Vol. 88 No. 5 pp. 1356–1363 ACTA GEOLOGICA SINICA (English Edition) Oct. 2014

Xinjiangoxylon Gen. Nov., a New Gymnosperm from the Latest Permian of China

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Abstract: Following the greatest known end-Permian mass extinction plants have low diversity. Lycopsids and conifers dominated on land. A new gymnosperm *Xinjiangoxylon* gen. nov. is proposed based on a woody stem specimen collected from the Upper Permian (latest, Changhsingian) Upper Guodikeng Formation of the Taoshuyuan section, Turpan, Xinjiang Uygur Autonomous Region, Northwest China. The decorticated stem is characterized by a complex pith, endarch primary xylem and a thick secondary xylem cylinder. Numerous petrified woods were found in the Changhsingian at this section. However, there are rare wood fossils in the Early Triassic. The abrupt decrease of fossil woods worldwide relates to the crisis at the end of the Permian. *Xinjiangoxylon turpanense* gen et. sp. nov. appears to represents one gymnosperm that existed in the latest Permian.

Keywords: Paleobotany, taxonomy, Gymnospermae, mass extinction, Late Permian, Xinjiang AR

1 Introduction

The mass extinction during the terminal Permian was the most severe biotic crisis among the "Big Five" mass extinctions with the disappearance of over 90% of species in the oceans and about 70% of species on land (Raup and Sepkoski, 1982; Jablonski, 1991; Signor, 1994; Raup, 1994; Erwin, 1994; Retallack, 1995; Schubert and Bottjer, 1995; Benton, 1995; Benton and Twitchett, 2003; Bambach et al., 2004). Although the mass extinction of terrestrial plants is controversial, the excessive dieback of arboreal plants (Visscher et al., 1996), the abrupt change of palynomorph assemblages (Peng et al., 2006; Yu et al., 2007), the widespread wildfires (Xie et al., 2007; Shao et al., 2012) and severe fungal proliferation (Visscher et al., 1996; Steiner et al., 2003; Peng et al., 2005; Visscher et al., 2011) indicate the disintegration of terrestrial ecosystems at the end of the Permian. Numerous petrified gymnosperm stems have been documented from the Late Permian of China (Zhang et al., 2006; Feng, 2012; Feng et al., 2008; 2010; 2011), whereas few specimens have been found near the Permian–Triassic Boundary.

Here we report a petrified gymnosperm stem from the latest Permian Changhsingian. It was collected from the upper part of Guodikeng Formation in Turpan, Xinjiang Uyghur Autonomous Region (AR). The distinct anatomical characteristics of the specimen represent a new genus and species of gymnosperm.

2 Geological Setting, Materials and Methods

The Taoshuyuan syncline is situated on the northwestern flank of the Turpan-Hami Basin in the foothills of Bogda Mountain, Xinjiang Uygur AR, northwestern China (Fig. 1). Since the 1980s, numerous investigations have been undertaken in the Permian–Triassic transitional deposits in this area (Fu and Deng, 1997; Shao et al., 1999; Li et al., 2004; Yang et al., 2007, 2010; Cao et al., 2008). Specimen XTTS-e was collected from the middle part of Guodikeng Formation, which is regarded as Late Permian (Li et al., 2004; Cao et al., 2008), in Daheyan Town, Turpan City on the southern limb of the Taoshuyuan Syncline (Fig. 2). In this area, the Guodikeng Formation is about 108

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Fig. 1. A sketch map of the fossil locality and adjacent areas in Xinjiang Uygur Autonomous Region, China.

m thick, and represented by pebbly, purplish-red fine sandstones, siltstones, and fine gray sandstones, siltstones. Based on the evidences from the paleomagnetic data, the organic carbon isotope data and the fossils, the Permian–Triassic boundary is placed in the upper part of the Guodikeng Formation (Li et al., 2004; Cao et al., 2008).

To study the anatomy, thin-sections were made using conventional cutting and polishing methods for optical microscopic observation. All slides were observed under optical microscopes (Leica DM4000B and Olympus BX51) and photographed using a Spot digital microscope camera system. The specimen and slides are housed in the State Key Laboratory of Geobiology and Environmental Geology, China University of Geosciences, Wuhan, China (WUGEG).

3 Systematics

Division Gymnospermophyta Sternberg, 1820
Class Coniferopsida Sternberg, 1820
Order Coniferales Sternberg, 1820
Family incertae sedes
Genus *Xinjiangoxylon* gen. nov.

Type and only specimen: *Xinjiangoxylon turpanense* Shi, Yu, Li, Chi et Zhang gen et. sp. nov.

Etymology: The generic name is derived from the Xinjiang Uygur Autonomous Region, where the type specimen was collected and the greek “oxylon” relates to wood.

Diagnosis: Woody stem with pith, primary xylem and secondary xylem. Pith solid, nonseptate, heterocellular, with parenchyma cells and sclerenchyma cells. Primary xylem endarch. Secondary xylem pycnoxylic. Growth rings present. Tracheids with uni- to triseriate araucarioid pits. Cross-field pits window-like, simple. Ray cells homogeneous, parenchymatous. Axial parenchyma cells present. Resin canals absent.

Xinjiangoxylon turpanense Shi, Yu, Li, Chi et Zhang gen et. sp. nov.

Etymology: The specific epithet is derived from the Turpan City, where the type specimen was collected.

Holotype: WUGEG XTTS-5

Diagnosis: Woody stem with pith, primary xylem

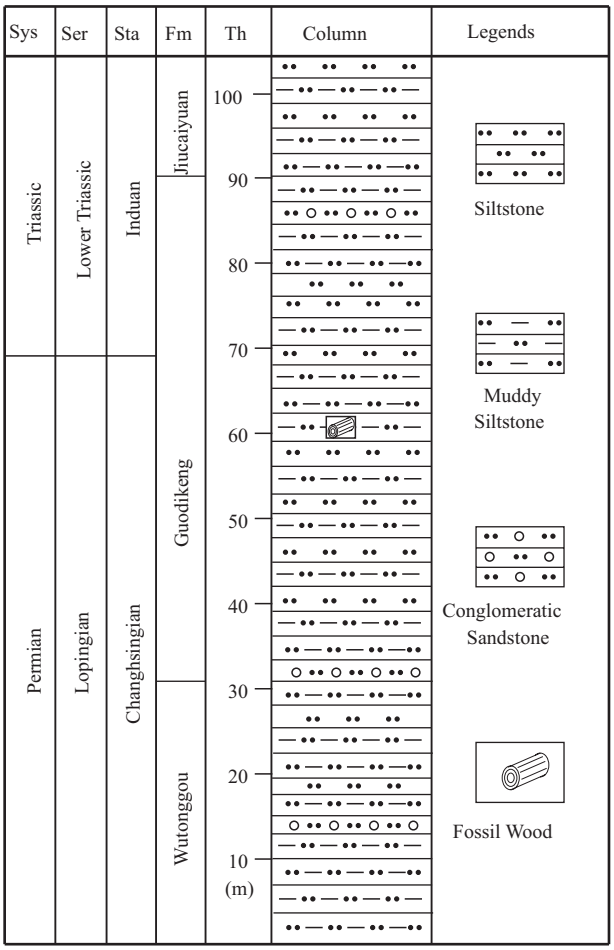

Fig. 2. Stratigraphic column of the sequences showing the fossil wood-bearing horizon in Taoshuyuan Section, Turpan, Xinjiang Uygur Autonomous Region, China.

and secondary xylem. Pith solid, nonseptate, heterocellular, with parenchyma cells, sclerenchyma cells, and secretory cells. Sclerenchyma cells circular or polygonal in transverse section, longitudinal extension. Primary xylem endarch with scalariform thickenings. Tracheids of the primary xylem with scalariform thickenings. Secondary xylem pycnoxylic. Growth rings present. Tracheids with uni- to triseriate araucarioid pits. Cross-fields with 1, partly 2 window-like simple pits. Rays homogeneous, parenchymatous and uniseriate, ranging from 1 to 16 cells in height. Longitudinally elongated axial parenchyma cells are irregularly distributed among the xylem tracheids. Resin canals absent.

Locality and Stratigraphy: Taoshuyuan section, Turpan City, Xinjiang Uygur Autonomous Region; Latest Permian Middle Guodikeng Formation.

4 Description

4.1 General features

The stem with a piece of a branch is about 12 cm long, with a maximum diameter of 6 cm. It is slightly deformed because of the lithification and not well preserved. It comprises pith, primary and secondary xylem and a branch trace (Fig. 3a).

4.2 Pith

The pith is approximately oval in outline, about 3.0×1.0–3.7×1.2 cm in size, and consists of parenchymous and sclerenchymous cells (Fig. 3b). In transverse section, the parenchyma cells are circular or polygonal, diameter 12.5 to 150 μm (n=100, mean=91.5 μm) (Fig. 3c). Sclerenchyma cells are circular or polygonal, 45 to 155 μm (n=100, mean=93.5 μm) in diameter (Fig. 3c). They have thick brown walls with dark contents in their centers.

In radial view, the parenchyma cells are flat, sub-rectangular and horizontally aligned, high 27.5 to 80 μm (n=100, mean=47.6 μm) (Fig. 3e). Those of the sclerenchyma are very long, 175 μm to 4.95 mm in length (Fig. 3d).

4.3 Primary xylem

The primary strands show endarch maturation (Fig. 3f). The tracheids of the primary xylem are scalariformly thickened (Fig. 4b).

4.4 Secondary xylem

The secondary xylem is pycnoxylic. Growth rings are distinct (Fig. 4a). Tracheids are rectangular or polygonal in transverse views, 12.5×15–37.5×62.5 μm in size (Fig. 4a). In longitudinal section, the ends of the tracheids are blunt and erect. Araucarioid-type bordered pits are uni- to triseriate on radial walls of the tracheids. When uniseriate, the pits are contiguous, circular or elliptical; when biseriate, pits are alternate, crowded hexagonal (Fig. 4c–d). The pits are 10 to 15 μm in diameter, with circular apertures.

Rays are homogeneous, parenchymatous and uniseriate. Ray parenchyma cells are circular, oval or rectangular, uniseriate, high 5 to 37.5 μm, and wide 5 to 25 μm in tangential views (Fig. 4h). Ray height is from 1 to 16 cells (P95≤9, n=200, mean=4.65) (Fig. 5).

Cross-field pits are windows-like. There are 1, partly 2 pits in each cross-field unit (Fig. 4f-g).

Isolated or vertically aligned axial parenchyma cells are longitudinally elongated and distributed among the xylem tracheids (Fig. 4e).

5 Comparisons

This petrified stem shares anatomical features with

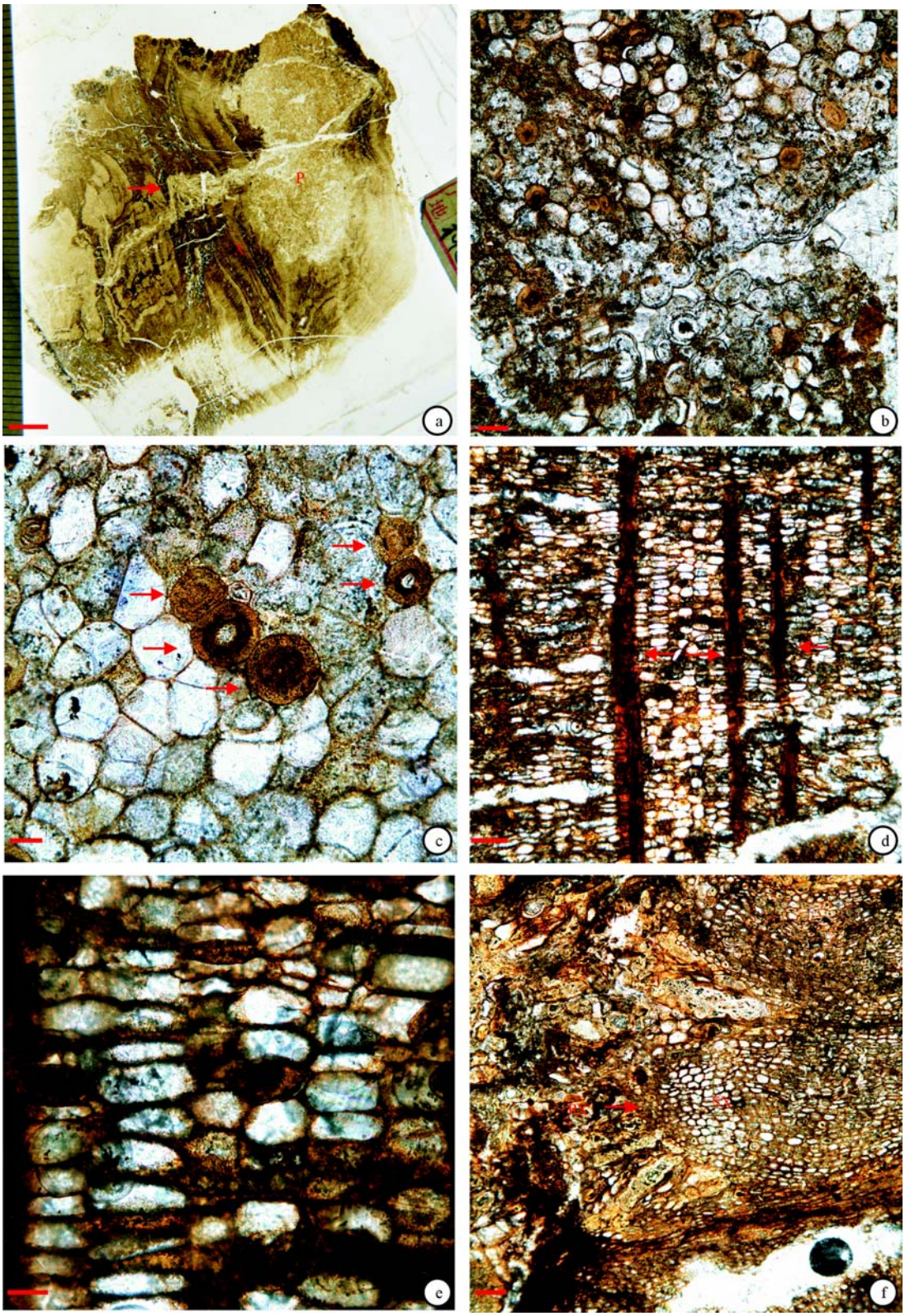

Fig. 3. *Xinjiangoxylon turpanense* gen et. sp. nov.

a, Transverse section (TS), showing the pith (P), xylem cylinder (X) and a branch trace (arrow), scale bar =0.5 cm; Slide No.: WUGEG XTTS-5-1; b, TS, showing the parenchyma cells and sclerenchyma cells, scale bar =100 μm; Slide No.: WUGEG XTTS-5-1; c, Radial longitudinal section (RLS), showing the sclerenchyma cells (arrows), scale bar =50 μm; Slide No.: WUGEG XTTS-5-1; d, TS, showing the sclerenchyma cells (arrows), scale bar =50 μm; Slide No.: WUGEG XTTS-5-2; e, RLS, showing the parenchyma cells of the pith, scale bar =50 μm; Slide No.: WUGEG XTTS-5-2; f, TS, showing the primary xylem (PX) and secondary xylem (SX), scale bar =100 μm; Slide No.: WUGEG XTTS-5-1. The specimen was collected from the upper part of the Guodikeng Formation at the Taoshuyuan section, Daheyan Town, Turpan, Xinjiang Uygur Autonomous Region and is deposited in the State Key Lab. of Geobiology and Environment Geology. Holotype: WUGEG XTTS-5.

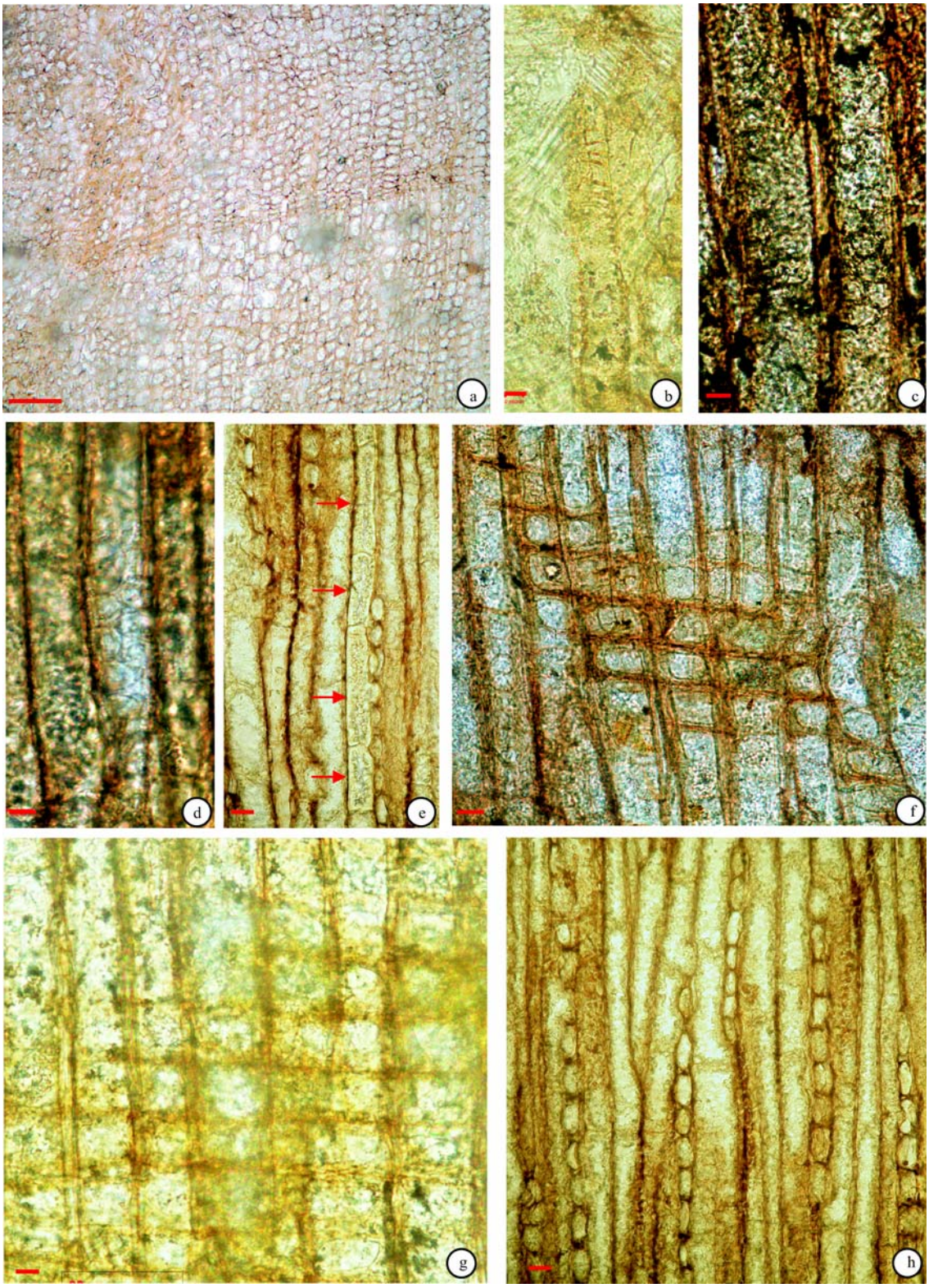

Fig. 4. *Xinjiangoxylon turpanense* gen et. sp. nov.

a, Transverse section (TS), showing a growth ring, scale bar =100 μm; Slide No.: WUGEG XTTS-5-1; b, Radial longitudinal section (RLS), showing the scalariform thickenings of the primary xylem tracheid, scale bar =10 μm; Slide No.: WUGEG XTTS-5-2; c, RLS, showing the biseriate or triseriate bordered pits on the radial wall of tracheids, scale bar =10 μm; Slide No.: WUGEG XTTS-5-2; d, RLS, showing the biseriate bordered pits on the radial wall of tracheids, scale bar =10 μm; Slide No.: WUGEG XTTS-5-3; e, Tangential longitudinal section (TLS), showing vertically aligned axial parenchyma cells (arrows), scale bar =20 μm; Slide No.: WUGEG XTTS-5-3; f-g, RLS, showing the window-like cross-field pits, scale bar =10 μm; Slide No.: WUGEG XTTS-5-2; h, TLS, showing the unseriate rays, scale bar =20 μm; Slide No.: WUGEG XTTS-5-3. The specimen was collected from the upper part of the Guodikeng Formation at the Taoshuyuan section, Daheyan Town, Turpan, Xinjiang Uygur Autonomous Region and is deposited in the State Key Lab. of Geobiology and Environment Geology. Holotype: WUGEG XTTS-5.

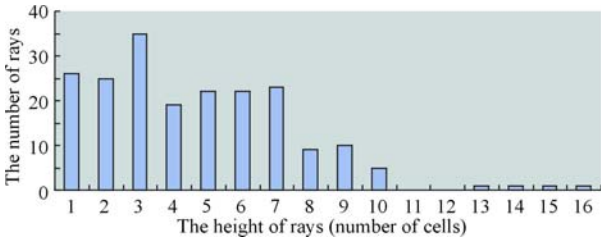

Fig. 5. Histogram showing the height–frequency distribution of 200 rays in tangential longitudinal section of *Xinjiangoxylon turpanense* gen et. sp. nov.

fossil and extant gymnospermous. The cordaitalean taxa always possess septate pith, which is different from *Xingjiangoxylon* gen. nov. (Falcon-Lang and Scott, 2000). Fossil ginkgophyte woods have complex piths and abundant axial parenchyma cells in the secondary xylem. The ends of the ginkgophyte tracheids are always bent, which is not seen in the present specimen. Therefore, we tentatively attribute *Xingjiangoxylon* gen. nov. to a possible coniferous affinity.

In China, several previously documented fossil gymnospermous woods show a heterogeneous pith, such as *Guizhouoxylon dahebianense* Tian et Li, 1992 (Tian and Li, 1992), *Walchiopremnon gaoi* Tian, Hu et Zhao, 1996 (Tian et al., 1996), *Damudoxylon zhoui* Zhang et Zheng, 2006 (Zhang et al., 2006), *Liaoningoxylon chaoyangense* Zhang et Zheng, 2006 (Zhang et al., 2006), *Sclerospiroxylon neimongolense* Zhang, Wang, Zheng, Yang, Li, Fu et Li, 2007 (Zhang et al., 2007), and *Shenoxylon mirabile* Feng, Wang et Rößler, 2011 (Feng et al., 2011).

The pith of *Guizhouoxylon dahebianense* consists of parenchyma cells, sclerenchyma cells and secretory cells. Also, all cells in the pith are longitudinal, which is different to the present wood. Besides, each cross-field unit has 3 to 8 pits and the tracheids in the early wood zones are scalariformly thickened (Tian and Li, 1992); these features all differ from *Xingjiangoxylon* gen. nov.

The pith of *Walchiopremnon gaoi* is similar to that of the new genus. However, pits on the walls of the secondary xylem tracheids are uniseriate (occasionally biseriate), and the 1 to 3 or more simple or cupressiod pits are in each cross-field unit (Tian et al., 1996), which is different from *Xingjiangoxylon* gen. nov.

Liaoningoxylon chaoyangense also possesses parenchyma cells and secretory ducts in its pith. Without axial parenchyma cells in the secondary xylem (Zhang et al., 2006), *Liaoningoxylon* is different from the present specimen. Another important feature is that rays in *Liaoningoxylon* are heterocellular, which is not seen in *Xingjiangoxylon* gen. nov.

The pith of *Damudoxylon zhoui* consists of parenchyma cells and secretory cells. However, the pits in each cross-field unit are many and small (Maheshwari, 1966; Zhang et al., 2006), which is different from *Xingjiangoxylon* gen. nov.

Sclerospiroxylon neimongolense differs from *Xingjiangoxylon* gen. nov. in its tertiary spiral thickening on its secondary xylem tracheids and cupressiod cross-field pits (Zhang et al., 2007).

Shenoxylon mirabile is characterized by an intramedullary sheath, and its cross-field pits are cupressoid (Feng et al., 2011). These make it different from *Xingjiangoxylon* gen. nov.

Medullopitys, *Phyllocladopitys*, *Medulloxylon*, *Septomedullopitys* were all established from the Permian of Africa, for woods with *Phyllocladoxylon*-type secondary xylem and heterogeneous pith (Lepekhina, 1972). The secondary xylem of *Xingjiangoxylon* gen. nov. is similar to that of *Phyllocladoxylon*, but *Xingjiangoxylon* gen. nov. possesses abundant axial parenchyma cells. Besides, *Medullopitys* and *Medulloxylon* have special short secretory canals in their pith, which differs from *Xingjiangoxylon* gen. nov.. The pith of *Septomedullopitys* possesses branched secretory canals, and *Phyllocladopitys* is mesarch or exarch. They are different from *Xingjiangoxylon* gen. nov. as well.

The pith of *Megaporoxylon* is homogeneous or heterogeneous. One or two simple pits are in each cross-field unit, which is similar to *Xingjiangoxylon* gen. nov. However, there are multiseriate pits on the walls of secondary xylem tracheids and rays are multiseriate (Maheshwari, 1966); these characters make *Megaporoxylon* different to the new genus.

6 Discussion

According to the data of δC_{org}, Cao et al. (2008) put the Permian–Triassic event boundary (PTEB) in the upper part of the Guodikeng Formation. And evidence from the paleomagnetic data drew a similar conclusion (Li et al., 2004). Numerous fossil woods have been collected in the late Late Permian at Taoshuyuan, Taodonggou and Taerlang sections on the northwestern flank of Turpan-Hami Basin. Three beds with abundant petrified woods were found in the Wutonggou Formation and the Guodikeng Formation on the both limbs of the Taoshuyuan syncline. So far, seven different species have been recognized (unpublished).

In the coastal and humid region, a large number of plant fossils were found as compressions and

impressions in the Late Permian in China. For the arid inland basin, plant fossils were preserved as fossil woods. These new wood fossils open up the opportunity to explore the forest composition and palaeoclimatic conditions before the collapse of the end-Permian ecosystem. No plant fossils were found in the Early Triassic in this area. This might be the result of the end-Permian mass extinction.

7 Conclusions

Xinjiangoxylon gen. nov. is a new genus of coniferous tree trunks. The complex pith, endarch primary xylem and pycnoxylic secondary xylem are distinct from those of other Permian and Triassic woods and those of extant gymnosperms. The abundant fossil woods give a chance to recognize the forest composition and palaeoclimatic conditions in the Late Permian Turpan-Hami Basin.

Acknowledgements

We are indebted to Prof. Zheng Shaolin (Shenyang Institute of Geology and Mineral Resources), Prof. Wang Shijun (Institute of Botany, the Chinese Academy of Sciences), Dr. Feng Zhuo (Yunnan University) and Prof. Jean Broutin (Université Pierre et Marie Curie) for their help in identifying the fossil wood and providing relevant materials. We thank Dr. Chu Daoliang (China University of Geosciences) for their assistance in the field. The study was supported by National Natural Science Foundation of China (Grant No. 40972002, 41272024), China Geological Survey (Grant No. 1212011120142) and State Key Laboratory of Biogeology and Environmental Geology (Grant No. GBL11302).

Manuscript rceived Oct. 26, 2013
accepted Feb. 18, 2014
edited by Susan Turner and Fei Hongcai

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