植物学通报 2000, 17(专辑):61~73
Chinese Bulletin of Botany

A Brief Review of the Mesozoic Filicopsida in China①

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Abstract The paper is to provide an account of features of Chinese Mesozoic Filicopsida and a brief description of the main progress in the studies of the Mesozoic Angiopteridaceae, Marattiaceae, Matoniaceae, Dipteridaceae, Osmundaceae, Cyatheaceae, Gleicheniaceae, Hymenophyllaceae, Schizaeaceae, Dicksoniaceae, Athyriaceae, Dryopteridaceae, Aspleniaceae and Pteridaceae, and particularly that of the *in situ* reproductive organ.

Key words Mesozoic, Filicopsida, Advance, China

1 Introduction

As the continental sediments play a dominant role in the Chinese Late Triassic, Jurassic and Cretaceous, there is an excellent fossil record of Mesozoic fern fossils in China. The most important elements of the fossil record are the beautiful sterile and fertile frond compression and impression and dispersed spores, while the silicon rhizomes and stems are relatively rare. The first collection and study of these fossils was made in the beginning of 20th century, and most of the descriptive papers have been published in the late 1980's. During recent years, many authors have paid greater attention to the reproductive structures of ferns and have made a considerable advance. This brief review deals with the main progress in the studies of the Mesozoic Filicopsida in China.

2 Stratigraphy and Distribution of Mesozoic Floras

2.1 Triassic

During the Early-Middle Triassic, the marine deposits occupy the Southern China, while the continental sediments are widely developed in the north of the Yangtze River, including the North, Northeast and Northwest China. Owing to the dry climate, the Early Triassic floras poorly occur and are represented by *Pleuromeia* flora in North China (Wang, 1989a; 1990a). Very few ferns are contained in this flora. The Middle Triassic floras are somewhat more developed than the earlier one and consist of some ferns, such as *Danaeopsis*, *Bernoullia* (Wang *et al.*, 1989b; 1990b; Huang *et al.*, 1980).

In the Late Triassic, continental deposits are extensively distributed in China except Tibet of the Tethys area. Because of the humid climate the floras flourish. Two phytogeographic provinces are distinct. Between the two provinces there is a boundary line—the Kunlun Mountains-Qinlin

① Supported by the National Scientific Foundation of China (49202017 and 4972008).
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Mountains-Dabie Mountain. The South Phytogeographic Province (south of the boundary line) is represented by *Dictyophyllum-Clathropteris* Flora, while the North Phytogeographic Province is represented by the *Danaeopsis-Bernoullia* Flora (Wu, 1983).

The *Dictyophyllum-Clathropteris* Flora has been reported from Baoding (Xu *et al*., 1979) and Xujiahe (Li, 1964; Ye *et al*., 1986; Wu, 1999) of Sichuan, Yipinglang of Yunnan (Li *et al*., 1976), North Guangdong (Wang, 1993), Fujian (Zhou, 1979), Xizang (Tibet) (Li *et al*., 1982; Wu, 1982a, b) and etc.. Ferns are very developed in this flora and are characterized by a great number of dipteridaceans and Angiopteridaceae, and many species of Matoniaceae, Marattiaceae, Osmundaceae and Gleicheniaceae.

The *Danaeopsis-Bernoullia* Flora has been described from North Shaanxi Province (Sze, 1956), Liaoning (Zhang *et al*., 1987; Mi *et al*., 1993), Xinjiang and Gansu. The fern group of this flora is composed of numbers of Osmundaceae, Angiopteridaceae and *Cladophlebis*, and a few of Dipteridaceae, Matoniaceae and Marattiaceae. However, the Tianqiaolin Flora from Jilin Province, Northeast China(Sun, 1993)is regarded as the *Dictyophyllum-Clathropteris* Flora because of many of Dipteridaceae, Marattiaceae and few of Angiopteridaceae and Osmundaceae.

2.2 Jurassic

The Early-Middle Jurassic nonmarine deposits are widely distributed almost all over China except South Tibet and west Yunnan Province of Southwest China, Guandong Province of South China and east Heilongjiang Province of Northeast China. The Kunlun Mountains-Qinlin Mountains-Dabie Mountain is still the boundary between the South and North Phytogeographic Provinces. The Lower Jurassic and lower part of the Middle Jurassic in the north of this boundary are coal-bearing strata that are rich in plant fossils. The Early Jurassic flora is named as *Neocalamites-Cladophlebis* Flora (Li *et al*., 1988), which has been reported from about 20 localities (Shenghui and Fen, 2000), such as Liaoning of Northeast China (Zhang *et al*., 1987; Mi *et al*., 1996), Gansu (Liu, 1982; Xu, 1986), Xinjiang (Wu *et al*., 1986) and Qinghai (Li *et al*., 1988) of Northwest China. A large number of *Cladophlebis* and a lot of osmundaceous elements represent the fern group. Although Dicksoniaceae appear in this flora, they are represented by 1 or 2 species that are characterized by small fronds and slender rachis.

The Middle Jurassic flora in North Phytogeographic Province is referred as *Coniopteris-Phoenicopsis* Flora (Sze, 1956), which have been mainly reported from Liaoning, Northeast China (Zhang *et al*., 1987; Mi *et al*., 1996), Beijing (Chen *et al*., 1984; Duan, 1987), Xinjiang (Shang *et al*., 1999), Qinghai (Li *et al*., 1988), Gansu (Sun, 1986) and Shaanxi (Huang *et al*., 1980), Northwest China. Dicksoniaceae are abundant with a great variety and dominate the flora. There are not only more than 10 species of *Coniopteris*, but also many of *Eboracia*, *Dicksonia* and *Gonatosorus* in *Coniopteris-Phoenicopsis* Flora Dipteridaceae still exist, though they have greatly declined. Osmundaceae are represented by many *Todites* and some new elements such as *Tuarella* and *Raphaelia*. *Cladophlebis* with large pinnules that have probable affinities with Osmundaceae are greatly developed. However, Marattiaceae, Matoniaceae, Schizaeaceae and *Gleichenites* of Gleiche-

niaceae rarely occur. It is of great significance that a species of Cyatheaceae *Cyathea ordosica* Chu is presented.

The Early Jurassic flora in the South Phytogeographic Province is known as *Marattiopsis-Otozamites* and *Todites princeps-Ptilophyllum* assemblages (Wu *et al.*, 1980; Zhou, 1984). The former one is discovered in the Early Jurassic, while the late one ranges from the later of the Early Jurassic to the Middle Jurassic. The Fhilicopsida in this flora include numbers of Dipteridaceae, Marattiaceae, Matoniaceae, Osmundaceae, Gleicheniaceae and Schizaeaceae. Dicksoniaceae firstly appear in *Marattiopsis-Otozamites* assemblage and are common in *Todites princeps-Ptilophylmum* assemblage.

Owing to a universal arid climate in Late Jurassic, the floras in China greatly decline and only very few ferns have been reported.

2.3 Cretaceous

The flora of the Early Cretaceous in Northeast China is very developed and consists of more than 200 species including about 100 species of fern (Zhang *et al.*, 1980; Zheng *et al.*, 1982; Li *et al*, 1986; Chen *et al.*, 1988; Deng, 1992, 1993, 1994, 1995a, b; 1997; Deng *et al.*, 1997; Deng and Chen, 1997). Dicksoniaceae flourish again and are represented by *Coniopteris* (with more than 10 species), *Dicksonia* (about 2 species) and *Acanthopteris*. Schizaeaceae are very common, but only *Ruffordia goepperti* (Dunk.) Seward had been found as foliate fossil. Osmundaceae, another common family, are frequently presented by *Osmunda*. Matoniaceae and Dipteridaceae are very rarely seen.

A distinct character of the Early Cretaceous Filicopsida in Northeast China is that the monolete spore members appear in the early of the Early Cretaceous and increase rapidly in the middle of the Early Cretaceous. There are about 20 species of these monolete ferns have been found (Deng, 1995c). The main elements are *Athyrium* of Athyriaceae, *Dryopterites* of Dryopteridaceae, *Arctopteris* and *Palibiniopteris* of Pteridaceae and *Asplenium* of Aspleniaceae. Most of these ferns have affinities with the extant genera.

During the Early Cretaceous, the South Phytogeographic Province expands northward to North and West China. The floras in the province relatively less developed. The Filicopsida consists of Weichseliaceae, Schizaeaceae, Matoniaceae and Gleicheniaceae. Dicksoniaceae are represented by a small number of 2 ~ 3 species and *Cladophlebis* is characterized by small pinnules. In Tibet, Gleicheniaceae and Schizaeaceae that are represented by *Klukia* and *Scleropteris* usually dominate the fern group.

From the Late of the Early Cretaceous (about Albian) to the end of the Mesozoic, the flora gradually declines along with the increase of Angiosperms. Only few ferns placed in *Asplenium*, *Dryopteris* and *Athyrium* have been recorded.

3 Angiopteridaceae

Danaeopsis, which is usually assigned to Angiopteridaceae flourishes in both the South and

North Phytogeographic Provinces during the Late Triassic, but disappears before the Early Jurassic. So it is considered as an exclusive Triassic genus. *Danaeopsis fecunda* Hall is the most common species, and *D. marantacea* (Presl.) Heer, *D. magnifolia* Huang et Zhou and *D. plana* (Emmons) are recorded as well. The fertile compressions show that the sporangia are closely scattered on the abaxial surface of the pinnae. However, the detailed structures of the sporangium and the spores *in situ* have not been examined.

4 Marattiaceae

The record of the Mesozoic marattiaceous fossil in China ranges from the Late Triassic to the Middle Jurassic. *Marattia* (= *Marattiopsis*) *asiatica* (Kaw.) Harris, *M. munsteri* (Goepp.) Schimp., *M. horensis* (Schimper), *M. paucicostata* Li and *M.* sp. have been described. *Marattiopsis asiatica* is the most common one, which is widely distributed in South and North China. Recently, the fertile organs and *in situ* spores of this species have been described and illustrated in detail (Wang, 1999). Its synangia are linear-shaped and attached on the secondary vein, which consist of 25 ~ 40 pairs of sporangia. Each sporangium contains a large number of monolete spores. The spores are elliptic with granular exine.

Bernoullia, another important Late Triassic fern of China, is also considered to belong to Marattiaceae. Its sporangia are in multi-row on the abaxial surface of the pinnae, but its spores *in situ* are still unknown.

5 Dipteridaceae

Dipteridaceae are represented by five genera: *Clathropteris*, *Dictyophyllum*, *Goeppertella*, *Hausmannia* (*Protorhipis*) and *Thaumatopteris* in China. This family reaches its peak of development in the Late Triassic and begins their decline in the Jurassic, and has been rarely recorded in the Late Jurassic and the Cretaceous. In the Late Triassic, the dipteridacean ferns, composed of about 30 species in 5 genera, dominate the floras in the South Phytogeographic Province. The main species are *Clathropteris elegans* Oishi, *C. meniscioides* Brongn., *C. mongugaica* Srebrodolskaka, *C. obovata* Oishi, *C. platyphylla* (Goeppert), *C. tenuinervis* Wu, *Dictyophyllum exile* (Brauns) Nath., *D. gracile* (Tur.-Ket.) Chu, *D. muensteri* (Gorppert), *D. nathorsti* Zeiller, *D. nilssoni* (Brongn.) Goeppert, *D. serratus* (Kurr.) Frentzen, *Hausmannia* (Protorhipis) *emeienis* Wu, *H. ussuriensis* Kryshtofovich, *Thaumatopteris brauniana* Popp., *T. contracta* Li et Tsao, *T. dunkeri* (Nathorst), *T. elongata* Oishi, *T. expansa* (Krysht. et Pryn.) Chu, *T. fuchsii* (Zeiller) Oishi et Yam., *T. huiliensis* Li et Tsao, *T. nodosa* Chu, *T. remauryi* (Zeiller) Oishi et Yam, *T. vieillardii* (Pel.) Oishi et Yam., *T. remauryi* (Zeiller), *Goeppertella microloba* (Schenk) Oishi et Yam., *G. kwangyuanensis* P. Lee, *G. xiangchengensis* Li et Wu and *G. memeria-watanabei* Oishi et Huzioka. However, although the dipteridacean ferns are also common in the North Phytogeographic Province, only *Dictyophyllum chengdeensis* Mi *et al.*, *D. nathorsti* Zeiller, *D. serratus* (Kurr.) Frentzen, *D.* sp., *Hausmannia* (*Protorhipis*) *ussuriensis*

Kryshtofovich and *Goeppertella* sp. have been reported.

In the Early and Middle Jurassic, Dipteridaceae are reduced to about 10 species in the South Phytogeographic Province, but relatively increase in the North Phytogeographic Province. The common species are *Clathropteris obovata* Oishi, *C. platyphylla* (Goeppert) Brongn., *C. pekingensis* Lee et Shen, *Dictyophyllum nathorsti* Zeiller, *D. nilssoni* (Brongniart) Goeppert, *Thaumatopteris hissarica* (Brick) Sextel, *T. schenki* Nathorst, *T. pusilla* (Nathorst) Oishi et Yam., *Hausmannia* (Protorhipis) leeiana Sze, *H. ussuriensis* Kryshtofovich, *H. nariwaensis* Oishi and *H. rara* Vakhrameev.

The *in situ* spores of *Clathropteris meniscioides* from Late Triassic of Sichuan, Southwest China have been examined (Lee, 1964). The spores are trilete, about 41 μm in diameter, sculptured with coarse granules.

6 Matoniaceae

The family Matoniaceae has a fossil record from the Triassic to the Early Cretaceous in both the North and South Phytogeographic Provinces of China, but has a relatively rich record in the South Phytogeographic Province. The chief numbers include *Phlebopteris affinis* Schenk, *Ph. angustiloba* (Presl) Raciborski, *Ph. brauni* (Goepp.) Hirmer et Hoerhammer, *Ph. digitata* Liu and *Ph. polypodioides* Brongn. In the Early Cretaceous, matoniaceous ferns are very rare in China except Tibet and eastern Heilongjiang, Northeast China. The common elements are *Matonidium goepperti* (Ettingshausen) Schenk, *Phlebopteris splendidus* Li and *Ph.* sp.. The sori, sporangia and spores *in situ* of *P. polypodioides* have been examined in detail (Wang and Mei, 1999). The spores are trilete, sub-triangular in polar view, about 36 ~ 56 μm in diameter, and with smooth surface, which are close to the dispersed spore *Dictyophyllidites harrisii* Couper.

7 Schizaeaceae

The schizaeaceous ferns appear reliably in the Early Jurassic, represented by *Klukia* and *Stachypteris*. However, in China the foliage fossils of Mesozoic Schizaeaceae are represented by a few species, which are of great stratigraphic significance. *Klukia exilis* (Phillips) Racoborski is found from the Lower Jurassic Nansuletu Group, Inner Mongolia, North China (Wang, 1984), and *Stachypteris alata* Zhou from the Lower Jurassic Guanyintan Formation of Hunan Province, Center China (Zhou, 1984). Both of these two species are identified based on fertile compressions, but no spores *in situ* have been obtained. Recently, the author (Deng and S. J. Wang, 2000) established a new genus *Klukiopsis* on the basis of a quite detailed observation of the type species *Klukiopsis jurassica*. This genus is characterized by the abaxial sporangia arranged in two rows, apical and complete annulus and more than 800 smooth trilete spores in each sorus. These characters demonstrate that *Klukiopsis* is distinct from both of the known fossil and extant schizaeaceous genera.

In the Lower Cretaceous, many dispersed spores genera, such as *Cicatricosisporites*, *Appendicisporites*, *Concavissimisporites*, *Lygodiumsporites* and *Pilosisporites*, are assigned to Schizaeaceae.