Origin of the Cathaysia flora in Asia

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Some obvious changes in floral components of the Cathaysia area occurred during the transition from Early Carboniferous to Late Carboniferous, which resulted in extinctions of many typical plant elements of the Lepidodendropsis flora, and began occurrences of a number of forerunners of the Cathaysia flora. Therefore, the Cathaysia flora did not originate from the Euramerica flora; it derived from the global identical Lepidodendropsis flora of the Early Carboniferous. From the beginning of the Namurian A, the Cathaysia flora gradually separates from the Lepidodendropsis flora. It can be recognized as an independent flora in the early Late Carboniferous (Namurian B to C). The flora is characterized by a variety of oriental species of lycopods and many endemic elements of ferns and pteridosperms, etc. It ranges from the beginning of early Late Carboniferous to the end of Permian.

Key-words—Cathaysia Flora, Lepidodendropsis Flora, Permian, Carboniferous, Asia.

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सारांश

एशिया में कैथेसिआ वनस्पतिजात की उत्पत्ति

सन केकिन

कैथेसिआ क्षेत्र के वनस्पतिजातीय अवयवों में प्रारम्भिक कार्बनीफेरस से अनंतिम कार्बनीफेरस के परिवर्तन के समय कुछ विशेष परिवर्तन हुए जिसके परिणामस्वरूप लेपिडोडेन्ड्रॉप्सिस वनस्पतिजात के बहुत से सामान्य पादप अवयवों का विलुप्तीकरण हो गया। इससे यह स्पष्ट होता है कि कैथेसिआ वनस्पतिजात की उत्पत्ति यूरामेरिका वनस्पतिजात से नहीं हुई है। वस्तुतः इसका उद्भव प्रारम्भिक कार्बनीफेरस कल्प के भूमण्डलीय लेपिडोडेन्ड्रॉप्सिस वनस्पतिजात से ही हुआ है। नामुरिअन ए. के प्रारम्भ से ही कैथेसिआ वनस्पतिजात लेपिडोडेन्ड्रॉप्सिस वनस्पतिजात से शनैःशनैः अलग हो गया। यह वनस्पतिजात लाइकोपोडी पौधों की अनेक जातियों तथा फर्नों एवं टेरिडोस्पर्मी पौधों की देशज जातियों आदि से अभिलक्षणित है। यह वनस्पतिजात प्रारम्भिक अनंतिम कार्बनीफेरस से परमी कल्प के अन्त तक पाया जाता है।

THE Cathaysia flora is one of four famous floras of Carboniferous and Permian periods in the world, which is mainly distributed in present-day China, Korea, Japan, Laos, Thailand, Indonesia and Malaysia. This flora is characterized by the genera *Cathaysiodendron, Lobatannularia, Tingia, Conchophyllum, Fascipteris, Emplectopteris, Emplectopteridium, Cathaysiopteris, Gigantopteris, Gigantonoclea* and a considerable number of endemic species, namely *Lepidodendron oculusfelis, L. posthumii, L. szeianum, Sphenophyllum sinocoreanum, Annularia orientalis, Pecopteris taiyunensis, Alethopteris norinii, Calipteridium koraiense, Taeniopteris mucronata, Psaronius sinensis, Pterophyllum daihoense, Psygmophyllum multipartitum,* etc. China is one of the most important localities of the Cathaysia flora in Asia.

The term Cathaysia flora was first proposed by Halle (1935). In fact, Cathaysia is the name used on Grabau's palaeogeographical maps for the Palaeozoic land mass in East Asia. Halle gave the term Cathaysia flora for the entire Carboniferous and Permian plant succession in East Asia. According to Halle, the Cathaysia flora is not synonymous with the Gigantopteris flora, because the latter corresponds to only the last phase of the Palaeozoic flora of Cathaysia.

Owing to the concerted efforts of Chinese and foreign palaeobotanists for more than a century, a great progress of studies on the Cathaysia flora has been made, but they do not still reach unanimity of views on its origin. At present three different viewpoints on the origin of the Cathaysia flora are listed as follows:

1. Lee Hsing - hsüeh (Li Xingxue, 1963), Li Xingxue and Yao Zhaoqi (1982) put forward that the Cathaysia flora had already become an independent flora in the Taiyuanian time (Stephanian), and this flora, known as the Early Cathaysia flora, was represented by the flora of Taiyuan Series in North China. Li Xingxue and Yao Zhaoqi (1982) further indicated that the Cathaysia flora was developed entirely out of Middle Carboniferous Euramerican flora in East Asia. At the same time they considered that this flora reached its development climax during the early Late Permian and got largely extinct by the beginning of the Triassic.
2. Chaloner and Meyen (1973) indicated that the Cathaysia area could already be recognized as a distinct floral province in Westphalian time. Their opinion was based on records of *Lepidodendron oculus-felis, Tingia, Conchophylum* and *Kaipingia* in Westphalian time.
3. Sun Keqin (1990) put forward that the origin age of the Cathaysia flora was in Namurian, and emphasized that the Cathaysia flora derived from the Lepidodendropsis flora of Early Carboniferous in the world. Seeing that the flora of the early Late Carboniferous (Namurian B and C) of the Cathaysia area was characterized by a variety of oriental lycopods and many endemic elements of ferns and pteridosperms, Sun Keqin (1993 1995), Mi Jiarong and Sun Keqin (1995) pointed out that the Cathaysia flora had become an independent flora in the early Late Carboniferous (Namurian B to C). It ranges from the beginning of the early Late Carboniferous to the end of the Permian in age.

It is known that the Lepidodendropsis flora of the Early Carboniferous is widely distributed all over the world and has similarities on a global scale. Jongmans (1952, 1954) considered that all Early Carboniferous plant assemblages belonged to the same phytogeographic province on the basis of the worldwide distribution of the genera *Lepidodendropsis, Rhacopteris* and *Triphyllopteris,* etc. It is possible that the Lepidodendropsis flora represents the floral appearance of the Late Devonian and the Early Carboniferous. This flora is characterized by *Lepidodendropsis, Sublepidodendron, Archaeosigillaria, Archaeocalamites, Sphenopteridium, Rhodeopteridium, Fryopsis, Cardipteridium* and *Anisopteris,* etc. (Chaloner & Lacey, 1973). Climatic differentiation was not obvious during the Early Carboniferous. This is a basic condition on which the Lepidodendropsis flora depends for existence. Raymond (1985) believed that both the poles became cooler at the end of the Early Carboniferous (Namurian A) and the region bordering Tethys became warmer. Owing to the climatic changes, some obvious changes in floral components of the Cathaysian, Euramerican, Angara and Gondwanan areas occurred during the transition from the Early to Late Carboniferous, which resulted in extinctions of some typical plant genera, such as *Lepidodendropsis, Sublepidodendron, Archaeocalamites, Triphyllopteris, Cardiopteridium, Rhacopteris, Fryopsis, Sphenopteridium, Rhodeopteridium* and *Adiantites,* etc. of the Early Carboniferous. In addition, these extinctions also included numerous species of lycopods, ferns and pteridosperms of this age. Moreover, a number of forerunners of the Cathaysia flora had already existed in the Cathaysia area during the late Early Carboniferous (Late Visean-Numurian A). Zhao Xiuhu *et al.* (1982) described fossil plants from the Tzushan Series in Yudu of Southern Jiangxi, China. Among them there are some oriental lepidophytes such as *Lepidodendron quadratum* Zhao et Wu, *L. yuduense* Zhao et Wu and *L.* cf. *shanyangense* Wu et He. They considered that the age of this flora belonged to the Late Visian to Naumurian. Mi Jiarong *et al.* (1990) described a number of fossil plants from the Early Carboniferous strata (Late Visean to Namurian A) of Benxi, Liaoning, including two Cathaysian species such as *Lepidodendron ninghsiaense* Lee and *Conchophyllum richthofenii* Schenk. Wu Xiuyuan (1992) described fossil plants from the Yangshan Formation the late Early Carboniferous (Visean to Early Namurian) in Gushi, Henan, China. Some species of lepidophytes reflect the oriental features of the

Cathaysia flora such as *Lepidodendron* aff. *aolungpylukense* Sze, *L.*cf. *shanyangense* Wu et He, *L. dabieshanense* Wu, L.?*gushiense* Wu, *Cathaysiodendron* sp. and *Bothrodendron flabellatum* Wu. These elements ought to be regarded as the forerunners of the Cathaysia flora. Chen Fen *et al.* (1995) studied fossil plants from the Carboniferous strata of Ningxia and adjacent regions, China. Among some fossil plants, some elements belong to the Cathaysian type such as *Lepidodendron ninghsiaense* Sze et Lee, *L. subrhomibcum* Gu et Zhi and *Tingia trilobata* Stockmans et Mathieu. These elements emerged from Early Namurian strata. The above mentioned facts show that the forerunners of the Cathaysia flora begin to occur in late Early Carboniferous, that is, the *Lepidodendropsis* flora is on the decline, while the Cathaysia flora begin to develop.

The genera *Paripteris* and *Linopteris* are regarded as the representative elements of the Euramerican type, which generally occur in the Westphalian strata of the Euramerican area. In the Cathaysian area, a number of species of *Paripteris* and *Linopteris* have been found in the Namurian strata, including *P. densissima* Gu et Zhi, *L. intricata* Gu et Zhi and *L. Lepida* Gu et Zhi. In addition, *Linopteris brongniartii* Gutbier and *L. neuropteroides* (Gutbier) Potonié were recorded from the Early Namurian strata (Li Xingxue *et al.*, 1974; Chen Fen *et al.*, 1995), while *Paripteris gigantea* (Sternberg) Gothan, *P. pseudogigantea* (Potonié) were described from the Visean to Namurian strata (Zhao Xiuhu *et al.* 1974; Chen Fen *et al.*, 1995). These facts show that *Paripteris* and *Linopteris* formerly considered to be the typical elements of the Euramerica flora are actually later than those of the Cathaysia flora in age. Therefore, *Paripteris* and *Linopteris* in the Cathaysian area could not be regarded as typical Euramerican elements. The Cathaysian and Euramerican areas were located in the equatorial region in a tropical climate during Carboniferous-Permian. Therefore, some plants from the two areas had certain similarities and showed parallel evolution. Thus, the Cathaysia flora did not originate from the Euramerica flora, while it derived from the Lepidodendropsis flora of the Early Carboniferous.

The flora of the Cathaysia area, considered to be of Namurian age, has a number of genera in common

Table 1 —Occurrence of the Cathaysian endemic species through the Namurian

Species	Age	Locality	Reference
Lepidodendron aloungpylukense Sze	Namurian	Delingha, Qinghai	Sze Hsingchien, 1960
L. cf. *aloungpylukense* Sze	Namurian B	Zhongwei, Ningxia	Wu Xiuyuan *et al.*, 1987
L. jiandeense Zhao et Chen	Namurian	Jiande, Zhejiang	Zhao Xiuhu *et al.*, 1986
L. ninghsiaense Sze et Lee	Namurian A and B	Hulusitai and Wuda, Inner Mongolia	Wu Xiuyuan *et al.*, 1987; Chen Fen *et al.*, 1995
L. quadratum Zhao et Wu	Namurian	Yudu, Jiangxi; Jiande, Zhejiang	Zhao Xiuhu *et al.*, 1982; Zhao Xiuhu *et al.*, 1986
L. cf. *shanyangense* Wu et He	Namurian	Yudu, Jiangxi	Zhao Xiuhu *et al.*, 1982
L. subrhombicum Gu et Zhi	Namurian A	Wuda, Inner Mongolia	Chen Fen *et al.*, 1995
L. yuduense Zhao et Wu	Namurian	Yudu, Jiangxi	Zhao Xiuhu *et al.*, 1982
Cathaysiodendron? sp.	Namurian C	Hulusitai, Inner Mongolia	Wu Xiuyuan *et al.*, 1987
Bothrodendron circulare Sze	Namurian B and C	Delingha, Qinghai	Sze Hsingchien, 1960
B. ellipticum Zhao	Namurian	Changshan, Zhejiang	Zhao Xiuhu *et al.*, 1986
B. reticulatum Sze	Namurian B and C	Delingha, Qinghai	Sze Hsingchien, 1960
Tingia trilobata Stockmans et Mathieu	Namurian A	Zhongning, Ningxia	Chen Fen *et al*, 1995
Conchophyllum richthofenii Schenk	Namurian A	Benxi, Liaoning	Mi Jiarong *et al*, 1990
Sphenopteris lee Sze	Namurian	Liucheng, Guangxi	Gu et Zhi, 1974
S. cf. *parabaeumleri* Sze	Namurian C	Zhongwei, Ningxia	Wu Xiuyuan *et al.*, 1987
Paripteris cardiopteroides (Bohlin)	Namurian B	Zhongwei, Ningxia	Wu Xiuyuan *et al.*, 1987
P. kaipingiana (Sze)	Namurian B and C	Dashetai, Inner Mongolia	Huang Benhong, 1987
P. otozamioides (Sze et Lee)	Namurian A to C	Zhongning, Ningxia	Chen Fen *et al*, 1995
Linopteris densissima Gu et Zhi	Namurian B	Zhongwei, Ningxia	Wu Xiuyuan *et al.*, 1987
L. intricata Gu et Zhi	Namurian A	Jingyuan, Gansu	Li Xingxue *et al.*, 1974
L. lepida Gu et Zhi	Namurian A	Jingyuan, Gansu	Li Xingxue *et al*, 1974
L. simplex Gu et Zhi	Namurian A	Zhongning, Ningxia	Chen Fen *et al.*, 1995
Alethopteris shidfenensis Huang	Namurian B and C	Dashetai, Inner Mongolia	Huang Benhong, 1987
Palaeoweichselia yuanii Sze	Namurian B and C	Dashetai, Inner Mongolia	Huang Benhong, 1987
Lopinopteris intercalata (Sze)	Namurian	Leping, Jiangxi	Gu et Zhi, 1974

with that of the Euramerica area such as *Lepidodendron, Bothrodendron, Paripteris* and *Linopteris,* etc., but it has already had numerous Cathaysian elements and endemic species, such as *Lepidodendron aolungpylukense, L. ninghsiaense, L. quadratum, L. subrhombicum, Cathaysiodendron?* sp., *Bothrodendron circulare, Conchophyllum richthofenii, Paripteris kaipingiana, Palaeoweichselia yuanii, Lopinopteris intercalata,* etc. A number of the Cathaysian endemic species occurred in the Namurian (see Table 1). The flora of the early Late Carboniferous (Namurian B and C) of the Cathaysian area is characterized by a variety of oriental species of lycopods and many endemic species of ferns and pteridosperms, etc. which exhibit an extensive distribution in time and space (see Table 1). The lycopods which were quite abundant during the early Late Carboniferous, included a number of Cathaysian species. In the early Late Carboniferous (Namurian B and C), the Cathaysia flora became an independent flora comprising mainly lycopods, ferns, pteridosperms, sphenopsids and cordaitean gymnosperms, which is called the *Lepidodendron aolungpylukense-Bothrodendron circulare* Assemblage. The Cathaysia flora is characterized by the gradual increase in sequence from the early Late Carboniferous to the early Late Permian. The Cathaysia flora ranges from the beginning of the early Late Carboniferous to the end of the Permian. The most obvious changes of dry climate and tectonic movement caused the extinction of the Cathaysia flora by the end of the Late Permian.

As a whole, the climatic changes made significant effect in the Lepidodendropsis flora during the transition from the Early Carboniferous to Late Carboniferous. The Cathaysia, Euramerica, Angara and Gondwana floras were all derived from the same Lepidodendropsis flora, but developed in different environments respectively.

REFERENCES

Chaloner WG & Lacey WS 1973. The distribution of Late Palaeozoic floras. *In*: Hughes NF (Editor)— *Organisms and continents through time. Spec. Pap. Palaeont.* **12**: 271-289.

Chloner WG & Meyen SV 1973. Carboniferous and Permian floras of the northern continents. *In*: Hallam A (Editor)— *Atlas of palaeobiogeography*: 186-187. Elsevier, Amsterdam.

Chen Fen, Zhou Hongrui, Sun Keqin, Jia Jinhua, Zhang Jianping & Wu Zhiguo 1995. Carboniferous flora in Ningxia and adjacent regions. *Geosci. J Graduate School, China Univ Geosci* **9**(1): 1-10 (Chinese with English Abstract).

Gu & Zhi 1974. *Palaeozoic plants from China*. Science Press, Beijing (in Chinese).

Halle TG 1935. On the distribution of the Late Palaeozoic flora in Asia. *Geogr. Ann.* **17**: 106-111.

Huang Benhong 1987. Middle - Late Carboniferous strata and fossil plants in Dashetai District, Nei Mongol. *Bull. Shenyang Inst. Geol. Min. Res., Chinese Acad. Geol. Sci.*: 1-27 (in Chinese with English Abstract).

Jongmans. WJ 1952. Some problems on Carboniferous stratigraphy. *Compt. Rend Congr. Avan. Edud. Stratigr. Carbon.*, **1**: 295-306.

Jongmans WJ 1954. The Carboniferous flora of Peru. *Bull. Brit. Mus. Nat. Hist. Geol.* **2**: 191-223.

Lee Hsing-hsüen 1963. *Fossil plants of the Yuehmenkou Series, North China. Palaent. sin.* N. Ser. A **6**: 1-185 (in Chinese and English).

Li Xingxue & Yao Zhaoqi 1982. A review of recent research on the Cathaysia flora in Asia. *Am. J. Bot.* **69** (3): 479-486.

Li Xingxue (Lee Hsing-hsüeh), Yao Zhaoqi (Yao Chao-qi), Cai Zhongyang (Tsai Chung-yang) & Wu Xiuyuan (Wu Siu-yüan) 1974. Carboniferous biostratigraphy of Tsingyuan District, E. Kansu, China. *Mem. Nanking Inst. Geol. Palaeont., Acad. sin.* **6**: 99-118 (in Chinese).

Mi Jiarong & Sun Keqin 1995. An inquiry on the origin of the Cathaysian flora. *J. Changchun Univ. Earth Sci.* **25** (1): 1-5 (in Chinese with English Abstract).

Mi Jiarong, Sun Keqin & Jin Jianhua 1990. Early Carboniferous fossil plants from Benxi, Liaoning. *J. Changchun Univ. Earth Sci.* **20**(4): 362-368 (in Chinese with English Astract).

Raymond A 1985. Floral diversity, phytogeography and climatic amelioration during the Early Carboniferous (Dinantian). *Paleobiology* **11** (3): 293-309.

Sun Keqin 1990. *Late Carboniferous and Early Permian flora and palaeoecology in the Zibo area, Shandong*. Ph. D. Thesis, Changchun College of Geology (in Chinese with English Abstract).

Sun Keqin 1993. Origin and formative mechanism of the Cathaysia flora. *In: Papers for the Ist Academic Conference of New Theory and New Viewpoint of China* : 289-294. China Science & Tech. Press (in Chinese).

Sun Keqin 1995. Origin of the Cathaysia flora. *Abstract, Int. Conf. Divers. Evolution of terrestrial plants in Geological Time (ICTPG), Nanjing*: 18-19.

Sze Hsingchien 1960. The Namurian flora form the Aolungpuluke region, Chinghai Province. *In:* Institute of Geology and Palaontology, Academia Sinica *et al.* (Editors) — *Contribution to geology of the Mt. Chilien*, Beijing: Science Press **4**(1): 13-21 (in Chinese).

Wu Xiuyuan 1992. Fossil plants from Yangshan Formation (Early Carboniferous) in Gushi, Henan. *Acta palaeont. sin.* **31**(5): 564-584 (in Chinese with English Abstract).

Wu Xiuyuan & Zhao Xiuhu 1987. Namurian flora Ningxia, China. *In*: Ningxia Bureau of Geology and Mineral Resources, Nangjing Institute of Geology and Palaeontology, Academia Sinica (Editors)— *Namurian strata and fossils of Ningxia, China*: 21-54. Nanjing Univ. Press (in Chinese with English Abstract).

Zhao Xiuhu & Wu Xiuyuan. 1982. Fossil plants from the Tzushan Series in Yudu of Southern Jingxi. *Acta Palaeont. sin.* **21**(6): 699-708 (in Chinese with English Abstract).

Zhao Xiuhu, Wu Xiuyuan & Chen Qishi 1986. Carboniferous flora in Western Zhejiang. *Mem. Nanjing Inst. Geol. Palaeont., Acad. sin.* **22**: 1- 70 (in Chinese with English Abstract).