1989). The Boquillas Formation is composed of argillaceous, flaggy limestone and chalk, the layers separated by thin calcareous clay layers. The clay layers thicken and the limestone layers thin in the uppermost part of the formation. The Pen Formation is characterized by poorly indurated, calcareous marine clay containing chalk layers a few

centimeters thick in the lower part and minor, sandy beds in the upper part. The Aguja Formation, the focus of this study, consists of gray and green clays with thin lignite and coal beds interbedded with light-brown or yellow to white sandstones (Figure 1). The formation gradually formed from marine clay in the lower part and continental clay and sandstone in the upper part. The Javelina Formation was deposited on a fluvial floodplain and consists of distinctive gray to purple mud interbedded with white to pale green sands that give the formation a characteristic variegated appearance (Henry et al., 1989).

Figure 1. Study site near the eastern boundary of Terlingua Ranch, Brewster County, Texas, showing the characteristic appearance of the Upper Cretaceous Aguja Formation. The Texas State University System Christmas Mountains property is in the upper left corner of the photograph.

Previous studies (Lehman, 1985; Wheeler and Lehman, 2005) have documented that conifer woods occur widely through several of these Upper Cretaceous strata: the coastal facies of the lower to middle Aguja Formation, the lowland fluvial flood-plain facies of the upper Aguja Formation, and the inland fluvial flood-plain facies of the Javelina Formation. The conifer woods that have been preserved in these intervals were in log jam assemblages found in proximity to their original growth environment. The logs were preserved in permineralized form, almost buried in the sandy coastal formation, while others were found as compressed carbonized logs in layers of lignitic mudstone and coal deposits that interfinger with the sandstone (Wheeler and Lehman, 2005).

The present study entails the identification of fossil conifer woods from the Cretaceous Aguja Formation of Terlingua Ranch based on comparisons with the structure of extant conifers and fossil material from nearby sites previously examined by other workers.

Extant wood specimens

Wood samples of thirty-nine extant conifer species (Table 1) were obtained from the International Wood Collectors Society. Three 1 cm^3 blocks of each sample were prepared and sectioned at 20–30 μm on an AO sliding microtome to produce cross, radial, and tangential sections. The sections were placed in Gooch crucibles, stained in a 1% solution of safranin in 50% ethanol, dehydrated through a graded series of ethanol (50%, 70%, 95%, 100%), transferred to a 1:1 mixture of 100% ethanol:SAFECLEAR (a xylene substitute) and fully cleared in three changes of pure SAFECLEAR. The sections were then mounted in Permount, examined with a Nikon Eclipse 50i compound microscope, and photographed with a Nikon DS-Fi1 digital camera system.

A list of anatomical features of importance in the identification of extant conifer woods was compiled from Richter et al. (2004). These features are presented in Table 2.

Fossil wood specimens

Samples of 17 petrified wood specimens collected from the Aguja Formation at Terlingua Ranch were thin-sectioned for anatomical study (Table 3). The samples represented specimens of intact logs (Figure 2), logs in various states of "decomposition" (Figure 3), and collections of "float," fragments of petrified wood of various sizes found lying on the surface of the ground (Figure 4). Each sample was cut into approximately 1 cm^3 blocks for the preparation of cross, radial, and tangential sections using a Kobalt® wet tile/stone saw (Model KB7005, Lowes Home Improvement Centers). One face of each block was ground smooth using 320 grit carborundum powder on a glass plate, affixed to a 25 x 75 mm glass slide with Norland Optical Adhesive 60 (Norland Products, Inc., Cranbury NJ) and cured under ultraviolet light. Once cured, thin sections were prepared by cutting away most of the block from the slide and grinding the remaining material until translucent on a Hillquist Model 1005 thin section machine (Hillquist, Inc., Denver, CO). Each section was then polished with either 400 or 600 grit carborundum powder on a glass plate and a cover slip mounted with Norland Optical Adhesive 60. Prepared sections were examined with a Nikon Eclipse 50i compound microscope and photographed with a Nikon DS-Fi1 digital camera system.

Identification of fossil woods

A suite of anatomical features similar to those that were examined in slides prepared from the extant wood specimens was observed and recorded for each of the

fossil samples (Table 4). In addition, a published key to genera of fossil conifer woods (Philippe and Bamford, 2008) was utilized to facilitate identification.

Figure 2. Intact log (sample no. 288) measuring approximately 3 m long and 0.35 m in diameter from the Aguja Formation of Terlingua Ranch.

Figure 3. "Decomposing" log (sample no. 095) measuring approximately 15 m long and 0.4 m in diameter from the Aguja Formation of Terlingua Ranch.

Figure 4. Float (sample no. 354) scattered on the surface of the Aguja Formation of Terlingua Ranch.

Table 1. Extant wood specimens examined in the present study.

Family	**Species**	**Origin**
Araucariaceae	*Agathis australis*	New Zealand
	Araucaria heterophylla	Norfolk Island
	Araucaria nemorosa	New Caledonia
Cupressaceae	*Athrotaxis selaginoides*	Tasmania
	Callitris glaucophylla	Australia
	Chamaecyparis lawsoniana	USA
	Chamaecyparis thyoides	USA
	Cupressus arizonica	USA
	Juniperus ashei	USA
	Juniperus occidentalis	USA
	Juniperus oxycedrus	Europe
	Juniperus virginiana	USA
	Metasequoia glyptostroboides	China
	Sequoiadendron giganteum	USA
	Sequoia sempervirens	USA
	Thuja occidentalis	USA
	Thuja plicata	USA
Pinaceae	*Abies fabri*	China
	Abies procera	USA
	Larix marschlinsii	USA

Table 1, continued. Extant wood specimens examined in the present study.

Family	**Species**	**Origin**
Pinaceae	*Picea abies*	Europe
	Picea engelmannii	USA
	Picea pungens	USA
	Pinus elliottii	USA
	Pinus nigra	Europe
	Pinus palustris	USA
	Pinus parviflora	Japan
	Pinus ponderosa	USA
	Pinus radiata	USA
	Pinus strobus	USA
	Pinus virginiana	USA
	Pseudotsuga menziesii	USA
	Tsuga canadensis	USA
	Tsuga caroliniana	USA
	Tsuga heterophylla	USA
Podocarpaceae	*Podocapus latifolius*	South Africa
	Podocarpus macrophyllus	China
Taxaceae	*Taxus brevifolia*	USA
	Taxus sp.	Japan

Table 2. Anatomical features of extant wood samples examined in the present study with corresponding abbreviations (after Richter et al., 2004).

1. Growth rings boundaries distinct (D) or indistinct (I) or absent (-).
2. Transition from early wood to latewood abrupt (A) or gradual (G).
3. Tracheid pitting in radial walls (early wood only) uniseriate (U) or multiseriate (M).
4. Tracheid pitting in radial walls (when 2+ seriate) alternate (A) or opposite (O).
5. Organic deposits in tracheids present (+) or absent (-).
6. Average tracheid length short (S; < 3000 μm), medium (M; 3000–5000 μm), or long (L; > 5000 μm).
7. Intercellular spaces (in cross section) present (+) or absent (-).
8. Latewood tracheids thin-walled (Tn; double wall thickness < radial lumen diameter) or thick-walled (Tk; double wall thickness > radial lumen diameter).
9. Tori present (+) or absent (-).
10. Torus extensions present (+) or absent (-).
11. Pits with notched borders present (+) or absent (-).
12. Warty layer present (+) or absent (-).
13. Helical thickenings in tracheids (in radial section) present (+) or absent (-).
14. Helical thickenings well-developed only in early wood (E), well-developed only in latewood (L), or present throughout the growth increment (T).
15. Helical thickenings single (S) or grouped (G).
16. Helical thickenings narrowly spaced (N; number of coils > 120 per mm) or widely spaced (W; number of coils < 120 per mm).

Table 2, continued. Important anatomical features of extant wood samples examined in the present study with corresponding abbreviations (after Richter et al., 2004).

17. Helical thickenings in ray tracheids present (+), rare (±), or absent (-).
18. Callitroid thickenings present (+) or absent (-).
19. Axial parenchyma diffuse (D), tangentially zonate (Z), or absent (-).
20. Transverse end walls of axial parenchyma smooth (S), irregularly thickened (I), or beaded (B).
21. Ray tracheids present (+) or absent (-).
22. Horizontal walls of ray tracheids smooth (S), dentate (D), or reticulate (R).
23. Ray tracheid pit borders angular (A) or with dentate thickenings (D).
24. End walls of ray parenchyma cells smooth (S) or distinctly pitted (P).
25. Horizontal walls of ray parenchyma cells smooth (S) or distinctly pitted (P).
26. Indentures present (+) or absent (-).
27. Cross-field pitting araucarioid (Ar), cupressoid (Cu), window-like (F), piceoid (Pc), pinoid (Pn), or taxodioid (Tx).
28. Average ray height low (L; < 5 cells), medium (M; 5 to 15 cells), or high (H; > 15 cells).
29. Rays uniseriate (U) or at least partly multiseriate (M).
30. Axial resin canals present (+) or absent (-).
31. Radial resin canals present (+) or absent (-).
32. Traumatic canals present (+) or absent (-).
33. Crystals present (+) or absent (-).

Table 3. Fossil wood samples examined in the present study.

Sample	Description	GPS Coordinates
095	Log (15 m x 0.4 m)	N 29° 26.366', W 103° 21.439'
189	Log (2.3 m x 0.3 m)	N 29° 26.679', W 103° 21.240'
193A	Float	N 29° 26.521', W 103° 21.296'
193B	Float	N 29° 26.521', W 103° 21.296'
200	Log (1 m x 0.2 m)	N 29° 26.581', W 103° 20.857'
271	Float	N 29° 26.581', W 103° 20.836'
287	Float	N 29° 28.427', W 103° 20.060'
288	Log (3 m x 0.3 m)	N 29° 28.375', W 103° 20.040'
349	Float	N 29° 28.485', W 103° 20.053'
350	Log	N 29° 28.565', W 103° 20.073'
351	Log	N 29° 28.550', W 103° 20.079'
352	Float	N 29° 28.538', W 103° 20.104'
354	Float	N 29° 28.594', W 103° 20.083'
355	Float	N 29° 28.618', W 103° 20.035'
356	Float	N 29° 28.541', W 103° 20.132'
357	Log	N 29° 28.546', W 103° 20.183'
358	Float	N 29° 28.556', W 103° 20.137'

Table 4. Anatomical features of fossil wood samples examined in the present study with corresponding abbreviations.

1. Growth ring boundaries distinct (D) or indistinct (I) or absent (-).
2. Transition from early wood to latewood transition abrupt (A) or gradual (G).
3. Tracheid pitting uniseriate (U) or biseriate (B).
4. Tracheid pitting in radial walls (when biseriate) alternate (A) or opposite (O).
5. Organic deposits in tracheids present (+) or absent (-).
6. Intercellular spaces (in cross section) present (+) or absent (-).
7. Latewood tracheids thin-walled (Tn; double wall thickness < radial lumen diameter) or thick-walled (Tk; double wall thickness > radial lumen diameter).
8. Tori present (+) or absent (-).
9. Pits with notched borders present (+) or absent (-).
10. Warty layer present (+) or absent (-).
11. Helical thickenings in tracheids (in radial section) present (+) or absent (-).
12. Helical thickenings well-developed only in early wood (E), well-developed only in latewood (L), or present throughout the growth increment (T).
13. Helical thickenings single (S) or grouped (G).
14. Callitroid thickenings present (+) or absent (-).
15. Axial parenchyma abundant (A; 10 or more/20x field) or rare (R; < 10/20x field).
16. Transverse end walls of axial parenchyma smooth (S), irregularly thickened (I), or beaded (B).
17. Ray tracheids present (+) or absent (-).

Table 4, continued. Anatomical features of fossil wood samples examined in the present study with corresponding abbreviations.

18. Horizontal walls of ray tracheids smooth (S), dentate (D), or reticulate (R).
19. End walls of ray parenchyma cells smooth (S) or distinctly pitted (P).
20. Horizontal walls of ray parenchyma cells smooth (S) or distinctly pitted (P).
21. Indentures present (+) or absent (-).
22. Cross-field pitting araucarioid (Ar), cupressoid (Cu), window-like (F), piceoid (Pc), pinoid (Pn), or taxodioid (Tx).
23. Average ray height low (L; < 5 cells), medium (M; 5 to 15 cells), or high (H; > 15 cells).
24. Rays uniseriate (U) or at least partly multiseriate (M).
25. Axial resin canals present (+) or absent (-).

III. RESULTS

Extant wood specimens

Examination of the prepared slides of extant woods revealed a wide diversity of structural features among the thirty-nine specimens studied. This diversity encompasses much of the variation in wood structure to be seen among extant conifers (Richter et al., 2004) and provides a database against which the fossil conifers from Terlingua Ranch can be compared. The characteristics of each of the extant wood samples are presented in Table 5.

Fossil wood specimens

The characteristics of the seventeen fossil wood samples collected from the Aguja Formation of eastern Terlingua Ranch are summarized in Table 6. An examination of these specimens revealed the occurrence of four distinct wood types: two cupressoid/podocarpoid woods that differed only in the presence or absence of distinct growth rings, a *Cupressinoxylon*-type wood, and a *Taxodioxylon*-type wood. Of the seventeen specimens examined, eleven were of the cupressoid/podocarpoid type, three were of the *Cupressinoxylon* type, and three were of the *Taxodioxylon* type.

Cupressinoxylon wood type

Two of the samples from the southern collection site (200, 271) that were somewhat isolated from the other samples at this site and one sample from the northern collection site (351) are referred to the genus *Cupressinoxylon* on the basis of longitudinal tracheids that are largely square or polygonal in outline and the presence of multiple cupressoid pits per cross-field (cupressoid pits have elliptical apertures that are narrowed than the border and that are wholly included within the limits of the pit border).

These woods are also characterized by indistinct growth rings, uniseriate to biseriate intertracheary pitting (the pitting opposite in the biseriate portions), thin tracheid walls, sparse to abundant axial parenchyma, and rays that are uniseriate or that have biseriate to multiseriate portions and that are medium to tall in height. Characteristics of the *Cupressinoxylon* wood type are illustrated in Figure 5.

***Taxodioxylon* wood type**

Three of the samples from the northern collection site (352, 355, 358) are characterized by taxodioid cross-field pitting. Taxodioid pits have large oval to circular apertures with the width of the aperture exceeding the width of its border at its widest point. These woods are also characterized by indistinct growth rings (distinct in one specimen), uniseriate to biseriate intertracheary pitting (the pitting opposite in the biseriate portions), septate tracheids with thin walls, sparse axial parenchyma, and rays that are uniseriate or that have biseriate to multiseriate portions and that are medium to tall in height and were identified as belonging to the genus *Taxodioxylon* using the key of Phillipe and Bamford (2008). Characteristics of the *Taxodioxylon* wood type are illustrated in Figures 6 and 7.

Cupressoid/podocarpoid wood type

The majority of the samples collected, four from the southern collection site (095, 189, 193A, 193B) and seven from the northern site (287, 288, 349, 350, 354, 356, 357), are referred to the general cupressoid/podocarpoid wood type described by Wheeler and Lehman (2005). In general, these woods are characterized by the absence of resin canals, ray tracheids, and helical thickenings, and the presence of smooth-walled axial and ray parenchyma cells and cross-fields with 1–2 cupressoid-taxodioid pits. Intertracheary

pitting is usually uniseriate but may be biseriate with an opposite pit arrangement. The rays are predominantly uniseriate but may have biseriate portions. Distinct growth rings are present in some of the specimens and are absent in others, but no other consistent differences were noted between these woods. Characteristics of the cupressoid/podocarpoid wood type are illustrated in Figure 8.

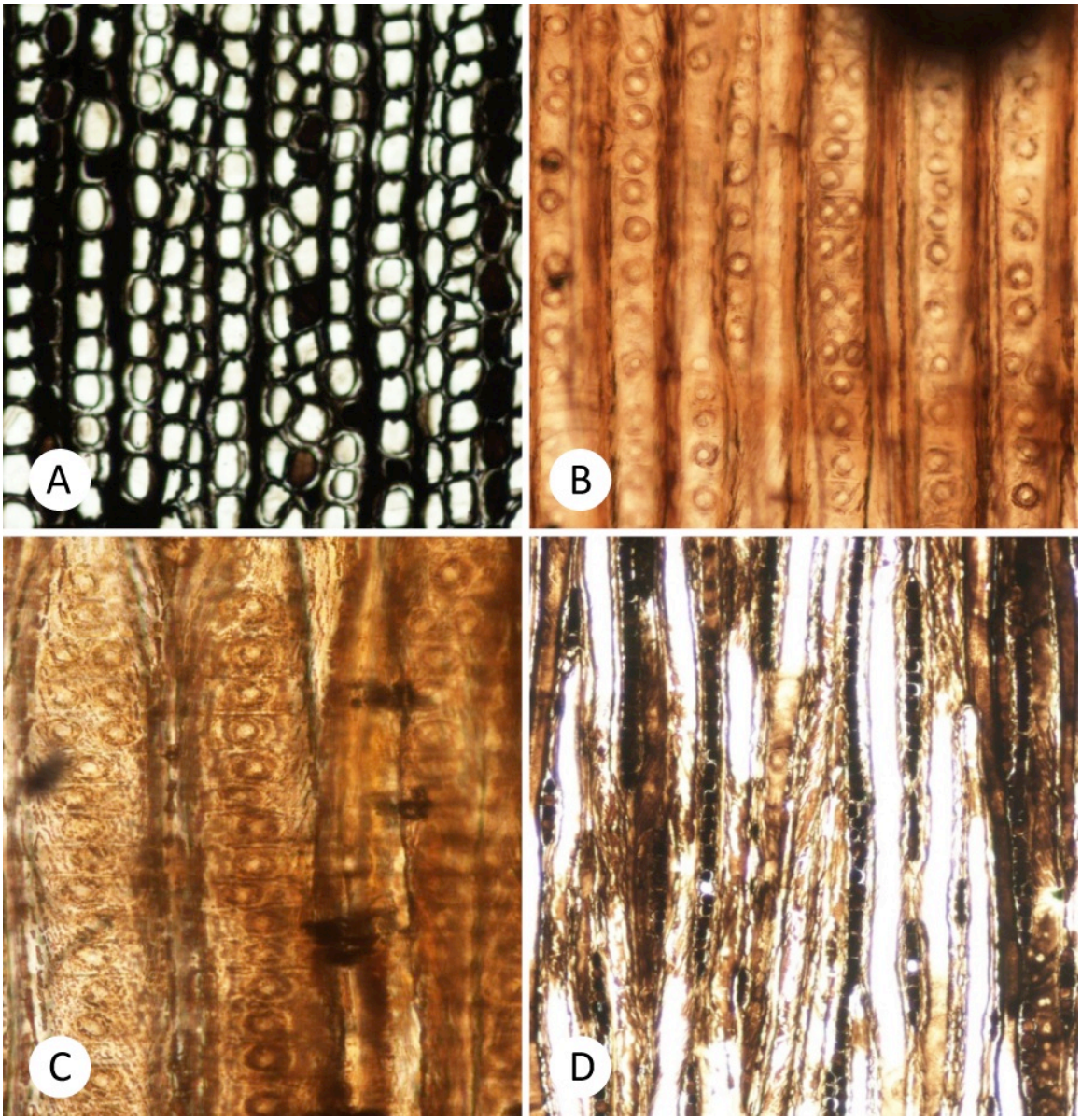

Figure 5. Features of *Cupressinoxylon* wood. A. Lack of growth rings or transition from early wood to latewood; tracheids rounded or angular; axial parenchyma with dark contents. B. Intertracheary pitting predominantly uniseriate, opposite when biseriate. C. Crassulae between circular bordered pits. D. Rays uniseriate to biseriate in part; rays to 95 cells in height.

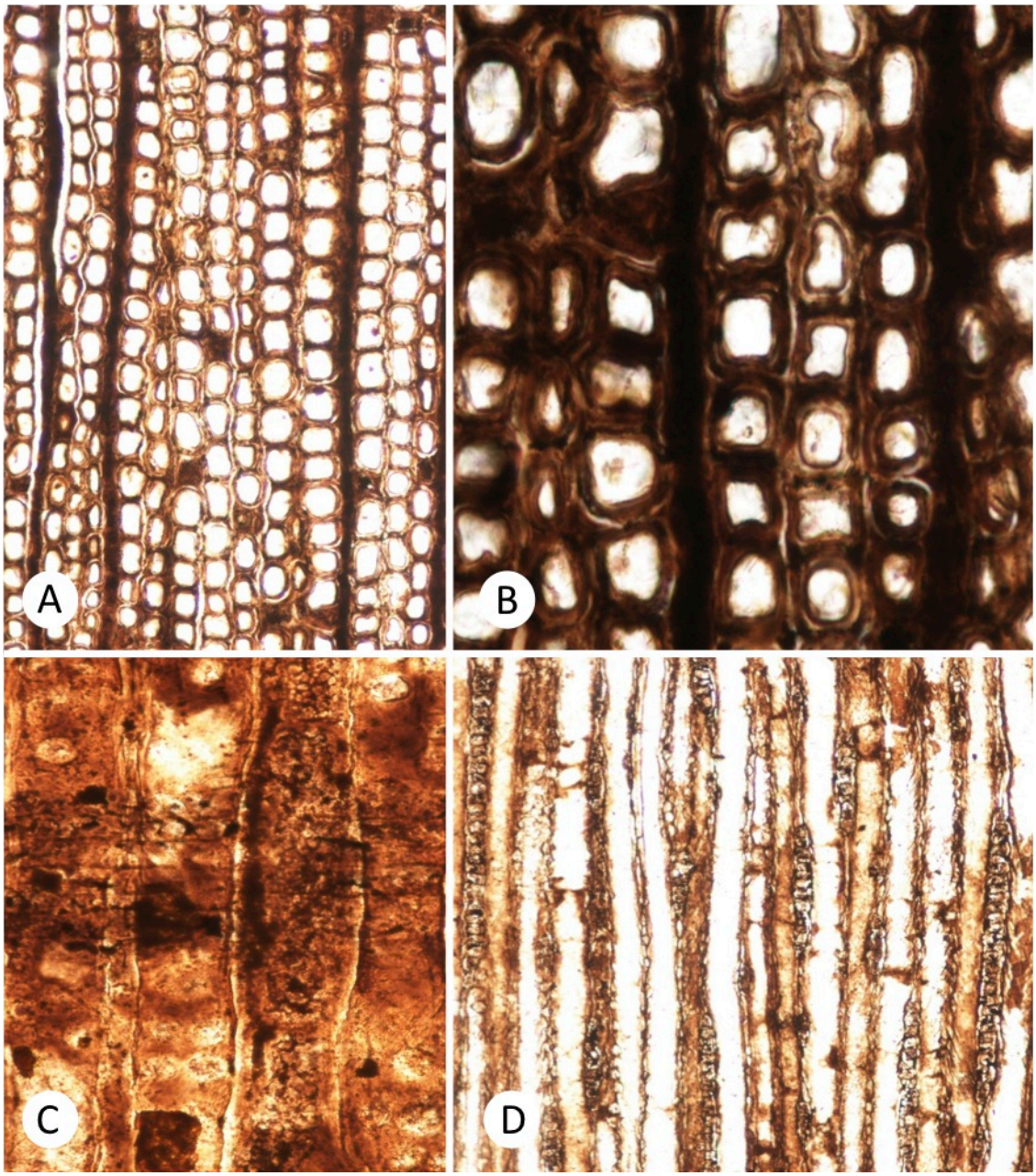

Figure 6. Features of *Taxodioxylon* wood. A. Lack of growth rings or transition from early wood to latewood; axial parenchyma rare. B. Tracheids circular to elliptical in cross section. C. Cross-field pitting taxodioid, either single or in pairs. D. Rays mostly uniseriate, mostly less than 30 cells high.

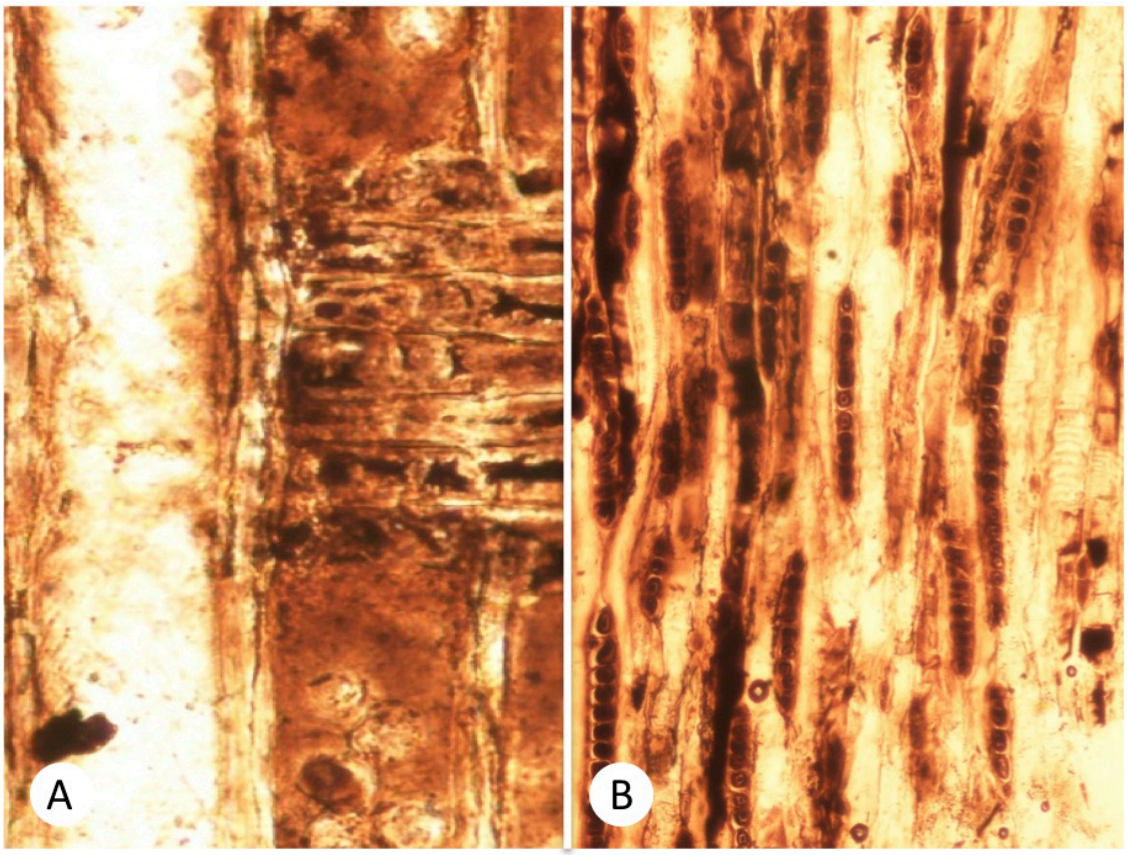

Figure 7. Features of *Taxodioxylon* wood. A. Tracheid pitting in radial walls uniseriate to biseriate, the pitting opposite when biseriate. B. Rays predominately uniseriate, ranging from 3 to 20 cells in height.

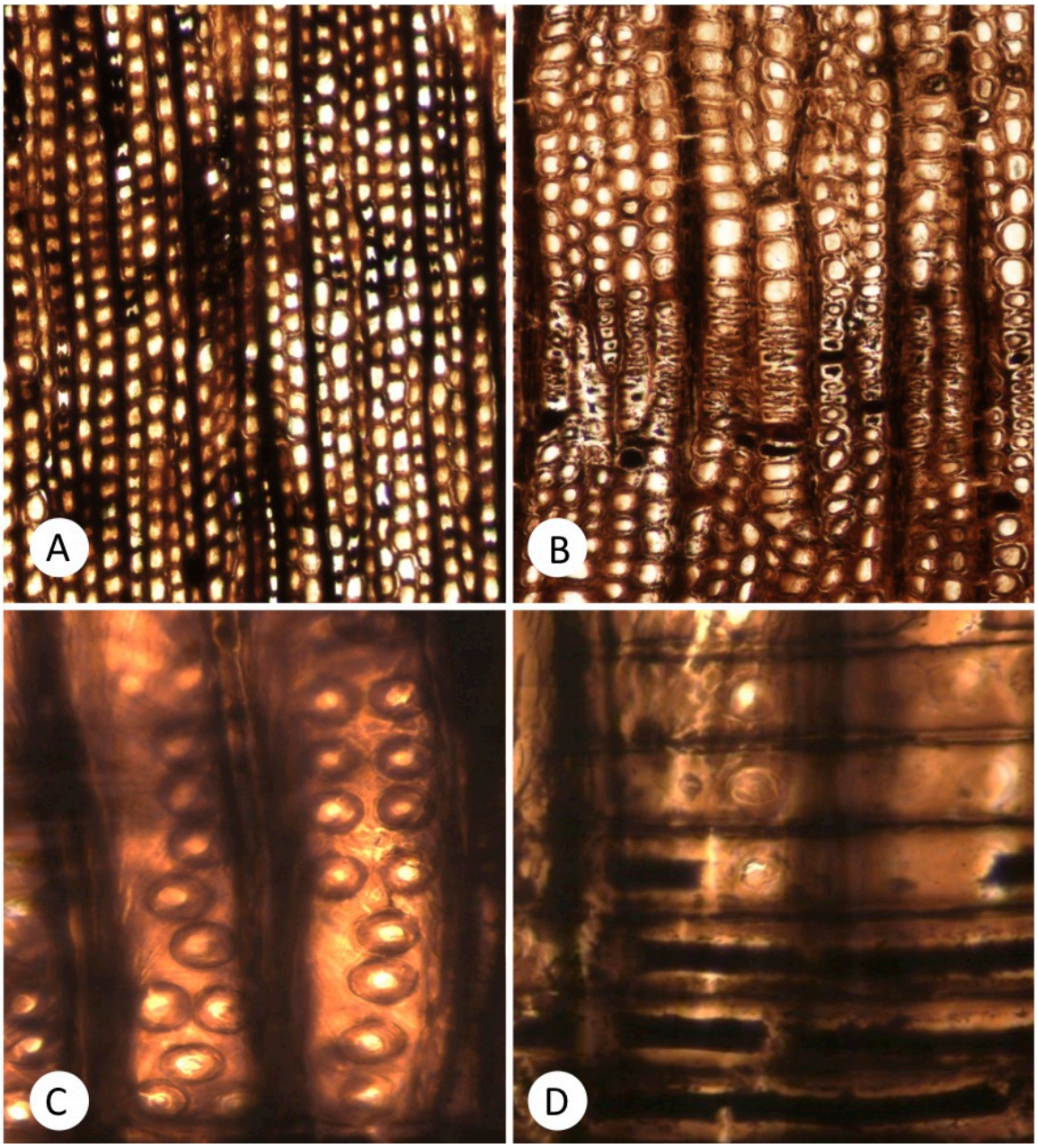

Figure 8. Features of cupressoid/podocarpoid woods. A. Lack of growth rings or transition from early wood to latewood (sample 356). B. Distinct transition from early wood to late wood (sample 352). C. Intertracheary pitting uniseriate to biseriate, the pitting opposite when biseriate. D. Cupressoid-taxodioid cross-field pitting.

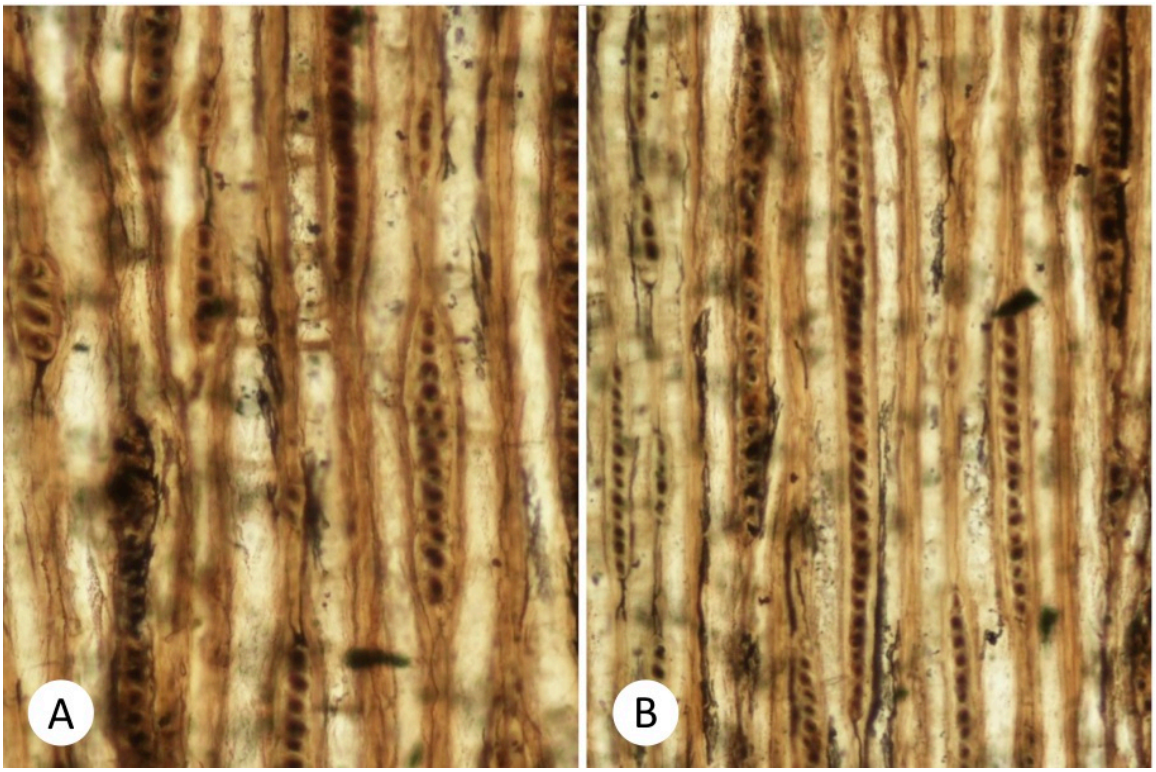

Figure 9. Features of cupressoid/podocarpoid woods. A. Tangential section showing short rays (mostly < 12 cells high) that are uniseriate with short biseriate portions (sample 095). B. Tangential section showing taller rays (up to 60 cells high) that are predominantly uniseriate.

Table 5. Wood anatomical characters of extant conifers examined in the present study.

Family Species	Araucariaceae *Agathis australis*	Araucariaceae *Araucaria heterophylla*	Araucariaceae *Araucaria nemorosa*	Cupressaceae *Athrotaxis selaginoides*	Cupressaceae *Callitris glaucophylla*
1. Growth ring boundaries distinct/indistinct	I	I	I	D	I
2. Earlywood-latewood transition abrupt/gradual	G	G	G	A	-
3. Tracheid pitting uniseriate/multiseriate	M	M	M	U	U
4. Multiseriate tracheid pitting alternate/opposite	A	A	A		
5. Organic deposits present/absent	-	-	+	-	-
6. Average tracheid length small/medium/long	S	M	S	S	S
7. Intercellular spaces present/absent	-	-	-	-	-
8. Latewood tracheid walls thin-/thick-walled	Tn	Tn	Tn	Tk	Tn
9. Tori present/absent	-	-	-	+	-
10. Torus extensions present/absent	-	-	-	+	-
11. Pits with notched borders present/absent	-	-	-	+	-
12. Warty layer present/absent	-	-	-	-	-
13. Helical thickenings in tracheids present/absent	-	-	-	-	-
14. Helical thickenings early/late/throughout					
15. Helical thickenings single/grouped					
16. Helical thickenings narrowly/widely spaced					
17. Helical thickenings in ray tracheids present/absent	-	-	-	-	-
18. Callitroid thickenings present/absent	-	-	-	-	+
19. Axial parenchyma diffuse/zonate/absent	-	-	-	Z	-

Table 5, continued. Wood anatomical characters of extant conifers examined in the present study.

Family Species	Araucariaceae *Agathis australis*	Araucariaceae *Araucaria heterophylla*	Araucariaceae *Araucaria nemorosa*	Cupressaceae *Athrotaxis selaginoides*	Cupressaceae *Callitris glaucophylla*
20. Transverse end walls smooth/irregular/beaded	S	S	S	S	S
21. Ray tracheids present/absent	-	-	-	-	-
22. Ray tracheid walls smooth/dentate/reticulate					
23. Ray tracheid pit borders angular/dentate					
24. Ray parenchyma endwalls smooth/pitted	S	S	S	S	S
25. Ray parenchyma horizontal walls smooth/pitted	S	S	S	S	S
26. Indentures present/absent	-	-	-	-	-
27. Cross-field pitting	Tx	Ar	Ar	Cu	Cu
28. Average ray height low/medium/high	M	M	M	L	M
29. Rays uniseriate/multiseriate	M	M	M	U	U
30. Axial resin canals present/absent	-	-	-	-	-
31. Radial resin canals present/absent	-	-	-	-	-
32. Traumatic resin canals present/absent	-	-	-	-	-
33. Crystals present/absent	-	-	-	-	-

Table 5, continued. Wood anatomical characters of extant conifers examined in the present study.

Family Species	Cupressaceae *Chamaecyparis lawsoniana*	Cupressaceae *Chamaecyparis thyoides*	Cupressaceae *Cupressus arizonica*	Cupressaceae *Juniperus ashei*	Cupressaceae *Juniperus occidentalis*
1. Growth ring boundaries distinct/indistinct	D	D	D	I	D
2. Earlywood-latewood transition abrupt/gradual	A	A	A	G	A
3. Tracheid pitting uniseriate/multiseriate	U	U	U	U	U
4. Multiseriate tracheid pitting alternate/opposite					
5. Organic deposits present/absent	-	-	-	-	-
6. Average tracheid length small/medium/long	S	S	S	S	S
7. Intercellular spaces present/absent	-	-	-	-	-
8. Latewood tracheid walls thin-/thick-walled	Tk	Tk	Tk	Tk	Tk
9. Tori present/absent	+	+	-	-	+
10. Torus extensions present/absent	+	+	-	-	+
11. Pits with notched borders present/absent	-	-	-	-	+
12. Warty layer present/absent	-	-	-	-	+
13. Helical thickenings in tracheids present/absent	-	-	-	-	-
14. Helical thickenings early/late/throughout					
15. Helical thickenings single/grouped					
16. Helical thickenings narrowly/widely spaced					
17. Helical thickenings in ray tracheids present/absent	-	-	-	-	-
18. Callitroid thickenings present/absent	-	-	-	-	-
19. Axial parenchyma diffuse/zonate/absent	Z	Z	D	Z	D

Table 5, continued. Wood anatomical characters of extant conifers examined in the present study.

Family Species	Cupressaceae *Chamaecyparis lawsoniana*	Cupressaceae *Chamaecyparis thyoides*	Cupressaceae *Cupressus arizonica*	Cupressaceae *Juniperus ashei*	Cupressaceae *Juniperus occidentalis*
20. Transverse end walls smooth/irregular/beaded	S	S	S	S	S
21. Ray tracheids present/absent	-	-	-	-	-
22. Ray tracheid walls smooth/dentate/reticulate					
23. Ray tracheid pit borders angular/dentate					
24. Ray parenchyma endwalls smooth/pitted	S	S	S	S	S
25. Ray parenchyma horizontal walls smooth/pitted	S	S	S	S	S
26. Indentures present/absent	-	-	+	-	-
27. Cross-field pitting	Pc	Pc	Cu	Cu	Cu
28. Average ray height low/medium/high	L	L	M	L	L
29. Rays uniseriate/multiseriate	U	U	U	U	U
30. Axial resin canals present/absent	-	-	-	-	-
31. Radial resin canals present/absent	-	-	-	-	-
32. Traumatic resin canals present/absent	-	-	-	-	-
33. Crystals present/absent	-	+	-	-	-

Table 5, continued. Wood anatomical characters of extant conifers examined in the present study.

Family Species	Cupressaceae *Juniperus oxycedrus*	Cupressaceae *Juniperus virginiana*	Cupressaceae *Metasequoia glyptostroboides*	Cupressaceae *Sequoiadendron giganteum*	Cupressaceae *Sequoia sempervirens*
1. Growth ring boundaries distinct/indistinct	D	I	D	I	D
2. Earlywood-latewood transition abrupt/gradual	A	G	A	G	A
3. Tracheid pitting uniseriate/multiseriate	U	U	U/M	U	U/M
4. Multiseriate tracheid pitting alternate/opposite			O		O
5. Organic deposits present/absent	-	-	-	-	-
6. Average tracheid length small/medium/long	S	S	M	S	M
7. Intercellular spaces present/absent	-	-	-	-	-
8. Latewood tracheid walls thin-/thick-walled	Tk	Tn	Tk	Tn	Tk
9. Tori present/absent	+	-	+	-	+
10. Torus extensions present/absent	+	-	+	-	+
11. Pits with notched borders present/absent	-	-	-	-	+
12. Warty layer present/absent	+	-	-	-	+
13. Helical thickenings in tracheids present/absent	-	-	-	-	-
14. Helical thickenings early/late/throughout					
15. Helical thickenings single/grouped					
16. Helical thickenings narrowly/widely spaced					
17. Helical thickenings in ray tracheids present/absent	-	-	-	-	-
18. Callitroid thickenings present/absent	-	-	-	-	+
19. Axial parenchyma diffuse/zonate/absent	Z	Z	-	-	D

Table 5, continued. Wood anatomical characters of extant conifers examined in the present study.

Family Species	Cupressaceae *Juniperus oxycedrus*	Cupressaceae *Juniperus virginiana*	Cupressaceae *Metasequoia glyptostroboides*	Cupressaceae *Sequoiadendron giganteum*	Cupressaceae *Sequoia sempervirens*
20. Transverse end walls smooth/irregular/beaded	S	S	S	S	S
21. Ray tracheids present/absent	-	-	-	-	-
22. Ray tracheid walls smooth/dentate/reticulate					
23. Ray tracheid pit borders angular/dentate					
24. Ray parenchyma endwalls smooth/pitted	S	S	S	S	S
25. Ray parenchyma horizontal walls smooth/pitted	S	S	S	S	S
26. Indentures present/absent	-	-	+	-	-
27. Cross-field pitting	Cu/Tx	Cu	Cu/Tx	Cu	Cu/Tx
28. Average ray height low/medium/high	L	M	M	M	M
29. Rays uniseriate/multiseriate	U	U	U	U/M	U/M
30. Axial resin canals present/absent	-	-	-	-	-
31. Radial resin canals present/absent	-	-	-	-	-
32. Traumatic resin canals present/absent	-	-	-	-	-
33. Crystals present/absent	-	-	-	-	-

Table 5, continued. Wood anatomical characters of extant conifers examined in the present study.

Family Species	Cupressaceae *Thuja occidentalis*	Cupressaceae *Thuja plicata*	Pinaceae *Abies fabri*	Pinaceae *Abies procera*	Pinaceae *Larix marschlinsii*
1. Growth ring boundaries distinct/indistinct	D	D	D	D	D
2. Earlywood-latewood transition abrupt/gradual	A	A	A	A	A
3. Tracheid pitting uniseriate/multiseriate	U/M	U	U	U	M
4. Multiseriate tracheid pitting alternate/opposite	O				O
5. Organic deposits present/absent	-	-	-	-	-
6. Average tracheid length small/medium/long	S	S	S	S	M
7. Intercellular spaces present/absent	-	-	-	-	+
8. Latewood tracheid walls thin-/thick-walled	Tk	Tk	Tk	Tk	Tk
9. Tori present/absent	+	+	+	+	+
10. Torus extensions present/absent	+	+	+	+	+
11. Pits with notched borders present/absent	-	-	+	-	+
12. Warty layer present/absent	-	-	-	-	+
13. Helical thickenings in tracheids present/absent	-	-	-	-	-
14. Helical thickenings early/late/throughout					
15. Helical thickenings single/grouped					
16. Helical thickenings narrowly/widely spaced					
17. Helical thickenings in ray tracheids present/absent	-	-	-	-	-
18. Callitroid thickenings present/absent	-	-	-	-	+
19. Axial parenchyma diffuse/zonate/absent	-	-	D	-	-

Table 5, continued. Wood anatomical characters of extant conifers examined in the present study.

Family Species	Cupressaceae *Thuja occidentalis*	Cupressaceae *Thuja plicata*	Pinaceae *Abies fabri*	Pinaceae *Abies procera*	Pinaceae *Larix marschlinsii*
20. Transverse end walls smooth/irregular/beaded	S	S	S	S	S
21. Ray tracheids present/absent	-	-	-	-	+
22. Ray tracheid walls smooth/dentate/reticulate					S
23. Ray tracheid pit borders angular/dentate					A
24. Ray parenchyma endwalls smooth/pitted	S	S	P	P	P
25. Ray parenchyma horizontal walls smooth/pitted	S	S	P	S	S
26. Indentures present/absent	-	-	+	-	+
27. Cross-field pitting	Cu	Cu	Pn	Pn	Pc
28. Average ray height low/medium/high	M	M	M	M	M
29. Rays uniseriate/multiseriate	U/M	U	U	U	U
30. Axial resin canals present/absent	-	-	-	-	+
31. Radial resin canals present/absent	-	-	-	-	+
32. Traumatic resin canals present/absent	-	-	-	-	-
33. Crystals present/absent	-	-	-	-	-

Table 5, continued. Wood anatomical characters of extant conifers examined in the present study.

Family Species	Pinaceae *Picea* *abies*	Pinaceae *Picea* *engelmannii*	Pinaceae *Picea* *pungens*	Pinaceae *Pinus* *elliotii*	Pinaceae *Pinus* *nigra*
1. Growth ring boundaries distinct/indistinct	D	D	D	D	D
2. Earlywood-latewood transition abrupt/gradual	A	A	A	A	A
3. Tracheid pitting uniseriate/multiseriate	U	U	U	M	U
4. Multiseriate tracheid pitting alternate/opposite				O	
5. Organic deposits present/absent	-	-	-	-	-
6. Average tracheid length small/medium/long	S	S	S	?	S
7. Intercellular spaces present/absent	+	+	+	+	+
8. Latewood tracheid walls thin-/thick-walled	Tk	Tk	Tk	Tk	Tn
9. Tori present/absent	+	+	+	+	+
10. Torus extensions present/absent	+	+	+	+	+
11. Pits with notched borders present/absent	-	+	-	+	-
12. Warty layer present/absent	-	-	-	+	-
13. Helical thickenings in tracheids present/absent	-	-	-	+	-
14. Helical thickenings early/late/throughout				T	
15. Helical thickenings single/grouped				S	
16. Helical thickenings narrowly/widely spaced				W	
17. Helical thickenings in ray tracheids present/absent	-	-	-	+	-
18. Callitroid thickenings present/absent	+	+	-	+	+
19. Axial parenchyma diffuse/zonate/absent	-	-	-	-	-

Table 5, continued. Wood anatomical characters of extant conifers examined in the present study.

Family Species	Pinaceae *Picea* *abies*	Pinaceae *Picea* *engelmannii*	Pinaceae *Picea* *pungens*	Pinaceae *Pinus* *elliottii*	Pinaceae *Pinus* *nigra*
20. Transverse end walls smooth/irregular/beaded	S	S	S	S	S
21. Ray tracheids present/absent	+	+	+	+	+
22. Ray tracheid walls smooth/dentate/reticulate	S	S	S	S	D
23. Ray tracheid pit borders angular/dentate	A	A	A	A	A
24. Ray parenchyma endwalls smooth/pitted	P	P	P	P	S
25. Ray parenchyma horizontal walls smooth/pitted	P	P	S	S	S
26. Indentures present/absent	+	+	+	+	-
27. Cross-field pitting	Pc	Pc	Pc	F	F
28. Average ray height low/medium/high	M	M	M	M	M
29. Rays uniseriate/multiseriate	U	U	U	U	U
30. Axial resin canals present/absent	+	-	+	+	+
31. Radial resin canals present/absent	+	-	+	-	+
32. Traumatic resin canals present/absent	-	-	-	+	-
33. Crystals present/absent	-	-	-	-	-

Table 5, continued. Wood anatomical characters of extant conifers examined in the present study.

Family Species	Pinaceae *Pinus palustris*	Pinaceae *Pinus parviflora*	Pinaceae *Pinus ponderosa*	Pinaceae *Pinus radiata*	Pinaceae *Pinus strobus*
1. Growth ring boundaries distinct/indistinct	D	D	D	D	D
2. Earlywood-latewood transition abrupt/gradual	A	A	A	A	A
3. Tracheid pitting uniseriate/multiseriate	M	U	U	U	U
4. Multiseriate tracheid pitting alternate/opposite	O				
5. Organic deposits present/absent	-	-	+	-	-
6. Average tracheid length small/medium/long	M	S	S	S	S
7. Intercellular spaces present/absent	+	+	+	+	+
8. Latewood tracheid walls thin-/thick-walled	Tk	Tn	Tn	Tk	Tn
9. Tori present/absent	+	+	+	+	+
10. Torus extensions present/absent	+	+	+	+	+
11. Pits with notched borders present/absent	-	-	-	-	-
12. Warty layer present/absent	-	-	-	-	-
13. Helical thickenings in tracheids present/absent	-	-	-	-	-
14. Helical thickenings early/late/throughout					
15. Helical thickenings single/grouped					
16. Helical thickenings narrowly/widely spaced					
17. Helical thickenings in ray tracheids present/absent	-	-	-	-	-
18. Callitroid thickenings present/absent	+	-	-	-	-
19. Axial parenchyma diffuse/zonate/absent	-	-	D	-	-

Table 5, continued. Wood anatomical characters of extant conifers examined in the present study.

Family Species	Pinaceae *Pinus palustris*	Pinaceae *Pinus parviflora*	Pinaceae *Pinus ponderosa*	Pinaceae *Pinus radiata*	Pinaceae *Pinus strobus*
20. Transverse end walls smooth/irregular/beaded	S	S	S	S	S
21. Ray tracheids present/absent	+	+	+	+	+
22. Ray tracheid walls smooth/dentate/reticulate	D	S	D	D	S
23. Ray tracheid pit borders angular/dentate	A	A	A	A	A
24. Ray parenchyma endwalls smooth/pitted	S	P	S	S	S
25. Ray parenchyma horizontal walls smooth/pitted	P	P	S	S	S
26. Indentures present/absent	-	-	-	-	-
27. Cross-field pitting	Pn	F	Pn	Pn	F
28. Average ray height low/medium/high	M	M	M	M	M
29. Rays uniseriate/multiseriate	U	U	U	U	U
30. Axial resin canals present/absent	+	-	+	+	+
31. Radial resin canals present/absent	+	+	-	-	-
32. Traumatic resin canals present/absent	-	-	+	+	+
33. Crystals present/absent	-	-	-	-	-

Table 5, continued. Wood anatomical characters of extant conifers examined in the present study.

Family Species	Pinaceae *Pinus virginiana*	Pinaceae *Pseudotsuga menziesii*	Pinaceae *Tsuga canadensis*	Pinaceae *Tsuga caroliniana*	Pinaceae *Tsuga caroliniana*
1. Growth ring boundaries distinct/indistinct	D	D	D	D	D
2. Earlywood-latewood transition abrupt/gradual	A	A	A	A	A
3. Tracheid pitting uniseriate/multiseriate	U	U	U	M	U
4. Multiseriate tracheid pitting alternate/opposite				O	
5. Organic deposits present/absent	-	+	-	-	-
6. Average tracheid length small/medium/long	M	S	S	S	S
7. Intercellular spaces present/absent	+	+	-	-	-
8. Latewood tracheid walls thin-/thick-walled	Tk	Tk	Tk	Tk	Tn
9. Tori present/absent	+	+	+	+	+
10. Torus extensions present/absent	+	+	+	+	+
11. Pits with notched borders present/absent	-	+	+	-	-
12. Warty layer present/absent	-	-	-	-	-
13. Helical thickenings in tracheids present/absent	-	+	-	-	-
14. Helical thickenings early/late/throughout		T			
15. Helical thickenings single/grouped		S			
16. Helical thickenings narrowly/widely spaced		W			
17. Helical thickenings in ray tracheids present/absent	-	+	-	-	-
18. Callitroid thickenings present/absent	-	+	+	+	-
19. Axial parenchyma diffuse/zonate/absent	-	-	-	-	-

Table 5, continued. Wood anatomical characters of extant conifers examined in the present study.

Family Species	Pinaceae *Pinus virginiana*	Pinaceae *Pseudotsuga menziesii*	Pinaceae *Tsuga canadensis*	Pinaceae *Tsuga caroliniana*	Pinaceae *Tsuga caroliniana*
20. Transverse end walls smooth/irregular/beaded	S	S	S	S	S
21. Ray tracheids present/absent	+	+	+	+	+
22. Ray tracheid walls smooth/dentate/reticulate	D	S	S	S	S
23. Ray tracheid pit borders angular/dentate	A	A	A	A	A
24. Ray parenchyma endwalls smooth/pitted	S	S	P	P	P
25. Ray parenchyma horizontal walls smooth/pitted	S	S	S	P	S
26. Indentures present/absent	-	+	-	+	+
27. Cross-field pitting	Pn	Pc	Pc	Pc	Pc
28. Average ray height low/medium/high	M	M	M	M	M
29. Rays uniseriate/multiseriate	U	U	U	M	U
30. Axial resin canals present/absent	+	+	-	-	-
31. Radial resin canals present/absent	+	+	-	-	-
32. Traumatic resin canals present/absent	-	-	-	-	-
33. Crystals present/absent	+	-	-	-	-

Table 5, continued. Wood anatomical characters of extant conifers examined in the present study.

Family Species	Pinaceae *Tsuga heterophylla*	Podocarpaceae *Podocarpus latifolius*	Podocarpaceae *Podocarpus macrophyllus*	Taxaceae *Taxus brevifolia*	Taxaceae *Taxus* sp.
1. Growth ring boundaries distinct/indistinct	D	I	D	D	D
2. Earlywood-latewood transition abrupt/gradual	A	G	A	A	A
3. Tracheid pitting uniseriate/multiseriate	U	U	U/M	M	U
4. Multiseriate tracheid pitting alternate/opposite			O	O	
5. Organic deposits present/absent	-	-	-	-	-
6. Average tracheid length small/medium/long	S	M	S	S	S
7. Intercellular spaces present/absent	-	-	-	-	-
8. Latewood tracheid walls thin-/thick-walled	Tk	Tn	Tk	Tk	Tk
9. Tori present/absent	+	-	+	+	+
10. Torus extensions present/absent	+	-	+	+	+
11. Pits with notched borders present/absent	-	-	-	+	+
12. Warty layer present/absent	-	-	-	-	-
13. Helical thickenings in tracheids present/absent	-	-	-	+	+
14. Helical thickenings early/late/throughout				T	T
15. Helical thickenings single/grouped				S	S
16. Helical thickenings narrowly/widely spaced				W	W
17. Helical thickenings in ray tracheids present/absent	-	-	-	+	+
18. Callitroid thickenings present/absent	-	+	+	-	-
19. Axial parenchyma diffuse/zonate/absent	-	D	D	-	-

Table 5, continued. Wood anatomical characters of extant conifers examined in the present study.

Family Species	Pinaceae *Tsuga heterophylla*	Podocarpaceae *Podocarpus latifolius*	Podocarpaceae *Podocarpus macrophyllus*	Taxaceae *Taxus brevifolia*	Taxaceae *Taxus* sp.
20. Transverse end walls smooth/irregular/beaded	S	S	B	S	S
21. Ray tracheids present/absent	+	-	-	-	-
22. Ray tracheid walls smooth/dentate/reticulate	S				
23. Ray tracheid pit borders angular/dentate	A				
24. Ray parenchyma endwalls smooth/pitted	S	S	S	S	S
25. Ray parenchyma horizontal walls smooth/pitted	S	S	S	S	S
26. Indentures present/absent	+	-	-	-	-
27. Cross-field pitting	Pc	Tx/Cu	Pc	Pc	Pc
28. Average ray height low/medium/high	M	M	M	M	M
29. Rays uniseriate/multiseriate	U	U	U	U	U
30. Axial resin canals present/absent	-	-	-	-	-
31. Radial resin canals present/absent	-	-	-	-	-
32. Traumatic resin canals present/absent	-	-	-	-	-
33. Crystals present/absent	-	-	-	-	-

Table 6. Wood anatomical characters of fossil conifers collected at Terlingua Ranch, Brewster County, Texas.

Sample:	095	189	193A	193B	200
1. Growth ring boundaries distinct/indistinct/absent	D	D	I	D	-
2. Earlywood-latewood transition abrupt/gradual	A	G	G	A	
3. Tracheid pitting uniseriate/biseriate	U/B	U/B	U/B	U	U/B
4. Multiseriate tracheid pitting alternate/opposite	O	O	O		O
5. Organic deposits present/absent	-	-	-	-	-
6. Intercellular spaces present/absent	-	-	-	-	-
7. Latewood tracheid walls thin-/thick-walled	Tn	Tn	-	Tn	Tn
8. Tori present/absent	-	-	-	-	-
9. Pits with notched borders present/absent	-	-	-	-	-
10. Warty layer present/absent	-	-	-	-	-
11. Helical thickenings in tracheids present/absent	-	-	-	-	-
12. Helical thickenings early/late/throughout					
13. Helical thickenings single/grouped					
14. Callitroid thickenings present/absent	-	-	-	-	-
15. Axial parenchyma abundant/rare	R	R	R	A	R

Table 6, continued. Wood anatomical characters of fossil conifers collected at Terlingua Ranch, Brewster County, Texas.

Sample:	095	189	193A	193B	200
16. Transverse end walls smooth/irregular/beaded	S	S	S	S	S
17. Ray tracheids present/absent	-	-	-	-	-
18. Ray tracheid walls smooth/dentate/reticulate					
19. Ray parenchyma endwalls smooth/pitted	S	S	S	S	S
20. Ray parenchyma horizontal walls smooth/pitted	S	S	S	S	S
21. Indentures present/absent	-	-	-	-	-
22. Cross-field pitting	Cu/Tx	Cu/Tx	Cu/Tx	Cu/Tx	Cu
23. Average ray height low/medium/high	M	M	M	H	
24. Rays uniseriate/multiseriate	U/M	U/M	U/M	U/M	U/M
25. Axial resin canals present/absent	-	-	-	-	-

Table 6, continued. Wood anatomical characters of fossil conifers collected at Terlingua Ranch, Brewster County, Texas.

Sample:	271	287	288	349	350
1. Growth ring boundaries distinct/indistinct/absent	I	D	I	I	I
2. Earlywood-latewood transition abrupt/gradual	G	A			
3. Tracheid pitting uniseriate/ biseriate	U/B	U	U/B	U/B	U/B
4. Multiseriate tracheid pitting alternate/opposite	O		O	O	O
5. Organic deposits present/absent	-	-	-	-	-
6. Intercellular spaces present/absent	-	-	-	-	-
7. Latewood tracheid walls thin-/thick-walled	Tn	Tn	Tn	Tn	Tn
8. Tori present/absent	-	-	-	-	-
9. Pits with notched borders present/absent	-	-	-	-	-
10. Warty layer present/absent	-	-	-	-	-
11. Helical thickenings in tracheids present/absent	-	-	-	-	-
12. Helical thickenings early/late/throughout					
13. Helical thickenings single/grouped					
14. Callitroid thickenings present/absent	+	-	-	-	-
15. Axial parenchyma abundant/rare	A	R	R	R	R

Table 6, continued. Wood anatomical characters of fossil conifers collected at Terlingua Ranch, Brewster County, Texas.

Sample:	271	287	288	349	350
16. Transverse end walls smooth/irregular/beaded	S	S	S	S	S
17. Ray tracheids present/absent	-	-	-	-	-
18. Ray tracheid walls smooth/dentate/reticulate					
19. Ray parenchyma endwalls smooth/pitted	S	S	S	S	S
20. Ray parenchyma horizontal walls smooth/pitted	S	S	S	S	S
21. Indentures present/absent	-	-	-	-	-
22. Cross-field pitting	Cu	Cu/Tx	Cu/Tx	Cu/Tx	Cu/Tx
23. Average ray height low/medium/high	M	M	M	M	M
24. Rays uniseriate/multiseriate	U/M	U/M	U/M	U/M	U/M
25. Axial resin canals present/absent	-	-	-	-	-

Table 6, continued. Wood anatomical characters of fossil conifers collected at Terlingua Ranch, Brewster County, Texas.

Sample:	351	352	354	355	356
1. Growth ring boundaries distinct/indistinct/absent	I	D	D	I	I
2. Earlywood-latewood transition abrupt/gradual		A	A		
3. Tracheid pitting uniseriate/ biseriate	U/B	U/B	U/B	U/B	U
4. Multiseriate tracheid pitting alternate/opposite	O	O	O	O	
5. Organic deposits present/absent	-	-	-	-	-
6. Intercellular spaces present/absent	-	-	-	-	-
7. Latewood tracheid walls thin-/thick-walled	Tn	Tn	Tn	Tn	Tn
8. Tori present/absent	-	-	-	-	-
9. Pits with notched borders present/absent	-	-	-	-	-
10. Warty layer present/absent	-	-	-	-	-
11. Helical thickenings in tracheids present/absent	-	-	-	-	-
12. Helical thickenings early/late/throughout					
13. Helical thickenings single/grouped					
14. Callitroid thickenings present/absent	+	-	-	-	-
15. Axial parenchyma abundant/rare	R	R	R	R	R

Table 6, continued. Wood anatomical characters of fossil conifers collected at Terlingua Ranch, Brewster County, Texas.

Sample:	351	352	354	355	356
16. Transverse end walls smooth/irregular/beaded	S	S	S	S	S
17. Ray tracheids present/absent	-	-	-	-	-
18. Ray tracheid walls smooth/dentate/reticulate					
19. Ray parenchyma endwalls smooth/pitted	S	S	S	S	S
20. Ray parenchyma horizontal walls smooth/pitted	S	S	S	S	S
21. Indentures present/absent	-	-	-	-	-
22. Cross-field pitting	Cu	Tx	Cu/Tx	Tx	Cu/Tx
23. Average ray height low/medium/high	H	M	M	H	M
24. Rays uniseriate/multiseriate	U/M	U/M	U/M	U/M	U/M
25. Axial resin canals present/absent	-	-	-	-	-

Table 6, continued. Wood anatomical characters of fossil conifers collected at Terlingua Ranch, Brewster County, Texas.

Sample:	357	358
1. Growth ring boundaries distinct/indistinct/absent	I	I
2. Earlywood-latewood transition abrupt/gradual		
3. Tracheid pitting uniseriate/ biseriate	U/B	U/B
4. Multiseriate tracheid pitting alternate/opposite	O	O
5. Organic deposits present/absent	-	-
6. Intercellular spaces present/absent	-	-
7. Latewood tracheid walls thin-/thick-walled	Tn	Tn
8. Tori present/absent	-	-
9. Pits with notched borders present/absent	-	-
10. Warty layer present/absent	-	-
11. Helical thickenings in tracheids present/absent	-	-
12. Helical thickenings early/late/throughout		
13. Helical thickenings single/grouped		
14. Callitroid thickenings present/absent	+	-
15. Axial parenchyma abundant/rare	R	R

Table 6, continued. Wood anatomical characters of fossil conifers collected at Terlingua Ranch, Brewster County, Texas.

Sample:	357	358
16. Transverse end walls smooth/irregular/beaded	S	S
17. Ray tracheids present/absent	-	-
18. Ray tracheid walls smooth/dentate/reticulate		
19. Ray parenchyma endwalls smooth/pitted	S	S
20. Ray parenchyma horizontal walls smooth/pitted	S	S
21. Indentures present/absent	-	-
22. Cross-field pitting	Cu/Tx	Tx
23. Average ray height low/medium/high	M	M
24. Rays uniseriate/multiseriate	U/M	U
25. Axial resin canals present/absent	-	-

IV. DISCUSSION

Only a handful of studies have documented the occurrence of fossil conifer woods from the Late Cretaceous (Campanian) western interior of North America. Ramanujam (1972) described fossil conifer woods from the Upper Cretaceous (Oldman Formation) of Alberta, Canada, including a *Taxodioxylon*-type wood and another form that Wheeler and Lehman (2005) suggested should be reassigned to *Cupressinoxylon*. Roberts and Hendrix (2000) described a taxodiaceous-cupressaceous forest from the Two Medicine Formation of Montana, while Falcon-Lang (2003) described a new *Cupressinoxylon* from this same formation. More recently, Wheeler and Lehman (2005) studied Late Cretaceous from the Aguja (Campanian) and Javelina (Maastrichtian) formations of Big Bend National Park, Texas, and documented the occurrence of *Cupressinoxylon*, a diverse collection of cupressoid/podocarpoid woods, and a few araucarioid woods from the former formation. Davies-Vollum et al. (2011) provided a description of a fossil forest from the Fruitland and Kirtland formations of the San Juan Basin in northwestern New Mexico that consisted of 68 fossil tree stumps and nine fossil logs and referred all 27 of the conifer stumps that were examined by thin-section analysis to *Cupressinoxylon*.

The fossil conifers of the Aguja Formation at Terlingua Ranch include specimens referable to at least three different taxa. The most abundant specimens can be characterized as cupressoid/podocarpoid type woods, sharing features such as a lack of resin canals, ray tracheids, and helical thickenings, and the presence of smooth-walled axial and ray parenchyma cells, cross-field pitting with 1–2 cupressoid-taxodioid pits, intertracheary pitting that is usually uniseriate but occasionally biseriate and opposite, and predominantly uniseriate rays. This combination of characteristics is typically found

in the conifer families Cupressaceae and Podocarpaceae (Phillipe and Bamford, 2008). Although these woods could, in principle, be considered to represent a single highly variable taxon, the variation that they exhibit is greater than that of either of the other two wood types recognized from the site and I have chosen to follow the lead of Wheeler and Lehman (2005) in not assigning these woods to a specific taxonomic group.

The cupressoid/podocarpoid woods from Terlingua Ranch are similar in many respects to the cupressoid/podocarpoid woods described from Big Bend National Park by Wheeler and Lehman (2005) but they do not fall into two clear anatomical classes as do the Big Bend woods. Wheeler and Lehman (2005) found that some of their cupressoid/podocarpoid woods were characterized by the presence of distinct growth rings and short rays (typically less than 25 cells high, while other of their cupressoid/podocarpoid woods were characterized by a lack of growth rings and tall rays with a maximum height of 30 cells or more. Among the Terlingua Ranch woods are specimens that exhibit distinct growth rings, as well as specimens in which growth rings are absent, but there is no clear correlation in these specimens between the presence or absence of growth rings and ray height.

Three of the Terlingua Ranch samples are referred to the genus *Cupressinoxylon* on the basis of longitudinal tracheids that are largely square or polygonal in outline and the presence of multiple cupressoid pits per cross-field. A single specimen referable to this morphogenus was described from Big Bend National Park by Wheeler and Lehman (2005). The occurrence of multiple specimens of *Cupressinoxylon* at Terlingua Ranch will allow us to better understand the range of anatomical variation in this morphogenus.

The remaining three Terlingua Ranch samples are referred to the morphogenus *Taxodioxylon*, primarily on the basis of their taxodioid cross-field pitting. Although *Taxodioxylon*-type woods have been reported previously from the Western Interior of North America, the earlier reports have been from northern localities along the Western Interior (Ramanujam and Stewart, 1969; Ramanujam, 1972). Wheeler and Lehman (2005) reported that one specimen of the woods from the Big Bend region contained a small region in which there appeared to be two taxodioid pits per cross-field and suggested that this sample could possibly represent *Taxodioxylon*, however, the present study represents the first definitive report of *Taxodioxylon*-type woods from the southern western interior of North America.

No araucarioid-type woods were identified among the specimens collected from Terlingua Ranch, although Wheeler and Lehman (2005) did describe a few such woods from nearby sites in Big Bend National Park. Most of their araucarioid woods were collected from the Paleocene Black Peaks Formation, however, and they suggested that the few samples obtained from the Aguja Formation may represent logs that had been transported outside of their original growth environment.

It is notable that all of the fossil wood specimens collected from the Aguja Formation of eastern Terlingua Ranch were coniferous and that no angiosperm wood was recovered from either of the collection sites. In their study of Big Bend woods, Wheeler and Lehman (2005) noted that conifer woods decrease dramatically in abundance as a component of fossil wood assemblages moving upward from the Campanian Aguja Formation through the Maastrichtian Javelina Formation to the Paleocene Black Peaks Formation.

According to Lehman (1985) and Wheeler and Lehman (2005), the lower portion of the upper shale member of the Aguja Formation represents a sandy, coastal delta environment that was deposited near the shoreline interspersed with areas of lignitic mudstone indicative of marginal marine conditions. Logs with cupressoid/podocarpoid characteristics were abundant in this interval, suggesting that conifer forests may have predominated in this coastal habitat. The upper portion of the upper shale member of the Aguja Formation consists of deposits indicative of a lowland freshwater floodplain environment situated some distance landward from the coast. In these strata Wheeler and Lehman (2005) found angiosperm woods to occur in equal or greater abundance than conifer woods, although the two wood types were rarely found to occur at the same sites. This observation suggests that conifers and angiosperms may have grown in separate stands or in different habitats within this inland floodplain environment and not occurred as mixed conifer-hardwood forests.

In the absence of a detailed stratigraphic section of the Aguja Formation at Terlingua Ranch, it is impossible to know with certainty in which environment these woods were deposited. However, by comparison with the results of Wheeler and Lehman (2005), it seems likely that the Terlingua Ranch collection sites are associated with the lower portion of the upper shale member of the Aguja Formation and that these woods represent the remnants of a cupressoid forest that dominated coastal environments along the southern portion of the western interior seaway during the Late Cretaceous.

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