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华夏植物群的起源、演替与分布

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提 要 对华夏植物群起源新观点作了补充论述,植物群的演替与分布也作了概要综述。还以附表显示晚古生代全球有关植物群地理区划及可能的渊源关系。

关键词 华夏植物群 起源 演替 分布 东亚

长期以来,华夏植物群被公认为石炭纪和二叠纪四大主要植物群之一,其他三者为欧美植物群,安加拉植物群和冈瓦纳植物群。

华夏植物群虽然包括许多欧美型的属,有些甚至连种名都和其他植物群的一样,但它可以下列一些地方性和标志性的属或类群的出现而识别:1)大羽羊齿类,2)织羊齿类,3)瓣轮叶类,4)齿叶类,5)束脉蕨类,6)贝叶属,7)带羊齿类(许多地方种),8)东方型鳞木类(李星学,1995)。

1 植物群的起源

自 1870 年李希霍芬(V.Richthofen)发现华夏植物群的首要代表类群——大羽羊齿植物起,华夏植物群的研究历史已有 120 多年(Li, 1996),但有关它的起源问题依然没有解决。

早石炭世以来,东亚植物群所在的气候和生态环境与西欧、北美的基本相似,而且其晚石炭世植物群尽管已有少量华夏植物群标志类群或地方种的存在,但许多属种仍然和欧美植物区的非常相似。因而,流行的观点是华夏植物群起源于早石炭世或维斯发期(Westphalian)的欧美植物群。但是,近年来,有些脉羊齿类,如 *Paripteris gigantea* 和许多种 *Linopteris* 先后始现于中国韦宪期(Visean)与纳缪尔 A 期(Namuria A)的发现,而它们在西欧是直到维斯发期才出现的。鳞木类植物在中国也出现早一些,有些东方型鳞木类发现于早石炭世。此外,*Lepidodendropsis* 和 *Sublepidodendron mirabile* 被视为欧美植物群区泥盆纪末与石炭纪初之交的标志性属种,在中国也较早地广布于中、晚泥盆世。更值得注意的是,某些特殊的楔叶类植物,如 *Sphenophyllum lungtanense* 和 *Xihuphyllum*(陈其 ,1988),在华南晚泥盆世就有发现。孢粉的研究记录多少也有类似现象。例如,双气囊粉(如 *Limitisporites*)在纳缪尔早期靖远组(相当 E_2 菊石带)已经出现,而在红土洼组下部(相当 H 菊石带)到上部(相当 R_2—G_1 菊石带)继续发育并多样化,而西欧的双气囊粉则是直到维斯发期才出现。同样情况也存在于某些动物化石中,例如,鱼类中的 *Bothriolepsis*,西方国家的传统观点是当作晚泥盆世标志化石对待的,在中国却出现于较老地层。因而,将欧美对地层古

生物研究的传统划分方案作为中国的对比标准，实在值得怀疑。据此，笔者等(李星学等，1993)曾认为，华夏植物群很可能起源于主要生存于中国早石炭世的前华夏植物群。

近来对东亚晚古生代大地构造的研究更为我们提供了有利于我们设想的论据。Grabau (1923—1924)最早提出的华夏古陆，通常认为是滋生华夏植物群的摇篮，近年来被重建或另名为华夏复合大陆(林金录，1987，1989)、大陆地体群(Metcalfe，1988)、微型大陆(Nie，Rowley and Ziegler，1990)、或古地块群(Cleal and Thomas，1991)等。这些大地构造单元都被认为是相隔若干距离而散布于同一海洋中的一些岛屿所组成。这种相互隔离的状态有利于生物地方性分子的发育。

2 植物群的演替

华夏植物群的发育、演替可分 3 个时期(Lee，1963)，即早、中、晚三期；每期又分 A、B 两段，每段包括 1—2 个植物组合。有关这些划分、地质时限、代表岩组以及相应的植物组合名称等均综合列于表 I 。

晚石炭世和早二叠世地层在华北分布很广，并且非常发育，从本溪组到石千峰组之间的生物地层及植物组合序列均未见明显间断。其中，较下部的岩层由海陆交互相沉积组成，层位较高则陆相成分增多，以至最后变成纯陆相沉积。因而，华北、特别是山西中部的太原被视为是研究华夏植物群演替的理想地区。

从表 I 可见：

1)．本溪组(相当西北地区的红土洼组)以具 *Paripteris gigantea-Linopteris neuropteroides-Conchophyllum richthofeni* 植物组合为特征，其中的石松类具最重要位置，真蕨及种子蕨纲居次，其它类别植物都比较少。此一植物组合显示了华夏植物群的一般面貌，它和欧美植物区晚石炭世植物群没有明显区别，但是华夏植物群特有的标志属种，如 *Conchophyllum* 属，齿叶类的 *Tingia hamaguchii*，东方型鳞木类的 *Lepidodendron oculus-felis*，*L．posthumii*，以及某些脉羊齿类的地方种(如 *Paripteris kaipingensis*，*Linopteris* spp．)已开始出现。

2)．太原组的中、上部，从前视为相当于西欧斯蒂芬期(Stephanian)沉积，由于 1987 年中国采用了国际流行的对石炭系的二分方案，现在几乎全部改归于早二叠世的阿舍利期(Asselian)。太原组植物群又名为 *Neuropteris ovata-Lepidodendron posthumii* 组合，石松类、楔叶纲、真蕨及种子蕨纲均为其优势类群。东方型鳞木类的特别发育是太原植物群与欧美植物区同期植物群明显的不同点之一。

由于太原组下部的植物化石在华北本部发现很少，其相当于西欧斯蒂芬期植物群的面貌还很不清楚。有些作者(Wu，1995，p．112)却认为，在内蒙古准噶尔煤田、陕北韩城居水河及宁夏中卫窑沟太原组下部产 I 类 *Montiparus-Triticites* 带的地层中发现的植物化石，可能代表中国的斯蒂芬期植物群。此一植物群含有太原组中、上部常见的那些重要分子，如东方鳞木类(即 *Lepidodendron oculus-felis*，*L．posthumii*，*L．szeianum*，*Cathaysiodendron nanpiaoense*)以及许多楔叶纲和栉羊齿类植物，而且像 *Neuropteris ovata* 和 *Tingia hamaguchii* 这些重要分子也不罕见。因而，太原组下部植物组合与其中、上部植物组合之间，很难发现有什么可靠的分类单元上的区别。中国石炭纪末与二叠纪初植物群之间没有明显的变化，这一现象与欧美植物区的情况一样。

表Ⅰ　华夏植物群各期及地理亚区植物组合及代表地层综合对比

Comprehensive correlations of age(stage), phase, subprovince, representative formation and plant assemblage of Cathaysian flora

世	期	植物群	期	段	华北亚区 代表地层	华北亚区 植物组合	华南亚区 代表地层	华南亚区 植物组合
晚二叠世	Kazanian—Tatarian	华夏植物群	晚期	B	石千峰组（孙家沟组）	*Ullmannia bronnii*-*Yuania magnifolia* 组合	宣威组上部（滇黔）大隆组（川桂）	*Gigantonoclea guizhouensis*-*Ullmannia* cf. *bronnii*-*Annularia pingloensis* 组合
晚二叠世	Kazanian—Tatarian	华夏植物群	晚期	A	上石盒子组 上部	*Gigantonoclea hallei*-*Lobatannularia heianensis*-*Psygmophyllum multipartitum* 组合	龙潭组（苏浙皖）翠屏山组（闽）宣威组下部（滇黔）	*Gigantopteris nicotianaefolia*-*Lobatannularia multifolia*-*Schizoneura manchuriensis* 组合
晚二叠世	Kazanian—Tatarian	华夏植物群	晚期	A	上石盒子组 下部	*Gigantonoclea lagrelii*- *Lobatannularia ensifolia*-*Fascipteris hallei* 组合		
早二叠世	Asselian—Sakmarian—Artinskian—Kungurian	华夏植物群	中期	B	下石盒子组	*Emplectopteris triangularis*-*Tingia carbonica*-*Cathtaysiopteris whitei* 组合	童子岩组（闽南）堰桥组（苏浙）末坝口组（湘南）	*Gigantonoclea fukienensis*-*Otofolium* spp.-*Tingia carbonica* 组合
早二叠世	Asselian—Sakmarian—Artinskian—Kungurian	华夏植物群	中期	A	山西组 太原组（中上部）	*Emplectopteridium alatum*-*Taeniopteris mucronata*-*Lobatannularia sinensis* 组合 *Neuropteris ovata*- *Lepidodendron posthumii* 组合	矿山场组（滇东）乐平组中下部（赣西北）梁山组（川陕）马鞍组（鄂西）	? *Emplectopteris triangularis*-*Lepidodendron oculus-felis* 组合
晚石炭世	Namurian B—Westphalian—Stephanian	华夏植物群	早期	B	太原组（下部）（晋祠砂岩组）	*Alethopteris huiana* 组合（?）	马平组（海相）	
晚石炭世	Namurian B—Westphalian—Stephanian	华夏植物群	早期	A	本溪组	*Paripteris gigantea*-*Linopteris neuropteroides*-*Conchophyllum richthofenii* 组合	叶家塘组上部（浙西）梓山组上部（赣）草凉驿组（陕）	*Paripteris gigantea*-*Karinopteris acuta* f. *obtusa* 组合

（据李星学,1995）

3)．太原组顶部与山西组底部之间虽然没有明显的间断，但山西组植物群却以鳞木类植物的突然衰微和 *Emplectopteris*， *Emplectopteridium*， *Lobatannularia sinensis* 等二叠纪华夏植物群特有分子，以及许多楔叶纲、真蕨及种子蕨纲新分子(不少于100种)的出现为标志。这都表明，在中国华北阿舍利期与萨克马尔(Sakmarian)－阿丁斯克期(Artinskian)之间很可能发生过一次植物群的大变化。

4)．将近早二叠世之末，下石盒子组沉积时，其气候也逐渐变为干燥，华夏植物群依然繁荣茂盛，达到其发育的顶峰。这表现在一些最重要的代表植物特别丰富，如大羽羊齿类的 *Gigantopteris*， *Gigantonoclea*， *Cathaysiopteris* 和 *Tingia carbonica*， *Emplectopteris triangularis*，楔叶纲的许多种以及带羊齿类的不少地方类型。此一时期，除河南中部、皖北与苏北还有些煤层发现外，华北本部的造煤作用已基本终止。

5)．晚二叠世早期，西北地区与华北本部相继变成更为干旱的环境，富含植物化石的上石盒子组由杂色碎屑岩组成。*Lobatannularia*， *Gigantonoclea*， *Fascipteris* 及 *Sphenophyllum* 等属达到最发育阶段，同时中生代分子增加到占植物群总数的40％。松柏类也在增长。煤层仅在河南中部、皖北及苏北某些层位可以见到。

6)．晚二叠世末期，更严峻的干旱气候笼罩着华北，这明显地反映在石千峰组以紫红色为主的沉积物上，只有一些耐旱的植物化石发现于其泥砂质结核体中。石千峰植物群的面貌可以 *Ullmannia bronnii*-*Yuania magnifolia* 植物组合为代表。它主要由一些单种单属并以松柏类占优势的植物组成。西欧蔡希斯坦(Zechstein)植物群的所有代表植物几乎都有出现是石千峰植物群的最大特色，虽然其总体组分还有40％的分子是从上石盒子植物群衍延而来(如 *Yuania* 属和 *Taeniopteris taiyuanensis*， *T*. *nystroemii*)。石千峰植物群也包含少量安加拉分子，如 *Tatarina*， *Phylladoderma* 等属。此一植物群这种有趣的组成成分还表明，北半球自晚石炭世以来的植物地理分区现象，几乎全部消失于晚二叠世之末，至少华北是如此。

在华南，晚石炭世晚期的沉积几乎全属海相。二叠纪沉积也以海相为主，夹有陆相，有时还杂有侵入岩、火山喷发岩和煤层。植物化石较少且保存较差，以致华夏植物群的研究程度也不如华北的深。但是，如表Ⅰ所示，华南各代表岩组及其植物组合与华北的大致可以对比，只是其晚二叠世晚期植物群，特别是在黔滇交界区和藏北一带，明显地不同于华北的石千峰植物群。这里植物群仍很茂密地分布于沿海沼泽地带，鳞木类植物虽种类极少，但个体量多而地域分布甚广。辉木型树蕨和大羽羊齿类仍常有发现，而且造煤作用一直进行到二叠纪末。所有这些都表明，当时华南湿热、多雨的环境，与华北石千峰植物群所在的非常干旱、燥热的生态环境极不相同。

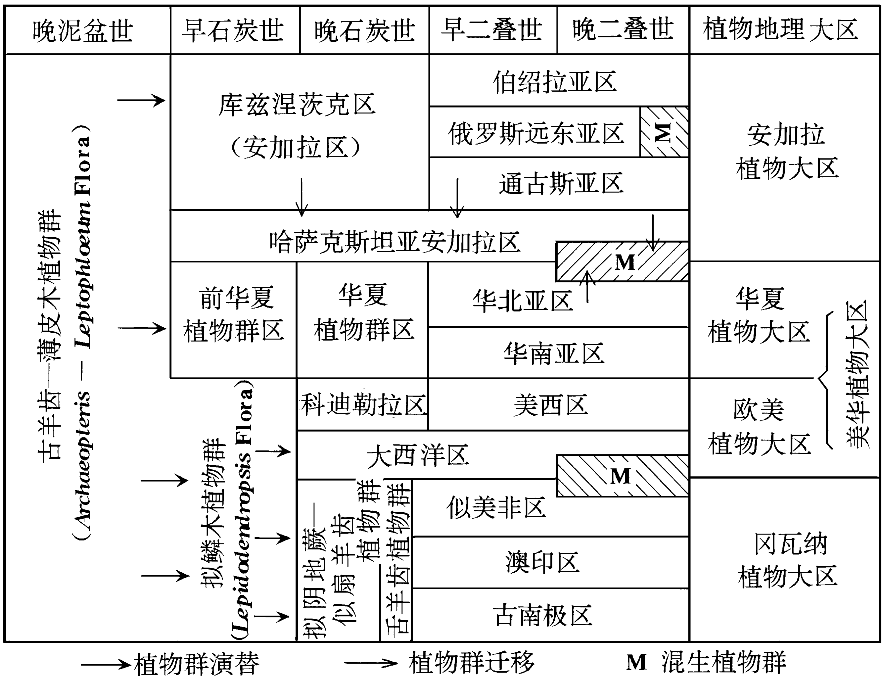
3 植物群的分布

华夏植物群的地质分布在前面已有叙述，晚古生代全球有关植物群地理区划与可能的渊源关系也概略示于表Ⅱ。只有其地理分布还待论述。

东亚广袤的地域中，除天山－兴安带以北的中国领域视为安加拉植物地理区以及藏南与滇西的较狭地带属于冈瓦纳植物地理区外，其余广阔的地带全属于华夏植物地理区。此

表Ⅱ　晚古生代全球植物地理区划示意

Chart showing possible phytoprovincialism during Late Palaeozoic



一植物地理区还可分为华北与华南两个亚区(Li and Yao, 1985; Li and Wu, 1996)。两者间的界线大约沿着西祁连山南麓、秦岭北侧、大别山北坡褶皱带,然后转向东北伸延,经连云港北端,再穿越黄海而遥接于日本中部 Maiya 的北侧。这两个亚区植物群的主体面貌相似,只是华南晚二叠世晚期,特别是西南地区的植物群远比华北石千峰组植物群生长繁茂。华南的晚石炭世沉积几乎全为海相而很少植物化石发现。

中国北部安加拉(亚安加拉)植物群与华夏植物群之间的界线比较清楚,西起于新疆南部的阿克苏,向东沿塔里木盆地北缘延伸而抵于西祁连山北坡,穿越龙首山,然后北东向穿越腾格里大沙漠和正镶白旗,再循西拉木伦河谷,连接四平—延吉大地构造线而入海。

有关划分冈瓦纳植物区与华夏植物华南亚区之间界线的资料还较少。然而,最近有人(Li and Wu, 1994)提出,此一界线可能沿青藏高原的班公错—丁青缝合线,伸至藏东昌都附近再急转南向,穿越云南西南部而接于泰马半岛中部的 Pham Som 与 Bentony-Raub 大地构造线,并继续南延和通过苏门答腊占碑西部而入印度洋,然后转成东西向并循爪哇南侧深海沟延伸,再穿越东北的 Banda 海域,遥接于西部新几内亚曾发现二叠纪冈瓦纳—华夏混生植物群的地带。

参　考　文　献

陈其　,1988: 浙江晚泥盆世西湖组楔叶类化石。古生物学报,**27**(4):404—415。

李星学、吴秀元、沈光隆等,1993: 北祁连山东段纳缪尔期地层和生物群。山东科技出版社。

林金录,1987: 石炭纪末的古地理。地震地质,**9**(2):91—94。

Cleal, C. J. and Thomas, A., 1991: Carboniferous and Permian palaeogeography. *In* Cleal, C. J. (ed), Plant fossils in geo-

logical investigation, the Palaeozoic. pp. 151—181, Ellis Horwovod Ltd., New York.
Grabau, A. W., 1923—1924: Stratigraphy of China. Part Ⅰ: 1—511, Geol. Surv. China, Peking.
Lee Hsing-hsueh (Li Xingxue), 1963: Fossil plants of the Yuehmenkou Series, North China. Palaeont. Sinica, Whole No: 148, New Ser. A, 6: 1—185 (in Chinese and English). Science Press, Beijing.
Li Xingxue and Yao Zhaoqi, 1985: Carboniferous and Permian floral province in Eastern Asia. *In* C. R. 9th Congr. Internat. Strat.—Geol., Carboniferous. Urbana, 1979, 5; pp. 95—101, Illinois Univ. Press, Urbana.
Li Xingxue and Shen Guanglong, 1992: Permian Phytoprovincialism in the Far East. Proceedings of International Symposium, Palaeont. Soc. Korea, Special Publication, I (1992): 1—26.
Li Xingxue and Wu Xiuyuan, 1994: The Cathaysian and Gondwana flora: their contribution to determining the boundary between Eastern Gondwana and Laurassia. Journ. S. Asian Earth Sci., **9** (4): 309—317.
Li Xingxue, 1995: Notes on the Cathaysian flora. *In* Li Xingxue *et al.*, (ed): Fossil floras of China through the Geological Ages. pp. 244—257, Guangdong Science and Technology Press, Guangzhou.
Li Xingxue, 1996: The Cathaysian flora: An overview. Palaeobotanist, **45**: 303—308.
Li Xingxue and Wu Xiuyuan, 1996: Late Paleozoic phytogeographic provinces in China and its adjacent regions. Rev. Palaeobot. Palyn., 90 (Special issue), pp. 41—62 (C. Wunk and H. W. pfefferkorn, eds.), Elsevier.
Lin Jinlu, 1989: Position of the Chinese blocks in a Late Carboniferous map. *In* C. R. 11th Internat. Strat. Geol. Carbon., Beijing, 1987, **4**: 231—234. Nanjing Univ. Press, Nanjing.
Metcalfe, I., 1988: Origin and assembly of Southeast Asian continental terranes. *In*: Gondwana and Tethys (edited by Audley Charles, M. G. and Hallam, A.). Geol. Soc. London, Special Pub., **37**: 101—108.
Nie Shangyou, Rowley, D. B. and Ziegler, A. M., 1990: Constraints on the location of the Asian microcontinents in Palaeo—Tethys during the Late Paleozoic. Paleozoic Paleogeography and Biogeography (edited by Mckeprocs, W. S. and Scotese, C. R.), Memoir, **12**: 397—409, Geol. Society, London.
Wu Xiuyuan, 1995: Carboniferous Floras. *In* Li Xingxue *et al.* (eds.): Fossil Floras of China through the geological Ages. pp. 78—126, Guangdong Science and Technology Press, Guangzhou.

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THE ORIGIN, EVOLUTION AND DISTRIBUTION OF THE CATHAYSIAN FLORA IN EAST ASIA

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Key wrods Cathaysian flora, origin, evolution, distribution, E. Asia

Summary

The Cathaysian flora has long been known as one of the four major floras during the Carboniferous and Permian times, the others being the Euramerica, Angara and Gondwana floras.

Although the Cathaysian flora includes many genera of Euramerican aspects, and some forms are even specifically identical with those of other floras, it is, however, distinguished by the presence of such endemic and characteristic genera or plant groups as: 1) gigantopterids, 2)

emplectopterids, 3) lobatannularians, 4) tingialeans, 5) fascipterids, 6) *Conchophyllum*, 7) taeniopterids (endemic spp.) and 8) Oriental lepidophytes (Li Xingxue, 1995).

1 Origin of the Flora

The research history of the Cathaysian flora, since the first founding of the leading taxonomic group-gigantopterids by V. Richthofen in 1870, has lasted for more than 120 years (Li Xingxue, 1996), but the origin of the flora still remains as yet unsolved.

The climate and ecological environment of the floras in East Asia resemble basically those of West Europe and North America since the Early Carboniferous time, and many genera and species of the Late Carboniferous flora in East Asia still have a great resemblance to some of the Euramerican Phytogeoprovince in spite of the fact that there existed a small number of plant groups or endemic forms which are typical of the Cathaysian flora. The prevailing opinion holds that the Cathaysian flora originated from the Early Carboniferous or Westphalian Euramerican flora. However, in recent years, some neuropterids, e.g. *Paripteris gigantea* and many forms of *Linopteris*, were found to make their first appearances in the Visean and Namurian A in China respectively, but they did not occur until the Westphalian in West Europe. Lepidophytic plants also appear to have occurred earlier in China, of which, some Oriental forms are found to appear in the Early Carboniferous. Moreover, *Lepidodendropsis*, and *Sublepidodendron mirabile* which are considered separately as diagnostic genera and species for the transition from latest Devonian to earliest Carboniferous in the Euramerican Phytogeoprovince, also have an earlier occurrence and wide distribution in the Middle and Late Devonian of China. It is further noteworthy that some characteristic plants of Sphenopsida, e.g. *Sphenophyllum lungtanense* and *Xihuphyllum* (Chen Qishi, 1988) are found in the Upper Devonian of South China. More or less similar phenomenon is also known in palynological records. For example, disaccate pollen (e.g. *Limitisporites*) already appear in the upper part of the Lower Namurian Tsingyuan Formation (equivalent to the ammonoid E_2 zone), and are progressively increased and diversified from the lower part (H zone) to the upper part (R_2—G_1 zones) of the Hongtuwa Formation, while in West Europe, they first appear in the Westphalian. The case is similar with some fossil animals. For example, the ichthyoid genus *Bothriolepsis* traditionally considered to be diagnostic of the Late Devonian in Western countries, occur in older strata in China. Therefore, it is doubtful whether the traditional European scheme for stratigraphical and palaeontological correlations should be applied in China. In consequence, it is proposed (Li Xingxue *et al*., 1993) that the Cathaysian flora might have originated from the Procathaysian flora which perhaps existed mainly in the Early Carboniferous in China.

Recent studies of the Late Palaeozoic geotectonics in East Asia also afford us evidence in favor of this proposition. The Cathaysian landmass first suggested by Grabau (1923—1924), which might be regarded as the cradle of the Cathaysian flora, has lately been reconstructed and

Tab. Ⅰ Comprehensive correlations of age (stage), phase, subprovince, representative formation and plant assemblage of Cathaysian flora

AGE	STAGE	FLORA	PHASE	MEMBER	Phytogeoprovince, representative formation and plant assemblage			
					North China Subprovince		South China Subprovince	
					Representat. formation	Plant assemblage	Representative formation	Plant assemblage
Late Permian	Kazanian-Tatarian	CATHAYSIAN	Late	B	Shihchienfeng (Sunjiagou) Fm.	*Ullmannia bronnii-Yuania magnifolia* Assemblage	Upper Hsuanwei Fm. (E. Yunnan and W. Guizhou); Talung Fm. (Sichuan and Guangxi)	*Gigantonoclea guizhouensis-Ullmannia* cf. *bronnii-Annularia pingloensis* Assemblage
				A	Upper Shihhotse Fm.: Upper Pt. Lower Pt.	*Gigantonoclea hallei-Lobatannularia heianensis-Psygmophyllum multipartitum* Assemblage *Gigantonoclea lagrelii-Lobatannularia ensifolia-Fascipteris hallei* Assemblage	Lungtan Fm. (Jiangsu, Zhejiang and Anhui); Tsuipingshan Fm. (Fujian); Lower Hsuanwei Fm. (E. Yunnan and W. Guizhou)	*Gigantopteris nicotianaefolia-Lobatannularia multifolia-Schizoneura manchuriensis* Assemblage
Early Permian	Asselian-Sakmarian-Artinskian-Kungurian		Middle	B	Lower Shihhotse Fm.	*Emplectopteris triangularis-Tingia carbonica-Cathaysiopteris whitei* Assemblage	Tungtzuyen Fm. (S. Fujian); Yanqiao Fm. (Jiangsu and Zhejiang); Luipakou Fm. (S. Hunan)	*Gigantonoclea fukienensis-Otofolium* spp.-*Tingia carbonica* Assemblage
				A	Shansi Fm. Taiyuan Fm. (U. and M. Pts.)	*Emplectopteridium alatum-Taeniopteris mucronata-Lobatannularia sinensis* Assemblage *Neuropteris ovata-Lepidodendron-posthumii* Assemblage	Kuangshanchang Fm. (E. Yunnan); M. and L. Loping Fm. (NW Jiangxi); Liangshan Fm. (Sichuan and Shaanxi); Ma'an Fm. (W. Hubei)	? *Emplectopteris triangularis-Lepidodendron oculus-felis* Assemblage
Late Carboniferous	Namurian-Westphalian-Stephanian		Early	B	Taiyuan Fm. (L. Pt.) (Chinzu Ss. complex)	*Alethopteris huiana* Assemblage(?)	Maping Fm. (marine)	
				A	Penchi Fm.	*Paripteris gigantea-Linopteris neuropteroides-Conchophyllum richthofenii* Assemblage	Upper Yehchiatang Fm. (W. Zhejiang); Upper Tzushan Fm. (Jiangxi); Tsaoliangyi Fm. (Shaanxi)	*Paripteris gigantea-Kaniopteris acuta* f. *obtusa* Assemblage

(after Li Xingxue, 1995)

renamed the Cathaysia Composite Continent (Lin Jinlu, 1987, 1989), continental Terranes (Metcalfe, 1988), Micro-continent (Nie *et al*., 1990), paleo-blocks (Cleal and Thomas, 1991), etc. All of these geotectonic units are supposed to consist of some islands which were situated in an open sea and generally separated from one another by a somewhat long distance. The condition was favorable to the development of endemic elements.

2 Evolution of the Flora

The Cathaysian flora can be divided into the Early, Middle and Late Phases (Li Xingxue, 1963), each phase is in turn divided into Members A and B and each member contains 1—2 plant assemblages. Here is a comprehensive summary of the current opinions on the geological duration of these subdivisions with their representative rock formations and corresponding plant assemblages (Table Ⅰ).

The Late Carboniferous and Permian deposits are rather well-developed and widespread in North China where the biostratigraphical sequences with the successional plant assemblages range from the Penchi Formation to the uppermost Shihchienfeng Formation without perceptible breaks. The rock formations in the lower part consist of alternating marine and terrestrial sediments, but gradually increasing in terrestrial content in their higher parts until becoming entirely terrestrial deposits. Thus North China, especially Taiyuan of central Shanxi, has been considered as an ideal region for studying the evolution of the Cathaysian flora.

As shown in Table Ⅰ:

1). The Penchi Formation (Hongtuwa Formation in Northwest China) is characterized by the *Paripteris gigantea*-*Linopteris neuropteroides*-*Conchophyllum richthofeni* Assemblage in which the Lycopsida take the most important place, Filicopsida and Pteridospermopsida the next, while other taxa are relatively less in number. This assemblage shows the general aspects in its Early Phase of the Cathaysian flora, with no significant difference from the Late Carboniferous flora of the Euramerican Phytogeoprovince, but with the first appearances of some typical Cathaysian elements such as the unique genus *Conchophyllum*, *Tingia hamaguchii* of tingialeans, the Oriental lepidophytes, i.e., *Lepidodendron oculus-felis*, *Lep. posthumii* and some endemic forms of neuropterids (e.g. *Paripteris kaipingensis*, *Linopteris* spp.).

2). The middle-upper part of the Taiyuan Formation considered previously as equivalent to the Stephanian of West Europe has been almost all referred to earlier Permian (Asselian) since 1987 owing to the current international twofold system for the Carboniferous accepted in China. The Taiyuan flora is named the *Neuropteris ovata*-*Lepidodendron posthumii* Assemblage in which Lycopsida together with Sphenopsida, Filicopsida and Pteridospermopsida are dominant groups. One of the assemblage features is the abundant appearance of the Oriental lepidophytes which distinguishes it from the coeval floras of the Euramerican Phytogeoprovince.

As very few plants are found from the lower part of the Taiyuan Formation in North China proper, the Stephanian flora is scarcely known. However, some authors have believed that the Stephanian flora of China may be represented by the plant fossils collected from the lower part of the Taiyuan Formation yielding the fusulinid *Montiparus*-*Triticites* zone in the Junggar coalfield of Nei Monggol, the Jishuihe section in Hancheng of North Shaanxi, the Yaogou section in Zhongwei of Ningxia, etc. (cf. Wu Xiuyuan, 1995, pp. 112—113). The flora contains the important elements recorded in the middle and upper parts of the Taiyuan Formation such as the Oriental lepidophytes (i. e., *Lepidodendron oculus-felis*, *Lep. posthumii*, *Lep. szeianum*, *Cathaysiodendron nanpiaoense*), many species of Sphenopsida and the pecopterids, and moreover, the important elements *Neuropteris ovata* and *Tingia hamaguchii* are by no means scarcely seen. It is thus difficult to find any definite taxonomic difference in the plant assemblages between the lower part and the middle-upper part of the Taiyuan Formation. There are neither obvious changes between the latest Carboniferous and the earliest Permian floras in China as in the Euramerican Phytogeoprovince.

3). Although there is no remarkable break between the uppermost part of the Taiyuan Formation and the lowest part of the Shansi Formation, the flora of the latter can be distinguished by a sudden decrease in the lepidophytes and the presence of such typical Permian Cathaysian elements as *Emplectopteris*, *Emplectopteridium*, *Lobatannularia sinensis* and many (no less than 100) new forms of Sphenopsida, Filicopsida and Pteridospermopsida. These indicate that a conspicuous floristic change might have taken place between the Asselian and the Sakmarian—Artinskian in North China.

4). Nearly at the end of Early Permian, when the Lower Shihhotse Formation was deposited and the climate became gradually drier, the Cathaysian flora grew even more luxuriantly and reached its acme. This is especially shown by its most important and exceptionally well-developed representative plants such as *Gigantopteris*, *Gigantonoclea*, *Cathaysiopteris* of the gigantopterids, *Tingia carbonica*, *Emplectopteris triangularis* and many new species of Sphenopsida and endemic forms of taeniopterids. At that time, the coal-forming process largely ended in North China proper except in central Henan, northern Anhui and northern Jiangsu where some coal seams still occurred.

5). At the early Late Permian, Northwest China and North China proper successively changed to rather dry and hot condition. The Upper Shihhotse Formation consists of variegated clastic deposits with plenty of plant fossils, among which *Lobatannularia*, *Gigantonoclea*, *Fascipteris* and *Sphenophyllum* reach their peak stage, while the Mesozoic forms increase to 40% of the whole flora. The conifers are also on the increase. Coal seams can only be found in certain horizons in central Henan, northern Anhui and northern Jiangsu.

6). During late Late Permian, more severe dry climate governed North China, as indicated by the prevailing purplish red sediments of the Shihchienfeng Formation, in which only some drought-enduring plants can be found in the silty, sandy concretions. In general aspects the Shihchienfeng flora, known as the *Ullmannia bronnii*-*Yuania magnifolia* Assemblage, consists mostly of genera numbered with single species and is dominated by conifers. It is distinguished by the presence of almost all the representative plants of the Zechstein flora, although 40% of the whole floristic components (e.g., the genus *Yuania*, and the species *Taeniopteris taiyuanensis*, *T. nystroemii*) are derived from the Upper Shihhotse flora. It contains also a few Angara elements, i.e., *Tatarina* and *Phylladoderma*. The interesting composition of the Shihchienfeng flora indicates further that the phytogeoprovincial features in the Norhtern Hemisphere since the Late Carboniferous almost completely disappeared near the close of Permian, at least in North China.

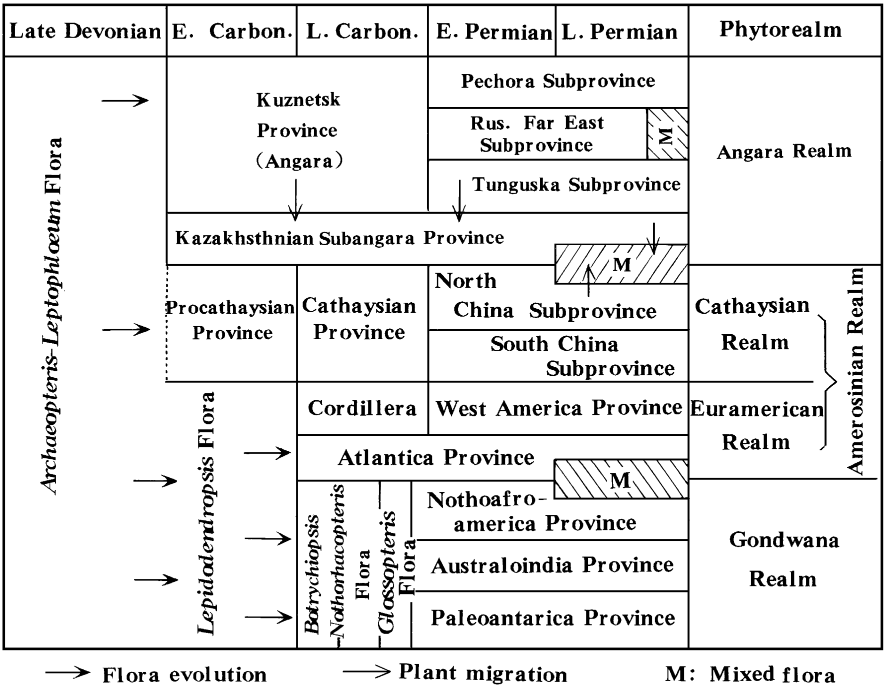
In South China, the late Late Carboniferous is nearly all of marine origin and the Permian consists chiefly of marine sediments intercalated with terrestrial and sometimes intrusive and/or volcanic rocks and coal seams. Since plant fossils are relatively rare and not well-preserved, the study on the Cathaysian flora is not so intensive as in North China. However, as shown in Table Ⅰ, the representative rock formations and their plant assemblages in South China can be approximately correlated with those of North China, with the exception of the late Late Permian flora. Especially in the border area of Yunnan and Guizhou as well as northern Xizang (Tibet), the late Late Permian floras differ greatly from the Shihchienfeng flora of North China. There were dense forests along with marine coast swamps and lepidodendroid plants, though only a few forms, occurred in high abundance and geographically with a wide distribution. Tree ferns of *Psaronius* and gigantopterids have often been found, and the coal-forming conditions persisted until the end of Permian. All these appear to indicate a hot, humid and rainy environment which was quite different from the hot and very dry ecological condition for the Shihchienfeng flora of North China.

3 Distribution of the Flora

The geological distribution of the Cathaysian flora has already been mentioned above, and the possible phytoprovincialism during Late Palaeozoic is briefly shown in Table Ⅱ. Here is a discussion on the geographical distribution of the flora.

In the vast expanse of East Asia, the area North of the Tianshan-Hinggan zone of China is recognized as the Angara Phytogeoprovince and the relatively narrow area of southern Xizang (Tibet) and western Yunnan belongs to the Gondwana Phytogeoprovince, while the remaining extensive area all belongs to the Cathaysian Phytogeoprovince. This phytogeoprovince can be further divided into the North China and South China Subprovinces (Li Xingxue and Yao Zhaoqi, 1985; Li Xingxue and Wu Xiuyuan, 1996). The boundary between both subprovinces runs roughly along the south foot of the West Qilian Mts., the north side of the Qinling Mts., the northern piedmont fold zone of the Dabie Mt., extending northeastward through north of Lianyuan Harbour and across the Yellow Sea, to the northern part of Maiya, central Japan. These two subprovinces are generally similar in main floristic aspects, but the late Late Permian floras in South China, especially in Southwest China were much more developed than the flora of the Shihchienfeng Formation in North China. The Late Carboniferous sediments in South China are almost completely of marine origin with few plant remains.

Tab. Ⅱ Chart showing possible phytoprovincialism during Late Palaeozoic



The boundary between the Cathaysian flora and the Angara (Subangara) flora in the northern part of North China is relatively clear. It begins in the Aksu district of southern Xinjinag, running eastward along the northern border of the Tarim Basin, reaching the northern slope of the West Qilian Mts. through the Longshou Mt., and then northeastward across the Tengger Desert, extending through the Zhengxiang Bei Qi, along the Xar Moron River Valley, and finally connected with the Siping-Yuanji geotectonic line before entering into the sea.

Our knowledge is still inadequate for determining the boundary between the South China Subprovince of the Cathaysian and the Gondwana Phytogeoprovince. It has been, however, proposed recently (Li Xingxue and Wu Xiuyuan, 1994) that possibly the boundary runs along the Bangong Co-Dêngqên suture of the Qinghai-Xizang plateau, and turns abruptly southward near Qamdo in eastern Xizang, and then extends through southwestern Yunnan to link up with the Pham Som and Bentony-Raub geotectonic zone of Thailand—Peninsular Malaysia. It continues further southwards across the west part of Djambi in East Sumatra to the Indian Ocean, and then changes to E-W direction along the deep sea trench south of Java and turns northeastward through the Banda Sea to connect with western New Guinea where a Permian mixed Cathaysian-Gondwana flora has been found.