Conifer wood from the Upper Jurassic of Utah, USA-Part II: *Araucarioxylon hoodii* sp. nov.

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Tidwell, William D & Medlyn, David A 1993. Conifer wood from the Upper Jurassic of Utah, USA-Part II: *Araucarioxylon hoodii* sp. nov. Palaeobotanist **42**(1) : 70-77

The new species, *Araucarioxylon hoodii*, collected from the Brushy Basin Member of the Upper Jurassic Morrison Formation in south central Utah, USA is compared to other species of *Araucarioxylon* and *Dadoxylon*. *Dadoxylon* (*Araucarioxylon*) *japonicum* Shimakura from Japan being the closest. They differ by the round to elliptical crossfield pits in *A. hoodii* having round apertures, lacking oppositely arranged tracheary pitting and having larger tangential pits of *A. hoodii*, whereas *Dadoxylon* (*A.*) *japonicum* has circular crossfield pits with obliquely elongated lenticular, included apertures. Opposite tracheary pits are often present in the latter species, and its tangential pits are smaller than *A. hoodii*. *Araucarioxylon hoodii* is the first member of this genus to be described with assurance from the Jurassic of the Colorado Plateau, USA. Associated fossil plants and the anatomical structure of *A. hoodii* suggest that it grew under a fairly equable, damp climate in which its growth rings were not well developed.

Key-words—*Araucarioxylon*, Fossil wood, Morrison Formation, Upper Jurassic, Utah.

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सारॉश

संयुक्त राज्य अमेरिका में उताह के उपरि जूराई कल्प से नई कोनिफर काष्ठ-भाग 2. *अॅराकेरिऑक्सीलॉन हुडाई* नव जाति

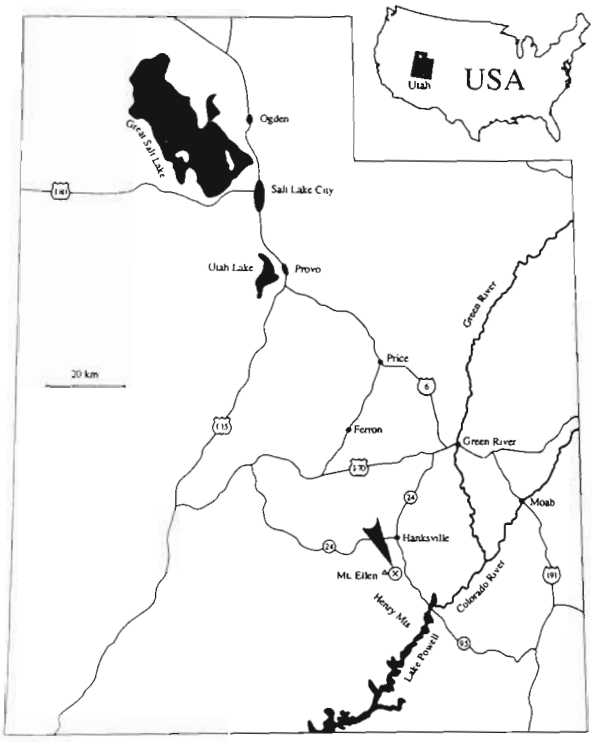
विलियम डी. टिडवेल एवं डेविड ए. मेडलिन

अमेरिका में दक्षिण केन्द्रीय उताह में उपरि जूराई मारिसन शैल-समूह के वर्णी द्रोणी सदस्य से एकत्रित ***अॅराकेरिऑक्सीलॉन हुडाई*** नव जाति की तुलना जापान में शिमाकुरा से उपलब्ध ***अॅराकेरिऑक्सीलॉन*** एवं ***डेडॉक्सीलॉन, डे. (अॅराकेरिऑक्सीलॉन) जेपोनिकम,*** की अन्य जाति से की गई है। गोलाकार छिद्रों से युक्त ***अॅ. हुडाई*** में ये गोलाकार से दीर्घवृत्ताकार क्रासित क्षेत्र गर्त्तों के कारण भिन्न हैं तथा ***अॅ. हुडाई*** की तरह वृहतर स्पर्शीय गर्त्तों से भी युक्त हैं परन्तु सम्मुख रूप से विन्यस्त वाहिकीय गर्त्तों से विहीन हैं। जबकि ***डेडॉक्सीलॉन (अॅ.) जेपोनिकम*** में तिरछे लम्बे मसूराकार छिद्रों के साथ-साथ वृत्ताकार क्रासित गर्त्त विद्यमान हैं। बाद वाली जाति में प्रायः सम्मुख वाहिकीय गर्त्त हैं तथा इसके स्पर्शीय गर्त्त ***अॅ. हुडाई*** से आकार में छोटे हैं। ***अॅराकेरिऑक्सीलॉन हुडाई*** अमेरिका में कोलोराडो पठार के जूराई कल्प से आत्मविश्वास के साथ वर्णित किया गया इस प्रजाति का पहला सदस्य है। सहयुक्त अश्मित पौधे एवं ***अॅ. हुडाई*** की शारीरीय संरचना से प्रस्तावित होता है कि यह जाति नम एवं समजलवायु में उगती थी जिसमें कि वृद्धि वलय पूर्ण विकसित नहीं थीं।

THE Upper Jurassic Morrison Formation is widely exposed on the Colorado Plateau, particularly in southern Utah, USA, where it consists of a complex sequence of lithologies that were deposited in a variety of non-marine environments. In the study area (Text-fig. 1), the formation has been divided into three members, viz., the Tidwell, Salt Wash, and Brushy Basin Members in ascending order (Peterson & Turner-Peterson, 1987). The fossil wood, upon which this report is based, is from the Brushy Basin Member near Mt. Ellen in the Henry Mountains, Utah. This report contains the first detailed description of an *Araucarioxylon* species from the Jurassic of the Colorado Plateau.

PREVIOUS INVESTIGATIONS

A variety of plant fossils represented by both petrifactions and compressions occurs in the Morrison Formation in south central Utah. They include the woods *Xenoxylon morrisonense* and *Protopiceoxylon resiniferous* from both the Salt Wash and Brushy Basin Members near Clay Point, an area south of the Henry Mountains, Utah (Medlyn & Tidwell, 1975, 1979). Short shoots assigned to *Behuninia* and *Steinerocaulis*, fossil conifer cones, fern rhizomes, and seeds, occur at the same locality as this wood (Bass, 1964; Tidwell & Medlyn, 1992). Numerous undescribed specimens of *Cycadeoidea*



Text-figure 1—Index map of Utah showing the collection locality (X) for *Araucarioxylon hoodii* sp. nov.

have also been collected from three sites in the Brushy Basin Member near Clay Point. One site contains small "cycad" stems in growth position which are associated with foliage that very likely was attached to the stems prior to burial. *Hermanophyton kirkbyorum* Arnold was found in the Salt Wash Member near the head of Hanson Creek in the southern part of the Henry Mountains area (Arnold, 1962). Other fossil plants reported from the Morrison Formation from localities within 70 km of the collection site for this wood are the osmundaceous taxa, *Millerocaulis wadei* (Tidwell & Rushforth 1970) Tidwell 1986 and *Osmundacaulis lemonii* Tidwell 1990a, from near Ferron and Moab, Utah; other species of *Hermanophyton* from the Brushy Basin Member of southwestern Colorado (Tidwell & Ash, 1990), and specimens of *Equisetum* sp., *Coniopteris hymenophylloides* Brongniart, *Cladophlebis* sp., *Nilssonia* sp., *Czekanowskia* sp. and *Brachyphyllum* sp. from southeastern Utah (Tidwell, 1990b). Scott (1961) mentioned having some specimens of *Araucarioxylon* from the Morrison Formation, but none were described.

MATERIAL AND METHODS

The permineralized wood specimen of the present study was collected from the Morrison Formation on the eastern flank of Mt. Ellen of the Henry Mountains, Utah. The specimen is 4 cm wide by 3 cm long. It consists of secondary wood only and its pith, primary xylem, phloem and cortex are not preserved. The fossil was studied by using ground thin sections.

DESCRIPTION

Genus—*Araucarioxylon* Kraus 1870

Araucarioxylon hoodii sp. nov.

Pl. 1, figs 1-6; Pl. 2, figs 1-6; Text-figs 1, 2

Diagnosis—Growth rings indistinct, when present often discontinuous, transition from early- to late-wood almost imperceptible; late-wood tracheids often heavily resinous; tracheids subangular, elliptical to subround in transverse section; lumen diameter 10-25 μm; tracheid walls 3-5 μm wide; radial tracheary pitting generally uniseriate, frequently biseriate, rarely triseriate, mostly contiguous, alternate, oppressed borders angular (hexagonal); pits 10-12 μm across, apertures circular, 5-7.5 μm, included; axial parenchyma absent; tracheary resin plugs numerous; tangential pitting occasionally present, same size and shape as radial pits; ray cells barrel-shaped, homocellular, parenchymatous, highly resiniferous, uniseriate, 1-18 (commonly 3-6) cells high, 35-38 per mm^2; ray cells 20-25 μm wide tangentially, 24-36 μm high, horizontal and tangential walls smooth, ray cell walls 3-4 μm thick, unpitted; cross-field pitting mostly obscured by resin; pits 7-12 in number, small 2-3 μm wide, round to subround, bordered; apertures round.

Repository—Brigham Young University no. 5102 (Holotype).

Locality—Eastern flank of Mt. Ellen, Henry Mountains, Utah (NE $^1/_4$, SW $^1/_4$, Sec. 25, T31S, R11E).

Horizon—Brushy Basin Member of the Morrison Formation; Late Jurassic.

Etymology—The specific epithet honors Mr. Glenn Hood of Lakewood, Colorado, USA for his donation of many specimens from the Mt. Ellen area and his continued interest in the Morrison flora.

DISCUSSION

The presence of araucarian tracheary pitting, indistinct or an absence of growth rings, and tracheary resin plugs in *Araucarioxylon hoodii* indicates that it may be allied to the Araucariaceae. Conifers exhibiting araucarian-type wood have been classified using a variety of different generic names in the last 150 years. They range from the Carboniferous to Recent in age. Their earliest report was by Whitham (1833), who described several species under the generic designation of *Pinites*. Fourteen years later, *Dadoxylon* was proposed by

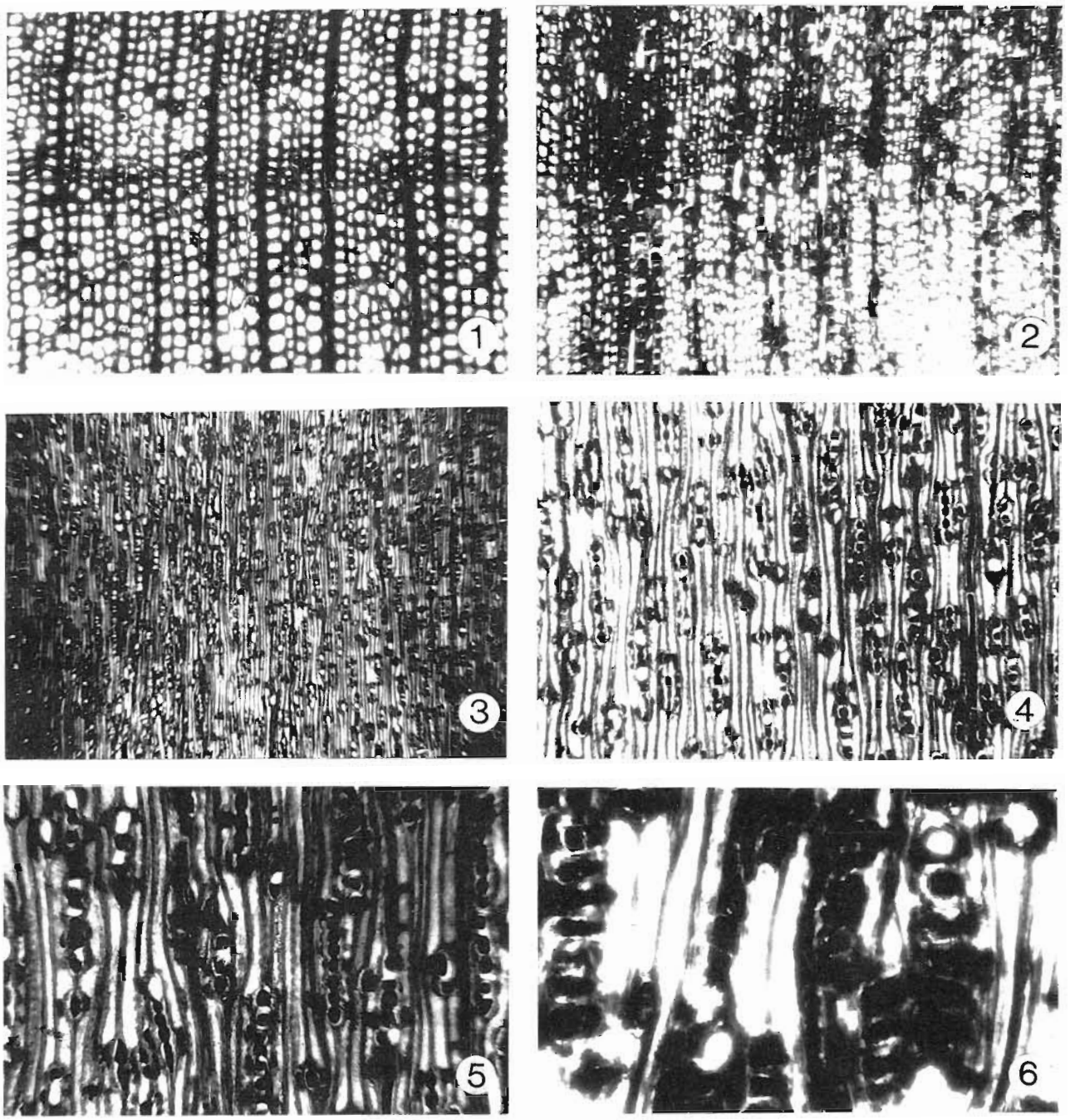


PLATE 1

1,2. *Araucarioxylon hoodii* sp. nov. (BYU 5102) : Transverse sections illustrating indistinct and incomplete growth rings. X 60.

3,4,5. Tangential views of resiniferous, uniseriate rays—3. X 20, 4. X 40, 5. X 80.

6. Ray cells that are oriented somewhat obliquely and filled with resiniferous contents showing how the contents obscure the cross-field pitting. X 160.

Endlicher (1847) for woods of similar anatomical characters. Seward (1919) commenting on this, referred to *Dadoxylon* as a non-committal genus, a notation he liked and adopted because it did not imply systematic relationships which could not be substantiated, particularly between araucarian and cordaitalean woods. He proposed adding qualifying terms such as *Araucarioxylon* or *Cordaioxylon* in parenthesis after *Dadoxylon* whenever evidence supported such denotation. Earlier, Göeppert (1844) had used the name *Araucarites*, but the name was pre-empted by Presl (1838), who had used it previously for impressions of

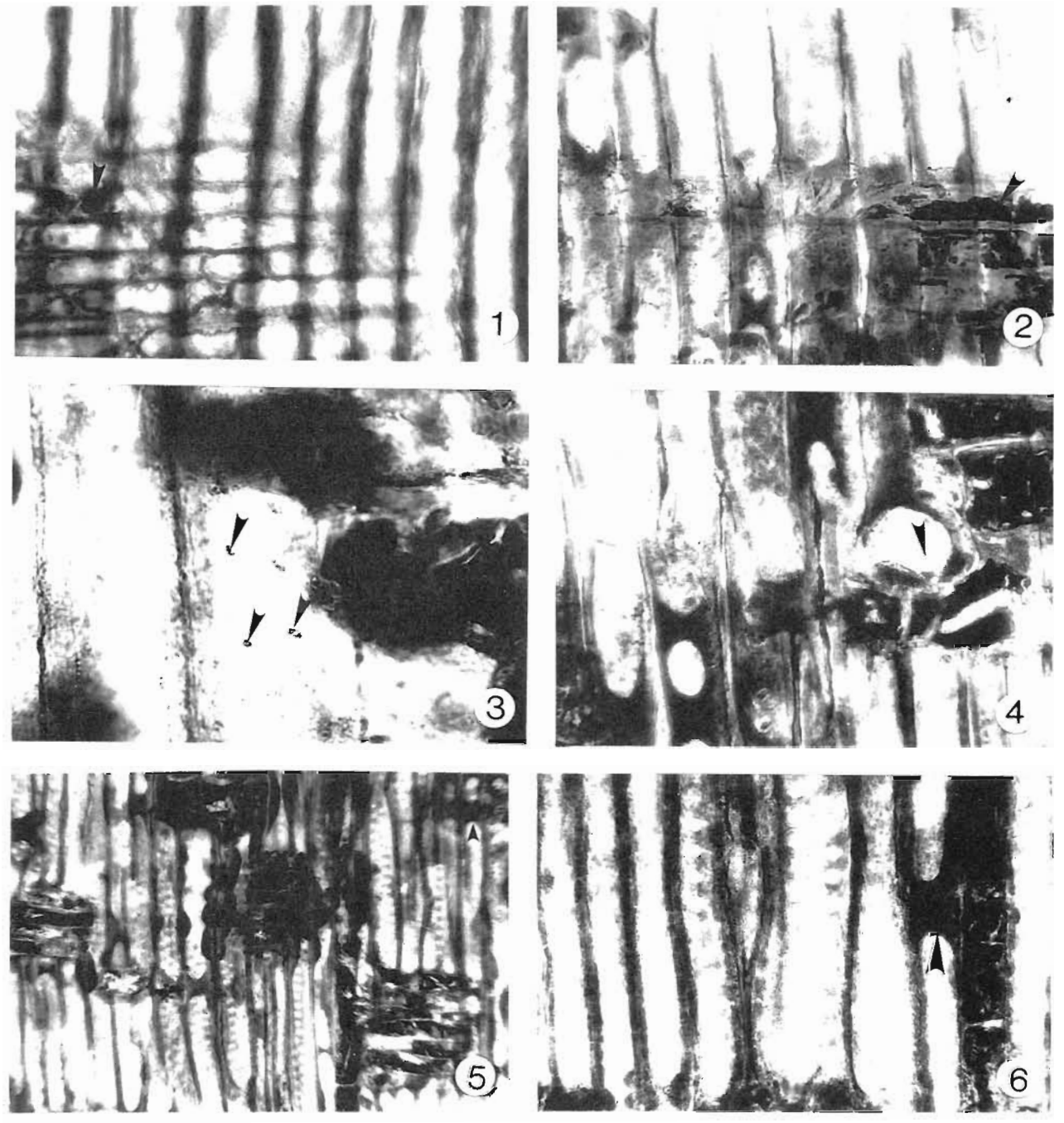


PLATE 2

All radial sections.

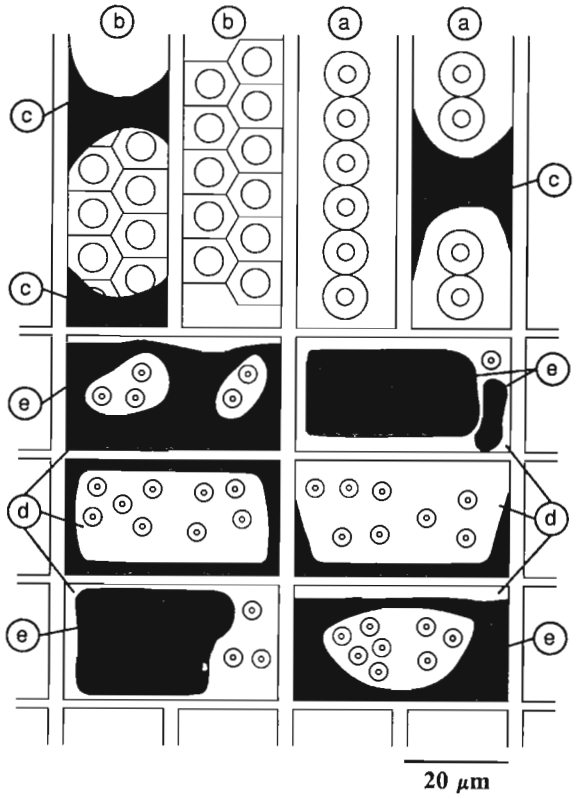
1,2 *Araucarioxylon hoodii* sp. nov. (BYU 5102) Rays containing an abundance of resiniferous contents (arrows), X 400.

3 Apertures only of crossfield pitting (arrows) illustrating their distribution. Their borders are poorly preserved, X 800.

4. Close-up of a round crossfield pit (arrow); note the round aperture and broad border, X 800

5,6 Radial sections illustrating uniseriate and biseriate pitting and resin plugs (arrows), X 400

leaves and cones. *Araucarioxylon* was erected by Kraus (1870), and since that time, there has been considerable debate about the appropriate designation of woods demonstrating a possible affinity to the Araucariaceae. Penhallow (1900), while working with North American species of *Dadoxylon*, lamented about the confusion in the literature concerning the systematic position of plants that should be properly assigned to *Dadoxylon*. Kräusel and Jain (1963), Sah and Jain (1963), and Vogellehner (1964) followed Gothan's (1905)



Text-figure 2—*Araucarioxylon hoodii* sp. nov. (BSIP 5102). Diagrammatic representation of the radial section illustrating the uniseriate pitting (**a**), biseriate pitting (**b**), resin plugs (**c**), ray cells containing round crossfield pits (**d**), and resin (**e**).

recommendation that all woods having araucarian and/or cordaitalean anatomy should be placed into *Dadoxylon* as a single nomenclatural taxon. Kräusel (1949) designated *Araucarioxylon* as the genus for all woods similar to *Agathis* or *Araucaria*. Knowlton (1889), Penhallow (1907), Stopes (1914), Holden (1914), Jeffrey (1917) and Torrey (1923) assigned Paleozoic araucarian-like woods to *Dadoxylon* and such woods of Mesozoic and Cenozoic age to *Araucarioxylon* (Prakash & Bande, 1980; Nishida, 1984; Srivastava & Prakash, 1984). Maheshwari (1972) suggested that such woods be assigned to *Araucarioxylon* if their rays are uniseriate or rarely partially biseriate and to *Dadoxylon* if their rays are typically wider than single-seriate. Lepekhina (1972) separated these genera on the large, non-septate pith without secretory canals of *Dadoxylon* and secondary wood only in *Araucarioxylon*, since the pith of the latter genus is unknown. Furthermore, *Parapalaeoxylon* was proposed for woods of this type with araucarian tracheal pitting and bordered cross field pits (Prasad, 1982).

Since the Morrison Formation is Jurassic in age, and because this wood is not likely to be a specimen of Paleozoic Cordaitales, we have chosen to assign it to *Araucarioxylon*.

COMPARISON

Araucarioxylon hoodii is very similar to the Paleozoic taxa, *Dadoxylon bengalense* Holden 1917 and *Araucarioxylon kumarpurensis* Bajpai & Singh 1986 from India, in having uniseriate to triseriate radial pitting, two to eight cross-field pits, and relatively high rays of one to nineteen cells. *Dadoxylon bengalense* has grouped or mixed pits, whereas both *A. kumarpurensis* and *A hoodii* invariably show araucarioid pitting. However, *A. kumarpurensis* has rare quadriseriate pitting that does not occur in *A hoodii*. *Araucarioxylon kumarpurensis* also lacks the tangential pitting that is present in *A hoodii*. The tangential pitting in the two Permian species, *A. ningarhense* Maheshwari 1965, 1972 and *A. loharense* Agashe & Gowda 1978 from India that are similar to *A. hoodii*, is frequently quadriseriate rather than uniseriate as in *A. hoodii*. The three Tertiary species from India, *D. eocenum* Chitaley 1949, *D. deccani* Shukla 1938, and *D. resinosum* Shukla 1944 also show some similarities to *A. hoodii*, but differ by having biseriate pitting in the tangential walls of their tracheids.

Dadoxylon septentrionale Gothan 1905 from Spitzbergen, *D.* (*A.*) *rajmahalense* Sahni 1931, *D.* (*A.*) *jurassicum* Bhardwaj 1953, *D. agathoides* Kräusel & Jain 1963, *D. jamudhiense* Maheshwari 1963, *D. amraparense* Sah & Jain 1963, *D. mandroense* Sah & Jain, *D. bindrabunense* Sah & Jain and *D. santalense* Sah & Jain, all from India, *A. nihongii* Nishida & Nishida 1984 from Japan, and *A. wyomingense* Andrews & Pannell 1942 from the USA can be separated from *A. hoodii* by their lack of tangential pitting that occurs in *A. hoodii*.

Species similar to *Araucarioxylon hoodii*, but having axial parenchyma that is absent in the wood of *A. hoodii* are: *D.* (*A.*) *aegyptiacum* Unger 1859, *D.* (*A.*) *paumierii* Loubiere 1935, *D.* (*A.*) *septatum* Boureau 1951 and *D.* (*A.*) *koufraense* Batton 1965 from the Mesozoic of North Africa; *D.* (*A.*) *breveradiatum* (Lignier) Seward 1919 and *D. alpinum* Lemoigne 1966 from the Mesozoic of France; *D.* (*A.*) *sidugawaense* Shimakura 1936 from the Jurassic of Japan; *A. noveboracense* Hollick & Jeffrey 1909, *A. texense* Torrey 1923 and *Agathoxylon lemonii* Tidwell & Thayn 1986 from the Mesozoic of New York, Texas, and Utah, respectively.

The Japanese Triassic species, *A. hujinamiense* Ogura 1960, *Protocedroxylon mineense* (Ogura) Nishida & Oishi 1982, which was originally described as *Araucarioxylon*, and the Lower Cretaceous species, *D. arduennense* Lemoigne & Demarcq 1967 from northern France, differ from *A. hoodii* in possessing tylosis-like structures in their tracheids which are absent in *A. hoodii*. The tyloses in these species resemble the resin plugs in *A. hoodii*, but do not have the biconcave shape of plugs (Kräusel & Jain, 1963).

Araucarioxylon hoodii can be separated from the two Triassic species, *D. chaneyi* Daugherty 1941 and *A. arixonicum* Knowlton 1888, from the Petrified Forest National Park, USA by having higher rays than *D. chaneyi* and from *A. arizonicum* by having 7-12 circular pits per crossfield as compared to 2-4 circular to oblong pits in *A. arizonicum* (Daugherty, 1941). Furthermore, in *A. arizonicum* tangential pitting is smaller than radial which are often separated, whereas in *A. hoodii* tangential and radial pitting are of the same size and radial pitting is generally contiguous.

Araucarioxylon novaezeelandii Stopes 1914 and *A. kiiense* Ogura 1944 from the Cretaceous of New Zealand and Japan respectively, have resin plugs, araucarian pitting, and lack axial parenchyma like *A. hoodii*. They are unlike the Morrison species by *A. novaezeelandii* having well-defined growth rings and thick-walled tracheids on each side of its rays, and by *A. kiiense* having only 2-6 small, half bordered pits per cross-field (Nishida & Nishida, 1983) rather than many as in *A. hoodii*.

The closest species to *A. hoodii* is *D.* (*A.*) *japonicum* Shimakura from the Jurassic (Shimakura, 1936) and the Lower Cretaceous (Shimakura, 1937; Nishida & Nishida, 1983) of Japan. However, they vary from one another by the circular crossfield pits with obliquely elongated lenticular, included apertures, often oppositely arranged tracheary pitting (Nishida & Nishida, 1983), and smaller tangential pits of *D.* (*A.*) *japonicum* which are not present in *A. hoodii*.

Araucarioxylon hoppertonae Knowlton 1899 from the Lower Cretaceous Lakota Formation of the Black Hills, South Dakota, USA differs from *A. hoodii* in having only one, or occasionally two pits per crossfield rather than having numerous pits as in *A. hoodii*.

Although Knowlton (1900) was uncertain of the genus, he described fossil wood from the Morrison Formation in the Freezeout Hills of Wyoming, USA as *Araucarioxylon? obscurum*. This species can be distinguished from *A. hoodii* in lacking araucarian-type tracheary pitting which is characteristic of *Araucarioxylon* and *A. hoodii*. Furthermore, a re-examination of Knowlton slides by the authors shows that *A? obscurum* has resin cells that were not reported by Knowlton and are not present in *A. hoodii*. This species of Knowlton actually represents another genus, not *Araucarioxylon*. Therefore, *A. hoodii* is the first definite *Araucarioxylon* species to be reported from the Morrison Formation.

PALEOECOLOGY

The wood structure of trees reflects the climate under which they grew (Creber & Chaloner, 1984a, 1984b, 1985; Ash & Creber, 1992). Therefore secondary wood organization in extinct plants furnishes reliable evidence for climatic conditions that prevailed in past geologic epochs where no modification of anatomical structure indicates a lack of periodicity in annual conditions of growth (Jeffrey, 1917). Secondary wood of living *Araucaria* generally shows the presence of growth rings, unless the species under consideration is of lowland tropical origin (Jeffrey, 1917) where the rings are lacking or indistinct. The lack of growth rings has been considered evidence for equable year-round temperature and rainfall (Creber & Chaloner, 1985) in humid areas (Creber, 1977). The indistinct and incomplete growth rings of *Araucarioxylon hoodii* are, therefore, similar to those in some living araucarian forms in that they are absent or very poorly developed, thus denoting a warm, humid climate with little or no seasonal fluctuation. *Xenoxylon morrisonense* from the Morrison Formation (Medlyn & Tidwell, 1975) has either indistinct growth rings or rings with narrow (2-3 cells wide) late-wood and very wide early-wood (41-180+ cells in width) which also indicates a complacent type of environment. However, *Protopiceoxylon resiniferous*, also from the Morrison (Medlyn & Tidwell, 1979), has well-developed growth rings showing a gradual transition from early- to late-wood, thus suggesting a paleoenvironment with seasonal variation. Apparently, *P. resiniferous*, *X. morrisonense* and *A. hoodii* did not grow in the same environment. One explanation for this discrepancy may be that before deposition, *P resiniferous* was transported a long distance from an upland environment where seasonal changes were present, whereas *A. hoodii* and *X. morrisonense* were components of a lowland flora and transported only relatively short distances. *Protopiceoxylon resiniferous* was deposited in a stream channel, and *A. hoodii* was likely preserved in a small pond alongwith fern rhizomes and the short shoots, *Behuninia* and *Steinerocaulis*, which also lack definite growth rings (Tidwell & Medlyn, 1992).

The numerous fern rhizomes in association with this wood, as well as the abundant specimens of the osmundaceous taxa (*M. wadei* and *O. lemonii*) a few kilometers northwest and northeast in the Brushy Basin, are indicative of a moist climate. Extant members of the Osmundaceae live in bogs, swamps, rain forests, and damp woodlands (Gould, 1981) of moist areas of eastern North America and tropical and temperate regions of Asia. These fossil fern species and *Araucarioxylon hoodii* probably lived under similar conditions, particularly in damp woodlands.

ACKNOWLEDGEMENTS

The authors wish to thank Glenn Hood for his aid with this study, Dr Francis Hueber of the Smithsonian

Institution for the loan of the types of *A? obscurum*, George Munzing and Leith Tidwell for their assistance with the thin-sections and illustrations, and special thanks to Dr S.R. Ash of Weber State University for reviewing the manuscript.

REFERENCES

Agashe SN & Gowda PRN 1978. Anatomical study of a gymnospermous wood from Lower Gondwana of Maharashtra. *Phytomorphology* **28**(3) : 269-274.

Andrews HN & Pannell E 1942. A fossil araucarian wood from western Wyoming. *Ann. Mo. bot. gdn* **29** : 283-285.

Arnold CA 1962. A *Rhexoxylon*-like stem from the Morrison Formation of Utah. *Am. J. Bot.* **49** : 883-886.

Ash SR & Creber GT 1992. Palaeoclimatic interpretation of the wood structures of the tree in the Chinle Formation (Upper Triassic), Petrified Forest National Park, Arizona, USA. *Palaeogeogr., Palaeoclimatol., Palaeoecol.* **96** : 299-317.

Bajpai U & Singh VK 1986. *Araucarioxylon kumarpurensis*, a new gymnospermous wood from the Upper Permian of West Bengal. *Palaeobotanist* **35** : 53-56.

Bass C 1964. Significant new fossil plant locality in Utah. *Contrib. Geol., Univ Wy.* **3**(2) : 94-95.

Batton G 1965. Contribution a l'etude anatomique et biostratigraphique de la flora du Continental interclaire saharien. *Publ. Ctre. Recb., Zone Arides. CRNS. Géol.* **6** 12-95

Bhardwaj DC 1953. Jurassic woods from the Rajmahal hills, Bihar *Palaeobotanist* **2** : 59-70.

Boureau E 1951. Etude Paleoxylologique du Sahara. (XIII) : Sur une nouvelle espece du Continental interclaire du Sahara Soudanais : *Dadoxylon (Araucarioxylon) septatum* n. sp. *Bull. Mus. Natn. D'Hist. Nat.* **23**(1) : 231-237.

Chitaley SD 1949. On a new species of *Dadoxylon*, *Dadoxylon eocenum* sp. nov. from the district of Chhindwara, C.P., India. *J. Indian bot. Soc* **28**(4) : 227-237.

Creber GT 1977. Tree rings : a natural data-storage system. *Biol. Rev. (London)* **52** : 349-383.

Creber GT & Chaloner WG 1984a. Influence of environmental factors on the wood structure of living and fossil trees. *Bot. Rev.* **50** : 358-448.

Creber GT & Chaloner WG 1984b. Climatic indications from growth rings in fossil wood. *In* Brenchley P (Editor)—*Fossil and climate.* Wiley, New York.

Creber GT & Chaloner WG 1985. Tree growth in the Mesozoic and Early Tertiary and the reconstruction of palaeoclimates. *Palaeogeogr., Palaeoclimatol., Palaeoecol.* **52** : 35-60.

Daugherty LH 1941. The Upper Triassic flora of Arizonia. *Carn. Instit. Wash. Publ.* **526** : 1-105.

Endlicher S 1847. *Synopsis Coniferalium Fossilium.* Sangalli.

Göeppert HR 1844. Uebersicht der Fossilen Flora Schlesiens, p. 218. *In* Wimmer F—*Flora von Schlesien* II. Breslau.

Gothan W 1905. Zur anatomie lebender und fossiler Gymnospermenholzer *Abb. Kaiserlich Preuss. geol. Landes. N.F.* **44** : 1-41

Gould RE 1981. The coal forming flora of the Walloon Coal Measures. *Coal Geol. (Australia)* **1** : 83-105.

Holden R 1914. Contributions to the anatomy of Mesozoic conifers. No. 2. Cretaceous lignites from Cliffwood, New Jersey. *Bot. Gaz.* **58** : 168-177

Holden R 1917. On the anatomy of two Palaeozoic stems from India. *Ann. Bot.* **31**(123,124) : 315-326.

Hollick A & Jeffrey EC 1909. Studies of Cretaceous coniferous remains from Kreischerville, New York. *Mem. New York bot. Gdn* **3** : 1-138.

Jeffrey EC 1917 *The anatomy of woody plants.* University of Chicago Press. Chicago, 478 pp.

Knowlton FH 1888. New species of fossil wood (*Araucarioxylon arizonicum*) from Arizonia and New Mexico. *Proc. U.S. Natn. Mus.* **11** : 1-4.

Knowlton FH 1889. A revision of the genus *Araucarioxylon* of Kraus, with compiled descriptions and partial synonymy of the species. *Proc. U.S. Natn. Mus.* **12** : 601-617

Knowlton FH 1899. *In* Ward LF—The Cretaceous Formation of the Black Hills as indicated by the fossil plants. *U.S. geol. Surv. Nineteenth Ann. Rep.*, pt. **2** : 644-645.

Knowlton FH 1900. Description of a new species of *Araucarioxylon* from the cycad bed of the Freezeout Hills, Carbon County, Wyoming. *U.S. geol. Surv. Twentieth Ann. Rep.*, pt. **2** : 418-419.

Kraus G 1870. Bois fossiles de coniferes. p. 363-385. *In* Schimper WP—*Traité de paléontologie végétale*, pt. **2**. Paris.

Kräusel R 1949. Die fossilen Koniferen-Hölzer (Unter Asschluss von *Araucarioxylon* Kraus) II. Tiel. Kitsche untersuchungen zur diagnostik lebender und fossiler Koniferen-Hölzer *Palaeontographica* **B89** : 83-203.

Kräusel R & Jain KP 1963. New fossil coniferous woods from the Rajmahal Hills, Bihar, India. *Palaeobotanist* **12**(1) : 59-67.

Lemoigne Y 1966. Sur une nouvelle espece de Coniferale Jurassique provenant des "Terres Noires" du Bassin de la Durance (*Dadoxylon alpinum* n. sp.). *Bull. Soc. géol. France* **8** : 393-397

Lemoigne Y & Demarcq G 1967. Nouvelle espece de *Dadoxylon* a tracheide septees provenant du Wealdien de Feron-Glageon (Nord). *Bull. Soc. géol. France* **9** : 53-56.

Lepekhina VG 1972. Woods of Palaeozoic pycnoxylic gymnosperms with special reference to North Eurasia representatives. *Palaeontographica* **B138** : 44-106.

Loubiere H 1935. Étude anatomique d'un bois minéralisé trouvé à Ouadi Halfa (Nubie). *Rev. Gén. Bot.* **47** : 480.

Maheshwari HK 1963. Studies in the Glossopteris flora of India—*Dadoxylon jamudhiense*: a new species of fossil wood from the Raniganj Stage of Jharia Coalfield, Bihar. *Palaeobotanist* **12** : 267-269.

Maheshwari HK 1965. Studies in the Glossopteris flora of India-24. On two new species of fossil woods from the Raniganj Stage of Raniganj Coalfield, Bengal. *Palaeobotanist* **13**(2) : 148-152.

Maheshwari HK 1972. Permian wood from Antarctica and revision of some Lower Gondwana wood taxa. *Palaeontographica* **B138** : 1-43.

Medlyn DA & Tidwell WD 1975. Conifer wood from the Upper Jurassic of Utah. Part I. *Xenoxylon morrisonense* sp. nov. *Am. J. Bot.* **62** : 203-208.

Medlyn DA & Tidwell WD 1979. A review of the genus *Protopiceoxylon* with emphasis on North American species. *Can. J. Bot.* **57** : 1451-1463.

Nishida M 1984. The anatomy and affinities of the petrified plants from the Tertiary of Chile II. *Araucarioxylon* from Quiriquina Island, near Concepción, p. 87-90. *In* Nishida M (Editor)—*Contributions to the Botany in the Andes.* **I**. Academia Scientific Book Inc., Tokyo.

Nishida M & Nishida H 1983. Petrified plants from the Cretaceous of the Kwanto Mountains, central Japan-I. *Bot. Mag.* **96** : 85-91.

Nishida M & Nishida H 1984. Structure and affinities of the petrified plants from the Cretaceous of northern Japan and Saghalien. I. Petrified plants from the Upper Cretaceous of Hokkaido (I). *Jap. J. Bot.* **59**(2) : 48-57.

Nishida M & Oishi T 1982. The identity of *Araucarioxylon mineense* and a new species of *Protocedroxylon* from the Triassic of Miné, Yamaguchi Prefecture. *Jap. J. Bot.* **57**(4) : 97-104.

Ogura Y 1944. Notes on fossil woods from Japan and Manchoukuo. *Jap. J. Bot.* **13** : 345-365.

Ogura Y 1960. Tyloses in tracheids in *Araucarioxylon*. *J. Fac. Sci. Univ. Tokyo, Sect. III (Bot.)* **7**(10) : 501-509.

Penhallow DP 1900. Notes on the North American species of *Dadoxylon*. *Trans. R. Soc. Canada* **6** : 51.

Penhallow DP 1907. *A manual of North American gymnosperms.* Ginn & Company, Boston.

Peterson E & Turner-Peterson CE 1987. The Morrison Formation of the Colorado Plateau : Recent advances in sedimentology, stratigraphy, and paleotectonics. *Hunteria* **2**(1) : 1-18.

Prakash U & Bande MB 1980. Some more fossil woods from the Tertiary of Burma. *Palaeobotanist* **26**(3) : 261-278.

Prasad MNV 1982. An annotated synopsis of the Indian Palaeozoic gymnospermous woods. *Rev. Palaeobot. Palynol.* **38** : 119-156

Presl 1938. *In* Sternberg G.K. 1820-1838. Versuch einer geognostischen-botanischen Darstellung der Flora der Vorwelt. *Leipsic und Prague* **7** : 203, 301

Sah SCD & Jain KP 1963. Some fossil woods from the Jurassic of Rajmahal Hills, Bihar, India. *Palaeobotanist* **12**(2) : 169-180.

Sahni B 1931 Revision of Indian fossil plants. II Coniferales (b. Petrifactions). *Mem. geol. Surv. India Palaeont. indica* (N.S.) **2** : 51-124.

Scott RA 1961. Fossil woods associated with uranium on the Colorado Plateau. *U.S. geol. Surv. Res. Publ.* **1961B** : B130-131.

Seward AC 1919. *Fossil Plants*-**IV**. Cambridge. 543 pp.

Shimakura M 1936. Studies on fossil woods from Japan and adjacent lands. *Contrib. I. Sci. Rep. Toboku Imperial Univ.*, Series II *(Geol.)* **18**(3) : 267-310.

Shimakura M 1937. Studies on fossil woods from Japan and adjacent lands. *Contr. II. Sci. Rep. Toboku Imperial Univ.*, Series II *(Geol.)* **19** : 1-73.

Shukla VB 1938. On a new species of *Dadoxylon, D. deccani* sp. nov., from Deccan Intertrappean series. *J. Indian bot. Soc.* **17** : 355-367.

Shukla VB 1944. *Dadoxylon resinosum* sp. nov. from the Chhindwara District of the Central Provinces. *J. Indian bot. Soc.* **23** : 83-90.

Srivastava GP & Prakash U 1984. Occurrence of araucarian wood from the Neogene of West Bengal, India. *Palaeobotanist* **32**(3) 236-242.

Stopes MC 1914. A new *Araucarioxylon* from New Zealand. *Ann. Bot.* **27** : 341-350.

Tidwell WD 1986. *Millerocaulis*, a new genus with species formerly in *Osmundacaulis* Miller (fossils : Osmundaceae). *Sida* **11**(4) : 401-405.

Tidwell WD 1990a. A new arborescent osmundaceous species (*Osmundacaulis lemonii* n. sp.) from the Upper Jurassic Morrison Formation. *Hunteria* **2**(7) : 1-12.

Tidwell WD 1990b. Preliminary report on the megafossil flora of the Upper Jurassic Morrison Formation. *Hunteria* **2**(8) : 1-11.

Tidwell WD & Ash SR 1990. On the Upper Jurassic stem *Hermanophyton* and its species from Colorado and Utah, USA. *Palaeontographica* **B218** : 77-92.

Tidwell WD & Medlyn DA 1992. Short shoots from the Upper Jurassic Morrison Formation, Utah, Wyoming and Colorado, USA. *Rev. Palaeobot. Palynol.* **71** : 219-238.

Tidwell WD & Rushforth SR 1970. *Osmundacaulis wadei*, a new osmundaceous species from the Morrison Formation (Jurassic) of Utah. *Bull. Torrey bot. Club* **97** : 137-144.

Tidwell WD & Thayn GF 1986. *Agathoxylon lemonii* sp. nov. from the Dakota Formation, Utah. *Great Basin Nat.* **46**(3) : 559-566.

Torrey RE 1923. The comparative anatomy and phylogeny of the Coniferales. Part 3. Mesozoic and Tertiary coniferous woods. *Mem. Boston Soc. Nat. Hist.* **6**(2) : 41-106.

Unger F 1859. Der versteinerte Wald bei Cairo und einige Lager verkieselten Holzes in Agypten. *Sitzber. K. Akad. Wissen. Wien.* **33** : 209-232.

Vogellehner D 1964. Zur nomenklatur der fossilen Holzgattung *Dadoxylon* Endlicher 1847. *Taxon* **13** : 233-237.

Whitham H 1833. *The internal structure of fossil vegetables, accompanied by representation of their internal structure, as seen through the microscope.* Blackwood, Edinburgh.