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Palaeocupressinoxylon uniseriale n. gen. n. sp., a gymnospermous wood from the upper Permian of Central Taodonggou, southern Bogda Mountains, northwestern China

Ming-Li Wan [a,*], Wan Yang [b], Jun Wang [a,c]

[a] *State Key Laboratory of Palaeobiology and Stratigraphy, Center for Excellence in Life and Paleoenvironment, Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, Nanjing 210008, China*

[b] *Geology and Geophysics Program, Missouri University of Science and Technology, Rolla, MO 65409, USA* [c] *University of Chinese Academy of Sciences, Beijing 100049, China*

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Abstract

A silicified wood, *Palaeocupressinoxylon uniseriale* n. gen. n. sp., is described from the upper Permian of the Central Taodonggou section, Turpan–Hami Basin, Xinjiang Uygur Autonomous Region, northwestern China. Multidisciplinary data including U–Pb ID–TIMS zircon dating, vertebrate and invertebrate biostratigraphic, and cyclostratigraphic correlation from current and previous studies indicate that the fossil bearing interval is Wuchiapingian (late Permian) in age. The pycnoxylic wood consists of thick-walled tracheids and parenchymatous rays. It is characterized by separated uniseriate radial tracheidal pits, uniseriate ray cells, and cupressoid cross-field pitting. The absence of growth rings in the wood, together with the occurrence of Argillisols, Gleysols, and Histosols above and below the fossil interval, suggests that a stable landscape and a perennially humid climate prevailed in the Taodonggou area during the Wuchiapingian.

Keywords: Wood anatomy; Abietinean radial pitting; Cupressoid cross-field pitting; Wuchiapingian; Angara flora

1. Introduction

China is the only country where the four distinct floras, Cathaysian, Angaran, Euramerican and Gondwanan, were developed during Carboniferous and Permian (Shen, 1995; Fig. 1A). Based on biogeographical patterns of fossil floras, northern Xinjiang was part of the Angaran phytoprovince in the Permian (Sun, 1989). Late Permian floras from this region are much more diverse than those from the lower and middle Permian (Hu, 1980, 1986; Dou and Sun, 1984, 1985a, 1985b, 1985c; Zhou and Zhou, 1986; Sun, 1989; Huang, 1995; Liu and Yao, 1996a, 1996b; Ouyang et al., 2003, 2004). Studies of the late Palaeozoic Angaran fossil woods in northern China have vastly increased in recent years, and more than 20 species have been reported (Zhang et al., 2007; Shi et al., 2014; Wan et al., 2014, 2016a, 2016b, 2017a, 2019a, 2019b; Wei et al., 2016). The rich fossil wood materials allowed identification of anatomical structures of the Permian gymnosperms. In addition, they provide a palaeoxylological view to the knowledge of floral diversities and their succession during the Permian. However, compared to the compression–impression foliages, wood anatomical researches in northern Xinjiang are still rare, and some of the gymnospermous woods were described from the deposits of ambiguous age (e.g., Sze, 1934; Wei et al., 2016). To date, three types of wood are recorded from the Wuchiapingian of northern Xinjiang (Wan et al., 2014, 2016b, 2017a). Among them, only one woody stem, *Septomedullopitys szei* Wan et al. with a *Protophyllocladoxylon*-type secondary xylem, has been reported from the southern Bogda Mountains (Wan et al., 2014). Despite of the highly diverse gymnosperms developed during the late Permian of the Bogda Mountains (Hu, 1980, 1986; Dou and Sun, 1984, 1985a, 1985b, 1985c; Zhou and Zhou, 1986; Sun,

* Corresponding author.

E-mail address: mlwan@nigpas.ac.cn (M.L. Wan).

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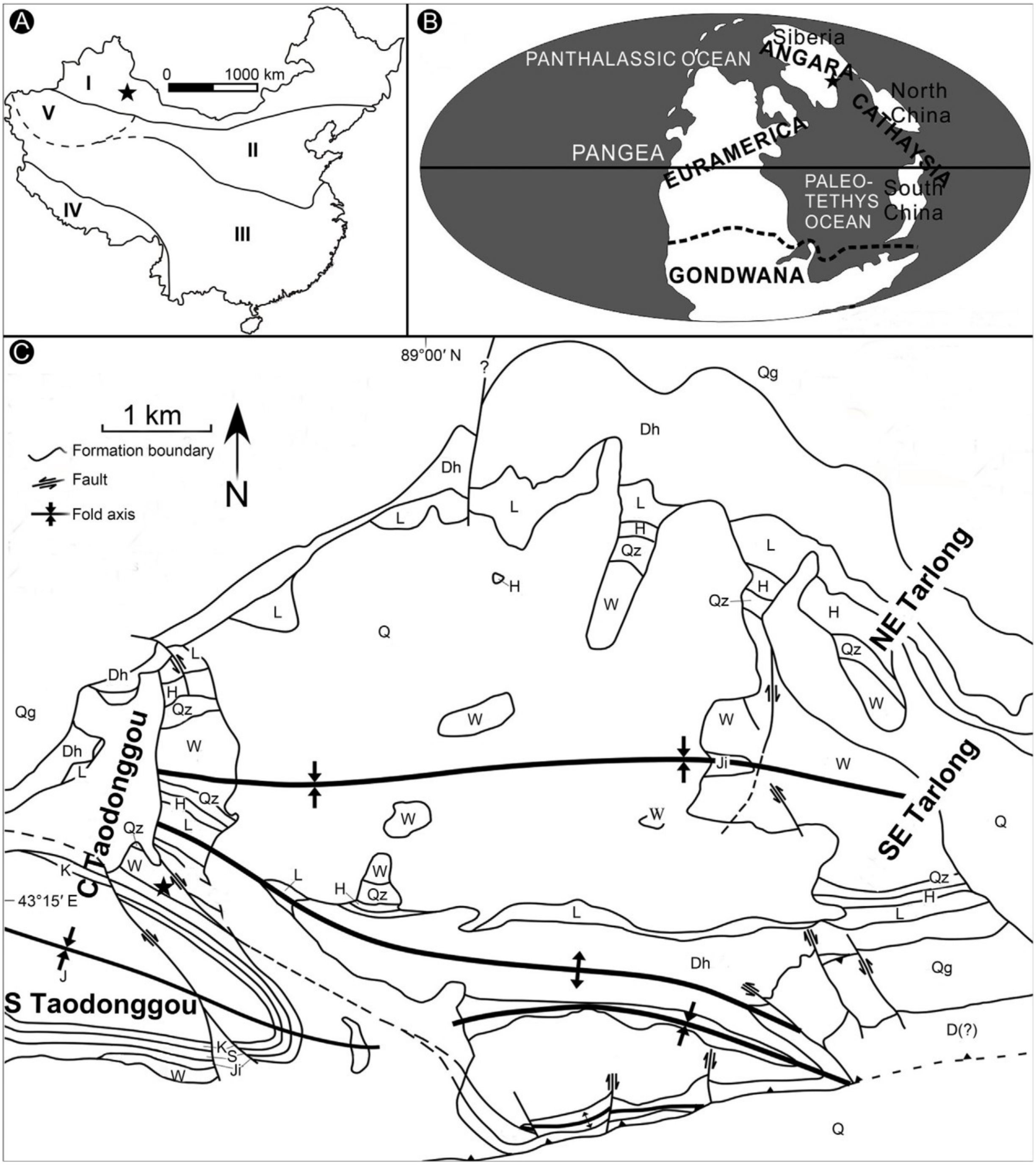

Fig.1.Mapsshowingthelocationofstudyarea.(A)ThelatePermianphytogeoprovincemap,modifiedafterShen(1995);I–AngaranprovinceinJunggar–Hinggan Region;II–Cathaysianprovince(NorthChinasubprovince);III–Cathaysianprovince(SouthChinasubprovince);IV–Gondwanaprovince;V–Angaranprovincein TarimPlate;the collectionsiteisshownbytheblackstar,whichisinthePermianAngaranphytoprovince(Meyen,1982,1987;Sun,1989).(B)Palaeogeographicmap ofPangaeaduringthe Permianshowingthefossilsite(star)intheeasternmostKazakhstanPlateatthemid-latitudeNEPangaea(S¸engörandNatal'in,1996;Ziegler etal.,1997;Scotese,2001;Liet al., 2004), modified after Scotese (2001). (C) Geological map of the Tarlong–Taodonggou area in Turpan–Hami Basin, southern Bogda Mountains, showing the fossil collectionsite(blackstar)inCentralTaodonggousection(CTaodonggou),modifiedafterYangetal.(2010)andObrist-Farner andYang(2017).Legends:D,Devonian;Dh, Daheyan Formation; H, Hongyanchi Formation; J, Jurassic; Ji, Jiucaiyuan Formation; K, Karamay Formation; L, Lucaogou Formation; Q, Quaternary; Qg, Qiergusitao Formation;Qz,QuanzijieFormation;S,ShaofanggouFormation;W,WutonggouandGuodikengformations.

1989;LiuandYao,1996a,1996b;Ouyangetal.,2003,2004), knowledgeontheiranatomyisextremelyscarce.

In this contribution, we describe a new gymnospermous wood from the uppermost Wutonggou Formation in the Central Taodonggou section, southern Bogda Mountains Xinjiang Uygur

Autonomous Region, northwestern China. Multidisciplinary data, including U–Pb ID–TIMS zircon dating, vertebrate and invertebrate biostratigraphic, and cyclostratigraphic correlation, indicates that the fossil bearing interval is of late Wuchiapingian (late Permian) in age. This wood is characterized by the uniseriate abietinean radial tracheidal pits and cupressoid cross-field pitting withoutparenchymaandresincanals. Theexceptionalpreservation quality of the material provides a palaeoxylological record to the Wuchiapingian flora in the research area. A persistently humid palaeoclimaticconditionin theWuchiapingianisinferredbasedon fossilwood,sedimentary andpalaeosolevidence.

2. Geologicalsetting,materialsandmethods

Thestudyarea,CentralTaodonggou,islocatedinthe southern foothillsoftheBogdaMountains,XinjiangUygur Autonomous Region, northwestern China, bordering the northwest margin of the Turpan–Hami Basin (Fig. 1A, B). It was located at the KazakhstanPlateatthemid-latitudeofnortheasternPangaea(Fig. 1C; S¸engör and Natal'in, 1996; Ziegler et al., 1997; Scotese, 2001; Li et al., 2004; Yang et al., 2010). In this area, uppermost CarboniferoustoLowerJurassicconglomerate,sandstone,shale, andminorlimestoneandvolcanicrocks aredepositedinalluvial, fluvial, and lacustrine environments (Fig. 1D; Liao et al., 1987; Cheng and Lucas, 1993; Carroll et al., 1995; Wartes et al., 2002; Greene et al., 2005; Yang et al., 2007, 2010). Based on the depositional environment interpretations on the basis of lateral facies and thickness changes, with reference to the stratal and basin geometries on seismic sections in nearby Turpan–Hami Basin, Yangetal.(2010)proposed thatstratainthestudyareawere deposited in a half graben (Tarlong–Taodonggou half graben). Palaeoclimatic conditions varied from humid to arid from the latest Carboniferous to Early Triassic in the study area, as interpreted from sedimentary and geochemical evidence (Yang et al., 2007, 2010; Thomas et al., 2011; Obrist-Farner and Yang, 2015,2016,2017;Liuetal., 2017,2019).

The fossil wood was collected from the Wutonggou loworder cycle (Fig. 2). This low-order cycle was defined by Yang et al. (2007, 2010) on the basis of long-term trends of interpreted depositional environments, and tectonic and palaeoclimatic conditions. The environments range from meandering stream, lacustrine deltaic, to lake margin; the climatic conditions are dominantly humid to subhumid; and the tectonic conditions are steadilysubsiding(Yangetal.,2007,2010;Thomasetal., 2011). The Wutonggou low-order cycle includes the Wutonggou and Guodikeng formations, and spans the Wuchiapingian, Changshingian and early Induan stages on the basis of palynological, palaeobotanical, and palaeozoological data, and U–Pb ID–TIMS zircon dating (Li et al., 1986; XBGMR, 1993; Cai, 1999; Yang et al., 2010; Fig. 2). In Central Taodonggou section, theWutonggoulow-ordercycleis329.3mthick(Yanget al., 2010).Thefossilintervalisabout130mbelowtheboundaryof theGuodikengandJiucaiyuanformations.Inalithostratigraphic context, our fossil wood is preserved in the uppermost part of the Wutonggou Formation. In the southwestern Tarlong and northeastern Tarlong sections, three U–Pb zircon radiometric ages demonstrate that the Wuchiapingian and Changhsingian boundaryislocatedintheupperpartoftheWutonggoulow-order cycle (Yang et al., 2010). The fossil interval in Central Taodonggou is of a late Wuchiapingian in age from a cyclostratigraphic correlation (Yang et al., 2010). The environmentofthefossil-bearing sandstonesandshaleshasbeen interpreted as a lacustrine delta (Yang et al., 2007, 2010), suggesting that the trees grew probably on a deltaic plain or in a nearbyfluvialenvironment.

The description and discussion of anatomical features of the fossilwoodinthisstudyusetheterminologyofRichteretal. (2004) andPhilippeandBamford(2008).Athin-sectionmicroscopicstudy of the wood indicates that they are well silicified. Thin section images were taken using a Leica DM5000 compound microscope and Leica DC 500 digital microscope camera system. The fossil woodandthinsectionsarestoredinthe PalaeobotanicalCollection of the Nanjing Institute of Geology and Palaeontology, Chinese AcademyofSciences.

3. Systematics

FossilGymnospermae

Genus*Palaeocupressinoxylon*Wan,YangetWangn.gen.

Etymology: The generic epithet indicates that the fossil wood is comparable to the *Cupressinoxylon* Göppert with an older distribution.

Typespecies:*Palaeocupressinoxylonuniseriale*Wan,Yanget Wangn.sp.

Generic diagnosis: Pycnoxylic secondary xylem, without axial parenchyma, ray tracheids and resin canals. Tracheids with uni- to multiseriate bordered pits with rounded to oval apertures on radial walls. Uniseriate radial tracheidal pits isolated. Multiseriate radial tracheidal pits distributed oppositely. Ray parenchyma homogeneous, commonly uniseriate, rarely biseriate. Cross-field pittingcupressoid.

*Palaeocupressinoxylonuniseriale*Wan,YangetWangn.sp.

(Fig.3)

Etymology: Thespecificepithetindicatesthattracheidsofthe fossil woodhasdominantlyuniseriatepittingonradialwalls.

Holotype:PB22953,andslidesPB22953–1toPB22953–5.

Repository: Palaeobotanic Collection of Nanjing Institute of GeologyandPalaeontology,ChineseAcademyofSciences.

Typelocality: Taodonggou,Turpan,XinjiangUygur Autonomous Region,China.

Stratigraphichorizon: WutonggouFormation.

Age: Wuchiapingian,Permian.

Speciesdiagnosis: Gymnospermoussecondaryxylem pycnoxylic andhomoxyleous,composedoftracheidsand parenchymatousrays, without axial resin canals, axial parenchyma and, ray tracheids.

Tracheidscircular,ovalor polygonal,sometimessquarish,incross section. Radial tracheidal pitting uniseriate, rarely with partially biseriate pits. Bordered pits rounded in outline with circular oval apertures,distributedseparately.Rayscommonlyuniseriate, rarely biseriate, 1–16 cells high. Ray parenchymatous cells procumbent, rectangular,withsmoothwalls.Cross-fieldpitting cupressoid-type.Eachcross-fieldwith1–4,mostly1–2pits. Cross-fieldpits ovaltocircular, bordered with elliptically oval orslit-like apertures.

Description:

All the fossil wood specimens have been fragmented by weathering into several small pieces. Pith, primary xylem, cortex and peridermal structures are not preserved. Only the secondary xylemhasbeenpreserved.Thefollowingdescriptionisbased onthe thinsectionsfromspecimenPB22953.

Thesecondaryxylemofthefossilwoodispycnoxylic,composed oftracheidsandparenchymatousrays.Growthringsare absent(Fig. 3A). Tracheids are crudely rounded to polygonal and, in some stances, squarish in cross section, about 25–50 m in diameter, and arranged in regular radial files (Fig. 3A). The thickness of tracheid wallsrangesfrom5to11m.Inthelongitudinalsection,tracheidsare long and tube-like with blunt ends. Bordered pits in the radial tracheidalwallsaregenerallyuniseriate(Fig.3B–E),rarelybiseriate (Fig. 3D, black arrow). The uniseriate radial tracheidal pits are rounded in shape, commonly widely scattered. The diameters of radial pits range from 9 to 12 m. Circular to oval apertures on the borderedpitsare3to 6 m in diameter. Radial pits occupy about half of the tracheid radial wall when uniseriate. Biseriate radial pitting is extremely rare in currentwoodspecimens(lessthan1%,n=500).When biseriate,the radial tracheid pits are oppositely and separately distributed, occupying approximately the whole tracheid radial walls (Fig. 3D, black arrow). Tracheids are long and tube-like, commonly with blunt endings (Fig. 3E, black arrows). Tangential pits, axial parenchyma,raytracheids,andresincanalsare absent.

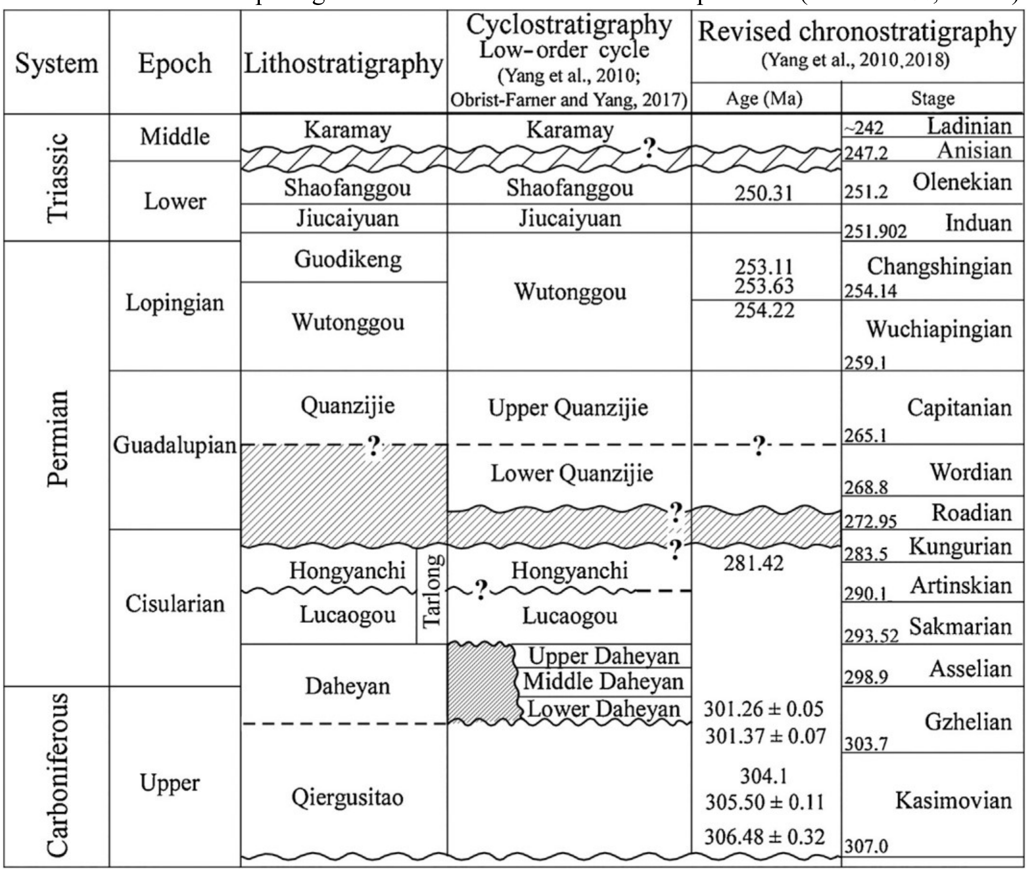

Fig.2.Chrono-,litho-,andcyclostratigraphyofPermian–TriassicstrataintheBogdaMountains,modifiedafterYangetal.(2010,2018)andObrist-FarnerandYang (2017).AbsoluteagesatstageboundariesfromtheInternationalChronostratigraphicChart(2018/08);Hachuredareasindicatemissingstrata.Wavylinesaremajor unconformities.Dashedlinesindicateuncertainagecorrelations.

Rays are homogeneous and commonly uniseriate, composed of parenchymatous cells (Fig. 3F, H). In radial section, parenchymatous ray cells are procumbent, rectangular and rangingfrom 80to210mlongand15to25mhigh(Fig.3F).Each ray cell spans 2–7, commonly 4–5 tracheids. Cell walls of ray parenchymatous cells are smooth. The vertical walls of ray cells are perpendiculartothehorizontalwalls(Fig.3F,blackarrows). In somecases,theverticalwallsareinclinedatanangleof40◦–60◦ (Fig. 3F, white arrows). Rays are 1–16 cells high (Fig. 3H, white arrows),and6cellsonaverage(n=300).Thecross-fieldpitting is of cupressoid-type (sensu Richter et al., 2004). There are 1–4, mostly 1–2 pits in each cross-field (Fig. 3G). Cross-field pits are oval to circular, bordered, with elliptically oval to slit-like apertures. Apertures are narrower than the border. Diameters of cross-fieldpitsrangefrom8to12m.

4. Comparison and discussion

Cross-field pitting is the most important feature for the late Palaeozoic gymnospermous wood identification (e.g., Lepekhina, 1972). One of the most typical characteristics of *Palaeocupressinoxylon* n. gen. is the occurrence of cupressoid (sensu Richter et al., 2004) type cross-field pitting. However, in literatures, the term "cupressoid" is not always given a clear definition (Philippe and Bamford, 2008). In addition, there is a great amount of confusion between the "cupressoid crossfield pitting" and the "araucarioid cross-field pitting" (Philippe and Bamford, 2008). Philippe (1995) tried to draw a clear line between those two types of cross-field pitting, and proposed that

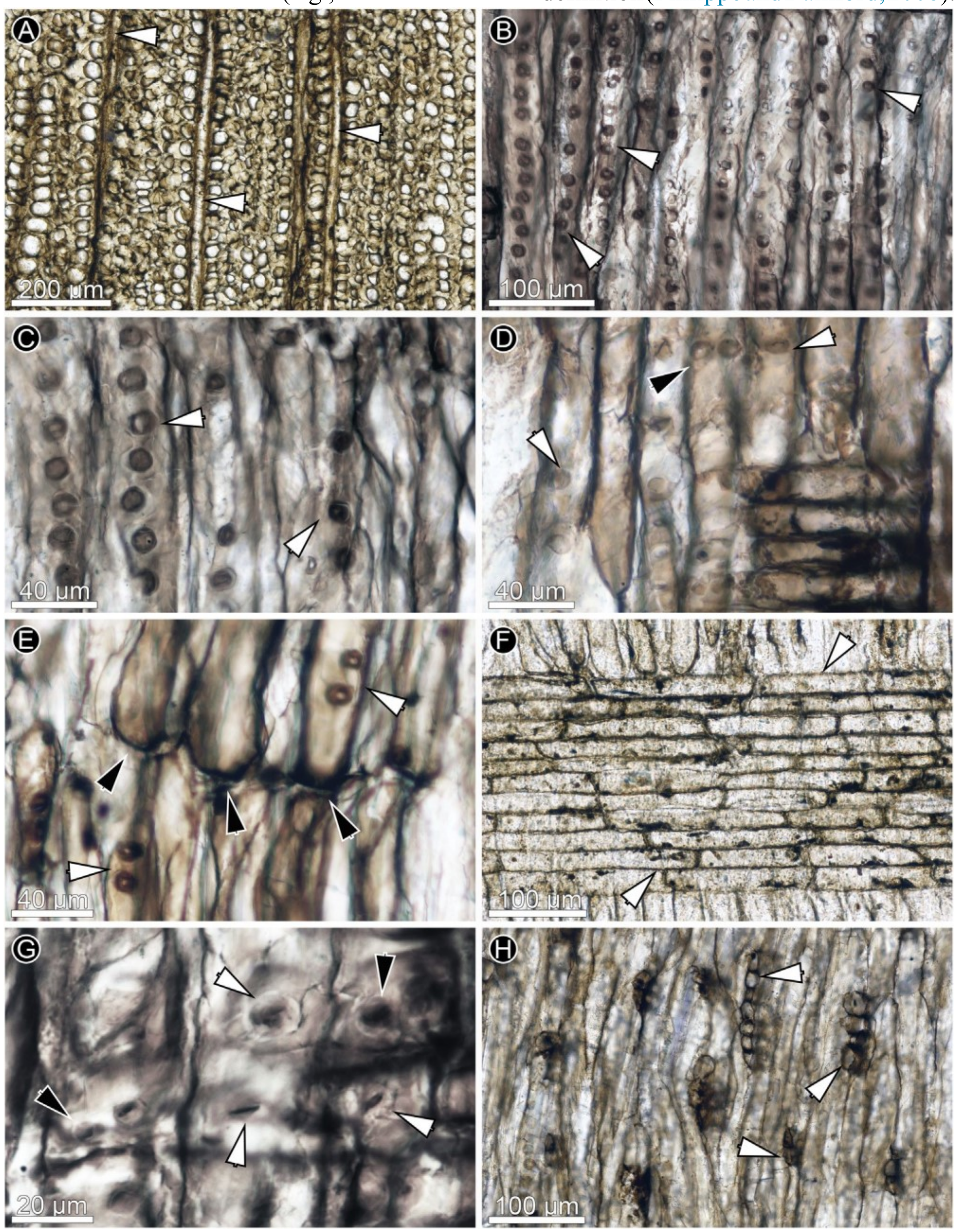

Fig. 3. Photomicrographs showing the wood structure of *Palaeocupressinoxylon uniseriale* n. gen. n. sp. from the Wuchiapingian Wutonggou Formation in Central Taodonggou section, Turpan–Hami Basin, southern Bogda Mountains. Collection number: PB22953; holotype. (A) Transverse section of the xylem, showing rounded to polygonal tracheids and ray cells (white arrows); slide number: PB22953–1. (B) Radial section of the xylem, showing uniseriate radial trachiedal pitting with separated bordered pits (white arrows); slide number: PB22953–2. (C) Enlarged photomicrograph of a radial section of the xylem, showing uniseriate radial trachiedal pitting with separated bordered pits (white arrows); slide number: PB22953–2. (D) Enlarged photomicrograph of a radial section of the xylem, showing uniseriate (white arrows) and partially biseriate (black arrow) radial trachiedal pitting with separated bordered pits; uniseriate pits are widely scattered; biseriate pits distribute oppositely (black arrow); slide number: PB22953–3. (E) Radial section of the xylem, showing uniseriate separated bordered pits on radial walls with rounded apertures (white arrows); black arrows point to tracheids with blunt ends; slide number: PB22953–3. (F) Radial section of the xylem, showing rectangular ray cells with smooth walls, spaning 2–7, commonly 4–5 tracheids (white arrows); slide number: PB22953–4. (G) Radial section of the xylem, showing the cupressoid cross-field pitting; there are commonly 1 (white arrows) to 2 (black arrows) bordered pits with oval to slit-like apertures in each field; slide number: PB22953–2. (H) Tangential section of the xylem, showing uniseriate rays (white arrows); slide number: PB22953–5.

"cupressoid cross-field" is a cross-field with few (usually no more than four) cupressoid oculipores, widely spaced and usually ordered in horizontal lines or columns. Here, we adopt the proposal from Philippe (1995). From this point of view, current wood is distinct from all the Palaeozoic fossil woods described in northern Xinjiang.

Generally, three types of secondary xylems have been described from the Permian of Bogda Mountains. Both *Septomedullopitys* Lepekhina and *Xinjiangoxylon* Shi et al. from the Wuchiapingian Wutonggou Formation of Tarlong–Taodonggou area, southern Bogda Mountains, have *Protophyllocladoxylon* type wood with 1–2, simple, large pits (window-like or Phyllocladoid) in each cross-field (Shi et al., 2014; Wan et al., 2014), which is different from current wood. *Ductoagathoxylon* Wan et al. from the Wuchiapingian Wutonggou Formation of Dalongkou, northern Bogda Mountains, contains *Agathoxylon*-type of wood with araucarioid cross-field pitting (Wan et al., 2017a). Five to twenty two bordered pits with alternate arrangement in each cross-field make it distinguishable from *Palaeocupressinoxylon*. *Sclerospiroxylon* (Prasad) Zhang et al. emend. from the Cisuralian Hongyanchi Formation of South Tarlong section, southern Bogda Mountains, is composed of *Prototaxoxylon*-type wood (Wan et al., 2019b). In addition, a charred wood, *Prototaxoxylon* Kräusel et Dolianiti, has been reported from the Wuchiapingian Wutonggou Formation of Dalongkou, northern Bogda Mountains (Wan et al., 2016b). This type of wood is characterized by more than four pits in each cross-field (Wan et al., 2019b), or pits with faint borders (Wan et al., 2016b), which is distinct from *Palaeocupressinoxylon*.

Pit arrangement on radial tracheidal walls, including contiguity and seriation, is a key character for identification of fossil genera and fossil species (Lepekhina, 1972; Maheshwari, 1972; Pant and Singh, 1987; Philippe and Bamford, 2008; Pujana et al., 2016). *Palaeocupressinoxylon uniseriale* n. gen. n. sp. has uniseriate radial tracheidal pits which are never contiguous (Fig. 3B–E). Based on the definition by Eckhold (1921) and Philippe and Bamford (2008), this type of pits can be attributed to the abietinean radial pitting. According to Wan et al. (2017a), most gymnospermous woods from the Angara flora in China have araucarian radial pitting. Among them, *Prototaxoxylon uniseriale* Prasad, *Sinopalaeospiroxylon baoligemiaoense* Zhang et al., *Sclerospiroxylon xinjiangensis* Wan et al., and *Sclerospiroxylon neimongolense* Zhang et al. are characterized by the occurrence of taxoid type third spiral thickenings on tracheidal walls (Zhang et al., 2007; Wan et al., 2016b, 2019b), which are absent in *Palaeocupressinoxylon uniseriale*. In Palaeozoic fossil woods, abietinean radial pitting is commonly recorded together with the araucarian radial pitting, forming a mixed type (Lepekhina, 1972; Maheshwari, 1972; Marguerier, 1973; Pant and Singh, 1987; Zheng et al., 2008). Pycnoxylic woods with only Abietinean radial pitting have scarcely been reported from the Palaeozoic.

Fourteen fossil genera of wood with purely abietinean radial pitting have been described from the Mesozoic (Philippe and Bamford, 2008). Among them, only three genera, *Cupressinoxylon* Göppert, *Tetraclinoxylon* Grambast, and *Widdringtonoxylon* Penny, have cupressoid cross-field pitting, which is comparable with *Palaeocupressinoxylon* (Göppert, 1850; Penny, 1947; Grambast, 1951). However, all of them have axial parenchyma, which is different from our wood. The occurrence of axial parenchyma in gymnospermous woods is a significant taxonomic feature (Richter et al., 2004; Zhang et al., 2007). The absence of axial parenchyma in the secondary xylem has been interpreted as a primitive character in conifers (Feng et al., 2012). The presence, abundance, and distribution of axial parenchyma in the secondary xylem are considered as important characters in the evolution of gymnosperm wood structure (Zhou and Jiang, 1994). Therefore, the absence of axial parenchyma in *Palaeocupressinoxylon* suggests a relatively more primitive position compared to *Cupressinoxylon*, *Tetraclinoxylon*, and *Widdringtonoxylon*.

Palaeocupressinoxylon is comparable to the secondary xylem of *Mesembrioxylon* Seward (Seward, 1919; Bhardwaj, 1953). *Mesembrioxylon* was erected for woods that are similar to *Cupressinoxylon* in abietinean radial tracheidal pitting. However, in *Mesembrioxylon*, axial parenchyma may not always present (Seward, 1919, p. 206), which is different from *Cupressinoxylon*. At least 30 species have been assigned to this *Mesembrioxylon* (Seward, 1919; Bhardwaj, 1953; Jain, 1964; Agashe, 1968; Nishida and Nishida, 1983; Thayn and Tidwell, 1984; Tidwell et al., 1998; Medlyn and Tidwell, 2002; Philippe et al., 2004; Pujana and Ruiz, 2017). Among them, wood of *Mesembrioxylon indicum* Bhardwaj from the Jurassic of the Rajmahal Hills, Bihar, India, highly resembles *Palaeocupressinoxylon uniseriale* in several aspects (Bhardwaj, 1953). Both of them have: (1) uniseriate radial tracheidal pitting; (2) bordered pits are separated; (3) absence of axial parenchyma, and tangential pits; (4) homogeneous and uniseriate rays; and (5) cupressoid cross-field pitting. However, rays are 1–5, average 2 cells high in *M. indicum*, much lower than those in *P. uniseriale*. In addition, only one cupressoid pit presents in each cross-field of *M. indicum*. *Palaeocupressinoxylon uniseriale* is distinct from *M. indicum* in the occurrence of 1–4, commonly 1–2 pits in each cross-field.

Mesembrioxylon was originally proposed to replace two fossil genera *Podocarpoxylon* Gothan and *Phyllocladoxylon* Gothan (Seward, 1919). However, Bamford and Philippe (2001) pointed out that both *Podocarpoxylon* and *Phyllocladoxylon* were valid, and from a palaeoxylological point of view, there was no need to abandon them. Furthermore, *Mesembrioxylon* is nomenclaturally illegitimate because the type species of this genus has never been assigned (Bamford and Philippe, 2001). Although our fossil wood from the Wuchiapingian of northwestern China shares great similarities with *Mesembrioxylon*, it is inappropriate to attribute it to any species of *Mesembrioxylon*. Based on the evidence and above discussion, we establish the new genus *Palaeocupressinoxylon* herein, and assign *Palaeocupressinoxylon uniseriale* as the type species. *Palaeocupressinoxylon* is characterized by the abietinean radial tracheidal pitting, homogeneous and parenchymatous rays, cupressoid cross-field pitting, and absence of axial parenchyma, resin canals and, ray tracheids.

The growth pattern of fossil wood may provide key information on regional palaeoclimate and vegetational palaeoecology in deep time (Creber and Chaloner, 1984; Falcon-Lang, 2005; Yang et al., 2013; Wan et al., 2016a, 2016c, 2017b, 2017c, 2017d, 2019b; Shi et al., 2017). Wood is produced by the vascular cambium (Creber and Chaloner, 1984; Evert, 2006; Beck, 2010). The factors that control the cambial activities and in turn the wood growth pattern are complex (Jacoby, 1989; Schweingruber, 1996). The presence of growth rings in fossil woods (Yang et al., 2013; Wan et al., 2016c, 2017a, 2017c, 2019b) and fossil charcoal (Falcon-Lang, 2000; Wan et al., 2016b) indicates seasonal variations in precipitation. Their absence, on the other hand, is commonly an indicator of a climate with a short or no dry season (Lepekhina, 1972; Creber and Chaloner, 1984; Yao et al., 1994; Wan et al., 2014, 2017d). The absence of growth rings in *Palaeocupressinoxylon uniseriale* and other fossil woods from the Wuchiapingian of the Tarlong–Taodonggou area that are not described here (Wan et al., 2014; and unpublished data), indicates that these trees grew in an environment that supported year-round continuous cambial activity. Precipitation seasonality is one of many factors affecting cambial activities that form a wood growth pattern (Jacoby, 1989; Schweingruber, 1996). The absence of growth rings suggests perennial precipitation with minimal monthly variations, and implies that the climatic condition at the growing site of the fossil trees during their life span was likely humid.

The humid conditions interpreted based on the absence of tree rings in our fossil wood are in general consistent with sedimentary, geochemical and palaeosol indicators in the Wuchiapingian of the study area (Brand et al., 1993; Wartes et al., 2002; Yang et al., 2007, 2010; Thomas et al., 2011; Liu et al., 2019). The Wutonggou low-order cycle at Central Taodonggou is interpreted to represent fluvial and deltaic deposition, with a thin (25 to 50 m) interval of lake margin to littoral non-deltaic siliciclastic deposits (Yang et al., 2010). Thick meandering stream and deltaic deposits suggest intense provenance weathering, large sediment production and transport by perennial river flows, and over-filled lake conditions, all of which indicate a great surplus of surface water budget and a wet–dry seasonality (Schumm, 1968; Miall, 1996). Abundant Histosols, Gleysols, and Argillisols are present within these deposits (Yang et al., 2007, 2010). Thomas et al. (2011) estimated a 900 to 1240 mm/yr mean annual precipitation (MAP) value using the CIA–K (chemical index of alteration minus Potassium) proxy data of the palaeosols. In general, these palaeosols are thought to represent soils formed within environments characterized by perennially wet or seasonally variable soil moisture regimes (Yang et al., 2010; Thomas et al., 2011). In summary, the climate in Tarlong–Taodonggou area in southern Bogda Mountains was generally humid with weak precipitation seasonality during the Wuchiapingian.

5. Conclusions

A new genus, *Palaeocupressinoxylon* n. gen., is proposed for a gymnospermous wood collected from the uppermost Wutonggou Formation (upper Wuchiapingian, upper Permian) in the southern Bogda Mountains, northwestern China. It contains Abietinean radial tracheidal pits, homogenous uniseriate rays, and cupressoid cross-field pitting. *Palaeocupressinoxylon uniseriale* n. gen. n. sp. is characterized by the uniseriate radial tracheidal pitting, with bordered pits that are never contiguous. Details of anatomy of this silicified wood add to the knowledge on the diversity of the Angara flora in the northeastern Pangaea during late Permian. The absence of growth rings in the described fossil wood, in combination with the sedimentary and geochemical evidence, indicates a humid climate with insignificant or no dry season in the Taodonggou area during the Wuchiapingian.

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