Chapter 9
Systematic Palaeontology: Part 1 Plant Fossils

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The classification of plant fossils adopted herein is generally consistent with that of extant plants (Table 9.1), according to the degree of plant differentiation, anatomical structure, nutritional mode, reproductive and life history types. However, the classification of plant fossils has its particularity. Due to the large body of most plants and the scattered preservation of various organs in the stratum, it brings some difficulties to the natural classification of some plant fossils, so it is often supplemented by artificial morphological classification.

The naming of plant fossils also follows Linnaeus's double name method and is named in Latin. In order to facilitate the understanding of the classification system and name meaning of plant fossils, the following table shows the classification system and corresponding word endings adopted by the simplified version of plant fossils, as well as the standard format when writing the names of genera and species of plant fossils (Table 9.2), in which the names of genera and species are named by the discoverer without word endings.

All the specimens described in this paper are preserved in the Laboratory of Geobiology, Faculty of Earth Sciences, China University of Geosciences, Wuhan, People's Republic of China, with the prefix of GWC, GWZ, YXC, YXM, GPT, CLC, GAXM,

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Table 9.1 Classification system of plants

Bryophyta		Early Paleozoic — Rec.	
Protopteridophyta		S-D	Ferns
Lycophyta		D — Rec.	
Sphenophyta(Arthrophyta)		D — Rec.	
Pteridophyta		D — Rec.	
Progymnospermophyta		D_{2-3} — P	Gymnosperms
Pteridospermophyta		D_3 — K_1	
Cycadophyta		D_3 — Rec.	
Ginkgophyta		P — Rec.	
Coniferophyta	Cordaitopsida	D_3 — T_1	
	Coniferopsida	C_2 — Rec.	
Gnetophyta		T — Rec.	
Anthophyta(Angiospermae)	Dicotyledones	(J_3?) — Rec.	Angiosperms
	Monocotyledones		

Table 9.2 Standard format to the names of genera and species of plant fossils

Classification System of Plants	Respective Suffix	Example
Kingdom		Plantae
Phylum	-phyta	Rhyniophyta
Subphylum	-phytina	
Class	-opsida	Rhyniopsida
Subclass	-idae	
Order	-ales	Rhyniales
Suborder	-ineae	
Family	-aceae	Rhyniaceae
Subfamily	-oideae	
Genus		*Rhynia*
Subgenus		
Species		*Aglaophyton (Rhynia) major*
Subspecies		

GHDSA and ZK. Abbreviations of localities (sections): GWC = Chahe section, Weining County, Guizhou Province; GWZ = Zhejue section, Weining County, Guizhou Province; YXC = Chinahe section, Xuanwei City, Yunnan Province; YXM = Mide section, Xuanwei City, Yunnan Province; GPT = Tucheng section, Panxian County, Guizhou Province; CLC = Chunlecun section, Hezhang County, Guizhou Province; GAXM = Xinmin section, Anshun City, Guizhou Province; GHDSA = Duanshan A section, Huishui County, Guizhou Province; ZK = Zuankong meaning drilling well), Fuyuan County, Yunnan Province.

Division Lycophyta

Class Lycopsida

Order Lepidocarpales

Family Lepidocarpaceae

Genus *Lepidodendron* Sternberg, 1820

Lepidodendron oculus-felis (Abbado) Zeiller, 1900 (Fig. 9.1-6)

1900 Lepidodendron oculus-felis (Abbado, 1900) Zeiller, in Ann. Mines Paris, 19:8, Pl.7

1963 Lepidodendron oculus-felis (Abbado, 1900) Zeiller, Paleontologica Sinica, Pl.8, Figs. 1–3; Pl.9, Figs. 1–2

1974 Lepidodendron oculus-felis, Paleozoic plants of China, p. 28, Pl.12, Fig. 5

Holotype:

Diagnosis (emended): Leaf cushion longitudinal rhombus, rhombus, rhomboid or lenticulated; length–width ratio is 2 to 1/2; crowded in range. Big leaf scar; the width slightly wider than the length; lenticulated to rhomboid; large vertex and base angle, sharp lateral angle; usually with lateral extensive line; situated in the middle or upper part of leaf cushion; sightly cat-eye-shaped; bundle scar wide "V" shape; lateral scar small, round, situated on the extension line of two neighbor lateral angle. Ligular pit situated on the top of leaf scar, occasionally concave. Leaf cushion usually flat; sometimes with faint ridge line and cross striation; occasionally small triagular pit on the top.

Material examined: GWC-21-15, GWC-21-17.

Occurrence: Upper Carboniferous Taiyuan Formation and Upper Permian Upper Shihezi Formation in North China, Gansu, Ningxia, Shaanxi, Liaoning; Early to Late Permian Qixia, Maokou and Longtan formaations in Fujian, Guangxi, Guangdong, Jiangsu and Xuanwei Formation in Western Guizhou and Eastern Yunnan.

Description (after Zeiller 1901). The cushions are crowed, rhomboidal in shape, about 1 cm broad by approximately 2 cm long. The leaf-scars are cats-eye-shaped, situated at a little above the middle of the cushions; upper and basal angles obtusely rounded; lateral angles acutely rounded. The broadly V-shaped vascular and two lateral cicatrices with round in shape, lie nearly one line. The ligule-scars are clear, round in shape, lies almost directly above the leaf-scars.

Discussion and Comparison. This species has a widespread geographical distribution in the Cathaysia-land and has often been described and illustrated. The impressions of the present specimens show the characteristic cats-eye-shaped leaf scars more or less distinctly.

Lepidodendron acutangulum (Halle) (Stockmans and Mathieu 1957) (Figs. 9.1-3, 9.1-4 and 9.1-11)

1900 Sigiillaria acutangula Abbado, in Palaeont. Sinica, Ser. A, Vol. I, 2 p. 5, Pl. II, Figs. 6–7

Fig. 9.1 1, 2 *Lepidodendron lepidophloides* Yao Locality: 1 Chahe section, Weining County, Guizhou Province Sample Number: GWC-17-1, 2 Chinahe section, Xuanwei City, Yunnan Province Sample Number: YXC-(-9)-3, 3, 4, 11 *Lepidodendron acutangulum* (Halle) Stockm. et Math. Locality: 3, 4 Mide section, Xuanwei City, Yunnan Province Sample Number: YXM (A)-43-1 11 Xinmin section, Anshun City, Guizhou Province Sample Number: GAXM11019, 5, 7 *Lepidodendron* sp. Locality: 5 Chinahe section, Xuanwei City, Yunnan Province Sample Number: YXC-(-9)-2, 7 Chahe section, Weining County, Guizhou Province Sample Number: GWC-21, 6 *Lepidodendron oculus-felis* (Abbado) Zeiller Locality: Chahe section, Weining County, Guizhou Province Sample Number: GWC-21-15, 8 *Lepidostrobophyllum* sp. Locality: Xinmin section, Anshun City, Guizhou Province Sample Number: GAXM11030, 9, 10 *Lepidostrobophyllum hastatum* (Lesq.) Chal Locality: Mide section, Xuanwei City, Yunnan Province Sample Number: YXC-(-6)-1A, YXC-(-6)-2A

1901 Lepidodendron oculus-felis (Abbado, 1900) Zeiller, in Ann. Mines Paris, 19:8, Pl.7

1957 Lepidodendron acutangula (Halle) Stockm. et Math., in Publ. Ass. et. Paleont. 32:56

1963 Lepidodendron oculus-felis (Abbado, 1900) Zeiller, Li, Paleontologica Sinica, Pl.15, Figs. 1–4

1974 Lepidodendron acutangula (Halle) Stockm. et Math., Li et al., Paleozoic plants of China, p.30, Pl.12, Figs. 1–4

Holotype:

Diagnosis (emended): Relatively big leaf cushion; rhomboid or lenticulated; densely spirally arranged. Leaf scar shape equals to the cushion, a little bit smaller; account for 2/3 area of leaf cushion; usually situates in the middle of leaf cushion; upper and basal angles wide, lateral angle sharp; the shape of leaf cushion resembles cat-eye. Big bundle scar, wide "V" shape. Lateral scar small and round. Leaf, bundle and lateral scars situated on the extension line of two neighbor lateral angle.

Material examined: YXM (A)-43-1.

Occurrence: Upper Permian Longtan Formation, in South China; occasionally in Upper Carboniferous Taiyuan and Shanxi formations, Lower Permian lower Shihezi Formation in North China.

Description (after Stockman and Mathieu). Leaf cushion and leaf scar transversely rhombic, with the lateral angle acute and elongated; leaf-scar 7 × 15 mm, cushions 9 × 22 mm; leaf-scar normally placed in the middle of the cushion. The margins of the leaf scars flatly arched, with somewhat concave sides; the lateral angles acute. The broadly V-shaped vascular and two lateral cicatrices with round in shape, lie in one line. The ligule-scars are clear, with a longitudinal cranny in shape, most directly above the leaf-scars. The surfaces of leaf cushions are smooth.

Discussion and Comparison. The shape of leaf cushion and leaf scar are similar to those of *Lepidodendron lepidophloides* (Yao et al. 1980), but they differ in that the lower margins of the leaf-scar and leaf cushions of *L. lepidophloides* are superposed.

Lepidodendron sp. aff. L. lepidophloides Yao, 1980 (Figs. 9.1-1, 9.1-2, 9.1-5 and 9.1-7)

1980 *Lepidodendron lepidophloides* Yao, p. 74, Pl.III, Figs. 1, 2, 6

Holotype: *Lepidodendron lepidophloides* Yao (1980), pl. 3, Fig. 1, 1a, 2, 6, deposited in the Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, impression fossil, from Xuanwei Formation (Lopingian), Panxian, Guizhou Province, Fuyuan and Xuanwei, Yunnan Formation, China.

Diagnosis: Leaf cushion spirally arranged, crowd, almost rhomboid. Leaf scar situates in the lower part of leaf cushion; upper edge nearly parallel to that of leaf cushion; cross leaf cushion's lower margin near lateral angle, or extension line cross in lateral

leaf angle; lower margin coincide with leaf cushion lower margin; account 1/3 area of leaf cushion. Bundle scar situates in the middle of leaf scar, wide "V" shape; lateral scar round; three scar range in a line. Ligular pit situate above leaf scar's top vertex angle; lengthwise crack like.

Material examined: GWZ-15-1, GWZ-42-1, GWC-21-17, GPT-17-1, GPT-18-1.

Occurrence: Zhejue and Chahe sections, Weining County, Guizhou; Late Permian Xuanwei Formation. Tucheng section, Panxian County, Guizhou; Early Triassic Kayitou Formation.

Description: Leaf cushion is relatively large, counter-rhombic, 8 mm high and 1.5 mm wide, densely and spirally arranged. Shape of leaf scar similar to leaf cushion but slightly smaller, with upper and lower sides slightly round and two lateral sharp corners, both its lower side and leaf cushion are the superposition. The vascular is located the center of the leaf scar, wide "V"-shaped. The lateral cicatrices are round. They lied in the line. The ligule-scar is unclear in shape.

Discussion and Comparison: Following Yao (1980), that the leaf cushions of this species being counter-rhombic and the lower sides of the leaf scar and cushion being the superposition are the character of the genus *Lepidophloios*. But it is different from genus *Lepidophloios* by the area's proportion of the leaf scar to the leaf cushion and the location of the ligule-scar. The big leaf scar and the leaf ligule-scar being just above the top angle are the character of genus *Lepidodendron* in Cathaysia flora. A similar single leaf-cushion has been found in Beds 17 and 18 in Tucheng section (Induan).

Genus ***Lepidostrobophyllum*** Hirmer, 1927

Lepidostrobophyllum hastatum (Lesq.) Chal, 1974 (Figs. 9.1-9, 9.1-10)

1974 *Lepidostrobophyllum hastatum* (Lesq.) Chal, Paleozoic plants of China, p. 36, Pl. 17, Figs. 7–9

Holotype: *Lepidostrobophyllum hastatum* (Lesq.) Chal (1974), p. 36, Pl. 17, Figs. 7–9, deposited in the Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, a pith cast, from Xuanwei Formation (Changhsingian), South China.

Diagnosis: Upper part of sporophyll is 15–17 mm in length; sharp apex; lower margin extends to halberd hamulus or ear-shape; 7 mm in width; distinct mid vein. Lower part of sporophyll is 8–10 mm in length; narrowing downwards; distinct mid ridge.

Material examined: YXC-(-6)-1A.

Occurrence: Upper Carboniferous Tangshan and Kaiping formations in Hebei, North China; Chinahe Section, Upper Permian Xuanwei Formation, Yunnan, South China.

Description: Upper part of Sporophyll is nearly 8 mm, with sharp apex, inferior margin significantly extends to hamulus of the halberd or ear shape, 5 mm wide, midrib is not obvious; Lower part of sporophll is nearly 3 mm, narrows downward

to triangular shape, midrib is obvious. Oval sporangium is preserved in the adaxial surface of sporophyll.

Discussion and Comparison: Lepidostrobophyllm is the sporophyll of Lepidodendrales, usually the upper part of it is lanceolate or ensiform, margin entire, single vein; the lower part is usually triangular shape; the adaxial surface of sporophyll ocassionally contains sporangium. This species is distinguished from others by typical halberd shape inferior margin and narrowed to triangular shape sporophyll lower part.

Genus ***Stigmaria*** Brongniart, 1822

Stigmaria ficoides (Sternb.) Brongniart, 1822 (Figs. 9.2-1, 9.2-2, 9.2-5 and 9.2-8)

1822 *Stigmaria ficoides* Brongniart, pp. 228, 239, Pl.2, Fig. 7

1927 Stigmaria ficoides, Halle, p. 181, Pl.49, Figs. 5, 11–12

1974 Stigmaria ficoides, Paleozoic plants of China, p. 37, Pl.21, Fig. 1

Holotype:

Diagnosis: Root scar round, umbilicate, spirally arranged. Surface flat, occasionally wrinkled.

Material examined: GWC-21-3, GWC-21-13, GWC-21-14, GWC-69-36; GWZ-36-2, GWZ-46-3, GWZ-47-2, GWZ-47-4, etc.

Occurrence: Lower Devonian to lower Upper Permian, all around the world.

Description: These specimens are found as often as any other fossil, especially in the "underclay" or "coal seam floor" immediately under coal seams from the four sections. Some impressions with the roots are still in position (Pl.5, Fig. 1). The root scars are small, about 2–3 mm in diameter, rather distant from each other in proportion to their size, and regularly placed. The scars are in all respects typical, having a black central dot of carbonaceous material corresponding to the vascular strand.

Discussion and Comparison:

Stigmaria rugulosa (Goth 1974) (Figs. 9.2-3, 9.2-10)

1974 *Stigmaria rugulosa* Goth, Paleozoic plants of China, p. 37, Pl.20, Figs. 6–7

Holotype: *Stigmaria rugulosa* Goth, 1974, p. 37, Pl.20, Figs. 6–7, deposited in the Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, a pith cast, from Xuanwei Formation (Changhsingian), South China.

Diagnosis: Root scar round, umbilicate. Wrinkled surface.

Material examined: GWZ-36-1, GWZ-46-5.

Occurrence: Upper Devonian Wutong Formation in Nanjing, South China; Lower Permian Shanxi Formation in Taiyuan, North China; Upper Permian Longtan Formation in Guangdong, South China; Carboniferous Wanshoushan Group in Yunnan,

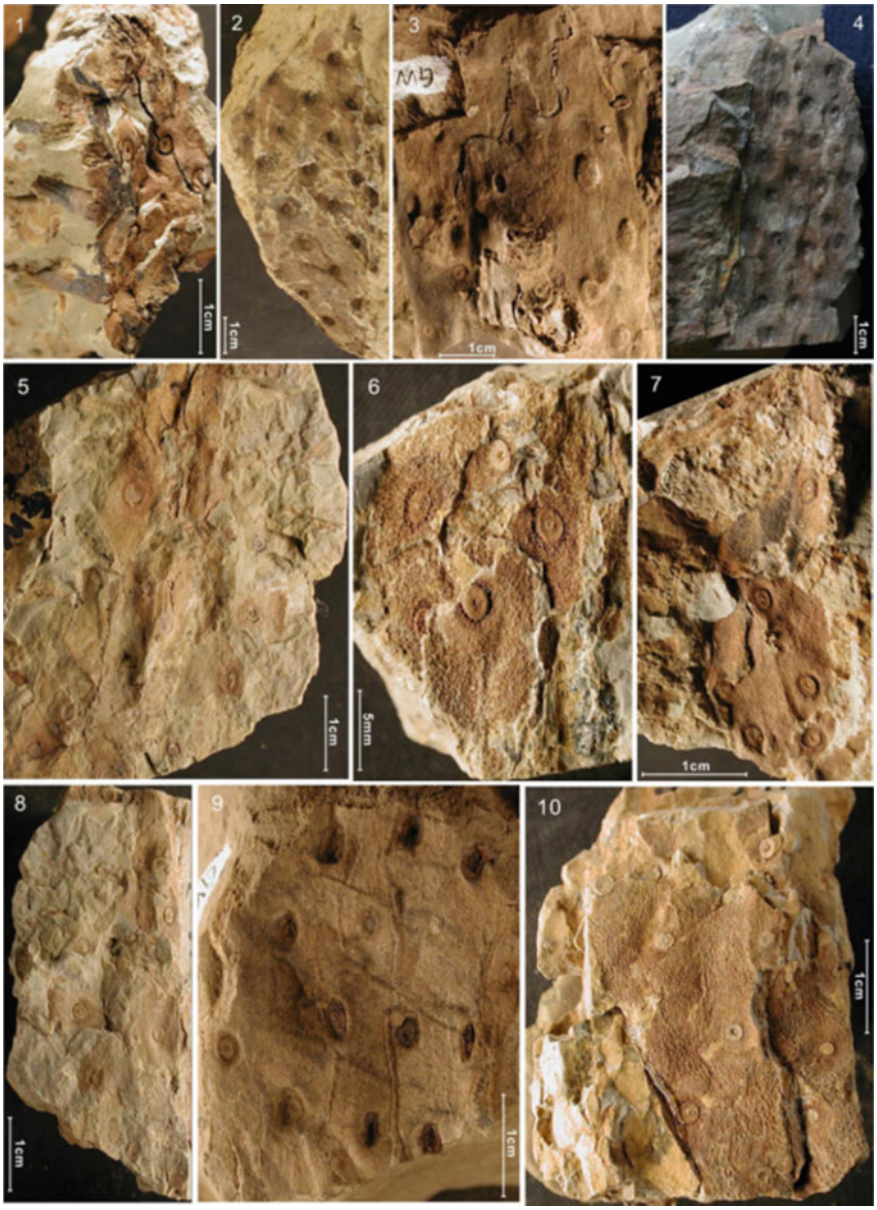

Fig. 9.2 1, 2, 5, 8 *Stigmaria ficoides* (Sternb.) Brongn. Locality: 1, 5, 8 Zhejue section, Weining County, Guizhou Province Sample Number: GWZ-47-2, GWZ-46-1, GWZ-46-3, 2 Chahe section, Weining County, Guizhou Province Sample Number: GWC-21-14, 3, 10 *Stigmaria rugulosa* Goth. Locality: Zhejue section, Weining County, Guizhou Province Sample Number: GWZ-36-1, GWZ-46-5, 4, 6, 7 *Stigmaria radiatopunctata* Goth. & Sze Locality: 4 Mide section, Xuanwei City, Yunnan Province Sample Number: CNH-8 + 0.5-1 6, 7 Zhejue section, Weining County, Guizhou Province Sample Number: GWZ-47-4, GWZ-46-7, 9 *Stigmaria* sp. Locality: Chahe section, Weining County, Guizhou Province

South China; Zhejue Section, Upper Permian Xuanwei Formation in Guizhou, South China.

Description: The specimen differs in having some longitudinally wave-shaped wrinkle on the surface of the compressions. Other character is the same as *Stigmaria ficoides*. Root scars round and umbilical.

Discussion and Comparison: The distinct feature of this species is that the surface of the compression has some longitudinally wave-shaped wrinkle, which is differ from the other species.

Stigmaria radiatopunctata (Goth and Sze 1974) (Figs. 9.2-4, 9.2-6 and 9.2-7)

1974 *Stigmaria radiatopunctata* Goth and Sze, Paleozoic plants of China, p. 37, Pl.20, Fig. 5

Holotype: *Stigmaria radiatopunctata* Goth and Sze, 1974, p. 37, Pl.20, Fig. 5, deposited in the Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, a pith cast, from Xuanwei Formation (Changhsingian), South China.

Diagnosis: Root scar oval, with margin. Radial convex rib on margin, like wheel. Longitudinal wrinkle on surface, countless dot between wrinkles.

Material examined: GWZ-46-7, GWZ-47-4.

Occurrence: Upper Devonian Wutong Formation in Jiangsu, South China; Zhejue Section Upper Permian Xuanwei Formation in Guizhou, South China.

Description: Root scar round or oblong, with costa. There are some radial and convex ribs on the costa, which look like a wheel. The surface between the root scars have longitudinally wave-shaped wrinkle.

Discussion and Comparison: Compared to *S. rugulosa*, the difference between the present specimens and *S. rugulosa* is that the latter have no costa in the root-scars and no radial ribs.

Order **Isoetales**

Family **Isoetaceae**

Genus *Lepacyclotes* (=*Annalepis*) Neuberg, 1936

Lepacyclotes (=*Annalepis*) *zeilleri* ((Fliche 1910) Yu emended, 2021) (Figs. 9.10-1 to 9.10-26)

2010 *Annalepis zeilleri*, Yu et al., Figs. 5, 1–12

2020 Tomiostrobus sinensis, Feng et al., Figs. 3–6

2021 Tomiostrobus (Annalepis) angusta, Yu et al.

Holotype: *Annalepis zeilleri*, Yu et al. 2010, Fig. 5, 1–12, deposited in China University of Geosciences (Wuhan), Main building, 5th floor, Basement NO. B104, a impression fossil, from Xuanwei Formation (Changhsingian), South China.

Diagnosis: (*Annalepis zeilleri*, emended after Fliche, Ye, Grauvogel-Stamm and Meng). Herbaceous; strobile close to spherical; diameter ranging from maximum 7 cm to minimum 3 cm; with spherical stem, 0.7–2.5 cm in diameter; without trophophyll. Sporophyll more or less cespitose; lanceolate, spatulate, oval, cuneate or listric; 1.6–3.2 cm in length; widest portion is in 1/4–1/3 from the top, 1.1–1.5 cm, sharp narrowing from here to the top and gently narrowing to the base; arrow apex, blunt stylus or blunt; base concave or truncature. Sporangium virgate; insert at the middle to lower and center of sporophyll adaxial surface; gradually extend from the base to the top; 0.7–2.6 cm in length, usually is the 2/3 of sporophyll, 0.3–0.7 cm in width; a longitudinal groove reaches the top from the base, with 5–6 trabecula on each side. A ligular scar and labellum situate slightly above the sporangium; ligular scar nearly round, 1 mm or more in diameter; labellum heart-round shape, 4 mm in length, 6 mm in width, with indistinct radial striae on the surface and mildly converge towards the top. Leaf apex grows out of the sporophyll phyllopodium, linear. Microspore equatorial outline is oval to wide-oval, 55–66.7 μm in diameter, 43.3–51.7 μm in height; monolote, reaching or close to equator; with narrow lip, 2 μm in width, constantly curve in the middle; extine is divided into inner and outer layers; the inner layer is slightly thicker than the outer layer; inner and outer layers are separated separation layer 8.3–16.7 μm in width; outer layer of extine approximately 1 μm in width, with coarse granular and spiny ornamentation on the surface; spine base 1–2 μm in width, 1–3.5 μm in length; spine apex sharp or blunt sharp. Megaspore unknown.

Feng et al. (2020) described that *Tomiostrobus sinensis* was heterosporous plant with helically arranged sporophylls, Smooth-margined sporophylls of various shapes, consisting of proximal fertile and distal sterile portions, proximal portion of the sporophyll bearing a single sporangium on the adaxial surface covered by a bell-shaped velum. A ligula is presented distal to the velum. The distal portion of the sporophyll gradually narrows from the proximal portion and has a long, tapering apex, which is commonly broken off leaving a frayed apex. Microsporophylls present on top of the protocorm, megasporophylls borne on the protocorm's mid- to lower parts. Megaspores of *Biharisporites* (Potonié 1956) Bharadwaj and Tiwari, 1970 type, trilete, with a pronounced alveolate wall.

Material examined: YXM (B)-19-1, YXM (B)-19-2, YXM (B)-21-27, GPT-17-4, GPT-17-3, GPT-18-2.

Occurrence: Early Triassic Kayitou Formation in western Guizhou and eastern Yunnan, South China.

Description: All the specimen are dispersed sporophyll; spatulate, cuneate or listric; 0.8–1.6 cm in length; widest portion is in 1/5–1/4 from the top, 0.5–0.8 cm, sharp narrowing from here to the top and gradually narrowing to the base; length–width ratio is around 2; arrow apex, usually broken and leave the base of leaf apex. Sporangium virgate;; stick close to the base and center of sporophyll adaxial surface; in most cases it gradullyy extend drom the base to the top, occasionally it narrows from the 2/3 of the top; 0.6–1.2 cm in length, 0.1–0.3 cm in width; a longitudinal

ridge extend from the sporangium base to the top. Ligular scar tightly attached to the sporangium top, smaller than 0.5 mm in diameter; oval.

Discussion and Comparison: The samples of this species are most abundant in the base of the Kayitou Formation. Presently most specimens are similar to the holotype *A. zeilleri* named by Fliche in shape of sporophyll and sporangium. Whereas, it is much more smaller than the *Annalepis zeilleri*. It also does not have Middle Triassic *Annalepis* typical arrow like leaf apex, and the Early Triassic lycopods has thin and tapering apex which is usually broken. Feng edit the genus *Annalepis* to *Tomiostrobus* in 2020. He proposed all the dispersed sporophyll of various shape belong to same species *Tomiostrobus sinensis* because the different shape sporophyll were preserved together. Without detailed in situ spore and cuticle data, we still keep the morphotype species name *zeilleri* and accept the genus name *Tomiostrobus* for Early Triassic lycopods.

Tomiostrobus* (*Annalepis*) *brevicystis (Meng 1995) (Figs. 10.2-1 to 10.2-21)

1995 *Annalepis brevicystis*, Meng et al., p. 20, Pl.3, 8–13

1998 *Annalepis brevicystis*, Meng et al., p. 773, Pl.I, Figs. 1–11, 1d

1998 *Annalepis brevicystis*, Meng et al., p. 48, Pl.9, Figs. 8–21; Pl.13, Figs. 11–18

2021 Tomiostrobus (Annalepis) angusta, Yu et al.

Holotype: *Annalepis brevicystis*, Meng et al. 1995, p. 20, Pl.3, 8–13, deposited in the Wuhan Geological Survey Center (Yichang Base), China Geological Survey, Yichang, Hubei, impression fossil, from Badong Formation (Anisian), Xianfeng, Hubei Province and Fengjie, Sichuan Province, China.

Diagnosis (*Annalepis zeilleri* emended after Meng 1995). Herbaceous, unknown stem. Sporophyll lanceolate, oval-lanceolate, spatulate, triangle; 4.5–7.5 cm in length, widest part situates in the base, 1.8–3 cm in width, narrows from the base to the top; tapering apex, concave or wide arcuate base. Sporangium insert at base or lower part of sporophyll adaxial surface; long-oval or short virgate; length is 1/5 of the sporophyll or more, 1.4–2 cm in length, 0.5–0.8 in width; with a longitudinal groove in the middle. Above the sporangium is a leaf ligule scar and labellum; leaf ligular scar is suborbicular, 1–1.5 mm in diameter; labellum heart-round shape; vague. Leaf apex linear to ribbon-like; with a bundle scar in the middle, both sides are composed of lots of rectangle-like compartments; 1.5–1.7 cm in length, 0.3 cm in width. Leaf membrane on both side of sporophyll bulge to indistinct ridge; parallel to side edge. Megaspore equatorial outline oval, 450–512 μm in diameter; thick trilete, reaching equator; extine baculate ornamentation on the surface, ornamentation of proximal surface contact zone is thin and delicate, baculate ornamentation on distal surface and equatorial region is dense and thick; terminus of baculate ornamentation inflate. Microspore unknown.

Material examined: YXM (B)-21-7a, b; YXM (B)-21-9.

Occurrence: Early Triassic Kayitou Formation in western Guizhou and eastern Yunnan, South China.

Description: All specimen is dispersedly preserved. Sporophyll triangular or ovate; 1.4–2.1 cm in length, 1.2–1.5 cm in width; the widest part usually in the base, distal portion gradually narrowing since the base, base arcuate. Sporangium obovate or stick-shaped, attached closely to the lower or basal part of the adaxial surface of the sporophyll; about 1/4 of length of sporophyll length, 0.3–0.4 cm in length, 0.3–0.5 cm in width; with a longitudinal groove at the median. Ligular pit oblong or round. Leaf-tip linear, vascular bundle scar located in the middle of the leaf-tip.

Discussion and Comparison: The distinct feature of the present specimens is the short sporangium, no more than 1/3 length of the sporophyll, commonly located on the base of the sporophyll, which differs from other species. *T. brevicystis* is the secondary in abundance to genus *Tomiostrobus* (*Annalepis*) in the Early Triassic Kayitou Formation.

Tomiostrobus* (*Annalepis*) *angusta (Meng 1995) (Figs. 10.2-22, 10.2-23 and 10.2-24)

1995 *Annalepis angusta*, Meng et al., p. 19, Pl.2, 7–9.

2021 Tomiostrobus (Annalepis) angusta, Yu et al.

Holotype: *Annalepis angusta*, Meng et al. 1995, p. 20, Pl.3, 8–13, deposited in the Wuhan Geological Survey Center (Yichang Base), China Geological Survey, Yichang, Hubei, impression fossil, from Badong Formation (Anisian), Xianfeng, Hubei Province and Fengjie, Sichuan Province, China.

Diagnosis (*Annalepis angusta* emended after Meng, 1995): Herbaceous. Sporophyll narrow and small, densely spirally arranged; overlap each other; each sporophyll is composed of an inflated distal portion and a stipiform proximal portion which sharply at first then gradually narrows toward the base; 15–22 mm in length, proximal portion 6 mm in width, distal portion 1.5 mm in width; blunt top, truncature base. Sporangium thin virgate, tightly attached to the stipiform portion on the adaxial of sporophyll; 3/4 of the sporophyll in length, top portion 3 mm in width, base 1 mm in width, with a longitudinal groove in the middle. Leaf apex extent out of the sporophyll phyllopodium, linear, 5 mm in length, 0.5 mm in width; with indistinct bundle scar in the middle; compartment of neither side is not clear. Ambilateral leaf membrane of sporangium is thin, less than 0.5 mm in width. Mega- and Microspore are unknown.

Material examined: YXM (B)-19-23, YXM (B)-21-5, YXM (B)-21-1, etc.

Occurrence: Early Triassic Kayitou Formation in western Guizhou and eastern Yunnan, South China.

Description: Dispersed sporophyll, small and narrow, consisting of inflated and stalk-shaped parts, 1.3–1.7 cm long, the broadest up to 1.0 cm, the top obtuse, the base broken. Sporangium thin stick-shaped, attached closely to central part of the stalk-shaped part of the ventral surface of sporophyll, length about 3/4 of length of

sporophyll, with a longitudinal groove at the median. Ligular pit is elliptic. Membrana leaf of both sides of sporangium is narrow, less than 1 mm in width.

Discussion and Comparison: This specimen is typical of stipiform sporophyll suddenly narrowing from 3/4 to 1/2 of the sporophyll, different from *T. zeilleri* and *T. brevicystis.*

***Tomiostrobus* (*Annalepis*) sp.** (Figs. 10.1-1 to 10.1-26; Figs. 10.2-25, 10.2-26)

Material examined: YXM(B)-21-37.

Occurrence: Early Triassic Kayitou Formation in western Guizhou and eastern Yunnan, South China.

Description: Sporophyll is rounded square to fan-shaped. The width is equal to or bigger than the length of the sporophyll. The width of it is almost the same in the whole fertile sporophyll. Sometimes the top part of the fertile portion is a little bit wider than the bottom. The sterile sporophyll-the leaf aepx is usally broken and only the base is preserved. The sporangium is in the longitudinal attached to the middle of the adaxial surface, rounded-rectangular. It has one vertical indistinct mid ridge, reaching from the bottom to the top of the sporangium, but not extending out of the sporangium.

Discussion and Comparison: The size and shape of those specimen is the transitional type of the *T. zeilleri* and *T. brevicystis*, which is rounder than the later two species. The leaf apex angle is also different from the *T. brevicystis.* Due to the lack of spore and cuticle data, those specimen is documented as on of the morphotype indeterminata species.

Division **Arthrophyta**

Class **Sphenopsida**

Order **Equisetales** Du Mortier, 1829

Family **Calamitaceae** Unger, 1840

Genus ***Paracalamites* Zalessky, 1927**

Type species: *Paracalamites striatus* Zalessky, 1927. Ufimian or Kazanian (Upper Permian) of the Daniko-Shor locality; Pechora Basin, The northeastern part of the European part of Russia.

Diagnosis (emended): a form genus, articulate stems and rhizomes, inner cast of the stems with opposite-in-node ribs. Most longitudinal rib and longitudinal groove pass straight through the node without alternation. A few ribs may occasionally alternate at the nodes.

Discussion and Comparison: *Paracalamites* is a form genus to which the isolated stem fragments from Lidgetton could be referred. However, there seems little to be gained by this, for there appears to be confusion as to the path of the ridges through the nodes in stems referred to it, for Rigby states: Zalessky erected this genus *Paracalamites* in 1932 to include Permian articulate stems and rhizomes having the

ribs of the pith cast opposite at each node, as in *Asterocalamites*, not alternating. Later Rigby continues: "From *Paracalamites* sp. described below it is thought that ribs dichotomise and recombine with adjacent ribs at nodes rather than dichotomise and recombine with themselves as in *Asterocaiamites*. He then goes on to describe the specimen as follows: Ribbing is distinct in only a few places. It is opposite at nodes on both the inner and outer surfaces. There is some slight resemblance to Stellotheca robusta.

Because *Paracalamites striatus* Zalessky, 1927, is typified by a rather indistinctive pith cast, the name *Paracalamitina striata* Zalessky, 1934, a name typified by a specimen showing the characteristic outer surface with scars of leaves and branches is preferred. Genus *Paracalamitina* is emended to include stem remains with branch and/or leaf scars and oppositely positioned ribs. *Paracalamitina* differs from *Calamitina* Weiss, which has alternating ribs, and from *Paracalamites* Zalessky by the presence of shoot and/or leaf scars. *Paracalamites* Zalessky should be used as a formal genus for inner cast of the stems with opposite-in-node ribs.

Paracalamites stenocostatus (Gu and Zhi 1974) (Figs.)

1974 *Paracalamites stenocostatus* Gu and Zhi, pp. 52, pl.29, Figs. 1–4

Holotype: *Paracalamites stenocostatus* Gu and Zhi, 1974, pl. 4, Fig. 8, deposited in the Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, a pith cast, from Xuanwei Formation (Changhsingian), Panxian, Guizhou Province, China.

Diagnosis (emended): Consisting of node and internode, internodes usually longer than broad. Longitudinal ribs are straight and narrow, widths are usually less than 1 mm. blunt or acute end. seldomly visible small and long-ovate infranodal scar. Longitudinal grooves are shallow and slender. Most longitudinal rib and longitudinal groove pass straight through the node without alternation. A few ribs may occasionally alternate at the nodes.

Occurrence: Upper Permian and Lower Triassic, widely distributed in Changxing county of Zhejiang Province, Anxi county of Fujian Province, Mojiang county of Yunnan Province and Lianzhou county of Guangdong Province, western Guizhou Province (Gu and Zhi 1974; Zhao et al. 1980; Wan et al. 2011) in addition to Xuanwei county of Yunnan.

Description: This species has internodes that are usually longer than broad, up to 3.9 cm long and 2.4 cm wide, and the nodes are not contracted. The nodal lines are straight. The flattened ribs separated by shallow and thin groove are narrow, with blunt or acute end. A few ribs may occasionally alternate at the nodes, while others meet end to end. They seldom have visible ovate infranodal scar.

Discussion and Comparison: Compared with the *Paracalamites stenocostatus*, the most obvious feature of *Calamites cistii* (Brongniart) and *Mesocalamites cistiformis* (Stur) is the staggered arrangement of longitudinal ribs and longitudinal grooves at

the node position. In general, the *Paracalamites* is characterised by the straight and narrow longitudinal rib, shallow and slender longitudinal groove, and most longitudinal rib and longitudinal groove pass straight through the node without alternation. A few ribs may occasionally alternate at the nodes.

Genus ***Annularia*** Sternberg, 1822

Type species: *Annularia spinulosa* Sternberg, 1822, from Sternberg's collection housed in the National Museum of Prague.

Diagnosis (emended): The lanceolate to obovate or spathulate shaped single-veined, dorsiventral, leaves of equal or unequal length, positioned in verticils radiating from the nodes with a narrow fused base forming a circular nodal disk. The articulated axes of all the three types of leafy shoots of the present collection show ridges and furrows. Robust leaf whorls borne on a slender stem, spreading out horizontally without cup like sheath. Probably have disk like leaf whorl; the leaves are united at the base up to more than 2/3 of their length. The leaves radiate from a shallow depression with a cuneate base, attachment directly at the nodes with little or no adherent leaf sheath; the leaf lamina is flat with an indistinct median vein.

Discussion: Comments on the morphology of *Annularia* and its taxonomic distinction *Annularia* von Sternberg, 1821 resembles *Asterophyllites* Brongniart, 1822. Both fossil-genera incorporate small Calamites-type axes bearing leaf-whorls (verticils) at each articulation (node), having single-veined leaves united at the base in each whorl. However, the leaves of *Annularia* are generally rigid and have different shapes (linear, lanceolate, oblanceolate and spathulate), with the broadest part in the middle of leaf. In contrast, leaves of *Asterophyllites* are considerably narrower with an acicular to filiform shape, and generally arranged in cup-shape whorls (e.g. Álvarez-Vázquez and Wagner 2016).

Annularia pingloensis (Gu and Zhi 1974) (Figs. 9.3-1 to 9.3-6)

1974 *Annularia pingloensis* (Sze); Gu and Zhi, p. 52, pl.29, Figs. 1–4

Holotype: *Annularia pingloensis* Gu and Zhi, 1974, pl. 29, Fig. 1–4, deposited in the Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, a impression fossil, from Heshan Formation (Lopingian), Pingle, Guangxi Province, China.

Diagnosis (emended). Leaves of a whorl usually less than 10 in number, linear and lanceolate in shape, with an acute apex, unequal in size, the undermost pair being the shortest, the other ones length equal, separately from each other. The midrib is distinct and runs into the apex. The impeller sometimes has upper blade defect.

Occurrence: Upper Permian and Lower Triassic. Xuanwei City, Yunnan Province, Weining County, Guizhou Province, Guangxi, China.

Description: The tri-branches are faint, and irregularly striated, 8 mm in width. The bi-branchs are slender and distichous, 2 mm in width. The length of the internodes is almost equal. Leaves of a whorl are usually less than 10 in number, linear and

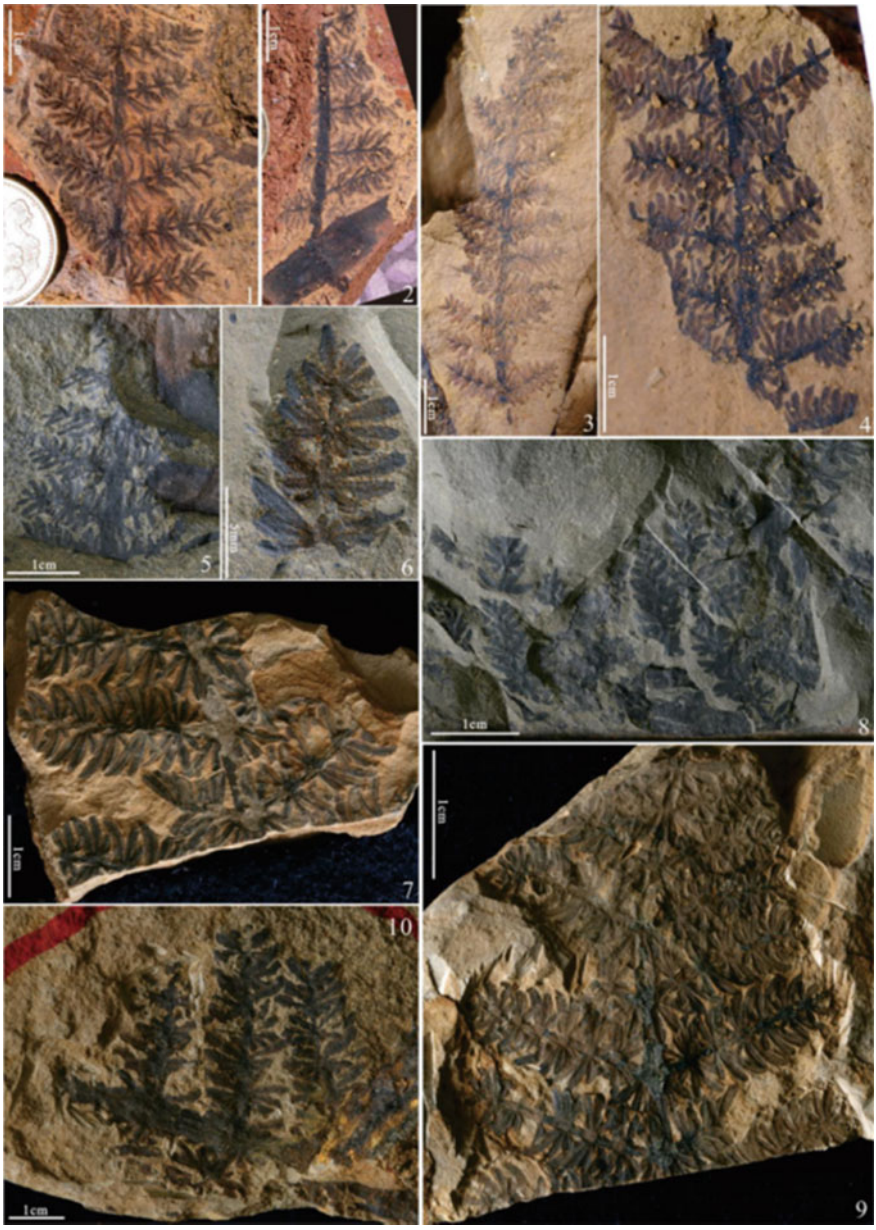

Fig. 9.3 1-6 *Annularia pingloensis* (Sze) Gu et Zhi Locality:1, 2 Mide section B, Xuanwei City, Yunnan Province Sample Number: YXM (B)-12-16, YXM (B)-12-17, 3, 4 Chahe section, Weining County, Guizhou Province Sample Number: GWC-18-97, GWC-18-98, 5, 6 Chinahe section, Xuanwei City, Yunnan Province Sample Number: YXC-(-1)-145A, YXC-(-1)-11, 7, 8, 9 *Annularia shirakii* Kawasaki Locality: 7, 9 Kele section, Hezhang County, Guizhou Province Sample Number: CLC-16-2, CLC-16-1, 8 Chinahe section, Xuanwei City, Yunnan Province Sample Number: CNH-0-18, 10 *Annularia hunanensis* Gu et Zhi Locality: Kele section, Hezhang County, Guizhou Province Sample Number: CLC-3-5

lanceolate in shape, with an acute apex, unequal in size, the uppermost pair being the longest and the other ones becoming smaller downward, separately from each other. The midrib is distinct and runs into the apex.

Discussion and Comparison: The difference between *Annularia shirakii* and *Annularia hunanensis* is that the internode shortening is not obvious and has midrib, and only the lowest pair is shorter.

Annularia shirakii (Figs. 9.3-7, 9.3-8, 9.3-9)

1927 *Annularia shirakii* Kawasaki, pp. 9, pl.XIV, Fig. 76

1927 *Annularia crassiuscula* Halle, pp. 34–36, pl.6, Figs. 10–11; pl.7, Figs. 10–13

1974 *Annularia shirakii* Kawasaki, Li and others, pp. 55, pl.31, Figs. 8–11

Holotype: *Annularia shirakii Kawasaki*, 1927, pl. XIV, Figs. 76, from Gaofangshan series (Lopingian), Panxian, Guizhou Province, North Korea.

Diagnosis (emended). All levels branche internodes length gradually shorten upward. Branch impeller at all levels sometimes with a lack of upper leaves, arranged in butterfly shape. Leaves shorter, on terminal branches up to 12 mm, usually shorter, lanceolate, slightly curved forward, widest in middle, apex rather pointed. The midrib is not obvious.

Occurrence: Upper Permian, in Guizhou, Yunnan, China.

Description: The bi-branch are slender, 1 mm in width. The lengths of the internodes gradually shorten upward. Leaves of a whorl are usually less than 10 in number, lanceolate in shape, with an acute apex, unequal in size, often slightly curved, widest in the middle of the leaf. The midrib is indistinct.

Discussion and Comparison: The main difference between this species and *Annularia papilioformis* Kaw is that the former has smaller leaves, closely arranged impellers, and appears in the middle and Late Permian (Paleozoic plants in China, 1974); the latter has not only larger leaves and loosely arranged impellers, but also appears in the early age, from the Late Carboniferous to the middle Permian (Gu and Zhi 1974). The leaves of *Annularia hunanensis* are smaller and the tip is round, the length difference between the upper and lower leaves is not obvious, and the leaves are not curved, while the leaves of *Annular shirakii* Kaw are larger and the tip is gradually pointed, and the upper leaves are obviously curved upward.

Genus ***Lobatannularia*** Kawasaki, 1927

Type species: *Lobatannularia inequifolia* Kawasaki, 1927 on the genus *Lobatannularia* Kawasaki 1927 from Permian beds in South Manchuria and Shanxi, China.

Diagnosis (Kon'no and Asama, 1950 emended): Shoot calamitina-type, slender, articulate; generally have unequal braches at node. Lateral leaf-whorl spreads out in one plane oblique or nearly parallel to the axis, being divided into two symmetrical

Fig. 9.4 1-6 *Lobatannularia multifolia* Kon'no et Asama Locality: 1, 4, 6 Chahe section, Weining County, Guizhou Province Sample Number: GWC-3-16, GWC-53-2, GWC-2-15, 2, 3 Chinahe section, Xuanwei City, Yunnan Province Sample Number: YXC-P_3x-9, CNH-3-0.5-1, 5 Tucheng section, Panxian County, Guizhou Province Sample Number: GPT-10-2, 7, 8, 9 *Lobatannularia cathaysiana* Yao Locality: 7 Chinahe section, Xuanwei City, Yunnan Province Sample Number: YXC-(-1)-8, 8, 9 Chahe section, Weining County, Guizhou Province Sample Number: GWC-18-29, GWC-21-4, 10-12 *Lobatannularia heianensis* (Kod.) Kawasaki Locality: 10 Chinahe section, Xuanwei City, Yunnan Province Sample Number: YXC-(-1)-40, 11 Chahe section, Weining County, Guizhou Province Sample Number: GWC-21-1, 12 Kele section, Hezhang County, Guizhou Province Sample Number: CLC-21-9-1, 13, 14 *Lobatannularia ensifolia* (Halle) Halle Locality: Chahe section, Weining County, Guizhou Sample Number: GWC-58-10, GWC-66-11, 15-17 *Schizoneura manchuriensis* Kon'no Locality: 15, 16 Chahe section, Weining County, Guizhou Sample Number: GWC-5-4, GWC-18-19, 17 Chinahe section, Xuanwei City, Yunnan Province Sample Number: YXC-(-1)-108 ▶

lobes; terminal one not divided into lobe, forming a single fan-shaped. Leaf-segments of each lobe roughly coherent along sutural lines, showing considerable difference in length, namely lowest one shortest and curved upward: leaf slender and uninerved, having both fan-shaped terminal whorl and special habit of branching to be called "Pseudo-dichotomous polypodial".

Discussion: *Annularia* has linear, oblanceolate or spatulate leaves and no lower leaf defect. Genus name used in Paleozoic *Lobatannularia* has two lobed impeller with more or less curved leaves. The lower leaves are obviously absent. The genus name is often used in Paleozoic and occasionally in Middle Triassic.

Lobatannularia cathaysiana (Yao, 1980) (Figs. 9.4-7, 9.4-8 and 9.4-9)

1927 *Annularia maxima* Halle, p. 13, pl.1, Figs. 8, 9

1927 *Annularia heianensis* (Kodaira), p. 27, pl.5, Figs. 13, 14

1930 *Annularia lingulatus*?, Chang, Geol. Kwangtung & Kwangsi, p. 2, pl.1, Figs. 1–3

1980 *Lobatannularia cathaysiana* Yao, pp. 76–77, pl.3, Fig. 5; pl.5, Figs. 1–6

Holotype: *Lobatannularia cathaysiana* Yao, 1980, pl.3, Fig. 5; pl.5, Figs. 1–6, deposited in the Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, a impression fossil, from Xuanwei Formation (Lopingian), Panxian, Guizhou Province, China.

Diagnosis (emended): Leaf whorled, 24–28 leaves in each whorl, being divided into two lobes. Leaves linear to counter-lanceolate, the apex is blunt. Leaves near to the proximal side bend falcate. The lateral leaves are longer than the upper and lower ones, and gradually broad towards the apex. The leaves are united for about two thirds or three fourths of their length. The leaves are very unequal in size, the smallest leaves at the lower portion of the branch, about one fifth of the length of the longest. 1–2 leaves near to the upper portion of the branch are straight and separated. The single midvein is wide and distinct.

Occurrence: Upper Permian, Guizhou, China.

Description: Leaf whorled, 24–28 leaves in each whorl, being divided into two lobes. Leaves linear to counter-lanceolate, the apex is blunt. Leaves near to the proximal side bend falcate. The lateral leaves are longer than the upper and lower ones, and gradually broad towards the apex. The leaves are united for about two thirds or three fourths of their length. The leaves are very unequal in size, the smallest leaves at the lower portion of the branch, about one fifth of the length of the longest. 1–2 leaves

near to the upper portion of the branch are straight and separated. The single midvein is wide and distinct.

Discussion and Comparison: The main character of the specimens is that 1–2 leaves near the upper portion of the lobe are relatively straight and departed, which length is not more than one-half of the longest one. This species is different from *L. heianensis* by: (1) *L. cathaysiana* has more leaves than *L. heianensis* in a whorl, the latter is 14–26 leaves; (2) linear or lanceolate, the leaf's apex is acute or blunt, but shows a projecting prickle (mucronate), the latter is spoon-shaped, blunt-tipped; (3) The angle between the two lobes in this species is bigger than the latter having 55–120°.

Lobatannularia multifolia (Kon'no and Asama, 1950) (Figs. 9.4-1 to 9.4-6)

1924 *Schizoneura heianensis* Kodarra, p. 163, pl.23, Fig. 2

1950 *Lobatannualria multifolia* Kon'no and Asama, p. 27, pl.4, Figs. 9–12

Holotype: *Lobatannualria multifolia* Kon'no and Asama, pl.4, Figs. 9–12. Deposited in the Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, a impression fossil, from Xuanwei Formation (Lopingian), Weining County, Guizhou Province, China.

Diagnosis (emended): Ultimate branch about 1–2 mm wide; internode 5–7 mm long, distinctly divided into two lobes, each lobe oblique obovate with 18–20 leaves; leaves completely connected, linear lanceolate, slightly curved upward; apex obtuse or subacute, widest near the apex. Leaves are very unequal in size, those at the lower portion of the valve being the smallest, are about one fourth of the longest leaf at the middle portion of the valve. The leaf has a single midvein.

Occurrence: Upper Permian, Anhui, Sichuan, Guizhou. In western Guizhou and eastern Yunnan, China.

Description: The impeller is obviously divided, with 20 leaves per valve, bending upward; the leaf length is 5–35 mm, the widest near the top; the leaf tip is blunt to subacute, almost all united, with single vein; the upper and lower leaves are wide.

Discussion and Comparison: *Lobatannualria nampoensis* (Kawasaki 1925) Kim and Kimura, 1988 is stem slender. Leaf-whorl borne at node, divided into two symmetrical lobes, obliquely attached to the stem, but the terminal whorl not divided into lobes, forming a single fan-shaped whorl. Leaf-whorl varying in size according to the position of the plant; towards the distal part it becoming shorter and smaller. *Lobatannualria multifolia* Kon'no and Asama impeller is obviously divided, the widest near the top; the leaf tip is blunt to subacute, almost all united, with single vein; the upper and lower leaves are wide.

Lobatannularia heianensis ((Kod.) Kaw, 1927) (Figs. 9.4-10, 9.4-11, 9.4-12)

1925 *Schizoneura heianensis* Kodaira, Kod., p.163, Pl.XXIII, Figs. 3–4

Holotype: *Lobatannularia heianensis* (Kod.), Kaw., 1927, pl.VI, Fig. 23. Form Kaisen Coal-field, a impression fossil, Pingan serise (Lopingian), North Korea.

Diagnosis (emended): The impeller obviously divided, with 12 (14)–14 (16) leaves per valve; the leaves linear lanceolate to lanceolate; except for 2–3 leaves near the lower lobe, little difference in leaf length, the tip more pointed, with short tip; most of the leaves are united, only the top is 3–5 mm apart; with single vein; obviously lower lobe deficiency.

Occurrence: Upper Permian, Guizhou and Yunnan, China.

Description: Ultimate branch about 1.5 mm wide, distinctly bivalvate, each valve oblique obovate with 8–10 leaves; most portion of the leaf is connected, only distal 2–4 mm near leaf apex is separated; leaves linear oblanceolate, about 1.5–2 mm wide, apex abruptly round and bearing a mucro. The leaves are very unequal in size; the smallest leaves being at the lower portion of the lobe, are about one fourth of the length of the longest, which curved upwards.

Discussion and Comparison: This species can be compared with *Lobatannslaria multifolis* Konno et Asama, but the latter one is not The tip of the leaf blade is almost completely connected without separation. This species is also slightly different from *L. cf. heianensis* (Kod.) Kaw (Paleozoic plants in China, 1974, pp. 57–58, pl.32, Figs. 11–12) which has been found in northern China. In the latter, the leaves are not spoon shaped, the tip is sharp, and the number of leaves per valve is more.

Lobatannularia ensifolia (Halle 1927, 1928) (Figs. 9.4-13, 9.4-14)

1927 *Annularites ensifolia* Halle, Halle, pp. 20–26, Pl.1, Figs. 1–5, Pl.2, Figs. 1–2, pp. 3, pl.4, Figs. 1–3

1974 *Lobatannularia ensifolia* (Halle) Halle, Paleozoic plants of China, pp. 57, pl.33, Figs. 1–2; pl.34, Fig. 1

Holotype: *Lobatannularia ensifolia* (Halle) Halle, 1974, pl.33, Figs. 1–2; pl.34, Fig. 1, deposited in the Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, a impression fossil, from Shihezi Formation (Lopingian), Taiyuan, Shanxi Province, China.

Diagnosis (emended): The last two branches divided into the last branches in pseudo dichotomous form (a pair of forked last branches are produced on each node, and each of them has an undeveloped branchlet on the outside). The impeller divided into two lobes, each of which has about 7–10 leaves. Leaves lanceolate, up to 8 cm long, the shortest about 1 cm, 5 mm wide, apex acuminate, base separated or slightly united, with single vein. The lower blade of impeller short, and the blade near the lower blade the shortest. The top impeller round to wide oval.

Occurrence: Upper Permian, Sichuan, Guizhou and Yunnan, China.

Description: The leaves number about 18 in a whorl (Pl.12, Fig. 1), more or less falcate, often confluent for a short distance, narrow lanceolate in shape, apex not preserved. The leaves are unequal in size, the smallest one at lower portion of the lobe, the largest being 3 or 4 times as long as the shortest. The midrib of the leaves is not very distinct.

Discussion and Comparison: *L. lingulata* (Halle 1927, 1928) impeller is obviously divided into 8–10 leaves per valve, the leaves are obviously upward curved and completely separated. The widest part is at the top, apically acutely needled; with single vein; the lower leaves are obviously absent. *Lobatannularia ensifolia* (Halle) Halle, 1974 each of which has about 7–10 leaves. Leaves is lanceolate and apex acuminate, which base separated or slightly united, with single vein. The lower blade of impeller is short, and the blade near the lower blade the shortest.

Genus ***Schizoneura*** Schimper et Mougeot, 1844

Type species: *Schizoneura paradoxa* Schimper & Mougeot, 1844, nom. cons. (Zijlstra et al. 2007).

Diagnosis (emended): Stems divided into long internodes and usually swollen nodes; nodes of main stems bearing whorls of leaves or branches; branch nodes bearing whorls of long, linear, single-veined leaves; immature whorls with leaves entirely fused along the lateral margins, forming a cylindrical sheath; mature whorls with leaves laterally fused into two or more strap-shaped, lanceolate or ovate leaf-sheath segments; in a few specimens, individual whorls with leaves free to their bases.

Discussion: *Schizoneura* was established by Schimper and Mougeot in 1844 based on specimens from the Early Triassic strata in France. The leaf stem of the leaf leaf is divided into segments and internodes, and the longitudinal rib and longitudinal groove are straight through the nodes. The leaves are slender and long than internode, each node is often 10–22, with single vein, and the edges are combined with two petals, and the stem is hugged on both sides of the node. The reproductive organs of the plant are spiked. The typical species of the three genera are not difficult to distinguish, but some transitional types of specimens can not be distinguished from each other. Generally, they are classified into the genus according to which typical species they are close to He et al. (1996).

Schizoneura manchuriensis (Kon' no, 1942) (Figs. 9.4-15, 9.4-16 and 9.4-17)

1960 *Schizoneura manchuriensis,* Kon' no, pp. 163–188, pl.16–20

1974 *Schizoneura manchuriensis,* Kon' no, pp.60, pl.34, Fig. 11; pl.35, Figs. 1–3

Holotype: *Schizoneura manchuriensis* Kon'no, 1942. pl.34, Fig. 11; pl.35, Figs. 1–3. from the *Gigantopteris nicotianaefolia*-bearing Formation in Penchihu Coal-field, Northeastern China.

Diagnosis (emended): The stem has nodes and internodes, and the internodes at the lower end of the branch may be the longest. The impeller consists of 8–16 leaves. The leaf sheath divided into two petals, opposite in shape, and inserted on the node in the form of half embracing stem. The leaf petals are oblong to lanceolate, 10–20 mm wide, 30–55 mm long, irregularly dehiscent or only apically dehiscent; the immature leaves at the top of the stem are connected with each other to form a roughly cylindrical closed sheath. The leaf blade is linear, about 60 mm long and only 20 mm wide. The tip is sharp and connected with each other, with obvious suture line

and single vein, accounting for about 1/2 of the leaf width. The reproductive organs are terminal, spicate, and consist of a round of sterile bracts with closed sheaths and 6–7 rounds of cyst stalks. There are 20–23 cyst stalks in each round. There are six sporangia in each sporangium stalk.

Occurrence: Upper Permian, Guizhou and Yunnan, China.

Description: Leaves number 8–12 in each whorl, linear to lanceolate. They are symmetrically divided into two parts (or half whorls), which are oblong in shape, look like the opposite. Each part is 5–10 mm wide and 28–30 mm long, containing of 4–6 leaves, each other irregularly split or united.

Discussion and Comparison: This species is similar to some species of the genus *Lobatannularia*, especially to the specimen of *Lobatannularia multifolia*, but the latter has more leaves, different length and slightly curved forward.

Division **Pteridophyta**

Class **Marattiales et filicales incertae sedis**

Genus ***Sphenopteris*** (Brongn.) Sternberg 1825

Sphenopteris cf. ***tenuis*** (Schenk) Halle emended, 1927 (Fig. 9.6-1, 1a)

1927 *Sphenopteris tenuis*, Halle, p. 58, Pl.15, Figs. 15–17.

1974 *Sphenopteris tenuis*, Paleozoic plants of China, p. 76, Pl.46, Figs. 5–6; Pl.47, Figs.1–7.

2009 *Sphenopteris tenuis*, Seyfullah and Hilton, 2009, pp. 205, Figs. 23–26.

Lectotype: Specimen S138382 comprising fertile frond as illustrated by Halle 1929 pl. 1, Figs. 1–4.

Syntype: Specimen S138062 comprising vegetative foliage as illustrated by Halle (1927) pl. 15, Fig. 17.

Diagnosis (Seyfullah and Hilton, 2009): Frond tripinnate or quadripinnate. Penultimate pinnae subopposite or alternate, triangular to lanceolate, with smooth, winged rachis. Ultimate pinnae alternate or subopposite, with winged rachis, ovate to lanceolate; pinnate, pinnatifid or serrate. Well-developed pinnules, forming an angle of about 30 with the parent rachis, lanceolate to oblanceolate, acute, tapering towards a rather broad decurrent base; pinnules in distal part of the frond and pinnae entire, confluent towards the extremities; becoming lobes of the ultimate pinnae; pinnules in the proximal part dissected into lobes, becoming more prominent towards frond base and eventually forming free pinnules. Fine but distinct median vein; secondary veins few, of almost the same strength as the median vein, at an acute angle to the midvein, in the larger lobed pinnules commonly bifurcating. Ovules borne on unmodified pinnules; attached to the base of the lateral pinnules, or to pinna rachis. Ovules ovoid or narrowly ovoid, 4–5 mm long and 2–2.5 mm wide, rounded at the base, with a hollow, tubular apex.

Material examined: GPT-10-4.

Occurrence: Tucheng section, Panxian County, Guizhou; Late Permian Xuanwei Formation.

Description: The rachis of the penultimate pinnae is smooth and winged. The ultimate pinnae are lanceolate; pinnate, pinnatifid and the pinnules are lanceolate to oblangceolate, tapering downwards but attached by a broad decurrent base.

Discussion and Comparison: The specimen in Figs. 6.1, 6.1a, 6.2 shows the characteristic rachis and pinnules of *S. tenuis*. But the venations of the present specimen are unclear, it may be well belong to *S.* cf. *tenuis*.

Genus ***Pecopteris*** Brongniant, 1822

Type Species: *Pecopteris penniformis* Brongniart, 1822, Middle Pennsylvanian (Upper Carboniferous); Dudweiler, Germany; Muséum national d'histoire naturelle (France).

Diagnosis (emended): Multiple pinnate frond; rachises surface smooth or with fine longitudinal lines, or scales, tumors, thorns and other attachments, some even with abnormal pinnules. Pinnules on either side or adaxial side of the rachises, usually linguiform, elliptic, or rectangular; entirely attached in the ultimate rachises or slightly contracted at the base; alternate or subopposite, touching or separated each other. Pinnules sides more or less parallel, margin generally entire, occasionally undulate or lobed. Pinnate venation, the midrib distinct usually, and the lateral veins not difurcating or several times.

Discussion: Genus *Pecopteris* has a widespread geographical distribution in the Cathaysia-land and has often been described. *Pecopteris* has traditionally been used as the name of a form fossil-genus of fern and fern-like fossil pinnate frond with small, dentate pinnules, regardless of their reproductive organs (Brongniart 1822). With expanding knowledge of the fructifications attached to these fronds, paleobotanists are trying to improve the classification with details of the sporangia. Most of the species which sporangia found show characters that seemed to suggest they had marattialean affinities and were attributed to various fossil–genera based on detailed differences in their sporangial structures.

Pecopteris gracilenta (Gu and Zhi 1974) (Fig. 9.5-10)

1974 *Pecopteris gracilenta* Gu and Zhi, Paleozoic plants of China, p. 95–96, Pl.65, Figs. 1–4

Holotype: *Pecopteris gracilenta* Gu and Zhi, 1974, p. 95–96, Pl.65, 1–4, deposited in the Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, impression fossil, from Upper Shihezi Formation (Guadalupian), Taiyuan, Shanxi Province, China.

Diagnosis (emended): Frond fragment at least tripinnate. Ultimate rachises thin, Pinnules thin lamina, with apices obtuse. The midrib not distinct usually, as slender as the lateral veins, and decurrent at the base; the lateral veins sparse and slender, not difurcating or once.


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◀**Fig. 9.5** 1 *Pecopteris (Asterotheca)* cf. *hemitelioides* Brongniort Locality: Chinahe section, Xuanwei City, Yunnan Province Sample Number: YXC-(-1)-44, 2-5 *Pecopteris (Asterotheca) guizhouensis* Zhang Locality: 2, 4 Chinahe section, Xuanwei City, Yunnan Province Sample Number: YXC-(-1)-98A, YXC-(-1)-175, 3 Zhejue section, Weining County, Guizhou Province Sample Number: GWZ-38-10, 5 Chahe section, Weining County, Guizhou Province Sample Number: GWC-58-3, 6-9 *Pecopteris (Asterotheca) orientalis* (Schenk) Potonie Locality: 6, 7, 9 Chahe section, Weining County, Guizhou Province Sample Number: GWC-18-59, GWC-58-31, GWC-18-61, 8 Chinahe section, Xuanwei City, Yunnan Province Sample Number: YXC-(-24)-1A, Fig. 10 *Pecopteris gracilenta* Gu et Zhi Locality: Chinahe section, Xuanwei City, Yunnan Province Sample Number: YXC-(-1)-126, 11, 12 *Pecopteris lativenosa* Halle Locality: 11 Chinahe section, Xuanwei City, Yunnan Province Sample Number: YXC-(-1)-15, 12 Chahe section, Weining County, Guizhou Province Sample Number: GWC-58–20, 13 *Pecopteris taiyuanensis* Halle Locality: Chinahe section, Xuanwei City, Yunnan Province Sample Number: YXC-(-6)-4, 14, 15 *Pecopteris sahnii* Hsu Locality: 14 Kele section, Hezhang County, Guizhou Province Sample Number: CLC-29–11-1, 15 Chahe section, Weining County, Guizhou Province Sample Number: GWC-58-28, 16, 17 *Pecopteris longifolioides* Zhang Locality: 16 Kele section, Hezhang County, Guizhou Province Sample Number: CLC-29-1-1, 17 Chahe section, Weining County, Guizhou Province Sample Number: GWC-18-2, 18 *Pecopteris marginata* Gu et Zhi Locality: Chahe section, Weining County, Guizhou Province Sample Number: GWC-58-14a, 19 *Pecopteris echinata* Gu et Zhi Locality: Chahe section, Weining County, Guizhou Province Sample Number: GWC-58-7b

Material examined: GWC-5-2, GWC-58-1.

Occurrence: Chahe section, Weining County, Guizhou; Late Permian Xuanwei Formation,

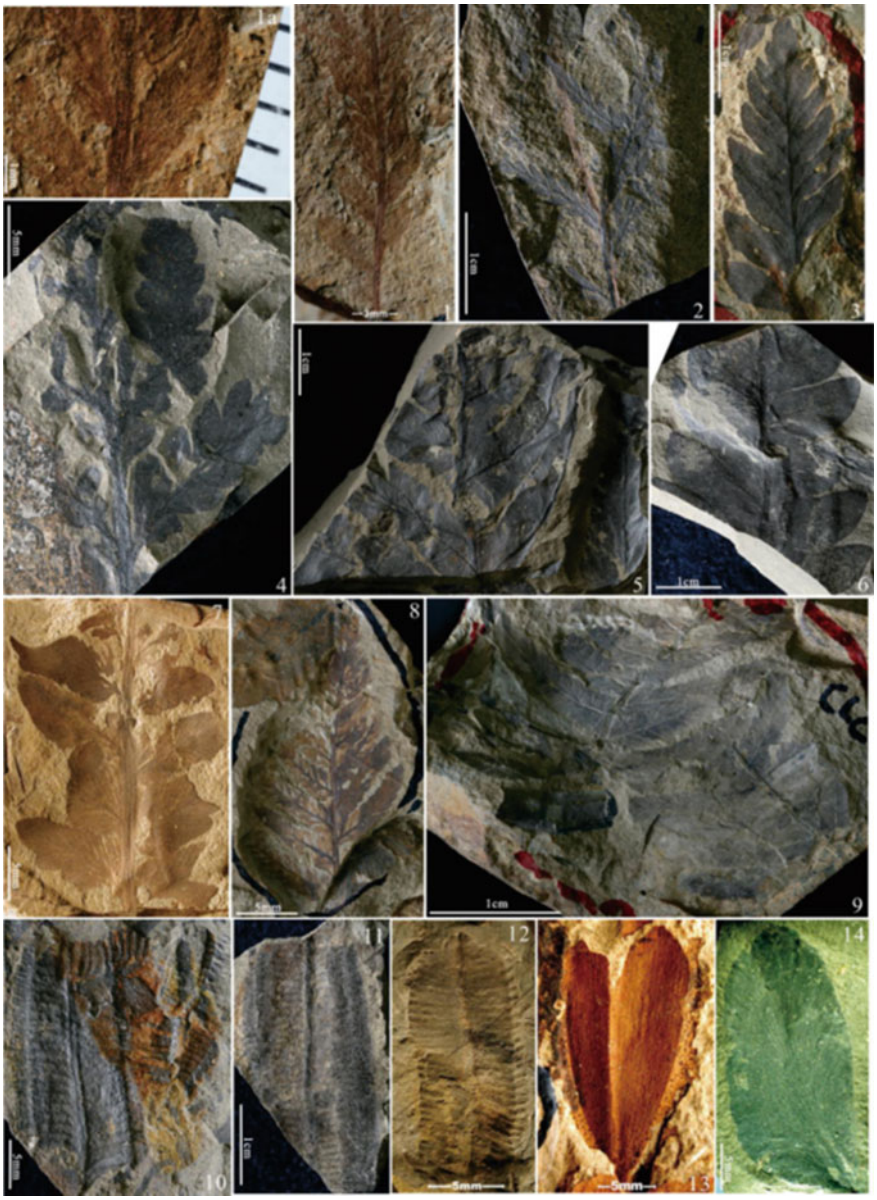
Description: The pinnules are well characterized by the very distinct and ascending venation. Ultimate rachis is very slender. The characteristic thin lamina is very distinct. The pinnules are ovate to oblong, forming an angle of about 45° with the pinna rachis. The apex of the pinnules is obtuse. The midrib is slender, slightly decurrent, attaining to the apex. The lateral veins are rare, arising at a narrow angle, bifurcating once or no; the first basal lateral veins at both distal and proximal sides of the midrib are very long. The first lateral veins at the proximal pinnules are given off from the decurrent part of the midrib.

Discussion and Comparison: The distinct feature of this species is that thin lamina and slender rachis and veins, which are differ from the other species of genus *Pecopteris.*

Pecopteris echinata (Gu and Zhi 1974) (Fig. 9.5-19)

1974 *Pecopteris echinata* Gu and Zhi, Paleozoic plants of China, p. 94; Pl.62, Figs. 12–13; Pl.63, Figs. 1–7

Holotype: *Pecopteris echinata* Gu and Zhi, p. 94; Pl.62, Figs. 12–13; Pl.63, Figs. 1–7, deposited in the Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, impression fossil, from Longtan Formation (Lopingian), Jiangning, Jiangsu Province, China.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◀**Fig. 9.6** 1, 1a *Sphenopteris* cf. *tenuis* Schenk Locality: Tucheng section, Panxian County, Guizhou Province Sample Number: GPT-10-4, 2 *Sphenopteris tenuis* Schenk Locality: Chinahe section, Xuanwei City, Yunnan Province Sample Number: YXC-(-1)-44, 3 *Cladophlebis* sp. Locality: Kele section, Hezhang County, Guizhou Province Sample Number: CLC-4-5, 4 *Cladophlebis manchurica* Kaw Locality: Chinahe section, Xuanwei City, Yunnan Province Sample Number: CNH-0-17, 5 *Cladophlebis nystroemii* Halle Locality: Chinahe section, Xuanwei City, Yunnan Province Sample Number: YXC-P_3x-10, 6, 7 *Cladophlebis permica* Lee et Wang Locality: 6 Chinahe section, Xuanwei City, Yunnan Province Sample Number: YXC-(-1)-169, 7 Chahe section, Weining County, Guizhou Province Sample Number: GWC-18-12a, 8, 9 *Cladophlebis fuyuanensis* Zhang Locality: Kele section, Hezhang County, Guizhou Province Sample Number: CLC-35-37, CLC-35-17, 10-12 *Guizhoua gregalis* Zhao Locality: 10, 11 Chinahe section, Xuanwei City, Yunnan Province Sample Number: YXC-P_3x-1, CNH-0-10B 12 Chahe section, Weining County, Guizhou Province Sample Number: GWC-58-17a, b, 13 *Tingia gerardii* Stockmans et Mathieu Locality: Chahe section, Weining County, Guizhou Province Sample Number: GWC-3-1, 14 *Linopteris* sp. Locality: Chahe section, Weining County, Guizhou Province Sample Number: GWC-58-29

Diagnosis (emended): The rachis thick. The pinnules bilateral symmetry, not uneven in length. The midrib distinct and slightly decurrent; the lateral veins bifurcating once near the midrib, and the upper branches bifurcating once again.

Material examined: GWC58-7b.

Occurrence: Chahe section, Weining County, Guizhou; Late Permian Xuanwei Formation. Chinahe section, Xuanwei County, Yunnan; Late Permian Xuanwei Formation.

Description: The ultimate pinnae is linear to lanceolate, the apex is obtuse. The pinnules are confluent at the base, ovate, oblong to lingulate, rather small, attaining a length of 2.5–3.5 mm and a breadth of 1.5–2 mm. with a rounded apex. The midrib is distinct, slightly decurrent. The lateral veins give off at an angle of 45° from the midrib, bifurcating once near the midrib. The branches of the lateral veins retain almost the same thickness before and after bifurcating.

Discussion and Comparison: The specimens are the same as *P. lativenosa* in the pinnule's shape, but the venations of the present specimens are denser than *P. lativenosa.*

Pecopteris* (*Asterotheca*) *guizhouensis (Figs. 9.5-2, 9.5-3, 9.5-4 and 9.5-5)

1980 *Pecopteris (Asterotheca) guizhouensis*, Zhang et al., p. 78, Pl.VIII, Figs. 2–3; Pl.X, Figs. 2–5, 2a

2011 *Pecopteris (Asterotheca) guizhouensis*, Wang et al., pp. 254–255, Pl.II, Fig. 9

Holotype: *Pecopteris (Asterotheca) guizhouensis* Zhang, p. 78, Pl.VIII, Figs. 2–3; Pl.X, Figs. 2–5, 2a, deposited in the Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, impression fossil, from Xuanwei Formation (Lopingian), Xuanwei, Yunnan Province, China.

Diagnosis (emended): Frond gigantic, at least bipinnate; ultimate pinnae linear, their sides parallel and contracting slowly to the apex. Pinnules relatively large, 5 mm in

length, 2 mm in width, alternate and touching closely each other. The midrib distinct and thick, extending strightly and separating near the apex. The fertile frond with same shape of the sterile one; the sporangia synangium belonging to *Asterotheca*-type, bearing in the reverse side of the fertile frond, slightly touching each other, generally 5–6 couples with 4 sporangia respectively.

Material examined: YXC-(-1)-98A, YXC-(-1)-175, GWZ-38-10, GWC-58-3.

Occurrence: Chinahe section, Xuanwei County, Yunnan; Late Permian Xuanwei Formation. Chahe and Zhejue sections, Weining County, Guizhou; Late Permian Xuanwei Formation.

Description: The pinna is linear. The pinnules are closely set, forming an angle of about 70–80° with the rachis, rectangular, straight or slightly falcate, with a broadly rounded apex. The margin thickens. The midrib is straight, separating near the apex. The lateral veins are simple and straight, not difurcating or once, arising at a 60–70 degree angle. The fertile frond seems to be of the same shape of the sterile one, margin of the pinnules indistinct. The sporangia are ovate, slightly separating each other, generally 5–6 couples, forming rounded synangia of 5–6 sporangia. The synangia are situated on the lateral veins about midway between the midrib and the margin and form two rows, one on each side of the midrib.

Discussion and Comparison: The samples of this species are gigantic relatively, with a broadly rounded apex, which differs from *P (Asterotheca). hemitelioides.*

Pecopteris* (*Asterotheca*) cf. *hemitelioides (Brongniort, 1974) (Fig. 9.5-1)

1974 *Pecopteris (Asterotheca) hemitelioides* Brongniart, Paleozoic plants of China, p. 87; Pl.55, Figs. 9–11; Pl.56, Figs. 1–2

2007 *Pecopteris* cf. *hemitelioides* Brongniart, Liu et Yao, p. 200, Pl.1, Fig. 10

Holotype: *Pecopteris (Asterotheca) hemitelioides* Brongniart, 1834, deposited in Muséum national d'histoire naturelle (France)., impression fossil, from Loire France

Diagnosis (emended): Multiple pinnate frond, Pinnules ligulate-oblong, the length about three times of the width, attaching in the ultimate rachises vertically; pinnules sides parallel, with a obtuse apex. Midrib thick and straight; the lateral veins not difurcating. The sporangia synangium belonging to *Asterotheca*-type.

Material examined: YXC-(-1)-44.

Occurrence: Chinahe section, Xuanwei County, Yunnan; Late Permian Xuanwei Formation.

Description: Frond fragment is at least bipinnate, the ultimate rachises are 2 mm wide, with fine longitudinal lines. Pinnules are alternate, forming a wide-angle with the rachis, ligulate oblong in shape, about 30–35 mm long and 7–10 mm wide; pinnules sides are parallel, with a obtuse apex; they are entirely attached in the ultimate rachises and slightly decurrent at the base. The midrib is 1 mm wide; thick and straight, separating near the apex; slightly decurrent. The lateral veins are thinner

than the midrib, extending outward near the midrib and not bifurcating, arising at a 50–60° angle.

Discussion and Comparison: Due to the lack of the fertile frond, this specimen is identified according to the morphology of the sterile pinnules. This specimen is typical of the ligulate-oblong pinnules and the simple lateral veins, which is seem to the *Pecopteris (Asterotheca) hemitelioides* Brongniart (Gu and Zhi 1974).

Pecopteris lativenosa (Halle 1927) (Figs. 9.5-11 and 9.5-12)

1927 *Pecopteris lativenosa*, Halle, pp. 86–87, Pl.25, Figs. 1–7

1974 *Pecopteris lativenosa*, Paleozoic plants of China, p. 94, Pl.62, Figs. 7–11

1989 *Pecopteris lativenosa*, Sze, p. 36, Pl.44, Figs. 1. 1a

2010 *Pecopteris lativenosa*, Sun et al., p. 346, Pl.204, Figs. 10, 11

Holotype: *Pecopteris lativenosa* Halle, pp. 86–87, Pl.25, Figs. 1–7, deposited in impression fossil, from Shanxi Province, China.

Diagnosis (emended): The pinnules bilateral symmetry, not uneven in length, with a slight contraction in the upper side and slightly decurrent in the lower side. The midrib distinct and decurrent; the lateral veins bifurcating once near the midrib, and the upper branches bifurcating once again; the first lateral vein at the proximal base arising from the decurrent part of the midrib, bifurcating more than 3 times, with a thicker apex near the margin.

Material examined: YXC-(-1)-15, GWC-58-20.

Occurrence: Chahe section, Weining County, Guizhou; Late Permian Xuanwei Formation.

Description: The figured specimen shows the very distinctive venation of this species. The rachis is stout. The pinnules are ovate in shape, slightly overlapping each other, with the broadly rounded apex and very slightly auriculate base. The midrib is distinct, slightly decurrent at the base, arising at a narrow angle, bending slightly forwards, divising near the apex. The lateral veins are thick and dense, arching, bifurcating close to the midrib, the distal branch occasionally dividing once.

Discussion and Comparison: Like the typical specimens of Central Shanxi (Halle 1927), the most prominent feature of the specimen is the venation. The midrib is strong, decurrent at the base, bending slightly forwards, persisting almost to the apex. The branches of secondary veins retain almost the same thickness the whole way to the margin. These characteristic are completely in accordance with which Halle pointed out. It is likely that the present specimen belongs to this species.

Pecopteris longifolioides (Figs. 9.5-16 and 9.5-17)

1980 *Pecopteris longifolioides* Zhang, p. 79, Pl. VII, Figs. 3–5, 3a, 5a

Holotype: *Pecopteris (Asterotheca) guizhouensis* Zhang, p. 79, Pl. VII, Figs. 3–5, 3a, 5a, deposited in the Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, impression fossil, from Xuanwei Formation (Lopingian), Xuanwei, Yunnan Province, China.

Diagnosis (emended). Frond gigantic, Ultimate pinnae lanceolate, 12 cm in length and 5 cm in width, with a slow contraction at the base; pinnule apices tapering toward the apex; the rachises surface with tumors. Pinnules ligulate-oblong, or slightly bending as the falcate shape; with bluntly rounded apex and slightly separated base; margin entire or undulate; uneven in length. The midrib distinct, not decurrent at the base. The lateral veins relatively dense and irregularity, difurcating several times.

Material examined: GWC-18-2, CLC-29-1-1.

Occurrence: Chahe Section, Weining County, Guizhou; Late Permian Xuanwei Formation. Kele Section, Hezhang County, Guizhou; Late Permian Xuanwei Formation.

Description: The ultimate rachis is strong, about 2 mm. broad. The pinnules are alternate, oblong or slightly bending as the falcate shape, with bluntly rounded apex and slightly separated base, attached by the whole of their base, 2.5 times longer than broad. The midrib is distinct, not decurrent at the base, almost extending to the apex of the pinnule. The lateral veins are very dense, giving off at narrow angle, bifurcating into two branchs near the midrib, of which the posterior branch bends outwards, dividing again; the anterior branch extends to a short distance onwards and dividing 2–3 times as co-axial type. All of the branches make up of a fascicle.

Discussion and Comparison: Compared to *P. longifolia,* the present specimens are distinguished by the large pinnae with elongating pinnules, complicated lateral veins. The ultimate pinnae of *P. longifolia* are short and its lateral veins are correspondingly simple.

Pecopteris marginata (Gu and Zhi 1974) (Fig. 9.5-18)

1974 *Pecopteris marginata* Gu and Zhi, Paleozoic plants of China, p. 91, Pl.56, Figs. 10–13

Holotype: *Pecopteris marginata* Gu and Zhi, p. 91, Pl.56, Figs. 10–12, deposited in the Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences; impression fossil; from Xuanwei Formation (Lopingian), Panxian, Guizhou Province, China.

Diagnosis (emended). Frond fragment at least bipinnate; ultimate pinnae linear. Pinnules ligule or subfalcate with a thickened margin, attaching in the ultimate rachises vertically. Midrib distinct and thick, not decurrent at the base usually. The lateral veins difurcating twice regularly, giving off at wide angle.

Material examined: GWC-58-14a.

Occurrence: Chahe and Zhejue sections, Weining County, Guizhou; Late Permian Xuanwei Formation.

Description: This specimen is fragments of an ultimate pinna. The rachis of the ultimate pinna is comparatively broad in proportion to the size of the pinnules. The ultimate pinna is linear, with the apex and base not preserved. The pinnules are ligule or subfalcate, the length is 2.5 times longer than the breadth, with an obtuse apex and thickened margin; the base slightly enlarging. The midrib is very distinct, arising at a wide angle or right angle from the rachis. The lateral veins are fine and dense, but indistinct, dividing twice. The margin of the pinnule shows a narrow zone.

Discussion and Comparison: This specimens is identical in all respects with those described and figured by Gu and Zhi (1974, p. 91, Pl.56, Figs. 10–13) as *P. marginata* from Xuanwei Formation of Panxian, Guizhou.

Pecopteris* (*Asterotheca*) *orientalis ((Schenk) Potonie, 1883) (Figs. 9.5-6, 9.5-7, 9.5-8 and 9.5-9)

1883 *Callipteridium orientale*, Schenk, p. 212, 217; Pl.30, Figs. 5–7; Pl.45, Figs. 2–12

1893 *Pecopteris orientalis*, Potonie, p. 90

1927 *Pecopteris (Asterotheca) orientalis*, Halle, p. 73, Pl.16, Figs. 1–7; Pl.17, Figs. 1–5

1974 *Pecopteris (Asterotheca) orientalis*, Paleozoic plants of China, p. 93, Pl.62, Figs. 1–4

1987 *Pecopteris orientalis*, Zhao et al., p. 80, Pl.12, Figs. 1–3, 3a; Pl.13, Figs. 4,4a

1992 *Pecopteris (Asterotheca) orientalis*, Sun, p. 34, Pl.10, Figs. 9–10

Holotype: Pecopteris (Asterotheca) orientalis (Schenk) Potonie,

Diagnosis (emended): The pinnules bilateral symmetry, not uneven in length, with a slight contraction in the upper side and slightly decurrent in the lower side. The midrib distinct and decurrent; the lateral veins bifurcating once near the midrib, and the upper branches bifurcating once again; the first lateral vein at the proximal base arising from the decurrent part of the midrib; the lateral veins bending occasionally, bifurcating once or not.

Material examined: GWC-18-59, GWC-18-61, GWC-58-31, YXC-(-24)-1A.

Occurrence: Chahe section, Weining County, Guizhou; Latest Permian and Earliest Triassic Xuanwei Formation. Chinahe section, Xuanwei County, Yunnan; Late Permian Xuanwei Formation.

Description: The rachis is broad. The ultimate pinnae are linear, opposite, with a rounded or obtuse apex. The pinnules are small, oblong to ovate, their sides more or less parallel; apex broadly rounded; they are closely set, slightly decurrent and slightly confluent, with a slight contraction of the proximal margin at the base; upper side often slightly convex. The midrib is not much thicker than the lateral veins,

decurrent at the base, bending slightly forward in the upper half of the pinnule. The lateral veins are straight and arching, bifurcating once generally close to the midvein. The first lateral vein at the proximal base arises from the decurrent part of the midrib.

Discussion and Comparison: According to the shape of the ultimate pinnae and pinnules, size and veination of the pinnules, these specimens belonged to this species.

Pecopteris sahnii (Hsu 1952) (Figs. 9.5-14 and 9.5-15)

1952 *Pecopteris sahnii*, Hsu, p. 250, Pl.3, Figs. 30, 33

1974 *Pecopteris sahnii*, Paleozoic plants of China, pp. 89–90, Pl.58, Figs. 14–16, Pl.59, Figs. 1–3

Holotype: *Pecopteris sahnii* Hsu, p. 250, Pl.3, Figs. 30, 33

Diagnosis (emended): Frond at least bipinnate. Ultimate pinnae linear, tapering toward the apex. Pinnules contiguous, thick, lingulate or nearly rectangular, with a rounded apex and a slightly decurrent base. Midvein thick, slightly decurrent or not at the base; lateral veins not bifurcate or occasionally bifurcate once; basal acroscopic lateral vein departing at an acute angle, then arching and bending inward, and the the first lateral vein at the proximal base arising from the decurrent part of the midrib.

Material examined: CLC-29-11-1, GWC-58-28.

Occurrence: Chahe section, Weining County, Guizhou; Late Permian Xuanwei Formation. Kele Section, Hezhang County, Guizhou; Late Permian Xuanwei Formation.

Description: The specimen is small and fragmentary, but well characterized by the veins. The ultimate rachis is straight. The pinnules are alternate or subopposite, touching each other, forming an angle of about 70–80° or a right angle with the rachis, ligule or nearly rectangular in shape, with an obtuse apex. The midrib is distinct but slender, slightly decurrent, attaining the apex. The lateral veins are straight, the same width as the midrib, forming an angle of about 40° with the midrib, not dividing or bifurcating once close to the midrib.

Discussion and Comparison: Compared to *P. hemitelioides* whose pinnules are narrow and long, the length being 4 times longer as the breadth, the midveins not decurrent, the lateral veins not bifurcating, the present specimen is different with it. The characters of the shape and veination of the present specimens is accordant with *Pecopteris sahnii*, so we assigin them to this species.

Pecopteris taiyuanensis (Halle 1927) (Fig. 9.5-13)

1927 *Pecopteris taiyuanensis*, Halle, p. 84, Pl. 21, Figs. 1–4

1974 *Pecopteris taiyuanensis*, Paleozoic plants of China, p. 93, Pl. 62, Figs. 5–6

1992 *Pecopteris taiyuanensis*, Sun, p. 35, Pl. 10, Fig. 11

Holotype: *Pecopteris taiyuanensis,* Halle, p. 84, Pl. 21, Figs. 1–4

Diagnosis (emended). Frond at least bipinnate; rachises thick and smooth; ultimate pinnae lanceolate. Pinnules bilateral symmetry, not uneven in length, with a with a rounded apex and a slightly decurrent base. Midrib distinct and decurren, persisting straightly and divising near the apex; the lateral veins thick and dense, curved, bifurcating once near the midrib, and the upper branches bifurcating once again occasionally; the first lateral vein at the proximal base arising from the decurrent part of the midrib, bifurcating twice or three times.

Material examined: YXC-(-6)-4.

Occurrence: Chinahe section, Xuanwei County, Yunnan; Late Permian Xuanwei Formation.

Description: The specimens partly show bipinnata pinnae, the ultimate pinnae are lanceolate. The pinnules are lingulate or ovate in shape, about 4–6 mm in length and 2–3 mm in width; pinnules are attached by the whole of their base, with a rounded apex and a slightly decurrent base. The midrib is distinct, more or less thicker than the lateral veins; slightly decurrent at the base, divising near the apex. The lateral veins are curved, bifurcating once near the midrib, and the upper branches bifurcating once again. The first lateral vein at the proximal base arises from the decurrent part of the midrib, arching strongly.

Discussion and Comparison: Compared to *P. anderssonii* whose pinnules are wide and long, the the midveins not distinct, the lateral veins thin and bifurcating more than three times, the present specimen is different with it. The characters of the shape and veination of the present specimens is accordant with *Pecopteris taiyuanensis*, so we assigin them to this species.

?*Pecopteris* sp. (Figs. 10.3-11, 10.3-13 and 10.3-14)

Material examined: YXC-(-25)-6.

Occurrence: Lower Triassic Kayitou Formation in Western Guizhou and Eastern Yunnan, South China.

Description: Preserved as single pinule. Relatively thin midrib and lateral veins branch at acute angle. Broken impression fossil, without distinct branching pattern.

Discussion and Comparison: Only based on the pinnule's shape and vein system, those are probably preserved Pecoteridales.

Genus ***Rajahia*** Kon'no, 1970

Type species:

Diagnosis (emended): The sacs are arranged in a single line into linear sacs, which are attached to the back of kohlrabi slices, are wrinkled and extremely small, and are tightly packed on both sides of side veins or branches.

Discussion: Occures in the late Permian. *Rajahia* in different areas has different characteristics, such as *R.guizhouensis'* axis width is small, kohane leaves are nearly

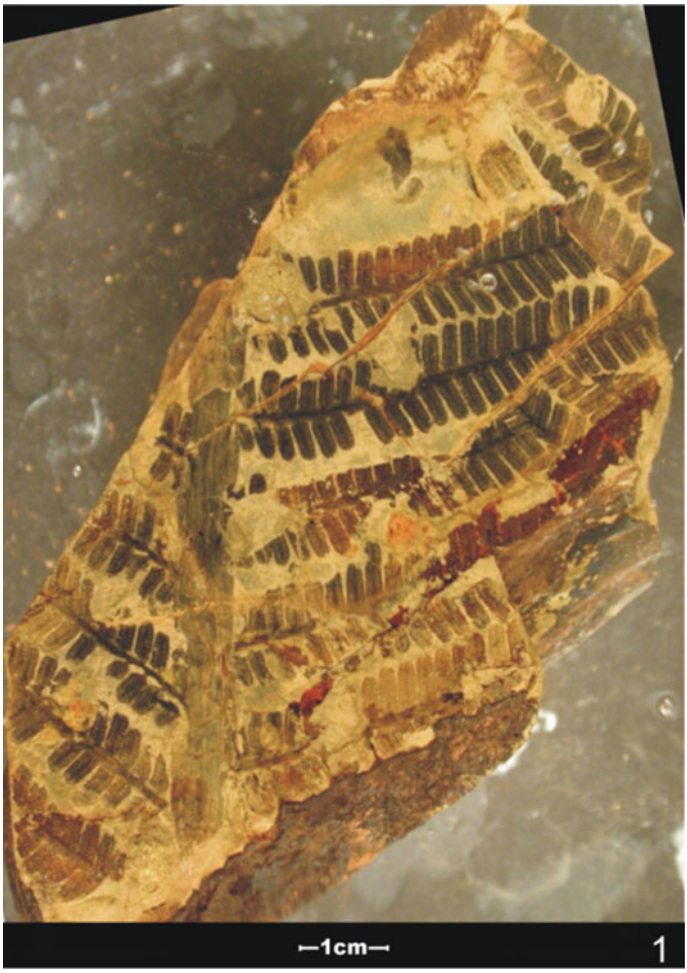

Fig. 9.7 1 *Rajahia guizhouensis* Zhang Locality: Chahe section, Weining County, Guizhou Province Sample Number: YWC-69-01

perpendicular to the axis, and there are more capsular piles; *R.changduensis*' kohane-shaped leaves are close at the base but not united, and its near-top part is sterile and does not have a capsular pile.

Rajahia guizhouensis (Figs. 9.7-1, 9.8-1)

1974 *Danaeites saraepontanus* Stur, Paleozoic plants of China, pp. 98–99, Pl.67, Figs. 9–12

1980 *Rajahia guizhouensis* Zhang, p. 80, Pl.XI, Figs. 2–4, 2a


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1cm

◀**Fig. 9.8** 1 *Rajahia guizhouensis* Zhang Locality: Chinahe section, Xuanwei City, Yunnan Province Sample Number: YXC-(-6)-5B, 2 *Fascipteris sinensis* (Stockm. et Math.) Gu et Zhi, Locality: Chinahe section, Xuanwei City, Yunnan Province Sample Number: YXC-(-1)-2, 3 *Fascipteris hallei* Kaw Locality: Chinahe section, Xuanwei City, Yunnan Province Sample Number: CNH-0-9, 4, 5 *Fascipteris densata* Gu et Zhi Locality: Chahe section, Weining County, Guizhou Province Sample Number: GWC-18-47, GWC-18-42, 6, 7, 8 *Fascipteris stena* Gu et Zhi Locality: 6 Kele section, Hezhang County, Guizhou Province Sample Number: CLC-3-4, 7 Chahe section, Weining County, Guizhou Province Sample Number: GWC-4-6a 8 Chinahe section, Xuanwei City, Yunnan Province Sample Number: YXC-(-1)-71A, 9, 10 *Neuropteridium guizhouensis* Zhang Locality: 9 Chinahe section, Xuanwei City, Yunnan Province Sample Number: YXC-(-11)-1A, 10 Chahe section, Weining County, Guizhou Province Sample Number: GWC-18-69, 11, 12 *Protoblechnum* (*Compsopteris*) *contracta* Gu et Zhi Locality: 11 Chahe section, Weining County, Guizhou Province Sample Number: GWC-58-4, 12 Zhejue section, Weining County, Guizhou Province Sample Number: GWZ-38-4, 13 *Compsopteris imparis* Gu et Zhi Locality: Chahe section, Weining County, Guizhou Province Sample Number: GWC-3-15, 14, 15 *Compsopteris punctinervis* Mo Locality: 14 Chahe section, Weining County, Guizhou Province Sample Number: GWC-28-1, 15 Chinahe section, Xuanwei City, Yunnan Province Sample Number: YXC-(-2)-3, 16, 17 *Compsopteris wongii* (Halle) Zal. Locality: 16 Kele section, Hezhang County, Guizhou Province Sample Number: CLC-35-20, 17 Zhejue section, Weining County, Guizhou Province Sample Number: GWZ-38-13

Holotype: *Rajahia guizhouensis*, Zhao Xiuhu et al. 1980. p. 80, pl. 11, Figs. 2–4, 2a, deposited in the Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, a impression fossil, from Xuanwei Formation (Changhsingian), Guizhou and Yunnan provinces, China.

Diagnosis (emended): Odd pinnate compound leaves, the last pinnae is linear-lanceolate, the tip is tapered, the last pinnae is thick and the small pinnae is sub-opposite, irregular, nearly perpendicular to the ventral edge of the pinnae, tightly packed or slightly separated, and the base is disconnected. The fully developed plumule has a long tongue shape, which can reach 13 mm in length and 5 mm in width, the base is slightly contracted, and the top is blunt; Midrib is thick and straight, extending to near the top; Lateral veins are sparse and generally do not diverge. There are 16–20 pairs of linear capsular piles on both sides of midvein on the back of reproductive plumule; The saccule pile consists of up to 24 saccules, which are oval to long oval, arranged in a row along the lateral veins and cling to each other.

Material examined: GWC-69–58, YXC-(-6)-5B.

Occurrence: Chahe section, Weining County, Guizhou; Earliest Triassic Xuanwei Formation.

Description: The present specimens show that the frond isat least odd-bipinnate, probably tripinnate. Rachis of the penultimate pinna is very strong, attaining a breadth of 5 mm on the impression, with longitudinal striation. The ultimate rachis is slender, about 1 mm broad. Ultimate pinnae closely set, alternate, linear to linear-lanceonate, gradually tapering to the apex, forming an angle about 60–80° with the rachis. Pinnules are closely set or slightly separate, forming an angle of 80–90° with the rachis, sub-alternate, oblong, 8–10 mm long and 3–4 mm wide, with slightly

contracted base and obtuse apex. The midrib is strong and straight, persisting almost to the apex. The lateral veins are sparse, simple.

Discussion and Comparison: Compared with *Rajahia minor* (Zhao 1980), *Rajahia guizhouensis*'midrib has more pairs of sacs on both sides, while the *R. minor* has wider feather axis.

Genus ***Cladophlebis*** (Brongniart 1849)

Type species: *Cladophlebis permica* Lee and Wang (1956).

Diagnosis (emended): Multiple pinnate compound leaves, small pinnate, mainly sickle-shaped, asymmetrical on both sides, slightly pointed or rounded at the top, attached to the feather axis with the whole base, with whole or serrated leaves, obvious midvein, scattered up to or near the top, and bifurcated lateral veins. As a pioneer, it began in Permian, but its number is not very large.

Discussion: *Cladophlebis* is similar to *Pecopteris*, with multiple pinnate compound leaves, and the pinnae is attached to the feather axis. However, the small feathers of *Cladophlebis* are mostly curved in sickle shape, and the top is sharp and convex and large; The small feather of *Pecopteris* is mainly tongue-shaped, oval or rectangular.

Cladophlebis yunnanensis

1980 *Cladophlebis yunnanensis* Zhang, p. 82, Pl.XIII, Figs. 6, 6a

Holotype: *Cladophlebis yunnanensis* Zhang, 1980, p. 82, Pl.XIII, Figs. 6, 6a, deposited in the Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, a impression fossil, from Xuanwei Formation (Changhsingian), Guizhou and Yunnan provinces, China.

Diagnosis (emended): The width of the last feather can reach more than 4.5 cm, and the length is unknown; Feather axis is thin, about 1 mm wide, with a longitudinal stripe. The pinna extends out at an angle of about 60, is tightly packed, sickle-shaped, 2.4 cm long and 1.1 cm wide, with sharp tip, connected base, and split into thick teeth with sharp forward extension at its side. Midrib is thin and obvious, extending at about 60, quite straight, reaching the top; The lateral veins extend at an angle of 20–30, and they diverge after about 1 mm, and then most of them diverge twice in a coaxial way.

Occurrence: Chahe section, Weining County, Guizhou; Late Permian Xuanwei Formation.

Description: The thin rachis is about 1 mm wide with a longitudinal striation. The falcate pinnule comes off at about 60-degree angle, is about 8 mm long and 4 mm wide; the apex acute, the base is confluent, the lateral margin is wave-shaped. The slender but prominent midvein departs at a 60-degree angle, straight, almost to the apex, decurrent at the base; the lateral veins come off at a 20–30 degree angle about 1 mm, then bifurating once or twice by the sympodium.

Discussion and Comparison: Compared to *Cladophlebis yunnanensis* which has thin and acute crenate margin, each tooth only has a lateral vein, the margin of the present specimen is wave-shaped, but the shape and vein of its pinnule is similar to *C. yunnanensis*.

Genus ***Fascipteris*** (Gu and Zhi 1974)

Type species: *Fascipteris hallei* (Kawasaki) Gu and Zhi (1974).

Diagnosis (emended): Feather-like compound leaves, small pinnate linear, base often contracted, whole or wavy. The middle vein is thick, and the lateral veins are bifurcated or branched several times to form vein bundles. Each vein bundle is equivalent to a shallow lobe at the edge of the pinna, and there is no adjacent vein or interbeam vein.

Discussion: Differ from *Validopteris* (Bert) in Europe as *Fascipteris* has no bundle vein. *Fascipteris* occurs in late Permian.

Fascipteris sinensis (Stockm. et Math.) (Gu and Zhi 1974) (Fig. 9.8-2)

1957 *Validopteris sinensis* Stockm. et Math., p. 22, pl.XIII, Figs. 2–3

1974 *Fascipteris sinensis* (Stockm. et Math.) Gu and Zhi, p. 100, pl.69, Figs. 5–7

Holotype: *Fascipteris sinensis* (Stockm. et Math.) Gu and Zhi 1974, p. 100, pl.69, Figs. 5–7, deposited in the Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, a impression fossil, from Xuanwei Formation (Changhsingian), Guizhou and Yunnan provinces, China.

Diagnosis (emended): The feathery leaf is narrow-band to linear, 1–2 cm wide, and its edge is microwave-like or blunt-toothed. The midvein is thick, about 2 mm, and the lateral veins bifurcate 3–4 times in a narrow angle and form bundles, almost perpendicular to the midvein. The width of vein bundle is less than 3 mm, and the outer two veins are slightly higher than the midrib and parallel to the edge of the chalcedony. Each vein of the vein bundle is nearly equal in thickness, but it is obviously thickened at the base of the vein bundle.

Material examined: YXC-(-1)-2.

Occurrence: Chahe section, Weining County, Guizhou; Late Permian Xuanwei Formation; Niulanshan, Yongding County, Fujian; Early Permian Tongziyan Formation.

Description: The present specimen is very small fragment of pinnule, probably linear in shape, with slightly sinuate margin. The breadth of the pinnule is about 1 cm, length unknown. The midrib is wide, thicker than the lateral veins which forming fascicles. The lateral veins of the each fascicle give off at a right angle, and bifurcating twice or three times at an acute angles. After twolateral veins lying in the margin of each fascicle run a short distance to the midrib, they are parallelly to the margin of the pinnule.

Discussion and Comparison: The vein's type of the present specimen is similar to that of *F. stena* Gu et Zhi, but the fascicle of the latter is not perpendicularity to the midrib. This species is compared to *F. recta* Gu et Zhi and *F. chongsoensis* (Kaw.) Li, Yao and Deng, their pinnules are the same as *F. sinensis* in shape, and the lateral veins give off at a right angle from the mibrib. The difference among them is that the lateral of the latter is very slender.

Fascipteris densata (Gu and Zhi 1974) (Figs. 9.8-4 and 9.8-5)

1974 *Fascipteris densata* Gu and Zhi, Paleozoic plants of China, pp. 100–101, pl.69, Figs. 8–14

Holotype: *Fascipteris densata* Gu and Zhi (1974), pp. 100–101, pl.69, Figs. 8–14, deposited in the Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, a impression fossil, from Xuanwei Formation (Changhsingian), Guizhou and Yunnan provinces, China.

Diagnosis (emended): Feathery leaves lanceolate, whole or crenate, blunt at the top, and eccentric at the base. The midvein is thick, and the lateral veins are bifurcated like narrow angle and axis for many times, forming a slightly outward curved vein bundle, and sometimes the branches are bifurcated again.

Material examined: GWC-18-47, GWC-18-42.

Occurrence: Chahe section, Weining County, Guizhou; Late Permian Xuanwei Formation; Funiushan, Zhenjiang City, Jiangsu; Late Permian Longtan Formation.

Description: The pinnules are well preserved, falcate or lanceolate in shape, with 2–3 pairs of lobes at the base of each pinnule, entire at the upper part of the pinnule. The midrib is straight or slightly curving forwards. The lateral veins bifurcating once, generally at a short distance and an acute angle from the midrib, forming fascicles. The anterior and posterior branches divide 2–3 times as dichotomous branching. The fascicles obviously bend upward.

Discussion and Comparison: The winglet of *Fascipteris densata* is lanceolate or sickle-shaped, while *Fascipteris* hallei's winglet is linear, and the branch of *F.hallei*'s side vein is no longer bifurcated, reaching the edge of the winglet, but the branch of *F.densata* sometimes bifurcates again.

Fascipteris stena (Gu and Zhi 1974) (Figs. 9.8-6, 9.8-7, 9.8-8 and 10.4-12)

1974 *Fascipteris stena* Gu et Zhi, Paleozoic plants of China, p. 101, pl.69, Figs. 15–17

Holotype: *Fascipteris stena* Gu and Zhi, 1974, p. 101, pl.69, Figs. 15–17, deposited in the Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, a impression fossil, from Xuanwei Formation (Changhsingian), Guizhou and Yunnan provinces, China.

Diagnosis (emended): The leaves are large, the small feathers are whole, the top is blunt, slightly curved, and the midrib is slightly thin; The lateral veins extend at wide

angles, and bifurcate at narrow angles for 5–6 times. The vein bundle is about 2 mm wide, long and narrow, and almost bends to one side.

Material examined: CLC-3–4, GWC-4-6a, YXC-(-1)-71A, YXC-(-25)-30.

Occurrence: Chahe section, Weining County, Guizhou; Late Permian Xuanwei Formation; Jiangning City, Jiangsu; Late Permian Longtan Formation; Upper Permian Xuanwei Formation and Early Triassic Kayitou Formation in Western Guizhou and Eastern Yunnan, South China.

Description: A single pinnule well preserved, oblong in shape, entire or slightly sinuate, with an obtuse apex. The midrib is slightly bending forwards. The lateral veins dividing once, generally at a short distance and an acute angle from the midrib, forming fascicles. The anterior and posterior branches divide 3–4 times as the dichotomous branching. The fascicles obviously bend, about 2 mm broad.

Discussion and Comparison: Compared to *F. hallei*, the difference is that the bifurcating times of the present specimens is less than *F. hallei*, the fascicle breadth is narrower than *F. hallei*.

Division **Progymnospermophyta**

Order **Noeggerathiales** (Nemejc 1931)

Family **Tingiales** (Halle 1925)

Genus ***Tingia*** (Halle 1925)

Type species: *Tingia carbonica* (Schenk 1883; Halle 1925)

Diagnosis (emended): Branches are feathery and dorsolateral, with leaves arranged in four rows, with two rows on top and two rows on the bottom. The front two rows of leaves are large (large leaves), which are wide wedge-shaped, inverted-oval, long oval or linear, and the base is extended, which is semi-stalk-shaped, twisted after extending, lying in the same plane with the axis, with the whole side edge, and the top often irregularly divided into teeth. The lower two rows of leaves are narrow and small (lobules), which are located on the back of branches, and often cling to branches and point to the front of branches. On the same branch, the middle leaves are longer and larger, the two ends are shorter and smaller, the veins are parallel, the base branches are more, and they go up to the top of the leaves roughly parallel and extend into the teeth.

Discussion: Compared to *Plagiozamites,* the veins on both sides of *Tingia* are parallel, and the leaves are whole and arranged in four rows. *Tingia* mainly occurs from late Carboniferous to late Permian.

Tingia gerardii (Stockmans and Mathieu 1939) (Fig. 9.6-13)

1939 *Tingia gerardii* Stockmans et Mathieu, Mus. Roy. Hist. Nat. Belgique; pl.24, Figs. 1–2

Holotype: *Tingia gerardii* Stockmans and Mathieu (1939), Mus. Roy. Hist. Nat. Belgique; pl.24, Figs. 1–2.

Diagnosis (emended): Obovate, with narrow lobes, round top, and little difference between large and small leaves.

Material examined: GWC-3–1.

Occurrence: Chahe section, Weining County, Guizhou; Late Permian Xuanwei Formation.

Description: The large leaves are obovate in shape, 18 mm long and 6 mm, the base decurrent, the lateral margin entire, the tip blunt and round. The veins parallel to the lateral margins, thin and dense, forked at the base. Small leaves are unknown.

Discussion and Comparison: Compared with *Tingia carbonica*, *Tingia gerardii* has smaller total width of branches, smaller axial width, inverted ovate leaves and nearly equal length and width of large and small leaves.

Tingia crassinervis (Halle 1927) (Fig. 9.6-14)

1925 *Tingia crassinervis* Halle, Geol. Surv. China Bull., 7: 6–8; pl. II, Figs. 2–3

1927 *Tingia crassinervis* Halle, Pal. Sinica, ser. A, 2(1): p. 234, pl. 61

Holotype: *Tingia crassinervis*, Halle (1925), p. 6, pl. 2.

Diagnosis (emended): Feathery leaf is oval or linear, with thick veins and similar vein density. The shape of large leaves changes greatly, with rounded or truncated tips and wide lobes. The leaflets at the base of branches are very wide and short, with rounded or truncated tips and no lobes.

Material examined: GWC-3-1.

Occurrence: Chahe section, Weining County, Guizhou; Late Permian Xuanwei Formation.

Description: The axis attains a breadth on the impression of 3 mm. The leaves oblong-oblanceolate, 30 mm long and 5–7 mm wide, apex of these leaves broadly blunt, round or truncate; the veins are strong.

Discussion and Comparison: To this species I have referred a few fragmentary specimens from the locality Chahe of Guizhou. The leaves are broader and oblong-oblanceolate in shape, the veins are coarser. The diagnosis of this species was given by Halle (1927, p. 234).

Division **Pteridospermophyta**

Order **Peltaspermales** (Nemejc 1968)

Family **Peltaspermaceae** (Thomas 1933)

Genus ***Peltaspermum*** (Harris 1937)

Type species: *Peltaspermum rotula* Harris, 1937. Rhaetian and Lower Liassic; East Greenland.

Diagnosis (emended): Plants with bipinnate, rarely pinnate or tripinnate fronds. Primary rachis robust, basal part naked. Pinnae subopposite ly or alternately attached

to the primary rachis. Rachides may be covered with blister-like swellings. Intercalary pinnules inserted in two lateral rows on the adaxial side of the primary rachis. Pinnules lanceolate, alethopteroid entire-margined to pinnately lobed. Intercalary pinnules resemble the other pinnules. Pinnule apex rounded or acute. Venation pinnate. Ovuliferous organs consist of elliptical to radially symmetrical, umbrella-shaped ovule-bearing discs. Discs with radiating ribs and lobed margin. Ovules attached to the lower surface of the discs in a ring around the insertion of the central stalk.

Discussion: *Peltaspermum* has been redefined by Poort and Kerp (1990) as a natural genus including sterile foliage and ovuliferous organs for the species *P. martinsii* (Galtier and Broutin 2008). They combined the sterile part *Callipteris martinsii* with the fertile part *Peltaspermum*, and these authors use the *Peltaspermum* as a natural genus. More recently Naugolnykh and Kerp (1996) combined some peltate discs, reported by Gomankov and Meyen (1986) from the Kungurian of the Fore-Urals, with sterile pinnae described by Zalessky as *Callipteris retensoria*, and regrouped into a natural taxo *Peltaspermum retensorium* (Zalessky). Nevertheless, in most cases the reproductive organ *Peltaspermum* hardly can be connected with the sterile part of plant, while based on the present sterile pinnule and fertile organ occurring in the same beds, I prefer to use the generic name *Peltaspermum* in sense of Harris (1937).

Peltaspermum lobulatum (Wang and Wang 1989) (Fig. 11.2–22)

1989 *Peltaspermum lobulatum* Wang et Wang, Shanxi Geology, Vol. 4, p. 34, Pl.V, Figs. 1, 4

Holotype: *Peltaspermum lobulatum* Wang and Wang (1989).

Diagnosis (emended): Small to medium-sized bipinnate, rarely pinnate or tripinnate fronds. Fronds overtopping in the apical portion, in some cases with double apical (pseudo-) dichotomies in larger, (partially) tripinnate fronds. Pinnae subopposite to alternate. Primary rachis with intercalary pinnules. Pinnules small, semi-circular, linguiform to elongate linguiform, broadly attached, decurrent to basally fused in the basal and apical frond portions and pinna apices, entire-margined, crenulate to pinnatifid. Pinnules thick and fleshy with rounded apices and a pinnate venation that is usually hidden by the thick cuticle. Leaves amphistomatic, stomata irregularly scattered; stomatal complexes sunken, monocyclic with 4–8 (usually 5–6) subsidiary cells; papillae may be present. Ovuliferous organs consisting of peltate discs with a central stalk and marginal lobes; upper surface with radiating ribs.

Material examined: GPT-22-1, GPT-22-5, GPT-23-6.

Occurrence: Tucheng section, Panxian County, Guizhou; Early Triassic Layitou Formation.

Description: Disc-like sporophyll, about 1 cm in diameter, with a rounded lobelet in margin consists of lobelets 8–10 in number. Lobules are sphenoidal in shape, with rounded apex, radially given off from a concave center, gradually becoming convex. Lateral margins of rib-lobules uniting side by side.

Discussion and Comparison: The main characteristic of the present specimens is with rounded lobelet, small in size. This species is similar to P. multicostatum Zhang et Shen named by Zhang et Shen (1987) from Nanshan Section, Gansu Province. They have a rounded lobelet in margin, but not forming a circular zone making up of the rounded lobelets to P. multicostatum. Compared to P. lobulatum named by Wang and Wang (1989), their features are completely same except that the present specimens are smaller than the latter.

?*Peltaspermum* sp. (Figs. 11.2-21, 11.1-23)

Material examined: GPT-22-6.

Occurrence: Tucheng section, Lower Triassic Kayitou Formation in Panxian County, Guizhou, South China.

Description: Fertile sporophyll consists of radially symmetrical peltate discs, about 6 mm in diameter, with a sinuate margin. The surface of peltate disc slightly depressed in central part. The restorable figure shows that the sporophyll has about 12 lobelets in number. Each lobule is spade-type in shape, radiating to the centre part, apex concave. Lateral margins of rib-lobules slightly uniting side by side.

Discussion and Comparison: As shown by the present specimen, the structure of peltate disc is unique. Based on fragments preserved, we temporarily assign this specimen as to genus? *Peltaspermum*.

Order **Peltaspermales**

Family **Peltaspermaceae**

Genus ***Germaropteris*** (Kustatscher et al. 2014)

Type species: *Germaropteris martinsii* (Germar in Kurtze 1839) Kustatscher, Kerp et Van Konijnenburg-van Cittert 2014.

Diagnosis (emended): Small to medium-sized bipinnate, rarely pinnate or tripinnate fronds. Fronds overtopping in the apical portion, in some cases with double apical (pseudo-)dichotomies in larger, (partially) tripinnate fronds. Pinnae subopposite to alternate. Primary rachis with intercalary pinnules. Pinnules small, semi-circular, linguiform to elongate linguiform, broadly attached, decurrent to basally fused in the basal and apical frond portions and pinna apices, entire-margined, crenulate to pinnatifid. Pinnules thick and fleshy with rounded apices and a pinnate venation that is usually hidden by the thick cuticle. Leaves amphistomatic, stomata irregularly scattered; stomatal complexes sunken, monocyclic with 4–8 (usually 5–6) subsidiary cells; papillae may be present. Ovuliferous organs consisting of peltate discs with a central stalk and marginal lobes; upper surface with radiating ribs.

Discussion: This genus is named after Ernst Friedrich Germar (1786–1853), which is monotypic but the type species has been long understood. Recently several species of *Alethopteris*, *Callipteris*, *Lepidopteris*, *Peltaspermum* are revised to *Germaropteris* (Kustarscher et al. 2014). Foliage and ovuliferous organs are described by Germar at first and Göppert (1850) respectively as different species. The species name was

firstly assigned to *Callipteris martinsii* (Germar in Kurtze). After longtime arguing, then the ovuliferous organ *Peltaspermum rotula* and pollen organ *Antevsia zeilleri* were reported and correlated with *Lepidopteris martinsii* foliage (Poort and Kerp 1990). Whereas, different types of foliage seemed to share same type of ovuliferous organ i.e., Lepidopteris and Scytophyllum Bornemann (1856). Based on the morphology analysis and cuticle study, Kustarscher established a new genus to refer to the first and well-studied peltasperms with both foliage and ovuliferous.

Germaropteris martinsii (Germar in Kurtze 1839) Kustatscher, Kerp et Van Konijnenburg-van Cittert (2014) (Figs. 11.2-1, 11.2-2, 11.2-3 and 11.2-4)

Foliage-selected synonymy

1839 *Alethopteris martinsii* Germar in Kurtze, pp. 34, 35, 38, pl. III, 2

1840 *Alethopteris martinsii* Germar, pp. 35–36

1846 *Alethopteris martinsii* Althaus, pl. 1, 3

1846 *Caulerpites crenulatus* Althaus, pl. I, 4

1848 Pecopteris (Alethopteris) martinsii Geinitz, p. 20

1862 *Alethopteris goepperti* Geinitz, p. 142, pl. XXV1, 7, 8

1906 Callipteris martinsii Zeiller, p. 71

1907 *Callipteris martinsi* Gothan pp. 1–4, Figs. 1, 2

1921 *Callipteris martinsi* Gothan and Nagalhard, pp. 451–453, pl. 6, 5, 6, pl. 7, 13

1928 *Callipteris martinsi* Weigelt, pp. 457, 458, pl. II, 14, 15, 26; pl. VII, 1–14, pl. 3, 7, 14, (22?)

1958 *Callipteris martinsi* Stoneley, pp. 313–315, Figs. 5, 6, pl. 37, 2, 5

1960 *Lepidopteris martinsii Townrow,* pp. 345–347, figs. lL, 2 J, 3G-K,4A, B, 5 J, 6D

1962 *Callipteris martinsi* Schweitzer, pp. 339–340, Fig. 4, pl. 1, 3, 4, pl. 3, I

1990 *Peltaspermum martinsii* Poort and Kerp (per partem), pp. 203, 206–208, 210, 214, 216, pl. I-V, pl. VI, 1 (per partem)

2012 *Lepidopteris martinsii*, Kustatscher et al., p. 4, pl. I, 7

Ovuliferous organs—selected synonymy

1850 *UIImannia bronni* Göppert, p. 188, pl. 20, (?21, 22), 24–26.

1864–65 *Ullmannia bronni* Göppert, pp. 226, 227, pl. 45, 21 23, 25.

1884 *Strobilites bronnii* Solms–Laubach, pp. 19–24, pl. II, 2–9, 16–19.

1944 *Strobilites bronnii* Florin, p. 447, pl. 169–170, 5–9, 13–2.

1958 *Strobilites bronni* Stoneley, p. 329, pl. 40, 7–11.

1990 *Peltaspermum martinsii* Poort and Kerp, pp. 207, 216–218, pl. VI, 1 (parte), 2–7, pl. VII, VIII.

2012 *Peltaspermum* sp. Kustatscher et al., p. 4, pl. I, 3.

Basionym: *Alethopteris martinsii* (Germar in Kurtze 1839), Commentatiode petrefactis quae schisto bituminoso mansfeldensi repriuntur, pp. 34–35.

Holotype: *Germaropteris martinsii* Germar in Kurtze, 1839, Kustatscher, Kerp et. Van Konijnenburg-van Cittert 2014.

Diagnosis (emended): Small to medium-sized bipinnate, rarely pinnate or tripinnate fronds. Fronds overtopping in the apical portion, in some cases with double apical (pseudo-)dichotomies in larger, (partially) tripinnate fronds. Pinnae subopposite to alternate. Primary rachis with intercalary pinnules. Pinnules small, semi-circular, linguiform to elongate linguiform, broadly attached, decurrent to basally fused in the basal and apical frond portions and pinna apices, entire-margined, crenulate to pinnatifid. Pinnules thick and fleshy with rounded apices and a pinnate venation that is usually hidden by the thick cuticle. Leaves amphistomatic, stomata irregularly scattered; stomatal complexes sunken, monocyclic with 4–8 (usually 5–6) subsidiary cells; papillae may be present. Ovuliferous organs consisting of peltate discs with a central stalk and marginal lobes; upper surface with radiating ribs.

Material examined: Registered specimens: YXM (A)-46-6; GPT-22-3, GPT-22–4, GPT-23-3, GPT-23-5, etc.

Occurrence: Mide section, Xuanwei City, Yunnan; Tucheng section, Panxian County, Guizhou; Early Triassic Kayitou Formation.

Description: These broken specimens shown in Fig. 14, possibly represent the terminal part of a pinna. Rachis is very thick. Pinnules alternate to subopposite, open to more or less right angle to the rachis, ovate. Leaf veins indistinct, lateral veins forking or sometimes simple, some of the proximal basal veins being apparently derived from the rachis.

Discussion and Comparison: All of the pinnae from Early Triassic Kayitou Formation, Panxian County, Guizhou, are incomplete, however the pinnae are slender and the sterile pinnules are somewhat similar to those in specimens of *Peltaspermum martinsii* illustrated by Poort and Kerp (1990) and Visscher et al. (2001).

Division **Pteridophyta** (Schimper 1869)

Order **Osmundales**

Family **Osmundaceae**

Genus ***Neuropteridium*** Schimper and Schenk, 1879

Type species: *Neuropteridium voltzii* (Brongniart 1828a) Schimper, 1879.Grès bigarre (Buntsandstein, early Anisian); Vosges (France).

Diagnosis (emended): *Neuropteridium voltzii* has longer (up to 7 cm) but narrower (4–6 mm) pinnules than *N. elegans*, resulting in a much larger length/width ratio. The pinnules are attached by almost their entire base, the apex is roundly acute. The venation is neuropterid with a clear midrib extending along about two-thirds of the pinnule. Secondary veins are numerous and fork two–three times.

Discussion: Brongniart's holotype (Brongniart 1828b) from the Vosges is a frond fragment over 20 cm long with a rachis c. 5 mm wide and pinnules that arise more or less perpendicularly. The pinnules are 4–5 cm long and 8–10 mm wide with a constricted base and a pointed apex. Schimper and Mougeot figured a frond fragment c. 25 cm long that includes the apical region. The width of the rachis decreases from 8 mm basally to 3 mm apically, and the apical pinnules arise at a smaller angle and also diminish in size. This material originates from the Upper Buntsandstein of the Vosges. Blanckenhorn also described and figured material from the surroundings of Floisdorf (Berg) near Kommern that consists of long frond fragments (up to 1 m long according to Blanckenhorn) with a rachis varying from 1 cm in width at the base to 2 mm at the apex. The pinnules are usually 4–5 cm long and 8–12 mm wide. The venation is in all cases the same as in our material. Blanckenhorn also described and figured one broad pinnule fragment as *N. voltzii* var. *latifolium*. This fragment is too small to be sure of its identification. As discussed above, Blanckenhorn created the species *N. bergense* from the same locality, which is characterized by shorter fronds (30–45 cm long), a rachis 5 mm wide, and pinnules 5–6 mm with an obtusely acute apex. Earlier he stated that the species were difficult to distinguish and we believe that *N. bergens*e is actually a smaller variety of *N. voltzii*. We have both forms in our collection as well.

Brongniart (1828b) described and figured the species *Sphenopteris palmetta* based on a specimen from the same beds in the Vosges as *N. voltzii*, stating that the pinnules resemble those of *N. voltzii* that were dissected during preservation, but that he thought these incisions were so regular that it was probably a different species. Goeppert (1836) transferred the species to his new genus *Asplenites*. Schimper (1869) considered that *Sphenopteris palmetta* was based on a poorly preserved *Neuropteris intermedia* frond. Fliche (1910) decided that the specimen would be better placed in the genus *Acrostichites* and that it was probably a poorly preserved specimen of.

A. *densifolius* Fontaine. However, we agree with Schimper (1869) that it is quite possible that the specimen is poorly preserved specimen of *N. voltzii*.

Neuropteridium guizhouense (Figs. 9.8-9 and 9.8-10)

1980 *Neuropteridium guizhouense* Zhang, p. 82, Pl.XIV, Figs. 3, 3a

Holotype: *Neuropteridium guizhouense* Zhang, deposited in the Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, from Late Permian Xuanwei Formation, Guizhou Province, China.

Diagnosis (emended): The last pinna may be up to 8 cm long and 4 cm wide, slowly contracting forward, with a single apical barb, with a thick Rachis 3 mm wide. The

pinnules are attached to the ventral surface and are ovate or lingual in different locations. Middle vein thick, base not extended; Lateral veins straight, extremely fine ‘membranous with sparse fine markings.

Material examined: GWC-18-69.

Occurrence: Late Permian Xuanwei Formation, Chahe section, Weining County, Guizhou.

Description: The shape of the pinna unknown, probably linear, attaining a breadth of at least 2.5 cm. Rachis is very thick, with a maximum breath of 4 mm. Pinnules closely arrange, forming an angle of about 80° with the rachis, oblong, with broadly rounded apex, strongly contracted and cordate at the base, more or less auriculate. The midvein is distinct, no decurrent, disappearing near the apex. The lateral veins are straight but dense, dividing 2–3 times.

Discussion and Comparison: The main characters of the present specimen are its thick and no decurrent midvein, straight, dense and slender lateral veins. *Neuropteridium coreanum* Koiwai is similar to the present species but they differ in that *N. coreanum* has smaller angle (40–50°) between pinnule and rachis, sinuate margin.

Division **Pteridospermatophyta**

Order **Peltaspermales**

Genus ***Compsopteris*** (Zalessky)

Type species: *Compsopteris adzvensis* Zalessky (1934).

Diagnosis (emended): Fronds pinnate, petiolate, with prominent rachis. Pinnules oblong, straight or slightly curving, with entire margins and rounded apex; pinnules small and attached about perpendicular to rachis in the basal frond portion, becoming longer and arising at increasingly acute angles towards the apex; lowermost pinnules with a constricted base; towards the apex, pinnules becoming more broadly attached to decurrent or auriculate. Frond apex forked to form a single, basally confuent pair of terminal pinnules. Venation alethopteroid; midrib strong, reaching close to tip; secondary veins arising at acute angles, simple or forking up to four times. Wing-like decurrent basiscopic pinnule portions with veins arising directly from rachis. Fronds amphistomatic; stomata haplocheilic, cyclocytic.

Discussion: The recent emendation of the genus lacked important information on cuticle features and included the following problematic terms that we have omitted here. The frond architecture was described as ‘imparipinnate’ whereas all sufficiently complete specimens instead show a forking apex with a terminal pinnule pair (Halle 1927). In addition, the terms ‘sphenopteroid’ and ‘pecopteroid’ were used to describe a constricted versus broadly attached pinnule base; these terms are, however, conventionally also used to describe venation and margin features, and are thus potentially misleading.

Compsopteris imparis (Gu and Zhi 1974) (Fig. 9.8-13)

1974 *Compsopteris imparis* Gu and Zhi, Paleozoic plants of China, p. 115, Pl.82, Figs. 7–8

Holotype: *Compsopteris imparis* Gu and Zhi (1974), deposited in the Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences,

Diagnosis (emended): Fronds pinnate, petiolate, with prominent rachis. Pinnules oblong, straight or slightly curving, with entire margins and rounded apex; pinnules small and attached about perpendicular to rachis in the basal frond portion, becoming longer and arising at increasingly acute angles towards the apex; lowermost pinnules with a constricted base; towards the apex, pinnules becoming more broadly attached to decurrent or auriculate. Frond apex forked to form a single, basally confuent pair of terminal pinnules. Venation alethopteroid; midrib strong, reaching close to tip; secondary veins arising at acute angles, simple or forking up to four times. Wing-like decurrent basiscopic pinnule portions with veins arising directly from rachis. Fronds amphistomatic; stomata haplocheilic, cyclocytic.

Material examined: GWC-3-7a, b, GWC-3-15.

Occurrence: Chahe section, Weining County, Yunnan; Late Permian Xuanwei Formation.

Description: The rachis is about 4 mm broad. The pinnule is oblong-ovate or lanceolate, alternate, attaining a breadth of 2.0 cm and a length of more than 3.5 cm, with oblique, contracted base, the apex not preserved. The margin is entire or slightly sinuate. The midvein is strong, about 1.5 mm. broad. The lateral veins arise at angles of about 30–40° from the midvein, arching upwards and dividing once near the midrib; each branch then bends outwards and bifurcating once, bending slightly forward near the margin and reaching the margin at wide angles. The veins at the margin number 30–35 per centimeter.

Discussion and Comparison: The main characters of this species are its petiole and obliquely cordiform base, thin and dense veins, which different from *C. contracta* in having a rare vein, the veins at the margin number 30–35 per centimeter.

Compsopteris punctinervis (Figs. 9.8-14, 9.8-15)

1980 *Compsopteris punctinervis* Mo, p. 82, pl. XVIII, Figs. 1–5, 1a

Holotype: *Compsopteris punctinervis* Mo, deposited in the Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences,

Diagnosis (emended): Fronds pinnate, petiolate, with prominent rachis. Pinnules oblong, straight or slightly curving, with entire margins and rounded apex; pinnules small and attached about perpendicular to rachis in the basal frond portion, becoming longer and arising at increasingly acute angles towards the apex; lowermost pinnules with a constricted base; towards the apex, pinnules becoming more broadly attached to decurrent or auriculate. Frond apex forked to form a single, basally confuent pair of terminal pinnules. Venation alethopteroid; midrib strong, reaching close to tip;

secondary veins arising at acute angles, simple or forking up to four times. Wing-like decurrent basiscopic pinnule portions with veins arising directly from rachis. Fronds amphistomatic; stomata haplocheilic, cyclocytic.

Material examined: GWC-28-1, GWC-69-18a, b.

Occurrence: Chahe section, Weining County, Guizhou; Late Permian and Early Triassic Xuanwei Formation.

Description: The pinnules are linear or lanceolate, the length and the breadth are unknown, with an entire margin. The apex not preserved, the base possibly contracted. The midvein disappears before reaching the apex (Pl.21, Fig. 3). The lateral veins are thin and dense, giving off at a 35-degree angle from the midvein as the fascicular-type, dividing 2–3 times, each branch is parallel and extends to the margin. The veins at the margin number 34–38 per centimeter.

Discussion and Comparison: The present specimens are distinguished by varying in shape and size, fascicular and dense veins which differ from *C. wongii* having rare vein, 15–20 per centimeter. Compared with the holotype species, the punctatus is not found on the surface of the present specimens.

Compsopteris wongii (Halle) (Zal 1974) (Figs. 9.8-16, 9.8-17)

1927 *Protoblechnum wongii* Halle, Halle, pp. 135–138, Pls.35, 36, pl.64, Fig. 12

1974 *Compsopteris wongii* (Halle) Zal., Paleozoic plants of China, p. 115, Pl.82, Figs. 1–3; Pl.130, Fig. 6

Holotype: *Compsopteris wongii* (Halle) Zal, 1974.

Diagnosis (emended): Fronds large (exceeding 40 cm in length), ovate in outline, petiolate, pinnate. Frond apex forking into two equally sized pinnules. Rachis prominent, channeled on upper side, keeled on lower. Pinnules closely spaced, arising at angles of 50–60° from the rachis in median portion of frond, in upper portion more oblique, in lower portion more extended, at the base commonly perpendicular. Pinnules broadly attached, basally decurrent toalmost confuent with or slightly overlapping the subjacent pinnule margin. Decurrent wings wide, in the upper frond portion fat, in lower portion curving towards upper side of rachis in an auriculate manner, becoming gradually more indistinct towards frond base, lacking in lowermost pinnules. Pinnules linear, entire-margined, gradually tapering towards obtuse or subacute apex. Venation alethopteroid; midrib strong, reaching close to tip; secondary veins arising at narrow angle, arching, reaching margin at angles of 50–60° in median pinnule portion, usually forking once or twice, rarely simple. Veins in auricles directly arising from rachis, almost perpendicularly, bifurcating once. Fronds amphistomatic. Rachis, midrib, and pinnule lamina stomatiferous. Epidermal cells of rachis, midrib, and costal felds polygonal-elongate, epidermal cells of intercostal felds polygonal-isodiametric. Haplocheilic stomata longitudinally oriented on rachis and midrib, randomly oriented and distributed on lamina; monocyclic to incompletely tricyclic. Large multicellular trichomes randomly distributed on rachis.

Material examined: GWZ-38-13; YXM(A)-21-3; GPT-10-6.

Occurrence: Chahe section, Weining County, Guizhou; Tucheng section, Panxian County, Guizhou; Mide section, Xuanwei City, Yunnan; Late Permian Xuanwei Formation.

Description: The specimen is very fragment, but its veins are clear. The midrib is strong. The lateral veins departing at an angle of 50°, arching, dichotomizing once or twice. Numbers of veins near the margin are 18–20 per centimeter at the margin.

Discussion and Comparison: *Compsopteris wongii* belongs to a group of foliage genera from the Late Palaeozoic, such as *Glenopteris, Nanshanopteris, Supaia*, and *Megalopteris* Dawson 1871. *Glenopteris* from the Lower Permian of Euramerica has often been proposed as a close relative of *Compsopteris wongii* (e.g., Halle 1927; White 1929; Krings et al. 2005). The type species *Glenopteris splendens* Sellards 1900 shares many similarities in macromorpholgy and especially epidermal anatomy with C. wongii; the main differences concern the architecture of the frond tip and the simple, indistinct venation in the former. Furthermore, cuticles of *C. wongii* do not show the peg-like projections in the anticlinal walls that are a typical feature of *G. splendens* (Krings et al. 2005), although anticlinal walls are thickened. Differences dfrom the second glenopteroid species *Nanshanopteris nervosa* Wan and Wang (2015) from China are mainly the same as from *G. splendens*, with the addition that epidermal cells of the former bear papillae (Wan and Wang 2015). However, papillae are not necessarily of high taxonomic relevance; they may instead refect paleoecological adaptation (Poort and Kerp 1990). Both of these glenopteroids occured in seasonal Permian environments: *G. splendens* from the Artinskian of Euramerica in a coastal environment periodically affected by seasonality and soil and ground water salinity (Krings et al. 2005), and *N. nervosa* from the Changhsingian of China on a well-drained lacustrine shore under a seasonally wet climate (Wan and Wang 2015). *C. wongii* from the Guadalupian of China clearly lived in a tropical, everwet environment close to a meandering river system (Liu and Yao 2007). It is therefore not surprising that epidermal features such as papillae, peg-like projections, or other supposedly xerophytic adaptations are absent.

Another interesting genus is *Supaia*, initially described from the Permian of Euramerica (White 1929). It differs from *Compsopteris* in its bipartite, imparipinnate frond architecture. Wang (1997) recorded *Supaia* fronds from the Capitanian Tianlongsi Formation (another name for the Upper Shihhotse Formation) of Shanxi and proposed it might represent a descendent of *Compsopteris wongii* that is morphologically adapted to a semi-arid environment. Pinnules of *S. contracta* Wang (1997) are amphistomatic, with monocyclic to dicyclic and slightly sunken stomata somewhat comparable to those of *C. wongii.* These similarities in the epidermal anatomy to *C. wongii* suggest a close relationship, with the main differences being the architecture, the contracted leaf bases, and the papillae on the cells of lower leaf sides of *S. contractum.*

Megalopteris from the Pennsylvanian of Euramerica is superfcially similar, but most species were described based on small fragments, yielding limited information on frond architecture and morphology that is insufcient for detailed comparison. Moreover, those three species for which cuticles have been described difer from *Compsopteris wongii* in that they are indicative of hypostomatic leaves (Florin 1933).

Genus ***Protoblechum*** (Lesquereux 1877)

Type species: *Protoblechum holdeni* (Lesquereux 1877).

Diagnosis (emended): Odd-numbered pinnate compound leaves, rachis ca. 3 mm wide, pinnules lanceolate, lateral entire, occasionally undulate, 4–5 cm long, ca. 1.5 cm wide, pinnules base oblique, apex acuminate. The width of mid vein is more than 1 mm, reaching to the tip of the pinnacle; Lateral veins fine, bifurcation 2–3 Times; The first bifurcation is close to the mid vein, then the second bifurcation bends outwards and divides again, and the first bifurcation extends a short distance toward the front of the pinnacle, then sharply bends outwards and divides again. At margin, about 50 veins per centimeter.

Description: *Protoblechum* was established by Lesquereux in 1897 based on fossil materials in Ohio, USA. Its model species is *P. holdeni* (Andrews) Lesquereux. This type species has been identified as a *Lethopteris holdeni* by Andrew S. The relationship of *Protoblechum* to *Glenopteris* Sellars, *Supaia* White and *Compsopteris* Zalcsssky is a question that paleobotanists often discuss and still have to be resolved. The root of the contradiction lies in how to treat the bifurcation character of feather shaft. The author agrees with the view of He et al. (1996) that: "Whether or not the feather shaft bifurcates has some significance in morphological taxonomy. The specimen of *Protoblechum wongii,* originally belonging to the genus *Pteropteris*, should be assigned to genus *Supaia,* while all others belong to the genus *Compsopteris.* Because none of the species in *Compsopteis* have been analyzed cuticles, it is not possible to compare with the plantain fern with cuticles characteristics in the former Soviet Union, temporarily placed in genus *Protoblechum.*" The feathered axes found in the Mojiang area have not been bifurcated, nor have they been analyzed by cuticle, so they are tentatively classified into the genus *Protoblechum.*

Protoblechnum contracta (Gu and Zhi 1974) (Figs. 9.8-11, 9.8-12)

1974 *Compsopteris contracta* Gu et Zhi, Paleozoic plants of China, p. 115, Pl.82, Figs. 4–6; Pl.83, Figs. 1–2, 3?

1999 *Protoblechnum contracta* Gu et Zhi, Chinese Science Bulletin, p. 382, Fig. 1

Holotype: *Protoblechnum contracta* Gu and Zhi (1974), deposited in the Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences.

Diagnosis (emended): Fronds pinnate, petiolate, with prominent rachis. Pinnules oblong, straight or slightly curving, with entire margins and rounded apex; pinnules small and attached about perpendicular to rachis in the basal frond portion, becoming longer and arising at increasingly acute angles towards the apex; lowermost pinnules

with a constricted base; towards the apex, pinnules becoming more broadly attached to decurrent or auriculate. Frond apex forked to form a single, basally confuent pair of terminal pinnules. Venation Alethopteroid; midrib strong, reaching close to tip; secondary veins arising at acute angles, simple or forking up to four times. Wing-like decurrent basiscopic pinnule portions with veins arising directly from rachis. Fronds amphistomatic; stomata haplocheilic, cyclocytic.

Material examined: GWC-3-20, GWC-3-21, GWC-58-4, GWC-58-6; GWZ-38-4 and so on.

Occurrence: Chahe and Zhejue sections, Weining County, Guizhou; Late Permian Xuanwei Formation and Early Triassic Kayitou Formation.

Description: The pinnule, with a petiole and obliquely cordiform base, is linear to lanceolate. The margin is entire or slightly sinuate. The midvein is distinct, about 1 mm broad, longitudinally striated. The lateral veins are dense, bifurcating twice or thrice. The first branching is near the midrib; the posterior branch bends downwards, dividing once. The anterior branch bends upwards for a short distance, dividing once or twice. All branches parallelly extend to the margin. The veins at the margin number 40–56 per centimeter.

Discussion and Comparison: The main characters of this species are its petiole and obliquely cordiform base, thin and dense veins, which different from *C. impairs* in having a rare vein, only 30–35 per centimeter.

Genus ***Linopteris*** Presl. 1838

Type species: *Linopteris gilkersonensis* Presl. 1838.

Diagnosis (emended): Frond pinnate or pinnatifid; pinnule oblong, straight, sessile; veins reticulate; areolm hexagonal, elongate in the centre, and somewhat parallel to the margins of the pinnule, afterwards oblique and then free near the margin; no midrib.

Discussion: This remarkable genus was established by Gutbier for those fossil ferns possessing the general habit of *Neuropteris*, but differing from it in having a somewhat radiate reticulate venation and no distinct midrib, in which latter character it differs from both *Lonchopteris* and *Woodwardites*. Four species are described,—the type, *Dictyopteris* Brongniartii, Gutbier (Verst. der Zwickauer Schwartz-Kohle, p. 63, pl. 2. f. 7, 9, 10), from the coal-schists of Saxony; *D. muensteri* is very frequent in the coal-measures of Southern Russia; *D. obliqua* Bunbury (Quart. Journ. Geol. Soe. iii. p. 427), from the coal-measures of Nova Scotia; and M. Brongniart mentions a fourth species from the eastern part of Egypt. Presl subsequently established a recent genus, *Dictyopteris*, for certain species of *Polypodium* having a reticulate venation and no free veins, as *P. attenuatum* Brown, and changed the name of the fossil genus to *Linopteris*; but the right of priority appears to belong to Gutbier. Mr. J. Smith, whose valuable researches and works on the recent ferns are well known, has substituted the name *Dictymia* for the living ferns assigned to *Dictyopteris* by Presl.

***Linopteris* sp.** Gutb (Fig. 9.6–14)

Diagnosis (emended): Frond pinnate or pinnatifid; pinnulm oblong, straight, sessile; veins reticulate; areolm hexagonal, elongate in the centre, and somewhat parallel to the margins of the pinnule, afterwards oblique and then free near the margin; no midrib.

Material examined: GWC-4-3a, b; GWC-58-29.

Occurrence: Chahe Section, Weining County, Guizhou; Late Permian Xuanwei Formation.

Description: The pinnule is oblong, 2.8 cm. Long and 1.3 cm broad, with oblique, contracted base and obtuse apex. The margin is entire or slightly sinuate. The midrib is no more than the half length of the pinnule. The lateral veins are fine and dense, repeatedly bifurcating, connected the network. The mesh is short, polygonal.

Discussion and Comparison: It is difficult to classify into known species due to incomplete preservation.

Order **Gigantopteridales**

Genus ***Gigantonoclea*** (Koidzumi 1936)

Type species: *Gigantonoclea lagrelii* (Halle) Koidzumi (1936).

Diagnosis (Wang 1999 emended): Frond pinnate compound, moderate to large in size. Pinnae mostly opposite or rarely subopposite-alternate sometimes coherent in terminal ones. Margins crenate or serrate, rarely undulate or even entire; upper margin decurrent at base; lower margin more or less constricted. Cordate bases andrarely modified pinnae triangular with entire base in attachment. Foliar vasculature of three orders of main vein: rachis of frond, misveins of pinnae, and secondary vein. All main veins delineate intercostal fields with two orders of anastomosing vein: tertiary veins and veinlets forming areolae. One or two dark-dots in each areola.

Discussion: Although the above diagnosis mainly follows the original by Koidzumi (1936), it has been emended to make it agree with current concepts of leaf architecture, and with the designation of venation based on the original description of *G. lagrelii* by Halle (1927). Halle's specimens distinctively have: pinnately compound fronds with more or less coherent terminal pinnae; pinnae mostly opposite with crenate or undulate margins; foliar vasculature consisting three orders of main veins (rachis, midveins and secondary veins) and two orders of anastomosing veins: tertiary veins and veinlets; and dark dots within each areola or mesh.

In order to avoid confusion, it is essential to define precisely the terms used to describe the various orders of veins. Following Foster and Hickey, main veins delimit the intercostal field(s) of the lamina and extend outward up to its margins. There are three orders of main vein: a rachis, reaching to the top of a frond; a midvein extending to the pinna apex; and a secondary vein extending to the pinna margins. Anastomosing veins form a network within an intercostal field, consisting of the tertiary veins,

Fig. 9.9 1, 1a *Gigantonoclea guizhouensis* Gu et Zhi Locality: Mide section, Xuanwei City, Yunnan Province Sample Number: YXM-2-4, 2, 3 *Gigantonoclea lagrelii* (Halle) Koidz**.** Locality: Chinahe section, Xuanwei City, Yunnan Province Sample Number: YXC-(-4)-1, CNH-0-15, 4, 4a *Gigantonoclea plumosa* Mo Locality: Tucheng section, Panxian County, Guizhou Province Sample Number: GPT-5-2a, 5 *Gigantonoclea rosulata* Gu et Zhi Locality: Chinahe section, Xuanwei City, Yunnan Province Sample Number: YXC-P_3x-2, 6, 6a *Gigantonoclea hallei* (Asama) Gu et Zhi Locality: Chahe section, Weining County, Guizhou Province Sample Number: GWC-29-1 7, 8, 9 *Gigantopteris nicotianaefolia* Schenk Locality: 7 Mide Section, Xuanwei City, Yunnan Province Sample Number: YXM (B)-12-1a, 8, 9 Chinahe section, Xuanwei City, Yunnan Province Sample Number: YXC-(-1)-84, YXC-(-1)-199, 10-13 *Gigantopteris dictyophylloides* Gu et Zhi Locality: 10, 11 Tucheng section, Panxian County, Guizhou Province Sample Number: GPT-5-11, GPT-5-12, 12, 12a Chahe section, Weining County, Guizhou Province Sample Number: GWC-69-13, 13 Chinahe section, Xuanwei City, Yunnan Province Sample Number: YXC-(-24)-2 ▶

and veinlets which include branches of the teriary vein, and veins developing into accessory meshes along both sides of the main vein. At its point of attachment, the rachis of a frond is much thicker than the midvein, which in turn is thicker than the secondary vein of a pinna, and which in turn must be rather thicker than a proceeding tertiary vein at its starting point. Finally, the tertiary veins must be thicker than the veinlets. All veinlets are of the same venation order, no matter what the number or grade of branching. Some veinlets may vary slightly in thickness but the variation is local and not strong enough to justify a stable and distinctive order.

The evolutionary series in leaf coherence proposed by Asama (1959) was reputedly reflected in changes in the venation, in particular in the increase in branching grade of the anastomosing vein. For example, a simple grade of vein branching occurs within a pinnatified lobe of a *Gigantonoclea lagrelii* pinna, a double grade of vein branching within a *G. hallei* pinna with coalesced pinnules, and a triple grade of vein branching within a 'leaf' of *G. taiyuanensis* consisting of coalesced pinnae. However, according to Hickey's (1979) rule, all these branching grades belong to the same venation order, consisting of a thicker tertiary vein and many thinner veinlets. A similar change occurs in the plumose-reticulate venation of the extant dicotyledon Quiina acutangula Ducke, where increasing grades of anastomosing veins within an intercostal field is related only to leaf ontogeny and not to phylogeny. Also, Trivett and Pigg (1996) indicated that the reticulate venation is not an adequate indicator of phylogeny.

Gigantonoclea lagrelii ((Halle) (Koidzumi 1989) (Figs. 9.9-2, 9.9-3)

1927 *Gigantopteris lagrelii*, Halle, pp. 170–172, Pl.46, Figs. 2–11, 12?

1934 *Gigantopteris lagrelii*, Kawasaki, Pl.LXVII, Figs. 189

1935 *Gigantopteris lagrelii*, Sze, p.159, Pl.1, Fig. 6

1936 *Gigantonoclea lagrelii* (Halle) Koidzumi, p. 138

1959 *Gigantonoclea lagrelii*, Asama, p. 57, Pl.5, Figs. 7–11


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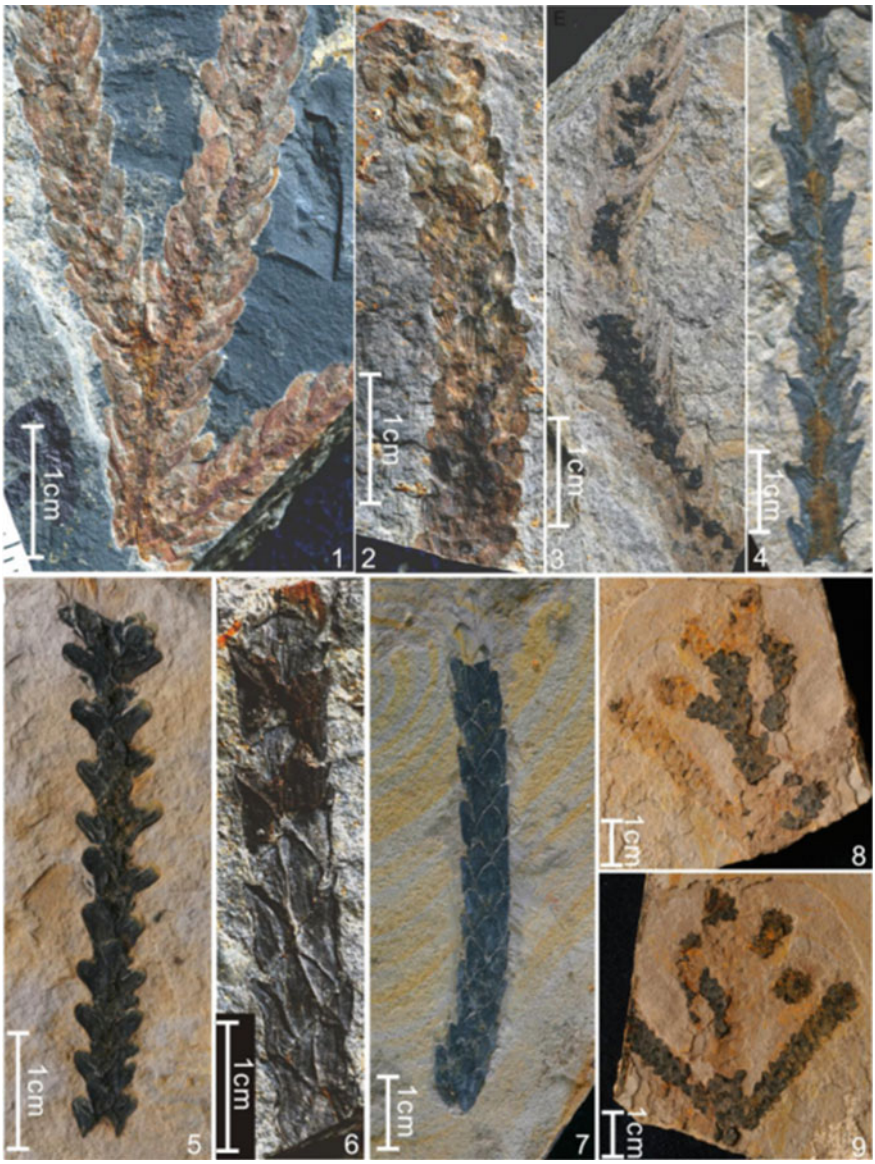

Fig. 9.10 1, 2 *Szecladia multinervia* Yao, Liu, Rothwell and Mapes Locality: Xinmin section, Anshun City, Guizhou Province Sample Number: GAXM11013, GAXM11016, 3 *Pseudoullmannia frumentarioides* He, Liang and Shen Locality: Duanshan-A section, Huishui County, Guizhou Province Sample Number: GHDSA3-1002, 4 *Anshuncladus* sp.3 Locality: Xinmin section, Anshun City, Guizhou Province Sample Number: GAXM11008, 5 *Anshuncladus* sp.3 Locality: Duanshan-A section, Huishui County, Guizhou Province Sample Number: GHDSA3-33, 6 *Anshuncladus* sp.2 Locality: Xinmin section, Anshun City, Guizhou Province Sample Number: GAXM11007, 7 *Anshuncladus* sp.2 Locality: Duanshan-B section, Huishui County, Guizhou Province Sample Number: GHDSB2-26, 8, 9 *Anshuncladus* sp.1 Locality: Duanshan-A section, Huishui County, Guizhou Province Sample Number: GHDSA3-458, GHDSA

1974 *Gigantonoclea lagrelii* (Halle) Koidz., Paleozoic plants of China, p. 126, Pl.95, Figs. 5–7

1980 Gigantonoclea lagrelii (Halle) Koidzumi; Zhang, pl. 1, Figs. 1–2

1989 Gigantonoclea lagrelii (Halle) Koidzumi; Si, p. 61, pl. 71, Figs. 3–5

Lectotype (Wang, 1999): Halle's plate 46, Fig. 6 from the 18th bed at East Hill, Taiyuan. Halle did not designate a type specimen. Subsequently, Si (1989, p. 203) proposed two of the original syntypes (Halle 1927, pl. 46, Figs. 6–7) as 'comparable types'.

Diagnosis (emended): At least one pinnate compound leaf; Ultimate rachis about 2 mm in width; Pinnae oblong, nearly 6 cm in length, 2.5 cm in width, crenated or sinuate margin, occasionally entire, tapered near apex, usually a little constricted at the base with a decurrent lower side but in rare cases are strongly constricted. More or less vaulted laminae on the adaxial surface, rolled downwards along the dentate-crenate margins. Midvein straight, prominent on the adaxial surface, grooved on adaxial surface, and extends from the rachis at 60–70°, maintains a thickness of about 1 mm for more or less equal intervals and disappears near the marginal teeth. Fine tertiary veins, rather prominent at the base and anasomosing. Veinlets form elongate areolae in the longitudinal direction, parallel to the tertiary areolae, black dots situate in the middle of the areolae. With accessory mesh at both side of the midvein and primary lateral vein; occasionally with blind vein, Laminae surfaces bear wrinkled relief.

Material examined: GWC-3-8a, b

Occurrence: Chahe section, Weining County, Guizhou; Late Permian Xuanwei Formation.

Description: Ultimate rachis about 2 mm broad. Frond oblong, the length is more than 2 cm, the broadest is 0.8 cm. Base of frond abruptly constracted, with deflected cordate outline, apex unknown. Margin of frond is entire or slightly sinuate. Midrib distinct but straight. First veins arise at an angle of 80° from the midrib, breaking off before reaching the margin; veinlets freely branching and anastomosing to form a network of elonglated, deltoid or more rarely polygonal meshes. On the specimens there are some black dots (possibly glandular traces or resin bodies) irregularly scattered on the surface of the pinnae. Accessory mesh is unclear and blind vein visible.

Discussion and Comparison: The present specimen is similar to *G. tenuinervis* Yang in having wavy pinna margin, and elongate ovate pinna shape, but they differ in that the latter had thin lamina, acute apex, thin veins. The meshes of the present specimen are similar to *G. cathaysiana* Yang, but it is differs from the latter in having entire margin. The main characters of *G. lagrelii* are that the pinnules have the first lateral veins, wavy margins. The present specimen is similar to this species.

Gigantonoclea guizhouensis (Gu and Zhi 1974) (Figs. 9.9-1, 1a)

1974 *Gigantonoclea guizhouensis* Gu and Zhi, Pl.96, Figs. 7–10

1980 *Gigantonoclea guizhouensis*, Tian, Tian et al., p. 27, text-Fig. 20

2006 *Pinnagigantonoclea guizhouensis* (Gu et Zhi) Yang, p.309, Pl.61, Figs. 4, 4a

Holotype: *Gigantonoclea guizhouensis*, Gu and Zhi (1974). Changhsingian (Upper Permian); Panxian county, Guizhou Province, southwestern China.

Diagnosis: At least one pinnate compound leaf. Pinnae oblong, nearly 10 cm in length, 4 cm in width; shallow serrate at the edge, sometimes entire margin. Midwein 1 mm in width; with two lateral veins, veinlets from elongate-polygonal areolae. No blind veins, vague accessory mesh, suture vein loom, situate downwards.

Material examined: GWC-18, GWC-21-6, GWC-29-3, GWC-GWZ-36-3; GWZ-42, GWZ-4; YXM (A)-2-4, YXM(A)-3, YXM (A)-4; YXM(B)-0-2; GPT-4-4, GPT-5-1, GPT-10-4, GPT-14-1; GPT-15-1, etc.

Occurrence: All of four sections; Late Permian Xuanwei Formation.

Description: The specimens are fragmentary, but to good advantage show the fine venations. The pinnate compound leaf, thin; the margin sinuate toothed. Midvein is strong, probably reaching to the apex, about 1 mm wide. First veins distinct, forming an angle of generally 50° with the midvein, straight or curving slightly forwards, running out into the margin. Secondary veins forming an angle of about 80° with the first veins, giving off fine lateral veins. The first veins are stronger than the secondary ones. The fine lateral veins (veinlets) originating at acute angles and dichotomizing to form elongate-polynogal meshes. No blind veins giving off from the fine veins. Suture veins are unclear.

Discussion and Comparison: The present specimens are the same as the holotype of *G. guizhouensis* named by Gu and Zhi in shape and veins. This species is similar to *G. hallei* in leaflet shape, but the latter have shorter polynogal meshes. Yang et al. assigned the species to genus *Pinnagigantonoclea* based on pinnate compound leaf. This species is abundant in upper Late Permian, and is widely distributed in western Guizhou and eastern Yunnan. It represents one of the dominant species during the late Cathaysian flora in South China.

Gigantonoclea hallei ((Asama) Gu and Zhi 1974) (Figs. 9.9-6, 6a)

1927 *Gigantopteris nicitianaefolia*, Halle, p. 162, Pls.43–44, 45

1959 *Bicoemplectopteris hallei* Asama, p. 57, pl. 2, Figs. 6–7 [refigured from Halle 1927, pl. 45, Figs. 3, 5]; pl.5, Figs. 1–6 [*non* pls 6–7]

1959 *Tricoemplectopteris taiyuanensis* Asama, p. 59, pl. 3, Fig. 4 [refigured from Halle 1927, pls 43–44, Fig. 9]

1974 *Gigantonoclea hallei* (Asama) 'Gu and Zhi', p. 127, pl. 99, Figs. 1–3 [refigured from Halle 1927, pls. 43–44, Fig. 1; pl. 45 Figs. 2, 5]; text-Figs. 103–3, 105

1974 *Gigantonoclea hallei* (Asama) Gu et Zhi, Paleozoic plants of China, p.127, Pl.99, Figs. 1–3

Lectotype: Halle' specimen (1927, pls 43–44, Fig. 1) from the 21st plant-bearing Bed of the 'Upper Shihhotze Series' at the East section of Taiyuan.

Diagnosis: Large in size, probably dichasial bifurcate in the upper part, odd pinnate compound leaf. Pinnae oblong, up to 14 cm in length, 5 cm in width, sharp apex, constricted base; deep serrated margin; several un-divided pinnae coalesce into apical pinnae, wide rhombus. Midvein nearly 1 mm in length, reach to the terminal of pinnule, with two lateral veins. Primary lateral vein reach margin tooth; secondary lateral vein form polygonal areolae. Accessory meshes long. Occasionally blind vein.

Material examined: GWC-29-1, GWC-29-3; GWZ-4-7; GPT-5-6.

Occurrence: Chahe and Zhejue sections, Weining County, Guizhou; Tucheng section, Panxian County, Guizhou; Late Permian Xuanwei Formation.

Description: The specimen shown by the following figure is part of frond. Pinna margin with sinuate-toothed. The midvein is about 1 mm broad, straight. The first lateral veins distinct, forming an angle of 70° with the midvein, straight or curving slightly forwards. Secondary veins are slender more than the first one, forming an angle of 80° with the first veins, giving off the veinlets. The veinlets freely branching, and anastomosing to form a network of irregularly polygonal mesh. The base veinlets from the adjacent secondary veins join each other to form a series of narrow and elongated rectangular accessory meshes extending along the first veins. No sutural and blind veins are seen.

Discussion and Comparison: This species is characterized by wide-form pinnae with large dentate-serrate margins, and a distinctive venation consisting of three orders of main veins (rachis, midvein and secondary veins) and two orders of anastomosing veins (tertiary veins and veinlets) which show two or three gradate branchings. Areolae are polygonal or a little elongate, and accessory areolae are developed along both the sides of the main veins. *G. lagrelii* has the same orders of venation, but differs markedly from *G. hallei* in having narrow-form pinnae, an anastomosing vein with only one grade of branching, and one or two clear black dots within each areola, but the dot is not visible or rather faint in the later areolae. *Gigantonoclea taiyuanensis* (Asama) 'Gu and Zhi' has been published based only on one specimen (Halle 1927, pls 43–44, Fig. 9). However, a careful examination of it shows a complete transition of venation between this specimen and the more typical *G. hallei*. For example, the specimen in Halle's plate 45, Figs. 3–5 shows the tertiary vein having the trace of 'the quaternary veinlet' which is that seen in the type of *G. taiyuanensis*. The best preserved specimens of Halle's (1927) *Gigantonoclea hallei* (e.g. pls 43–44, Fig. 1) could be inferred to represent the upper part of a rather large frond, whereas other fragmentary specimens could represent pinna fragments also from large fronds. What is certain is that the species must have had large enough fronds in order to yield such huge lamina segments as the '*G. taiyuanensis*' specimen.

Gigantonoclea plumosa (Figs. 9.9-4, 4a)

1980 *Gigantonoclea plumosa* Mo, p. 83, Pl.XVI, Figs. 1–3, 1a, 2a)

Holotype: *Gigantonoclea plumosa* Mo, 1980, pl. XVI, Figs. 1–3, 1a, 2a, deposited in the Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, from Xuanwei Formation (Changhsingian), western Guizhou and eastern Yunnan area, China.

Diagnosis: Pinnae linear, 4 cm in width, margin straight or slightly sinuate. Midwein nearly 1.5 mm in width. Primary lateral vein thick, extend from the midvein at about 70° then go straight, slightly curve upwards near the margin, and gradually disperse till disappear. Secondary vein thin, extend from the primary vein at 30°, straight or slightly curve, fork 1–3 times, forking vein parallel to each other and connect to narrow lanceolate mesh during extending, forking vein of secondary vein extend slightly downwards to the middle of adjacent primary vein, connect with each other to loom suture line.

Material examined: YXM (A)-21-2; GPT-5-2, GPT-5-4, etc.

Occurrence: Mide section, Xuanwei City, Yunnan; Tucheng section, Panxian County, Guizhou; Late Permian Xuanwei Formation.

Description: The lateral margin is slightly sinuate. The midvein is about 1 mm wide. The primary lateral veins are strong and thick, depart at a 70-degree angle from the midvein and straightly extend nearly to the margin, then slightly curve upward and gradually disperse. The secondary lateral veins are fine, depart at an 80-degree angle from the primary lateral veins, straight or slightly curved, fork 3–4 times; the forking veins almost are parallel to extend ahead, each other connect to form narrow but long, lanceolate-shaped meshes. Forking veins of the secondary lateral veins extend to the middle of two adjacent primary lateral veins, each other connects to form the obscure seam.

Discussion and Comparison: This species is different from *G. guizhouensis* in that the latter's mesh being short. This species is different from *Cathaysiopteris whitei* by the secondary lateral veins of the latter forking 1–2 times, not forming the network, having a prominent seam veins.

Genus ***Gigantopteris*** Schenk ex Potonié, 1902 emend

Type species: *Gigantopteris nicotianaefolia* Schenk ex Potonié, 1902, emend.

Diagnosis: Megaphylls with pinnate venation. Lamina displays at least four orders of venation. Penultimate order veins form large reticulate polygonal meshes within which finer ultimate order veinlets anastomose to form meshes and blind endings. Areoles imperfect to incompletely closed, randomly oriented, of irregular shape.

Discussion: The generic diagnosis is emended to highlight the complex nature of the higher order venation, particularly the occurrence of meshes within meshes, otherwise called *Zuzammengesetzte Maschenaderung* (Li and Yao 1983), that act to

differentiate this genus from other genera of gigantopterid, particularly *Gigantonoclea.* The diagnosis is also emended such that it is not based on the unproven status of the leaf/leaflet as compound or simple.

Gigantopteris dictyophylloides (Gu and Zhi 1974) (Figs. 9.9-10, -11, 9.9-12 and 9.9-13)

1927 *Gigantopteris dictyophylloides* Gu and Zhi, Paleozoic plants of China, pp. 130–131, Pl.102, Figs. 1–6

1974 *Gigantopteris dictyophylloides* Gu and Zhi, pp. 130–131, pl. 102, Figs. 1–6; text-Figs. 11. 2, 103.4

1989 Gigantopteris dictyophylloides Guo et al., p. 166

1993 *Gigantopteris dictyophylloides* Guo et al., pp. 94–95, pl. 2, Figs. 1–15

2004 *Gigantopteris dictyophylloides* Guo et al.; Glasspool et al., pp. 1356–1357, Pl. 2, Fig. 5

Holotype: *Gigantopteris dictyophylloides* Gu and Zhi (1974), pl. 102, Figs. 1–2, deposited in the Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, from Xuanwei Formation (Changhsingian), western Guizhou and eastern Yunnan area, China.

Diagnosis: Widely crenate megaphylls with pinnate venation. Tertiary veins anastomose, branches may be of higher or same order. Anastomosed branches form a reticulum of irregular polygonal meshes. Within these meshes veinlets anastomose into small meshes forming well-developed orientated, typically polygonal areoles, with frequent blind endings. No accessory meshes occur along the higher order veins.

Material examined: GPT-5-7, GWC-58-23, GWC-32-3; GPT-4-5, GPT-5–3, GPT-10-5; YXM (B)-12-7, GWC-69-13, etc.

Occurrence: Late Permian and Early Triassic Xuanwei Formation.

Description: Material referable to this species consists of many fragments which show the distinct venation and the shape of mesh. The midvein is strong and flat, reaching to the apex. The primary veins are distinct, giving off at an angle of 60–65° from the midvein, disappearing without reaching to the margin. Secondary veins are narrower more than the primary veins, giving out at about a 50° angle from the primary veins. The tertiary veins give out at a wide-angle and irregularly branching and anastomosing with each other, forming big and polygonal meshes. The fine veins in the big meshes connect each other forming regular but small polygonal meshes. There constantly are the blind veins in the small meshes.

Discussion and Comparison: The main characters of the present specimens are the primary veins shorten, disappearing before extending to the margin, and the shapes of small mesh regular, having blind veins in small meshes. The diagnosis has been emended to provide a standardised terminology (sensu Hickey 1979) and to emphasize less strongly the order of the finer veins. These veinlets are ultimately reduced in width. However, just above the point of anastomosis, they are frequently

of the same width as below it, and as such may be considered of comparable order. The species is distinguished from *G. nicotianaefolia* in having a crenate margin, in the regular distribution of the veinlets forming the areoles, in the frequent occurrence of blind endings and, in the absence of even poorly defined accessory meshes.

Gigantopteris* (*Megalopteris*) *nicotianaefolia (Figs. 9.9-7, 9.9-9)

1883 *Megalopteris nicotianaefolia* Schenk, pp. 238–239, pl. 32, Fig. 6

1902 *Gigantopteris nicotianaefolia* Schenk ex Potonie´, in Engler and Prantl, vol. 1, part 4, p. 513

1930 *Gigantopteris nicotianaefolia* Schenk; Chu, p. 6, pl. 4, Fig. 1

1933 *Gigantopteris nicotianaefolia* Schenk; Gothan and Sze, pp. 23–26, pl. 4, Fig. 1a

1940 *Gigantopteris nicotianaefolia* Schenk; Shimakura, pp. 11–13, Pl.1, Figs. 1–2, 5, Pl. 7, Figs. 1–2

1974 *Gigantopteris nicotianaefolia* Schenk, emend. Gu and Zhi, p. 130, pl. 100, Figs. 2–4; pl. 101, Fig. 1; text-figs 103 (5), 108

1983 *Gigantopteris nicotianaefolia* Schenk; Yao, pp. 1–8, pl. 1, Figs. 1–6; pl. 2, Figs. 1–5; pl. 3, Figs. 1–5; text-Fig. 3b

2004 *Gigantopteris nicotianaefolia* Schenk; Glasspool et al., pp. 1357–1358, Pl. 2, Figs. 1–4

Basionym: *Megalopteris nicotianaefolia* Schenk, A., 1883. Steinkohlenpflanzen. In v. Richthofen, China IV, pp. 238–239, pl. 31, Fig. 3c; pl. 32, Figs. 6, 8; pl. 33, Figs. 1–2; pl. 35, Fig. 6.

Lectotype: *Gigantopteris nicotianaefolia* (Schenk 1883, pl. 32, Fig. 6; this paper, Pl. 1, Fig. 1; Pl. 2, Fig. 1; Pl. 3, Figs. 1–6).

Diagnosis: Obovate-elliptic-oblong, entire margined, sometimes slightly revolute megaphylls with pinnate eucamptodromous venation. Lamina apex roundly acute. Primary vein stout-massive. Tertiary veins anastomose, branches may be of higher or same order. Anastomosed branches form reticulum of irregular polygonal meshes. Within these meshes veinlets anastomose into small meshes forming imperfect to incompletely closed, randomly oriented areoles, with occasional blind endings. Poorly developed accessory meshes may occur along secondary veins.

Material examined: GWC-48-1, GWC-58-48a, b, GWC-69-32; YXM-12-1a, b; etc.

Occurrence: Chahe section, Weining County, Guizhou; Mide section, Xuanwei City, Yunnan; Late Permian Xuanwei Formation.

Description: The specimens shown in the following figures possibly represent the middle- upper parts of the frond. Lager simple leaf, oblongate or ovate, attaining a length of more than 12 cm and a breadth of more than 6 cm, with entire or slightly sinuate margin and obtuse apex. The midvein is wide but flat, reaching to the apex.

The primary veins are distinct, giving off at an angle of 70–80° from the midvein, reaching to the margin. Secondary veins are narrower more than the primary veins, giving out at about a 50 degree angle from the primary veins. The tertiary veins give out at a wide-angle and irregularly branching and anastomosing with each other, forming big rhombic or polygonal meshes. The fine veins in the big meshes connect each other forming irregularly small polygonal meshes.

Discussion and Comparison: The major characters of this species are its simple leaf, fine veins forming the irregularly small meshes and occasional blind veins, which can be used to distinguish it from *G. dictyophylloides*.

Order **Gymnospermae**

Family **Coniferopsida**

Genus ***Anshuncladus*** gen. nov.

Type species: *Anshuncladus xinminensis* sp. nov. Late Permian Changhsingian Talung Formation in South China.

Diagnosis: Typical of monopodial branching, spiral to opposite-decussate arrangement of leaf shoots and scale-like leaves. Leave oval, triangular or rhombic with varying outlines. Apices beaked, bluntly rounded or bluntly pointed. Leaves helically arrayed, slightly overlapped, strongly decurrent with broad base, detached in upper part, concave ventrally, conves dorsally, with distinct median keel. Leaf margin sometimes wrinkled. Leaf amphistomatous. Epidermal cell polygonal and isodiametric, with broad, straight anticlinal wall and smooth periclinal wall. Papillae absent, radial line sometimes appear on surface of epidermal cell, of which the corners are rounded. Stomata evenly distribute in discontinuous row. Stomatal complexes often circular, oval and occasionally filled with plugs. Stomatal arrangement cyclitic with two kidney-shaped guard cells, sunken and always badly preserved. Number of subsidiary cells commonly four or five, rarely three and six. Cuticles on subsidiary cell surface thicker than other parts, forming distinct ring.

Discussion: *Anshuncladus* is a morphotype established after the macro morphology and micro character of the leaf and shoot fossils. The scientific name originate in the name of fossil locality and the preserved shoots: Anshun (County) + Cladus (Shoot). It could be distinguished from the same layer preserved *Pseudoullmannia* for the scale-like leavies. The later has long lanceolate-shape leaves; it is differ from *Szecladia* according to the vein structure, *Anshuncladus* only has one midvein, while *Szecladia* has 7–8 veins. The subsidiary cell number is the main difference between *Anshuncladus* and *Ullmannia*, the later of which is wildly distributed in our country and elsewhere like Europe and America. According to the leaf outline, whether leaf is amphistomatous or not, the shape of epidermal cell, with papillae or not, the amount of subsidiary cell and stomata in row or not, *Anshuncladus* could be distinguished from other similar conifer plants of Permian and Triassic. The comparison between *Anshuncladus* and other coeval or similarly-aged fossil conifers is preliminarily displayed in Table 9.3. Recently only one shoot with female cone has been found. Together with the leaf outline and epidermal structure, *Anshuncladus*

Table 9.3 Comparison between *Anshuncladus* and similar genus

Genus		*Anshuncladus*	*Ullmannia*	*Pseudoullmannia*	*Szecladia*	*Pagiophyllum*	*Brachyphyllum*	*Pseudovoltzia*	*Voltzia*	*Ortiseia*	*Quadrocladus*	*Majonica*
Reference		This paper	Taylor, 1982; Wang et al., 1986; Yang et al., 1994	He et al., 1996	Yao et al., 2000	Kendall, 1948; Adams, 1951; Liu and Yao, 2013	Kendall, 1947; Kendall, 1949; Raab et al., 1986; Ham et al., 2003	Arnold, 1947; Clement-Westerhof, 1984; Schweitzer, 1986	Zhou, 1979; Diez, 1996	Clement-Westerhof, 1984	Kerp, 1996; Meyen, 1997	Clement-Westerhof, 1987
Leaf morphology	Outline	oval, triangular, rhombic; apex beaked, bluntly rounded, bluntly pointed, inturned; spiral arrangement	oval, lanceolate; apex bluntly pointed, bandy; spiral arrangement	linear, long lanceolate; apex pointed; spiral arrangement	oval; apex obtuse, inturned;spiral or imbricate arrangement	wide triangular; strongly decurrent; apex acute, inturned; loosely spiral arrangement	wide triangular; strongly decurrent; apex short and bluntly pointed; margin folds inward; spiral arrangement	narrow triangular; lanceolate; apex acute or obtuse; spiral arrangement (fake lateral arrangement)	lanceolate, triangular, falcate in lateral view; apex pointed or bluntly pointed; loosely spiral arrangement	oval, triangular, lanceolate; apex acute or bluntly pointed; tapering slightly at the base; spiral arrangement	linear, shovel-shaped, sub-triangular; apex acute or bluntly pointed; spiral arrangement	narrow sub-triangular, oval; apex acute or bluntly pointed; decurrent; spiral arrangement
	Branching	irregularly	irregularly	irregularly	irregularly	irregularly,at an angle of 40°	pinnately or alternately	–	irregularly	pinnately	irregularly	–
	Vein	mid-ridge	mid-vein,fine longitudinal stripes	fine longitudinal stripes	7-8 veins	mid-ridge, fine longitudinal stripes	mid-ridge, serveral longitudinal stripes	–	mid-vein	–	–	–
Trichome bases, papillae		none	none	–	–	–	one papillae on each subsidiary cell	papillae	–	papillae	papillae occasionally	papillae
Epidermal cells		polygonal, isodiametric, straight anticlinal walls	isodiametric, retangle, straight anticlinal walls	retangle, straight anticlinal walls	–	retangle, wide and straight anticlinal walls	retangle and short; straight anticlinal walls	polygonal	–	isodiametric, straight anticlinal walls	–	small, isodiametric, thin anticlinal walls
Stomata	Stomata	amphistomatic	amphistomatic	–	–	amphistomatic	amphistomatic	–	–	–	amphistomatic	–
	Distribution	evenly, in discontinuous rows, not in bands	–	–	–	in bands, wide as one stoma	gernerally in rows	–	–	in rows	irregularly	irregularly
	Subsidiary cells	commonly 4-5; rarely 3 and 6	8-10	–	–	3-6	4-7	7-8, much smaller that epidermal cell	–	4-8	3-7, usually 4-5, very similar to epidermal cell	–
	Stomatal porus	occasionally filled with plugs	–	–	–	–	–	–	–	–	–	–
Taxonomic position		Voltziaceae?	Voltziaceae	Lepidodendrales-Lepidodendron?	Podocarpaceae ?			Voltziaceae	Voltziaceae	Walchiaceae		Majonicaceae

could be included in coniferopsida. However, due to the lack of seed-scale complex, in-situ pollen grain, fossil wood anatomical structure and the vague of the cone, it is hard to classify *Anshuncladus* to any recent family.

Occurrence: Marine facies Xinmin, Duanshan and Kejiao sections, Talung Formation of Changhsingian in western Guizhou and eastern Yunnan area.

***Anshuncladus* sp.1 sp. nov.** (Figs. 9.10-8, 9.10-9)

2019 *Anshuncladus* sp.1 Li and Yu, p. 35, pl. 3, fig A-I; pl. 4, fig. F–H; pl. 6, fig A-E; pl. 7, pl. 8

Holotype: *Anshuncladus* sp.1 Li and Yu, 2019, GHDSA3-58, pl. 3, Fig. E, deposited in China University of Geosciences (Wuhan) State key laboratory of Biogeology and Environmental Geology, an impression fossil with cuticle preserved, from Dalong Formation (Changhsingian), Duanshan County, Guizhou Province, South China.

Paratype. *Anshuncladus* sp.1 Li and Yu, 2019, GHDSA3-61, pl. 3, Fig. E, deposited in China University of Geosciences (Wuhan) State key laboratory of Biogeology and Environmental Geology, an impression fossil with cuticle preserved, from Dalong Formation (Changhsingian), Duanshan County, Guizhou Province, South China.

Diagnosis: More than tertiary branch, monopodial branching from leaf axil at 30°–50°. Single preserved longest terminal shoot is more than 12 cm long, Every branch accordingly shorten. Shoot loosely helically arranged, subalternate. Leaf scale like, spirally arrayed and imbricate arranged; Leaf distal portion away from axis, medium Degree of Freedom (DOF); Leaf base decurrent, rhombic or oval, middle and lower portion widest and taper till the apex; with a distinct mid-ridge. Leave apex blunt. Leaf margin curves occasionally.

Occurrence: Upper Permian, western Guizhou and eastern Yunnan, South China.

Description: The specimen is at least tertiary branch, and is monopodial branching from the leaf axil at 30°–50°. The single preserved longest terminal shoot is more than 12 cm long. Every branch accordingly shorten. Longer leaf is about 6–8.5 mm long, approximately 3.5–5.5 mm broad, shorter leaf is about 2–5 mm long, roughly 2.5–3.5 mm broad. The shoot is loosely helically arranged, and is subalternate. Leaf is scale like, spirally arrayed and imbricate arranged. The distal portion of leaf is away from the axis and the Degree of Freedom (DOF) is medium. Leaf base is decurrent. Leaves exposed in the front is usually rhombic or oval, the middle and lower portion is the widest and taper till the apex. Leave apex is blunt. Leaf margin curves occasionally. Leaf has a distinct mid-ridge.

Fertile shoot is up to 6 cm long, and could be divided into three potion from the bottom to the top. The base is shoot bearing sterile leaves and is 2.5 cm in length, 1.2 cm in width. The middle portion is shoot with reduced sterile leaves, and is 2 cm in length and 0.3 cm in width. The reduced top bears a female cone. It is turbinate, slightly nutant, 15.cm in length, and the widest part is the top, is 1 cm broad. Seed scale is oval, and spiral arrayed.

Discussion and Comparison: This kind of specimen is the largest amounts and the branching structure is the best preserved, also is the only one bearing female cone. However, it's hard to establish a new species without more anatomic data. The difference between Anshuncladus sp. 1, A. sp. 2 and A. sp.3 are listed in the key tab. 4.

***Anshuncladus* sp.2 sp. nov.** (Figs. 9.10–6, 9.10–7)

2019 *Anshuncladus* sp.2 Li and Yu, p. 35–36, pl. 5, Fig. A-G

Holotype: *Anshuncladus* sp.2 Li and Yu, 2019, GAXM11007, pl. 5, Fig. B, deposited in China University of Geosciences (Wuhan) State key laboratory of Biogeology and Environmental Geology, an impression fossil with cuticle preserved, from Dalong Formation (Changhsingian), Anshun County, Guizhou Province, South China.

Diagnosis: Width of shoots and branches even. Leaf scale like, spirally arrayed and closely detached to axis; upper portion slightly off axis, DOF extremely low; partly regularly arranged, subalternate; leaf thick, rhomic, oval to triangular, with blunt apex; leaf base decurrent and encase. Leaf margin occasionally curved, with a distinct mid-ridge. Concave ventrally, convex dorsally near the mid-ridge.

Occurrence: Upper Permian, western Guizhou and eastern Yunnan, South China.

Description: The width of shoots and branches are even. Leaf is scale like, spirally arrayed and closely detached to axis. The upper portion is slightly off axis, and the DOF is extremely low. Part of the specimen are arranged more regularly, and is subalternate. Leaf is thick, rhomic, oval to triangular, with blunt apex. The base of leaf is decurrent and encase. Leaf margin occasionally curved. Leaf has a distinct mid-ridge. The later leaf indicates the adaxial surface is concave and the abaxial surface is convex near the mid-ridge.

Discussion and Comparison: This specimen resembles *Anshuncladus* sp.1, so is the epidermal structure. The main difference is the detached degree of leaf to the axis. Due to the closely detachment to the axis, the arrangement of leaf transfer from irregular spiral to more regular. In some specimen, there are apparent subalternate arrangement of leaves, which is important to the conifers' evolution. So we take this as the key identification of different species.

***Anshuncladus* sp.3** (Figs. 9.10-4, 9.10-5)

2019 *Anshuncladus* sp.3 Li and Yu, p. 36, pl. 4, Fig. A–E

Holotype: *Anshuncladus* sp.3 Li and Yu, 2019, GAXM11008, pl. 4, Fig. A, deposited in China University of Geosciences (Wuhan) State key laboratory of Biogeology and Environmental Geology, an impression fossil with cuticle preserved, from Dalong Formation (Changhsingian), Anshun County, Guizhou Province, South China.

Diagnosis: With fine shoots. Leaf small, scale-like, loosely spirally arrayed, spacing 0.1–1.0 cm unequally, subalternate, detached with the axis at wide angle (60°–90°),

Table 9.4 Identification key of *Anshuncladus* species

I.Leaves densely helically arranged
1. Leaves' distal portion away from the axis, medium Degree of Freedom (DOF)
Anshuncladus sp.1
2. Leaves' distal portion closely detached to the axis, extremely low DOF
Anshuncladus sp.2
I. Leaves loosely arranged, subalternate, distal portion away from the axis, high DOF
Anshuncladus sp.3

DOF is high. Leaf pex is blunt or bluntly round, usually recurved in the direction of adaxial portion. Leaf base intensely decurrent. Mid-ridge unclear.

Occurrence: Upper Permian, western Guizhou and eastern Yunnan, South China.

Description: The specimen has fine shoots. Leaf is small, scale-like, loosely spirally arrayed, and spacing 0.1–1.0 cm unequally. The leaf is subalternate, detached with the axis at wide angle (60°–90°), and the DOF is high. The leaf pex is blunt or bluntly round, usually recurved in the direction of adaxial portion. The leaf base intensely decurrent. Due to the bad preservation of leaves in the front of the middle axis, so the mid-ridge is not clear.

Discussion and Comparison: This species is distinct from other two sspecies due to the thin shoots, small leaves, low amounts of epidermal stomata which is scattered and the structure is hard to recognize. It is suspected to be the young shoots of the other two species or belongs to totally different genus (Table 9.4).

Genus ***Szecladia*** (Yao et al. 2000)

Type species: *Szecladia multinervia* (Yao et al. 2000). Changhsingian (Upper Permian); Guizhou and Guangxi provinces, South China.

Diagnosis: Vegetative conifer shoots with irregular branching, helical phyllotaxis, and small imbricating leaves. Leaves roughly ovate, broadly attached, with several veins. Stems eus.

Discussion: The generic name *Szecladia* consists of the surname Sze and cladus (Greek klados 5 branch), and is proposed in honor of the late Professor H. C. Sze, distinguished palaeobotanist and founder of paleobotany in China, who first described fossil conifers of this kind from the Guangxi Autonomous Region (Sze 1940).

Szecladia multinervia (Yao, Liu, Rothwell and Mapes, 2000) (Figs. 9.10-1, 9.10-2)

1940 *Ullmannia* aff. *bronnii* Goeppert (? sp. nov.), Sze, p. 156, taf. I, Figd. 1–8

1974 *Ullmannia* cf. *bronnii* Goeppert, Gu and Zhi, p. 154, pl. 121, Fig. 6; pl. 122, Figs. 1, 3, 4

1980 *Ullmannia* cf. *bronnii* Goeppert, Zhao et al., pl. XVII, Figs. 6, 6a

1985 *Ullmannia bronnii* Goeppert, Feng and Zhu, p. 203, pl. I, Figs. 1–3

1996 *Pseudoullmannia bronnioides* He, Liang and Shen, p. 169, part (non holotype, pl. 69, Fig. 6)

2000 *Szecladia multinervia* Yao, Liu Rothwell and Mapes, p. 525, Figs. 3–5

Holotype: *Szecladia multinervia* Yao et al. (2000), Figs. 3.1, 3.2, 4.1, 4.3, 4.4, 4.7, 5.1–5.7, deposited in the Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, from Tulong Formation, Upper Permian, Guangxi Province, South China.

Diagnosis: Ultimate branches generally 3–8 mm wide with leaves up to 6 mm long and 3 mm wide, with inwardly bending tip; leaves commonly contain seven to eight parallel veins with uniseriate bundle sheaths. Secondary xylem tracheids commonly 11–22 mm in diameter with uniseriate circular bordered pits; rays uniseriate, one to three cells high with large, simple cross field pits. Ground tissues of pith, cortex and leaves contain nests of sclereids. Well developed periderm interior to leaf bases of penultimate branches.

Occurrence: Duanshan, Xinmin sections of Changhsingian in western Guizhou and eastern Yunnan area, South China. Dongluo Section of Changhsingian in Guangxi.

Description: The largest specimens of *Szecladia multinervia* show two orders of irregularly branched stems with imbricating, helically-arranged leaves attached throughout leafy stems range 3.3–8 mm in diameter. Leaves are up to 6 mm long and 3 mm wide, and are loosely appressed to the stem with a tip that bends slightly inward. In surface views the leaves are roughly ovate, broadly attached, widest in the midregion, and taper to a bluntly rounded apex. Each leaf displays several prominent longitudinal striations that represent the positions of approximately seven to eight veins. In cross sections the leaves are elliptical near the base, becoming wider and more blade like distally.

Discussion and Comparison: *Szecladia multinervia* displays a distinctive suite of conifer characters that clearly distinguish it from previously described genera. Among Paleozoic seed plants, irregularly branched shoots with uniformly small helically arranged leaves like those of *Szecladia* are known only for conifers. Also characteristic of conifers, are the endarch eustele with leaf traces that initially diverge as a single bundle and the dense wood with uniseriate circular bordered pits of *Szecladia*. Distinct longitudinal striations of the leaves are shared by *Szecladia*, species of *Ullmannia* (Goeppert 1850), and Pseudoullmannia (He et al. 1996). However, in *Ullmannia* the striations represent stomatal furrows on the surface of leaves with a single midvein, whereas in *Szecladia* they are formed by several parallel veins. The structural nature of the striations in *Pseudoullmannia* is not known. Among Paleozoic conifers with small leaves, only *Szecladia* displays several leaf traces. Although leaf size and shape in *Szecladia* and *Ullmannia* are similar, as are the inwardly curved, bluntly rounded apices, multiveined leaves clearly distinguish *Szecladia*

from species of *Ullmannia*. The leaves of both *Pseudoullmannia frumentalioides* and the holotype of *P. bronnioides* are relatively longer and narrower than those of *Szecladia* and *Ullmannia*, and are terminated by a relatively straight, acutely pointed apex (He et al. 1996). Multiveined leaves are found in several Paleozoic and Triassic coniferophyte taxa worldwide. These include Paleozoic Cordaitean leaves from Euramerica, Cathaysia and Angara that are usually referred to *Cordaites* (Rothwell 1988; Halle 1927; Meyen 1987), coniferophyte leaves from Angara that are assignable to *Rufloria* and *Lepeophyllum* (Meyen 1978, 1987), and others of unknown affinity (e.g., *Pelourdea* Halle 1927; *Phylladoderma*, Meyen 1988). The Triassic conifers *Aethophyllum* from France (Grauvogel-Stamm 1978) and *Heidiphyllum* from Gondwana deposits (Anderson and Anderson 1985) also have several parallel veins, but those genera comprise species with leaves that are all much larger, mesomorphic, strap-shaped forms.

The growth form and reproductive structures of *Szecladia multinervia* remain unknown. General features of the stelar architecture and leaf-trace divergence in *Szecladia* are similar to those of the Pennsylvanian *Walchian* conifers from North America (Rothwell et al. 1997) as well as to those found in more recent conifer families. The relatively widely spaced, uniseriat circular bordered pits of the small, secondary tracheids, and the simple cross field pitting of *Szecladia* are suggestive of the Podocarpaceae, but similar characters also occur in the wood of some pinaceous species. However, in the Pinaceae there are usually prominent resin canals that do not occur in *Szecladia*. Multiveined leaves are present in both Szecladia and many species of the Podocarpaceae, including the Triassic *Notophytum krauselii* from Antarctica (Axsmith et al. 1998) and the Upper Triassic Stalagma samara from Hunan, China (Zhou 1983). This feature further suggests podocarpaceous affinities for *Szecladia*. However, multiveined strap-shaped leaves are characteristic of many other Mesozoic conifers whose familial affinities are uncertain (Axsmith et al. 1998). Although we suspect that *Szecladia* may be allied with the Podocarpaceae, in the absence of reproductive organs, familial affinities of the genus cannot be determined with confidence.

Genus ***Pseudoullmania*** (He et al. 1996)

Type species: *Pseudoullmania frumentalioides* He et al. (1996). Late Permian of South China.

Diagnosis: See that of *Pseudoullmania frumentalioides*.

Discussion: The same specimen from South China were referred to *Ullmania* Goeppert. He studied the shape and epidermal structure and insisted those specimen were greatly different from those of West Europe. However there is no evidence of their higher taxanomy, and He et al. (1996) suspected it may not belong to conifers for the reason that the rectangular contour of cell walls more resemble young shoot of lepidodendroid plant.

Pseudoullmannia frumentarioides (He et al. 1996) (Fig. 9.10-3)

1977 *Ullmannia furmentaria* Goeppert, Feng et al., p. 671, pl. 251, Figs. 1–2

1979 *Ullmannia furmentaria* (Schlotheim) Goeppert, Yang and Chen, p. 137, pl. 46, Figs. 2–4; pl. 47, Figs. 1–3

1996 *Pseudoullmannia frumentarioides* He, Liang and Shen, p. 87, pl. 69, Figs. 1–5; pl. 70, Fig. 2; pl. 96, Figs. 1, 2

Holotype: *Pseudoullmannia frumentarioides* He et al. (1996), pl. 69, Figs. 1–5; pl. 70, Fig. 2; pl. 96. Deposited in the Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, from Lower Laoshan Submember and Wangpanli Member of Loping Formation in South China.

Diagnosis: Shoot irregularly arranged, with spirally and densely arranged leaves. Leaves lanceolate in shape, apex acute, about 8–15 mm in length and about 2 mm in width at the base, base decurrent, leaf surface striated. Midrib invisible. Lower epidermal cells comparatively small, about 10 μm in length and 2 μm in width, rectangular in shape, lateral walls straight and regularly arranged, no stomata recognized. Upper cuticle unknown.

Occurrence: Duanshan, Xinmin sections of Changhsingian in western Guizhou and eastern Yunnan area, South China. Dongluo Section of Changhsingian in Guangxi.

Description: The penultimate shoots of our specimens are 6–10 mm in width, both ultimate and penultimate shoots bear spirally arranged leaves. Leaves are lanceolate, about 13–10 mm in length and 2 mm in width at the broadest lower part. Leaf apex is acute and the base is slightly contracted. There are not midvein found, and several parrallel veins can be seen on the better preserved dorsal surface.

Discussion and Comparison: The present specimen are completely identical with those of *Ullmania frumentaria* described by Fong, Yang and Chao et al. While our specimen has linear to leaves, obtuse leaf apex and strongly convex and geniculated lateral sides. Compared with *Ullmania frumentaria*, our specimen has no midvein. The epidermal cells are isodiametric polygonal and stomata are regularly longitudinally oriented. According to all the difference listed, our specimens are different from *Ullmania frumentaria.*

Danaeites saraepontanus Stur, Paleozoic plants of China.

References

Anderson JM, Anderson HM (1985) Palaeoflora of Southern Africa: prodromus of South African megafloras, devonian to lower cretaceous. Balkema, Rotterdam, p 567

Asama K (1959) Systematic study of so-called *Gigantopteris.* Sci Rep Tohoku Univ 2nd Ser (Geol) 31:1–72

Axsmith BJ, Taylor TN, Taylor EL (1998) A new fossil conifer from the Triassic of North America: implications for models of ovulate cone scale evolution. Int J Plant Sci 159:358–366

Brongniart A (1822) Sur la Classification et la Distribution des Végétaux Fossiles en Général, et Sur Ceux des Terrains de Sédiment Supérieur en Particulier. Imprimerie De A. Belin, Paris, pp 1–91 (also in Mémoires du Muséum d'Histoire Naturelle, 8:203–240, 297–348)

Brongniart A (1828a) Essai d'une flora du grès bigarre. Annales de Science Naturelles, 1st Ser 15:435–460

Brongniart A (1828b) Prodrome D'une Histoire des végétaux fossiles. Dictionnaire des Science Naturelles 57:1–223

Feng Z, Wei HB, Guo Y, He XY, Sui Q, Zhou Y, Liu HY, Gou XD, Lu Y (2020) From rainforest to herbland: New insights into land plant responses to the End-Permian Mass Extinction. Earth-Sci Rev 204:103153

Fliche P (1910) Flore fossile du Trias en Lorraine et Franche-Comté (avec des considérations finales par M. R. Zeiller. Bulletin De La Société Des Sciences De Nancy III, XI 1:222–286

Florin R (1933) Studien uber die Cycadales des Mesozoikums. Kungliga Svenska Vetenskapsakademiens Handlingar 12:1–134

Galtier J, Broutin J (2008) Floras from red beds of the Permian Basin of Lodève (Southern France). J Iberian Geol 34(1):57–72

Gomankov AV, Meyen SV (1979) On representatives of the family Peltaspermaceae from the Permian deposits of the Russian platform. Paleontol Zh 2:124–138

Gomankov AV, Meyen SV (1986) *Tataria* flora (composition and distribution in the Late Permian of Eurasia). Akademii Nauk SSSR, Ordena Trudovogo Krasnogo Znameni Geologicheskii Institut, 401:1–174 (in Russian)

Göppert HR (1850) Monographie der fossilen Coniferen. Hollandsche Maatschappÿ Wetensch. Natuurk. Verh. 6:1–286

Grauvogel-Stamm L (1978) La flore du Grès à Voltzia (Buntsandstein supérieur) des Vosges du Nord (France). Morphologie, anatomie, interprétations phylogénique et paléogéographique. Sci Géol Bull 50:1–225

Gu Z, Zhi L (1974) Palaeozoic plants from China. Nanjing Institute of Geology and Palaeontology, Institute of Botany, Academia Sinica. Science press, Beijing, pp 1–277

Halle TG (1925) *Tingia*, a new genus of fossil plant from the Permian of China (preliminary note). Bull Geol Soc China 7:1–12

Halle TG (1927) Fossil plants from southwestern China. Palaeontologia Sinica Ser A 1(2):1–26

Harris TM (1937) The fossil flora of Scoresby sound, East Greenland. Part. 5: Stratigraphic relations of the plant beds. Medd Grønland 112(2):1–114

He XL, Liang DS, Sheng SZ (1996) The Permian Floras from Jiangxi, China. China University of Minings Press, Xuzhou, pp 1–201

Kon'no E, Asama K (1950) On the genus *Lobatannularia* Kawasaki 1927 from Permian Beds in South Manchuria and Shansi, China. Short Pap. IGPC 1:18–31

Krings M, DiMichele WA, Kerp H, Taylor TN (2005) Frond morphology and epidermal anatomy of Glenopteris splendens (Pteridospermopsida, Peltaspermales) from the Permian of Kansas, USA. N M Mus Nat Hist Sci Bull 30:171

Kustatscher E, Bauer K, Butzmann R, Fischer TC, Meller B, van Konijnenburg-van Cittert JHA, Kerp H, (2014) Sphenophytes, pteridosperms and possible cycads from the Wuchiapingian (Lopingian, Permian) of Bletterbach (Dolomites, Northern Italy). Rev Palaeobot Palynol 208:65–82

Lesquereux L (1877) A species of fungus recently discovered in the shales of the Darlington coal bed (lower productive coal measures, Alleghany River series) at Cannelton, in Beaver County, Pennsylvania. Proc Am Philos Soc 17:173–175

Li XX, Yao ZQ (1983) Current studies of gigantopterids. Palaeontologia Cathayana 1:319–326

Liu LJ, Yao ZQ (2007) Plant megafossils from the Permian Changhsingian marine deposits of Fusui, Guangxi, china. Acta Palaeontologica Sinica 46(2):195–212

Meyen SV (1987) Fundamentals of palaeobotany. Chapman and Hall, London

Naugolnykh SV, Kerp H (1996) Aspects of Permian palaeobotany and palynology. XIV. On the oldest known peltasperms with radially symmetrical ovuliferous discs from the Kungurian (uppermost Lower Permian) of the Fore-Urals (Russia). Rev Palaeobot Palynol 91(1–4):35–62

Poort RJ, Kerp JHF (1990) Aspects of Permian palaeobotany and palynology. XI. On the recognition of true Peltasperms in the Upper Permian of western and central Europe and a reclassification of species formerly included in *Peltaspermum* Harris. Rev Palaeobotany Palynol 63(3–4):197–225

Potonie H (1902) Ueber die fossilen Filicales im Allgemeinen etc. Emgler & Frantl: Die naturlichen Pflanzenfamilien. Teil 1, Abteil. 4, 513

Potonié R (1956) Synopsis der Gattungen der Sporae dispersae I. Teil: Sporites. Amt für Bodenforschung, Hannover

Rothwell GW (1988) Cordaitales. In: Beck CB (ed) Origin and evolution of gymnosperms, pp 273–297. Columbia University Press, New York

Rothwell GW, Mapes G, Mapes RH (1997) Late Paleozoic conifers of North America: structure, diversity and occurrences. Rev Paleobot Palynol 95:95–113

Schenk A (1883) Pflanzen aus der Steinkohlen formation. In: Richthofen F von. China, 4. Berlin, pp 238–239

Schimper WP (1869) Traité de Paléontologie végétale ou la flore du monde primitif dans ses rapports avec les formations géologiques et la flore du monde actuel. Tome premier. Baillière J.B. et Fils, Paris, p 732

Stockmans F, Mathieu FF (1939) La Flore paleozoique du Bassin houiller de Kaiping (China). Mus Roy Hist Nat, Belgique, pp 49–165

Trivett ML, Pigg KB (1996) A survey of reticulate venation among fossil and living land plants. In: Taylor DW, Hickey LJ (eds) Flowering plant origin, evolution and phylogeny, pp 8–31. Chapman and Hall, New York, NY

Visscher H, Kerp H, Clement-Westerhof JA, Looy CV (2001) Permian floras of the Southern Alps. Naturae Bresciana, Annali del Museo Civico di Scienze Naturali di Brescia, Monografia 25:117–123

Wan ML, Shi H, Wang DY (2011) Latest Permian Cathaysian Flora from Yangbazhai, Mojiang in Yunnan Province. Acta Palaeont Sinica 50(2):251–267

Wang ZQ (1997) Permian Supaia fronds and an associated Autunia fructification from Shanxi, China. Palaeontology 40:245–277

Wang ZQ, Wang LX (1989) Earlier early Triassic fossil plants in the Shiqianfeng Group in North China. Shanxi Geol 14(1):23–40 (in Chinese with English abstract)

White D (1929) Flora of the Hermit shale, Grand Canyon, Arizona. Bull Carnegie Inst Wash 405:1–221

Yao ZQ, Xu JT, Zhen ZG, Mo ZG (1980) Late Permian biostratigraphy and the Permian-Triassic boundary in Western Guizhou and Eastern Yunnan. In: Nanjing Institute of Geology and Palaeontology (ed), Stratigraphy and palaeontology of Late Permain coal-bearing formations in Western Guizhou and Eastern Yunnan. Science Press, Beijing, pp 1–69. (In Chinese)

Yao ZQ, Liu LJ, Rothwell WG et al (2000) Szecladia new genus, a Late Permian conifer with multiveined leaves from South China. J Paleontol 74:524–531

Zhao XG, Mo ZG, Zhang SZ, Yao ZQ (1980) Late Permian fossil floras of western Guizhou and eastern Yunnan. In: Nanjing Institute of Geology and Palaeontology, Academica Sinica, (ed.), Late Permian coal-bearing strata and palaeontological fauna in western Guizhou and eastern Yunnan. Science Press, Beijing, pp 70–122 (in Chinese)

Zhou ZY (1983) *Stalagma samara*, a new Podocarpaceous conifer with monocolpate pollen from the Upper Triassic of Hunan, China. Palaeontographica B 185:56–78

Zijlstra G, Kustatscher E, van Konijnenburg-van Cittert JHA (2007) Proposals to conserve the names *Schizoneura* against *Convallarites* and *S. paradoxa* against *C. erecta* (fossil Sphenopsida). Taxon 56:965–966