The Cathaysian flora : An overview

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Li XX 1996. The Cathaysian flora : An overview. *Palaeobotanist* **45** : 303-308.

Beginning with the first discovery of gigantopteroid fossils from the Permian coal formation in Hunan province, South China by Richthofen in 1870, the research history of the Cathaysian flora may be divided into three stages: 1. Initial Stage (1870-1926); 2. Founding Stage (1927-1959); 3. Flourishing Stage (1960- present). The paper emphasizes that a good progress has been made in the third stage mainly by the Chinese palaeobotanists and palynologists. An attempt is also made to carry out some problems and prospects for researches of the Cathaysian flora in the near future.

Key-words—Cathaysian flora, Gigantopteris flora, China.

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सारांश

कैथेसिआ वनस्पतिजात : विशेष समालोचना

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दक्षिण चीन में हुनान प्रान्त में परमियन कोयला शैल-समूह से जाइगेन्टॉप्टेरिड अश्मित पौधों के प्रथम अभिलेख से लेकर अब तक के कैथेसिआ वनस्पतिजात का अनुसन्धान इतिहास तीन चरणों में विभक्त किया जा सकता है जिन्हें (1) प्रारम्भिक चरण (1870–1926), (2) संस्थापन चरण (1927–1959), एवं (3) विकसित अवस्था (1960 से अब तक) के नाम से जाना जाता है। प्रस्तुत शोध-पत्र यह प्रदर्शित करता है कि तीसरे चरण में सर्वाधिक प्रगति हुई है जिसका श्रेय मुख्यतया चीनी विज्ञानीयों को जाता है। भविष्य में कैथेसिआ वनस्पतिजात पर किये जाने वाले अनुसन्धान कार्य के विषय में भी विवेचना की गई है।

BRIEF HISTORY

The research history of the Cathaysian flora is divided into three stages.

1. Initial Stage (1870-1926)—It began with the first discovery of *Gigantopteris* in 1870 from the Permian coal series in Hunan, S. China (Richthofen, 1877, 1912). The gigantopterid plants were first described by Schenk in 1883 as *Megalopteris nicotianaefolia* Schenk, and later he changed the generic name to *Gigantopteris* (*vide* Potonié 1902, p. 513) owing to the name *Megalopteris* had been preempted. Since then, such type of plant fossils has not only been found in many localities from East Asia, but also often from southwestern U.S.A. White (1912) in a paper dealing with the geographical relation between the Permian floras of NE Asia and SW U.S.A. proposed the term Gigantopteris flora for these floras, which has subsequently been widely accepted and well-known.

2. Founding Stage (1927-1959)—A fairly large amount of collections and publications on the Permo-Carboniferous plants in East Asia were done during this time. The most remarkable contribution is the monograph "Palaeozoic plants from Central Shansi" in 1927 by Halle, in which the basic aspects and diagnostic elements of the Permo-Carboniferous floras of North China have been made clear. In 1935 and 1937, Halle suggested "the Cathaysia (Cathaysian) flora" to replace "the Gigantopteris flora" representing all the Carboniferous and Permian floras in East Asia because all gigantopterids are confined to the Permian. Other important contributions include Kawasaki's (1927-1939) work on the Heinan flora of Korea, Jongmans and Gothan's (1935) on the Djambi flora of Sumatra, Koidzumi's (1934, 1936) on the Gigantopteris flora, Stockmans and Mathieu's (1939, 1957) on the Permo-Carboniferous floras of Kaiping Basin, Hebei Province, N. China, Sze's (1953) Atlas of the Palaeozoic plants of China and Asama's (1959) study on so-called *Gigantopteris*. All these monographic works together with many other short articles, added much to our knowledge about the Cathaysian flora in East Asia. Nearly all of

the publications appeared during this stage concerning the Cathaysian flora were more or less affected by Halle's academic ideas. However, the accumulation of numerous fossil and relevant stratigraphic data, especially those piled up since the founding of New China in 1949, have laid a good foundation for the rapid development in the next stage.

3. Flourishing Stage (1960-Present)—A good progress has been made in this period in China, mainly by the Chinese palaeobotanists and palynologists.

Li (1963, 1964) gave a comprehensive description of the flora from the Taiyuan and Shansi formations (collectively the Yuemenkou Series) in North China and for the first time proposed six plant assemblages ranging from Late Westphalian to the close of Permian which, though revised in later works, laid a solid basis for subdivision and correlation of similar plant-bearing strata in various places of East Asia (Table 1).

The study of the Cathaysian flora in South China lagged somewhat behind that of N. China largely because nearly all the Upper Carboniferous is of marine origin, and the Permian is poorly exposed. A pioneer systematic study of fossil plants from the Lungtan Formation in Jiangsu was done by Zhou Zhiyan (1962). Some of the significant specimens and interesting viewpoints in his unpublished thesis have been later incorporated in the "Palaeozoic plants of China" by Gu and Zhi (1974). For example, '*Gigantopteris*' with simple netted venation from N. China and Korean Peninsula, etc. has proven to be quite different from real *Gigantopteris* with a complicated compound net venation typically from S. China, and, therefore, Koidzumi's name *Gigantonoclea* was proposed for specimens of the former type (Gu & Zhi, 1974).

The palynological study of the Cathaysian flora began with the publication of a paper dealing with the Permo-Carboniferous miospores from the Kaiping Basin, Hebei Province by Imgrund (1960). Subsequently mainly through the efforts made by Ouyang Shu (1962, 1964 and afterwards) and Gao Lianda (1984, 1985, 1989) as well as by more than a dozen of other Chinese palynologists, the palynological results have not only led to the establishment of palyno-sequences of assemblages (or zones) from the Permian in S. China and Carboniferous-Permian in N. China which are very useful in regional stratigraphic dating and correlation, but also provided valuable information in palaeobotany.

Almost all academic works in China were at a standstill during the so-called Great Culture Revolution (1966-1976). However, a handbook, "Palaeozoic plants of China", was compiled by Gu and Zhi in 1974. Nearly all important Palaeozoic plant fossils (mainly Carboniferous and Permian) ever described and formally published in China prior to 1966 have been included, revised and illustrated. In addition, it provides a brief description of the main features and developmental stages of the Cathaysian flora.

A significant progress has been made on the study of Cathaysian flora since China's pursuing the Policy of Reform and Open at the end of 1978. Relatively important contributions are as follows :

In North China

(i) Discovery and study of fossil plants from the Shihchienfeng Formation (s.s., i.e., Shihchienfeng Formation) composed mainly of red beds by Wang Ziqiang *et al.* (1978, 1987, 1989) : The Shihchienfeng assemblage contains almost all the representatives of European Zechstein flora in association with a few Cathaysian elements originated from the flora of the Upper Shihhotse Formation and some plants characteristics of the Western Angara Permian flora. It is dominated by conifers, apparently different from those of the earlier phases of the Cathaysian flora.

(ii) Restudies on the flora of the Penchi Formation (Wu *et al.*, 1987; Zhang *et al.*, 1987; Huang, 1987a, b): The Penchi flora, formerly named the *Neuropteris gigantea - Linopteris neuropteroides* assemblage of Westphalian and considered to be a component part of the Euramerican flora, has now been renamed as *Paripteris gigantea - Linopteris neuropteroides - Conchophyllum richthofeni* Assemblage representing the earliest plant assemblage of the Cathaysian flora ranging from Late Namurian to Westphalian. The Penchi Formation might have been deposited on Cambro-Ordovician denudation surface and diachronous in different areas.

(iii) Discovery and study on Late Palaeozoic flora with diverse, beautifully preserved gigantopterids in Yuxian, Henan Province (Yang, 1985, 1987): Because the gigantopterids are found from successive horizons and show varied vein patterns, they are of vital importance in discussing the evolution and ecology of this group of plants.

(iv) The publication of the posthumous work of Sze's (1989) Late Palaeozoic plants from the Qingshuihe Region of Inner Mongolia and the Hequ District of NW Shansi : A systematic description of 53 genera and 162 species from the Penchi Formation to the Upper Shihhotse Formation in Inner Mongolia and NW Shansi has been given. This study not only enriched the known contents of the Cathaysian flora, but also afforded new information on the phylogeny and systematics of Late Palaeozoic plants in E. Asia. One of the salient features is the abundance of Sphenopsida and the scarcity of gigantopterids, i.e., *Gigantonoclea lagrelii* (Halle). This flora appears to be under the influence of a comparatively drier climate as compared with that occurred in Central Shanxi.

In South China

(i) The study on Late Permian plants and their geological distribution from W. Guizhou and E. Yunnan has palaeobotanical and biostratigraphic significance (Zhao *et al.*, 1979).

(ii) In a re-investigation of the *Gigantopteris*-bearing coal series and its biota formerly regarded as early Late Permian, Li and Yao (1980) pointed out that the principle Permian coal-forming periods in S. China show a tendency of westward displacement from late Early Permian to the close of Permian, and the main workable coal seams became gradually higher and higher in level. The late Late Permian flora is quite different from that of the coeval Shihchienfeng flora of N. China due to different climatic and ecological background.

(iii) Discovery of a Glossopteris flora mixed with a few Cathaysian forms from the Qubu Formation in S. Xizang (Tibet) (Hsu, 1976; Hsu *et al.*, 1990; Li, 1983; Li *et al.*, 1991), and the findings of typical Late Cathaysian flora in coal-bearing deposits from N. and E. Xizang (Li et Yao, 1981a, b; Li, 1986) are of special importance both in view of phytogeography and geotectonics.

(iv) Discovery of coal balls containing well-preserved plant remains first made by Tian (1979) and Tian *et al.* (1980) from the Late Permian coal-bearing formation in Shuicheng, Guizhou Province, and then by others and Tian from then 11 localities on N. China, S. China and NW China, ranging from Late Namurian to the end of Permian. The anatomical research on these plants has considerably complemented our knowledge of the Cathaysian flora in China, especially in plant communities, taphonomy and ecology.

(v) Attempts have been made on the origin, development, phytogeography, climate and ecology of Cathaysian flora as well as on the reproductive organs, taphonomy and ecological environment of gigantopterids (Yao, 1983; Li *et al.*, 1985, 1993; Yang, 1987; Wang, 1989; etc.). Re-evaluation to some Cathaysian elements, such as tingialeans (Gao *et al.*, 1989) and psygmophylleans (Yao, 1991), is also of significance in taxonomy.

Important contributions by foreign colleagues

(i) Except several papers on materials collected in recent years and co-operated with Chinese palaeobotanists (Laveine *et al.*, 1987, 1989, 1993), almost all others are based on materials obtained from China before the founding of New China, such as Late Palaeozoic plants from Yuerhhong, Kansu (Bohlin, 1971, 1976); evolution and classification of Sphenophyllales in Cathaysia land (Asama, 1970); Permian microflora from NW Shansi (Kaiser, 1976); Upper Permian flora from the Nanshan Section, N. China (Durante, 1983, 1992), etc.

(ii) Noteworthy results related to the Cathaysian flora outside China include : (1) on gigantopterids from SW U.S.A. (Mamay, 1986a, b, 1988, 1989, etc.); (2) new findings on mixed floras including Hazro, Anatolia of Turkey (Wagner, 1962), Nishatbagh of Kashmir (Singh *et al.*, 1982; Pant *et al.*, 1984), Russian Far East (Burage, 1973; Zimina, 1967, 1983), Guadalcanal of SE Spain (Broutin, 1982, 1986) and W. New Guinea of Indonesia (Jongmans, 1940; Visser *et al.*, 1962). All of them are Permian in age and of special interest. However, while discussing mixed floras, the accurate identification of florally diagnostic elements is essential, and in this regard much work remains to be done.

(iii) The Cathaysian floras of SE Asia were studied mainly by Japanese colleagues (Kon'no *et al.*, 1970 a, b, 1971; Asama, 1966, 1976; Asama *et al.*, 1968). Some of the identifications, especially for the gigantopterids, need revision.

(iv) The Maiya Permian flora in N. Honshu, C. Japan (Asama, 1956, 1967) deserves special notice because it contains *Cathaysiopteris whitei* (Halle) closely associated with fauna of the *Parafusulina*

Zone in deposits most probably similar to the Maokouan (Kungurian), S. China.

(v) The Cathaysian flora of the Korean peninsular has long been known to be almost identical both in composition and stratigraphic sequences with that of N. China, because they occurred in the same geotectonic unit—the Sino-Korean paraplatform. Some new findings in the southern part of the Peninsula show that the contents of the floristic composition and the quantity of coal seams are not so rich as those in N. China (Chun, 1985, 1987; Lee Daisung, ed., 1987).

For a more comprehensive understanding on the Cathaysian flora and the evolution and classification of gigantopterids, the colleagues are advised to refer the two paragraphs in the Chapter 6 of our monograph "Fossil floras of China through the geological ages" recently published in English version, of which the Chinese version will appear slightly later.

PROBLEMS AND PROSPECTS

1. There are at least three different views about the origin and development of the Cathaysian flora in China. It deserves deepgoing and arduous studies on the basis of multiple disciplines of sciences so that reasonable and convincing conclusions can be acquired.
2. The origin and evolution of gigantopterids are also important problems much concerned by palaeobotanists. This long-standing and disputed subject needs to be studied from different lines of evidence. Various clues indicate that its origin might have been heterogeneous and its evolution may involve both gradual and explosive (or dramatic, sudden) ways.
3. China, covering a vast territory, has widely distributed terrestrial, and marine-terrestrial transitional sediments with various and abundant fossils since Devonian, and is the only country where simultaneously four Carboniferous-Permian floras occur. Detailed studies on the botanical, geological and geographical relations between the Cathaysian flora and the other three floras will be in favour of interpreting some relevant problems in a global scale.
4. The relationship of gigantopterids distributed along both sides of the Pacific, i.e., northeastern Asia and southwestern U.S.A., has attracted much attention and been studied since the early part of this century (White, 1912; Halle, 1935, 1937; etc.), but little advance has been made. Judging from the successive findings made in last 30 years of gigantopterids in Asia Minor (Turkey), Mediterranean, Venezuela and Mexico, etc., it seems more reasonable to search the migrating or intermingling paths along the marginal areas of the Paleo-Tethys than that along NE Asia and striding across the Bering Sea as some authors supposed many years ago.
5. Break-through advance will be made if further study paid attention to the morphology, taxonomic position and ecological environment of some significant plant groups or index forms of the Cathaysian flora, such as tingialeans (probable including two different taxonomic groups) and *Lobatannularia* (occurring in almost all Permian mixed floras).
6. The Permian mixed flora, although not undisputable in its definition or even its existence, is another problem concerned by scientists of the world and involves various fields of earth and life sciences. Judging from the regular distribution of the mixed floras, i.e., the Cathaysian flora intermingled southwards with the Gondwana (*Glossopteris*) flora and northwards with the Angara flora, it merits further study for solving some relevant problems.
7. The close relation between the most abundant Permian coal seams and the Cathaysian floras in E. Asia, and the occurrences of gigantopterids in the areas along the coasts of the Paleo-Tethys, seem to reflect the existence of grand forests zonally spanning in the N. Hemisphere. Therefore, the study of geographical and geological distribution of the Cathaysian flora and its representative as well as the coal-forming mechanisms (such as some Permian coal seams in Leping of Jiangxi, Zhejiang (Hsieh, 1933; Han *et al.*, 1983) almost entirely composed of lepidodendroid(?) cortices will be of highly practical value in coal prospecting and exploitation.
8. Chinese geologists have adopted the two-fold instead of three-fold subdivision for the Carboniferous since the 9th ICC in 1987. This has led to the assignment of the 3/4 part of the Taiyuan Formation in its type-section of Taiyuan, C. Shanxi, which had been regarded as Stephanian, to the lowest Permian, and the remaining part, only ca. 20 m in thickness (i.e., the Chinzu

Sandstone Complex), contains very rare fossil plants. Consequently, the distribution and real aspect of the Stephanian flora in China became a perplex problem which needs urgently be clarified so as to be in favour of the correlation of the relevant strata and floras between E. Asia and Euramerican Provinces.

9. The discoveries of fossil Cycadales or cycads from the Permian in North China have been repeatedly reported in recent years (Zhang et Mo, 1981; Zhu et Du, 1981; Gao *et al.*, 1989). They are the oldest records with a highest number of localities ever known from the world (outside China Cycadaleans only occasionally reported from the Permian in USA). Further anatomical and systematic study on these fossils will probably make remarkable progress in approaching the origin and early dispersion and evolution of Cycadophytes.

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