Chapter 1
Literature Review

Jianxin Yu, Xiao Shi, and Hui Li

A good study has been made of the marine facies Permian–Triassic boundary stratigraphy sequence, biome change and geological events. Meishan D section in Changxing of Zhejiang, China and its base of 27c bed has been chosen as the GSSP (Yin et al. 2001) due to the work of the Chinese geologists for decades since Yin et al. suggested that the first appearance of the Conodont species *Hindeodus parvus* should mark the base boundary of the Triassic. This definite has put a good end to the important boundary stratigraphic study in marine environment.

However, the determination of GSSP for the marine Permian–Triassic boundary arouses people's interests to work out an accessory section and point of terrestrial facies for such a boundary. Attention is focused on the interrelationship between the environmental change and biologic extinction when the continent was more sensitive and critical in preserving the fossils. It will be more complicated to determine a stratotype boundary because of particularity of the biologic preservation on land. Therefore, some specialists working for the boundary stratigraphy suggest to make a continental boundary stratigraphy division and correlation to those of the marine facies (Lozovsky 1991; Lucas et al. 1992). While some geologists tend to find terrestrial accessory section and point (ASP) in South Africa (Lucas et al. 1996) as the Permian–Triassic Beaufort Group of Karoo Basin yields abundant vertebrates and

J. Yu (✉)
China University of Geosciences (Wuhan), Wuhan, Hubei, P.R. China
e-mail: yujianxin@cug.edu.cn

X. Shi
College of Earth Sciences, Jilin University, Changchun, Jilin, P.R. China
e-mail: xiaoshi@jlu.edu.cn

H. Li
Jiangxi Key Laboratory for Mass Spectrometry and Instrumentation, East China University of Technology, Nanchang, P.R. China
e-mail: huili_201860188@ecut.edu.cn

J. Yu et al. (eds.), *Plants and Palynomorphs around the Permian-Triassic Boundary of South China*, New Records of the Great Dying in South China,
https://doi.org/10.1007/978-981-19-1492-8_1

is thus an important area for the study of terrestrial Permian–Triassic boundary. In contrast, China, located in the eastern Tethys area, is not only one of the best studied areas for marine facies Permian–Triassic stratigraphy boundary in the world, but also an area with well-developed terrestrial Permian–Triassic strata. Particularly, the Junggar Basin in Xinjiang consists of a complete series of continental Permian–Triassic sequence with continuous depositions and fine outcrops and also contains abundant fossil fauna (e.g. ostracods, bivalves, vertebrates) and fossil plant near Permian–Triassic boundary. It is one of the ideal areas to study and establish a terrestrial Permian–Triassic stratotype Section and Point. In addition, similar areas for the ASP are found in Moscow Terrane of Russia, Ural areas of Kazakhstan, Sydney Basin and Bowen Basin of Australia, and Germany and its adjacent areas.

1.1 International Studies

1.1.1 Research of Terrestrial Permian–Triassic Boundary

It is known in the study of the terrestrial stratigraphic sections that terrestrial vertebrates diversify apparently above and below the Permian–Triassic boundary. Angara flora in Russia and Cathaysian flora in China, prosperous in Late Permian, disappeared at the end of the epoch and thus fossil plants could rarely be found in early Early Triassic. It was only in basalmost Triassic that some simple new plant assemblages began to appear. In Sydney Basin, southeastern Australia, there is obvious change of terrestrial plants, with the sudden decrease in flora diversity and local species diversity and the total disappearance of Glossopterids. It was not until Middle Triassic that the flora began to recovery in the area. While in Israel, *Lueckisporites virkkiae* assemblage, the gymnosperm pollen, predominant in Late Permian disappeared totally in the claystone below the boundary but marine acritarch and large amount of Lycopsida spore occurred instead. This indicates an important break in the palynomorph assemblages. Ochev (1973) attributes the change of vertebrates at terrestrial Permian–Triassic boundary to the change of sedimentary facies and suggests that the real change should happen between Early and Middle Triassic. On the contrary, Smith (1995) and Ward (2000) believe that the biologic extinction must have influenced the environment during their study of the Permian–Triassic boundary in Karoo Basin, South Africa. It is generally thought that the change of bended river into braided river reflects the increase of the river slope, and that this is resulted from the orogeny, which is the idea of some early researchers of the Karoo Basin. However, Smith (1995) and Ward (2000) maintained that no tectonic orogeny has happened near the Permian–Triassic boundary. Therefore, the change of the river type, from the highly bended river to lowly bended river (anomaly layer) in Late Permian to braided river deposition in Early Triassic, should have been caused by the biologic extinction rather than the change of the slope. They stated that the increase of the deposition load caused the bended river to change into braided river when the ground surface,

especially the river bank, lost its protection from the plants because of the biologic extinction, in particular the death of plants of large root systems in big numbers. This kind of biologic extinction and environment change of global characteristics should lead to the ^{13}C deviation near the Permian–Triassic boundary.

The paleobiologists (Visscher et al. 1996; Peng et al. 2006) has found a fungi events in the terrestrial Permian–Triassic boundary strata from Europe, North America, Africa, Australia, Madagascar, Israel, Greenland and South China, characterized by the widespread *Reduviasporonites* (*Tympanicysta*) and the equivalent *Chordecystia*, which can be correlated in paleontology and geochemistry with other records. They believe that this fungi event could have been brought about by the serious air pollution caused by the large-scale volcanic eruption in Siberia. While Krassilov (1999) assumes that this could be resulted from the ground water rise and wide distribution of rivers due to the global transgression. Wang Ziqiang (1997) has also found a large number of fungi and algae traces in the remains of gymnosperm in North China and also a lot of small tumors on the seeds owing to the parasitic fungi. He proposes that the terrestrial ecosystem evolution falls into three steps: progressive declining of the ecosystems in Permian, collapse of the ecosystems (cluster extinction) in Late Permian and continual revival and development of the ecosystem in Triassic. He suggests that the entire biologic evolution is closely related to the environment change-the global desertification (the change from semi-arid climate to arid climate).

1.1.2 Research to Terrestrial Permian–Triassic Transition Flora

Before 1920s, almost all the paleobotanic research was completed by international specialists. Even at the present time, the Chinese research level in the field of paleobotany may be 10 years behind that of other countries. For the research on the terrestrial Permian–Triassic plants is now mainly conducted in Europe, America, Australia and India. The following aspects are focused on the study of the biologic evolution between Paleozoic and Mesozoic.

1. International Cooperative Research on the response of the equatorial subtropical vegetation to the Ice Age in Late Paleozoic, reorganization of Terrestrial Plant Ecosystem during the end of an Ice age: "A Geosystems Approach to the Interterrestrial Comparison of Early and Mid-Permian floras". This group makes up of many paleobotanists from china, France, Holand, Germany, Brazil and South Africa and so on. The scientific implication of this collaborative research lies in the fact that the global greenhouse effect triggered by the glacier melting in Late Paleozoic is more correlative than other elements in other ages and/or since Late Cenozoic in the geologic history and so can be used to infer the climate change in modern times. It is assumed that the rapid glacier melting resulted in the obvious change of the floras, including extinction, spatial distribution

changes of the equatorial and temperate zone vegetation, and even the vegetation structural change on a global scale. Although the Late Paleozoic floras and their geographic distribution are different from those in the present earth, their change mechanism, the geographic distribution features and changing ratio may be the pattern for the correlation of the similar modern greenhouse effect in the world.

2. One of the international paleobotanic research focuses is on the ecologic characteristics of the floras for different floral Provinces in the critical P/T geologic period, from the angle of relationship between the fossil plant taphonomy and cuticles anatomy and the environment change and the response of the vegetation to the global climate change in Late Paleozoic to make a prediction of future CO2 change in atmosphere.
3. International paleobotanists are now more interested in the sudden (unexpected) mass extinction of the floras in the end of Permian and the new Lycophyta flora in Early Triassic. Some of them believe that the former happened in a long time with only variations of time in different areas, while others tend to agree that the catastrophic event is related with the vascular plant evolution (Retallack 1995; Eshet et al. 1995; Steiner et al. 2003; Nowak et al. 2019, 2020).

1.2 Studies in China

The terrestrial Permian–Triassic strata in China is mainly distributed in its northern area, while they are outcropped in a few numbers on the massif margins in the southern area, with typical area found in western Guizhou and eastern Yunnan.

1.2.1 Establishinga Fairly Complete Framework of Stratigraphic Units in Western Guizhou and Eastern Yunnan

Many geologists have done great jobs on the strata formed at the turn of Permian and Triassic in their previous researches. Yang Ruiji, Li Peixian, Zhou Tongshun and Qu Lifan have made a systematic study of the terrestrial Permian–Triassic strata in Dalongkou, Jimsar of Xinjiang, which is presented in their monograph "Terrestrial Permian–Triassic Stratigraphy and Faunas, Dalongkou, Jimsar of Xinjiang". Li Zishun, Zhan Lipei and Dai Jinye have made a detailed study of the marine strata near Permian–Triassic boundary in Sichuan and Shaanxi, represented by their book "Permian–Triassic Biostratigraphy and eventostratigraphy in Northern Sichuan and South Shaanxi". The research groups headed by the two academicians, Prof. Yang Zunyi and Prof. Yin Hongfu, have made world-known achievements in the study of the Permain-Triassic stratigraphy. They have already finished many projects funded by IGCP (IGCP-106,203,359) and China Natural Science Fund, represented by their

books “Permian–Triassic Boundary Strata and Faunas in South China”, “Permian–Triassic Transition Geologic Events in South China”, “Permo-Triassic Events in the Eastern Tethys” and “Proceedings of the International Conference on Pangea and the Paleozoic–Mesozoic Transition”.

Terrestrial Permian–Triassic stratigraphic study in South China started in 1930s, when some famous geologists, Yue Senxun, Huangjiqing, Wang Zhuquan et al. made investigations of the Late Permian strata in the area. In 1970s, Nanjing Institute of Geology and Paleontology of the Chinese Academy of Science made a special study of Permian–Triassic biostratigraphy, represented by their books “Late Permian Coal-bearing Strata and Palaeontological Fauna in western Guizhou and eastern Yunnan” and “Palynology of Upper Permian and Lower Triassic Strata of Fuyuan District, eastern Yunnan”.

On the base of the previous worker, the further study (including paleontology, event stratigraphy, sequence stratigraphy and the analysis of biomarker and geochemistry (Wang and Yin 2001; Peng et al. 2002, 2005, 2006; Yang et al. 2005; Yin et al. 2007; Yu et al. 2007, 2010, 2015; Chu et al. 2016, 2020; Feng et al. 2019) in western Guizhou and eastern Yunnan has developed one after the other in recent years. These studies had laid a good foundation for further research on the Permian–Triassic boundary correlation with the marine section, patterns of extinction and survival of the flora and so on in South China.

1.2.2 Research on the Paleofloras

The study of Permian floras in China can be said to be closely related with the coal exploration and the discovery of gigantopterids. However, such study made with modern method was mainly started by some European scholars roughly in mid nineteenth century. Schenk (1883), Halle (1927), and Stockmans and Mathieu (1939) studied Permian plant fossils and made their publications one after the other. Although literature on this aspect is rather rare and the record of the fossils beds is not clear, the particularity of the Permian floras dominated by gigantopterids is quite outstanding. “Palaeozoic Plants from Central Shansi”, published by the famous Sweden paleobotanist Halle in 1927 is considered as the classic for the Carboniferous and Permian flora studies, thus a milestone for the Chinese paleobotanic development indicating a new stage for the Permian flora study in China.

It was in 1930s that the Chinese geologists and paleobotanists began their studies on Permian flora. Among whom Sze (1933, 1942, 1947) made greater contributions. The birth of New China brought the spring of science to the study of the paleoflora. Some new and important achievements written by the Chinese paleobotanists were made either in depth or on scale of the study. The studies include chiefly (1) the classification and evolution of gigantopterides by some scholars (Li and Yao 1983a, b; Yao and Crane 1986) based on their morphologic classification, propagation organs, wood anatomy and alteration; (2) the discovery and investigation of the Permian

Glossopterids flora from Qinghai-Tibet plateau, Cathaysian flora and the Cathaysian-Gondwana mixed flora(?), represented by the achievements made by Li and Yao, Li Xingxue (1986), Xu et al. and Li et al. (1991), which have filled up the blank of the Permian flora research in the area and provided practical example for the approach to the forming and evolution of the plateau and the relationship between Cathaysian flora and Gondwana flora; (3) study of the geographic system of the Permian plants: represented by the achievements made by Li et al. (1980), who is the first to divide the Cathaysian flora into North China flora subregion and South China subregion and by Xu Ren and Li Xingxue (1986), who have discussed respectively the relationship between the Gondwana flora and Cathaysian flora in terms of plate tectonics; and (4) some new understandings in the study of the Permian–Triassic plant alteration and extinction, illustrated by the publications of Yao Zhaoqi et al. (1980) and Ouyang Shu (1980), Wang Ziqiang (1993 and 1997), Fang Zongjie (2004) and Yu et al. (2007).

The Triassic flora research in China began in the late nineteenth century, mainly represented by the study of the plant fossils from Xujiahe of Sichuan made by German paleobotanist Schenk (1884). The first Chinese paleobotanist on the Triassic flora should be late Si Xingjian (Sze 1933, 1935, 1936), who studied the plant fossils from the Late Triassic coal-bearing strata. After this study was the study of the Yanchang flora in north Shaanxi made by Pan Zhongxiang (Pan 1936). Great achievements have been made in this area since 1949, especially in the discovery and detailed investigation of the Late Triassic flora fossils.

However, the Early and Middle Triassic floras were first formally reported in China only at the end of 1970s. The first discovery of *Pleuromeia* from Early Triassic Heshanggou Formation in Qinshui Basin, Shanxi made by Wang Ziqiang (Wang Lixin et al. 1978) aroused the great attention of the paleobontanists both from China and other countries. At the same time, Zhou et al. (1979) reported the discovery of late Early Triassic flora in Jiuqujiang of Qionghai, Hainan, which laid the foundation for the Early Triassic flora research in South China. More research made by Meng Fansong (1992) in the area has enriched the study of the Early Triassic flora. Since 1980s, new advances have been made in the Early Triassic research in North China, especially the flora study of the upper part of Shihchienfeng Group., Liujiaogou Formation and Heshanggou Formation (Wang Ziqiang 1982; Wang Ziqiang et al. 1990). This not only clarifies the basically same characteristics of the Early Triassic flora in North China as those from the West European Buntsandstein flora, but also provides important evidence for the formal classification of the Shihchienfeng Group in the area. Moreover, the discovery of *Annularia shirakii* Kaw., *Gigantopteris dictyophylloides* Gu et Zhi, etc. in the basement of the Lower Triassic Kayitou Formation on the border of Yunnan and Guizhou (Yao et al. 1978, 1980) and their occurrence in the same layers or overlying layers of the Early Triassic bivalves should be of great significance for the understanding of the floral assemblages in the beginning of Triassic in South China and for the evidences of continuous deposition between Paleozoic and Mesozoic.

Presently, the Chinese Triassic flora studies are characterized by the noticeable progress in the entire reconstruction of the ancient plants, reproductive biology, plant anatomy and systematic evolution. More achievements are also made in the

comprehensive study of the geographic provinces based on the data of plate tectonics, paleomagnetism and paleozoology (Wu Shunqing 1983; Wang Ziqiang 1985; Yin Hongfu et al. 1986; Sun Ge 1987, 1993; Yu et al. 2010; Feng et al. 2019).

To sum up, the Chinese studies of Permian–Triassic plants have undergone over one hundred years of history. They have developed from the morphologic description to the probing of basic theories, integrating rich practical information with the study of the global geologic system. This indicates that paleobotany parallels with other basic geologic theories in studying the whole earth.

1.3 Studies in the Research Area for the Monograph

The research area situated on the border of western Guizhou and eastern Yunnan, belongs to the South China subregion of Cathaysian flora. In this area, coal-bearing strata of terrestrial and marine-terrestrial facies are developed with abundant gigantopterids. The earliest study was started by Xie Jiarong, who studied the Permian–Triassic fossil plants when investigating Xuanwei coal series. Then, Yunnan Geological Bureau and Guizhou Geological Bureau made some simple collection and identifications of plant fossils to determine the dating of coal beds when prospecting coal in the area. While the real systematic study of the Permian–Triassic flora in the area began in 1970 and 1980s. During this time, paleobotanists and palynologists, represented by Yao Zhaoqi (1978), Zhao Xiugu (1980) and Ouyang Shu (1986), clarified the Permian–Triassic flora assemblage outlook and main characteristics with the study of the preserved fossil plants. Their results suggest that the genera and species of the assemblage in the bottom of the Lower Triassic are very monotonous, containing relict elements of Late Permian Cathaysian flora, and thus should represent the declining period of the flora.

Recently, many scholars have been making further research of the Permian–Triassic biologic extinction in the area. For instance, Wang and Yin (2001), in their study of the boundary strata in the area, proposes that an extinction event happened in the terrestrial biome in the turn from Permian and Triassic and the plants alternated in sudden change while showing a progressive alternation in the process. Yang et al. (2005), Yin et al. (2007) and Yu et al. (2007, 2015) point out that the composition of the flora near the boundary does not have substantial change, showing only a gradual reduction of the genera and species number, and so they should be of an extinction mode of multi-stages. Whereas the finding of many new plant fossils in Kayitou Formation of marine-terrestrial transition strata in the last ten years has certainly provided new information for the boundary determination and the study of the plant revival after the extinction (Yu et al. 2010; Feng et al. 2019).

It should be noted that arguments are now heated on the geological time of Kayitou Formation, for it has a lack of standard fossils. Yao et al. (1980) assumes that it should be Early Triassic. Wang and Yin (2001) suggest that this formation should be a time-crossing lithostratigraphic unit in the terrestrial strata such as those in Zhejue of Weining and Mide and Laibin of Xuanwei and should be the deposition of late Late

Permian and early Early Triassic and that the marine facies deposition in Panxian-Shuicheng area should be Early Triassic. Liu and Yao (2002) think that it should be the earliest Triassic. Chen Jinhua, on the other hand, believes that the marine strata of the Kayitou Formation should be the product of transgression in Late Permian and so should be dated Latest Permian. Until now, the geological age of Kayitou Formation is divergent in the field of paleonotology (Shen et al. 2011; Yu et al. 2015; Chu et al. 2016; Feng et al. 2019).

References

Chu DL, Yu JX, Tong JN, Benton MJ, Song HY, Huang YF, Song T, Tian L (2016) Biostratigraphic correlation and mass extinction during the Permian-Triassic transition in terrestrial-marine siliciclastic settings of South China. Glob Planet Change 146:67–88

Chu DL, Grasby SE, Song HJ, Corso JD, Wang Y, Mather TA, Wu Y, Song HY, Shu WC, Tong JN, Wignall PB (2020) Ecological disturbance in tropical peatlands prior to marine Permian-Triassic mass extinction. Geology 48:288–292

Eshet Y, Rampino MR, Visscher H (1995) Fungal event and palynological record of ecological crisis and recovery across the Permian-Triassic boundary. Geology 23:967–970

Fang ZJ (2004) The Permian-Triassic boundary crisis: patterns of extinction, collapse of various ecosystems, and their causes. In: Rong JY, Fang ZJ (eds) Mass extinction and recovery, evidences from the Palaeozoic and Triassic of South China. University of Science and Technology of China Press, Hefei, pp 785–928 (in Chinese with English summary)

Feng Z, Bertling M, Noll R, Ślipiński A, Roessler R (2019) Beetle borings in wood with host response in early Permian conifers from Germany. PalZ 93(3):409–421

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

Krassilov VA, Afonin SA, Barinova SS (1999) Tympanicysta and the terminal Permian events. Permophiles 35:16–17

Li XX (1986) The mixed Permian Cathaysia-Gondwana flora. Palaeobotanist 35(2):211–222

Li XX, Yao ZQ (1983a) Fructifications of gigantopterids from South China. Palaeontographica Abstract B 85(13):11–26

Li XX, Yao ZQ (1983b) Current Studies of Gigantopterids. Palaeontologia Cathayana 1:319–326

Li XX, Rigby J, Wu YM (1991) A biostratigraphical comparison between the Lower Gondwana flora of south Xizang (Tibet) and Kashmir. In. Utrid HR, Campos AC (eds) Gondwana Seven Proceedings. Univ. Sao Paulo, Brazil, pp 533–538

Li XX (1980) New advances of studies in the Cathaysia flora. In. Scientific paper on geology for international exchange. Prepared for the 26th International Geological Congress (4), Stratigraphy and Palaeontology. Beijing: Geological Publishing House, pp 73–81 (in Chinese with English summary)

Liu LJ, Yao ZQ (2002) Geological age of the Kayitou Formation. J Stratigr 26(3):235–237

Lozovsky VR (1991) Proposal for a new working group on continental beds at the Permian/Triassic boundary in the continental series. Permophyles 19:7–11

Lucas SG, Lozovsky VR, Cheng ZW (1992) Proposal to STS for formation of a working group on the nonmarine Triassic timescale. Albertiana 10:41

Lucas SG, Kozur H, Molina-Garza R (1996) Reconsideration of Dalongkou as an auxiliary GSSP for the Permian-Triassic boundary. Albertiana 18:10–11

Meng FS (1992) Fossil Plants. In: Yichang Institute of Geology and Mineral Resources et al., eds. Geology of Hainan Island, 1. Stratigraphy and Palaeology. Beijing: Geological Publishing House: 166–170, 175–183 (in Chinese)

Nowak H, Vérard C, Kustatscher E (2020) Palaeophytogeographical patterns across the Permian-Triassic boundary. Front Earth Sci 8:609
Nowak H, Schneebeli-Hermann E, Kustatscher E (2019) No mass extinction for land plants at the Permian-Triassic transition. Nature Communications 10(1)
Ochev VG (1973) About the character of the changes in fauna of terrestrial vertebrates at the boundary of the Permian and Triassic. Bull Moip Ser Geol 48:1
Ouyang S, Li ZP (1980) The micro-floral in the Kayitou Bed of Fuyuan, Yunnan and its stratigraphic and paleobotanic significance. 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 123–194 (in Chinese)
Ouyang S (1986) Palynology of upper Permian and lower Triassic strata of Fuyuan district, eastern Yunnan. Science Press, Beijing, pp 122 (in Chinese with English Summary)
Peng YQ, Wang SY, Wang YF, Yang FQ (2002) A proposed area for the study of the Accessory Section and Point of the Terrestrial Permian-Triassic boundary. J China Univ Geosci 13:157–162
Peng YQ, Zhang SX, Yu JX, Yang FQ, Gao YQ, Shi GR (2005) High-resolution terrestrial Permian-Triassic eventostratigraphic boundary in western Guizhou and eastern Yunnan, southwestern China. Palaeogeogr Palaeoclimatol Palaeoecol 215:285–295
Peng YQ, Yu JX, Gao YQ, Yang FQ (2006) Palynological assemblages of non-marine rocks at the Permian-Triassic boundary, western Guizhou and eastern Yunnan, South China. J Asian Earth Sci 28:291–305
Retallack GJ (1995) Permian-Triassic life crisis on land. Science 267(5194):77–80
Schenk A (1884) Die wahrend der Reise des Grafen Bela Szechenyi in China gesamlten fossilien Pflanzen. Palaeontographica 31(3):163–182
Schenk A., 1883. Pflanzen aus der Steinkohlen Formation. In: Richthofen F von. China, 4. Berlin: 238–239.
Shen WJ, Sun YG, Lin YT, Liu DH, Chai PX (2011) Evidence for wildfire in the Meishan Section and implications for Permian-Triassic events. Geochim Cosmochim Acta 27:1992–2006
Smith RMH (1995) Changing fluvial environments across the Permian-Triassic boundary in the Karoo Basin, South Africa and possible causes of tetrapod extinction. Palaeogeogr Palaeoclimatol Palaeoecol 117:81–104
Steiner MB, Eshet Y, Rampino M, Schwindt DM (2003) Fungal abundance spike and the Permian-Triassic boundary in the Karoo Supergroup (South Africa). Palaeogeogr Palaeoclimatol Palaeoecol 194:405–414
Stockmans F, Mathieu FF (1939) La Flore paleozoique du Bassin houiller de Kaiping (China). Mus Roy Hist Nat, Belgique:49–165
Sun G (1987) On late Triassic geofloras in China and principles for palaeophytogeographic regionalization. Acta Geol Sinica 61(1):1–9
Sze HC (1933) Fossil Pflanzen aus Shensi, Szechuan und Kueichow. Palaeont Sinica Ser A 1(3):1–32
Sze HC (1936) Ueber einen Vorl/iufer von Pterophyllum in der Unteren Shihhotze Serie in Shansi. Bull Geol Soc China 15(4):467–476
Sze HC (1942) Ueber ein neues Exemplar von Psaronius aus dem Omeishan Basalt in Weining (Kueichou) mit besonderer Berticksichtigung des Alters des Basaltes in Stidwestchina. Bull Geol Soc China 22(1–2):105–131
Sze HC (1947) On the structure of Psaronius sinensis from the Omeishan Basalt Series in Southwestern China. J Geol Amer 55(3):160–166
Sze HC (1935) Ueber das Vorkommen von Callipteris conferta Sternb. in der Unteren Shihhotze Serie in central Shansi. Bull Geol Soc China 14(4):569–578
Visscher H, Brinkhuis H, Dilcher DL, Elsik WC, Eshet Y, Looy CV, Rampino MR, Traverse A (1996) The terminal paleozoic fungal event: evidence of terrestrial ecosystem destabilization and collapse. Proc Natl Acad Sci USA 93(5):2155–2158
Wang ZQ (1997) Permian Supaia fronds and an associated Autunia fructification from Shanxi, China. Palaeontology 40:245–277

Wang ZQ, Wang LX (1982) A new species of the lycopsid Pleuromeia from the Early Triassic of Shanxi, China and its ecology. Palaeontology 25(1):215–225

Wang ZQ, Wang LX (1990) Late Early Triassic fossil plants from upper part of the Shiqianfeng Group in North China. Shanxi Geol 14(1):23–40 (in Chinese with English abstract)

Wang LX, Xie ZM, Wang ZQ (1978) On the occurrence of *Pleuromeia* from the Qinshui Basin in Shanxi Province. Acta Palaeont Sinica 17(2):195–212 (in Chinese wtih English abstract)

Wang SY, Yin HF (2001) Study on terrestrial Permian-Triassic boundary in eastern Yunnan and western Guizhou. China University of Geosciences Press, Wuhan, pp 88. (in Chinese with English abstract)

Wang ZQ (1993) Evolutionary ecosystem of Permian–Triassic redbeds in North China: a historical record of global desertification. In: Lucas SG and Morales M. (eds)

Ward PD, Montgomery DR, Smith RMH (2000) Altered river morphology in South Africa related to the Permian-Triassic extinction. Science 289:1740–1743

Wu SQ (1983) On the Late Triassic, Lower and Middle Jurassic floras and phytogeographic provinces of China. In: Editorial Committee of Fundamental Theory of Palaeontological Book Series (ed) Palaeobiogeographic provinces of China. Beijing: Science Press, pp 121–130 (in Chinese)

Yang FQ, Yin HF, Yu JX, Zhang SX, Huang JH, Peng YQ, Huang QS, Zhao QM (2005) Study of the terrestrial Permian-Triassic boundary in Chahe, Weining, Guizhou province. Sci China (series D) 35:519–529 (in Chinese)

Yao ZQ (1978) On the age of "Gigantopteris coal series" and Gigantopteris-flora in South China. Acta Palaeontol Sin 17:81–89 (in Chinese with English abstract)

Yao Z, Crane PR (1986) Gigantopterid leaves with cuticles from the Lower Permian of China

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)

Yin HF, Feng QL, Lai XL, Baud A, Tong JN (2007) The protracted Permo-Triassic crisis and multi-episode extinction around the Permian-Triassic boundary. Glob Planet Change 55:1–20

Yu JX, Peng YQ, Zhang SX, Yang FQ, Zhao QM, Huang QS (2007) Terrestrial events across the Permian- Triassic boundary along the Yunnan-Guizhou border, SW China. Global Planet Change 55:193–208

Yu JX, Broutin J, Huang QS, Grauvogel-Stamm L (2010) *Annalepis*, a pioneering lycopsid genus in the recovery of the Triassic land flora in South China. C. R. Palevol. 9:479–486

Yu JX, Broutin J, Chen ZQ, Shi X, Li H, Chu DL, Huang QS (2015) Vegetation changeover across the Permian-Triassic boundary in Southwest China extinction, survival, recovery and palaeoclimate: a critical review. Earth-Sci Rev 149:203–224

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, Li BX (1979) A preliminary study of the Early Triassic plants from the Qionghai District Hainan Island. Acta Palaeotol Sin 18(5):444–466 (In Chinese with English abstract)