Evolution and comparison of the Gondwana flora and the Cathaysia flora

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By the Late Palaeozoic, during the Late Carboniferous and Permian, the global vegetation was distinguishable into four main geobotanical provinces : Euramerican, Angara, Gondwana and Cathaysia. The largest of these four provinces was the Gondwana Supercontinent comprising two segments—(i) Western Gondwana consisting of South America and Africa possibly Iran-Afganistan, and (ii) Eastern Gondwana consisting of Antarctica, Australia and India. The Cathaysia flora is the main flora of the Carboniferous and the Permian mainly distributed in present day China, Korea, Japan, Laos, Thailand, Indonesia and Malaysia. It is generally accepted that a typical Gondwana flora is of Early Permian to Late Triassic in age. India and China are most important and significant and well studied regions for Gondwana and Cathaysia floras in Asia. A comparative account of the Gondwana and Cathaysia flora, their origin, development and extinction are reviewed and discussed in the foregoing pages. Mixed floras of Cathaysian and Gondwanian affinities from Qinghai-Xizang Plateau (Tibet) and Kashmir are also reviewed and discussed.

Key-words— Evolution, Gondwana flora, Cathaysia flora.

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सारांश

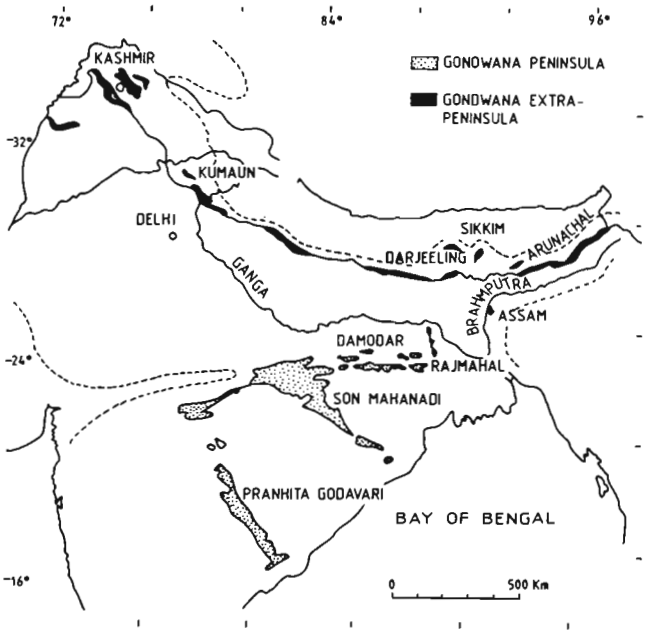
गोंडवाना एवं कैथेसिआ वनस्पतिजातों का विकास और तुलना

शैला चन्द्रा एवं सन केकिन

अनंतिम कार्बनीफेरस से परमियन काल तक भूमण्डलीय वनस्पति को यूरामेरिकन, अंगारा, गोंडवाना और कैथेसिआ नामक चार भूवनस्पतिक प्रदेशों में विभाजित किया जा सकता है। इन सभी में गोंडवाना महाद्वीप सबसे बड़ा था। इसके दो भाग थे (1) पश्चिमी गोंडवाना जिसमें दक्षिण अमेरिका एवं अफ्रीका, सम्भवतया ईरान और अफगानिस्तान थे, (2) पूर्वी गोंडवाना जिसमें अंटार्कटिका, ऑस्ट्रेलिया एवं भारत थे। कार्बनीफेरस काल का मुख्य वनस्पतिजात कैथैसिआ वनस्पतिजात था। परमियन वनस्पतिजात मुख्यतया चीन, कोरिया, जापान, लाओस, थाइलैंड, इंडोनेशिया एवं मलेशिया में मिलता है। सामान्यतया यह माना जाता है कि गोंडवाना वनस्पतिजात प्रारम्भिक परमियन से अनंतिम ट्रायॅसिक आयु का है। गोंडवाना एवं कैथेसिआ वनस्पतिजातों के अध्ययन हेतु भारत एवं चीन दो मुख्य देश हैं। इस शोध-पत्र में कैथेसिआ और गोंडवाना वनस्पतिजातों की तुलना, उनकी उत्पत्ति, विकास एवं विलुप्तीकरण पर विवेचना की गई है। इसके अतिरिक्त कैथेसिआ और गोंडवाना के वनस्पतिजातों से सजातीयता व्यक्त करने वाले मिश्रित वनस्पतिजातों पर भी विवेचना की गई है।

LOWER GONDWANA FLORA OF INDIA

THE Gondwana of India can broadly be classified into two main areas—Peninsular and Extra-peninsular (Map 1). The flora is generally divided into Lower Gondwana and Upper Gondwana and sometimes a third as Middle Gondwana in between the Lower and Upper. The Lower Gondwana flora is known as the Glossopteris flora after its main element *Glossopterts* and is richly preserved in five formations—Talchir, Karharbari, Barakar, Barren Measures or Kulti and Raniganj in ascending order (Table 1). The Lower Gondwana is typically developed in a series of basins in the Damodar, Son-Mahanadi and Narmada grabens. The Extra-peninsular occurrences are in Kashmir, Kumaun Hills, Bhutan, Sikkim, Darjeeling and as far as Assam in the north east. The



Map 1—Peninsular and extra-peninsular Gondwana basins of India.

base of the Peninsular Gondwana is characterised by glacial or fluvio-glacial boulder beds which is recognisable in all the intracratonic basins of the country. After the ice cap receded, the glacial event was followed by deposition of sands, shales, marshes and lacustrine environments for about 40 million years. There were occasional incursions of the sea which left behind intermittent thin marine deposits.

The Lower Gondwana flora includes few characteristic plants, most of them are largely restricted to the Gondwana countries. The botanical relationship of most of the fossil forms is tentative as few are known with their fructifications. The flora is mainly represented by bryophytes, lycophytes, arthrophytes, filicophytes and amongst the gymnosperms Cordaitales, Cycadales, Coniferales, Ginkgoales and Glossopteridales. The peninsular Lower Gondwana taxa are shown in Table 2. A complete upto-date list of taxa in various basins has recently been given by Maheshwari (1992).

As is evident there are still important gaps in our knowledge regarding Lower Gondwana plants. Recent observations prove the existence of bacteria, algae and fungi in various formations. The bryophytes appeared quite early in the Permian but their absence in the Middle and the Late Permian is intriguing though they are recorded again in Triassic and Jurassic. The lycopods as such are rarely reported from the late Early Permian and existed right up to the Late Permian. Lycopods do not show variety in forms though they are present in appreciable number throughout as evidenced by spores

Table 1 — Lower Gondwana Formations of India

STANDARD SCALE			LITHOSTRATIGRAPHIC UNITS					
			DAMODAR VALLEY	SATPURA BASIN	SON VALLEY	RAJMAHAL REGION	WARDHA VALLEY	MAHANADI VALLEY
P	TATARIAN		RANIGANJ FORMATION	BIJORI FORMATION	PALI FORMATION	RANIGANJ FORMATION	KAMTHI FORMATION	KAMTHI FORMATION
E	KAZANIAN		KULTI FORMATION	MOTUR FORMATION			KULTI FORMATION	KULTI FORMATION
R M I A N	ARTINSKIAN	UPPER	BARAKAR FORMATION	BARAKAR FORMATION	BARAKAR FORMATION	BARAKAR FORMATION	BARAKAR FORMATION	BARAKAR FORMATION
		LOWER	KARHARBARI FORMATION	KARHARBARI FORMATION	KARHARBARI FORMATION			KARHARBARI FORMATION
	SAKMARIAN		TALCHIR FORMATION	TALCHIR FORMATION	TALCHIR FORMATION	TALCHIR FORMATION	TALCHIR FORMATION	TALCHIR FORMATION

Table 2 — Lower Gondwana flora of peninsular India

Bryophyta	-		*Hepatites*	
			Umariaphyllites	
			Talchirophyllites	
			Sakasenaphyllites	
Lycophyta	-		*Cyclodendron*	
Arthrophyta	-		Common	Rare
			Phyllotheca	*Barakaria*
			Lelstotheca	*Gondwanophyton*
			Schizoneura	*Bengalia*
			Raniganjia	*Benlightfootia*
			Trizygia	
Filicophyta	-		Common	Rare
			Neomariopteris	*Trithecopteris*
			Damudopteris	*Leleopteris*
			Dizeugotheca	*Gondwanidium*
			Asansolia	*Cuticulatopteris*
			Damudosaurus	*Cuticulatopteris*
Gymnospermophyta	-	Cordaitales	Common	Rare
			Noeggerathiopsis	*Cordaites*
			(=Pantophyllum)	*Euryphyllum*
		Coniferales	Common	Rare
			Buriadia	*Walkomiella*
				Paranocladus
				Searsolia
		Cycadales	Common	Rare
			Pseudoctenis	*Senia*
				Pteronilssonia
		Ginkgoales	Common	Rare
				Ginkgophyllum
				Platyphyllum
				Handapaphyllum
				Saportaea
				Rhipidopsis
				Psygmophyllum
				Ginkgoites
		Glossopteridales	Leaf forms	
			Common	Rare
			Glossopteris	*Palaeovittaria*
			Gangamopteris	*Rhabdotaenia*
			Noeggerathiopsis	*Belemnopteris*
				Rubidgea
				Surangephyllum
			Fertile forms	
			Common	Rare
			Dictyopteridium	*Denkania*
			Plumsteadiostrobus	*Jambadostrobus*
			Scutum	*Venustostrobus*
			Ottokaria	*Veekaysinghia*
			Lidgettonia	*Birbalia*
			Eretmonia	*Senotheca*
			Glossotheca	*Nesowalesia*
				Kendostrobus
				Indocarpus
Woods		*Dadoxylon* and many others of unknown affinities		
Root		*Vertebraria*		
Scales	-	*Sceroma* and many others		

and megaspores. Arthrophytes seem to be an ancient group of plants persistently and uniformly represented by stems and spores throughout the Permian and variety of forms in the Middle and Late Permian. Fern and fern allies also developed in the same pattern as arthrophytes showing their maximum development in the Late Permian. The class gymnosperms with its several orders evolved steadily throughout the Permian. Conifers appeared quite early on the scene but they never formed conspicuous vegetation and their occurrence is also very localised. Cordaitales and allied forms show steady development in Early and Late Permian but they were altogether absent in the Middle Permian. Cycads and Ginkgoales appeared much later in the Permian and never formed a uniform and conspicuous vegetation. *Gangamopteris* of the Glossopteridales appeared first in the Early Permian and formed major constituent of the vegetation along with *Noeggerathiopsis*. *Glossopteris* appeared almost simultaneously and quickly occupied the major part of the land forming conspicuous vegetation of the Middle and Late Permian and lingered up to the Triassic (Chandra, 1992). The basic pattern of the Gondwana flora was laid in the Talchir as patchy not so dense vegetation in pockets under cold deglaciated conditions. The first lowland, coal-swamp, deciduous forest dominated by *Gangamopteris*/ *Noeggerathiopsis* shrubs and trees developed during Karharbari period under not so cold but humid conditions. *Glossopteris* dominated dense, deciduous, lowland coal swamp forests appeared during Barakar time under warm and humid climatic conditions. The first upland floras appeared in the Kulti time were not so dense forest under warm, but not so humid conditions. Again there was shift of floras in the low lying river valleys in the Raniganj time to give rise to very dense, swampy vegetation dominated by *Glossopteris* and allied forms under very warm and humid conditions. At the same time some of the *Glossopteris* dominated deciduous forests developed in upland areas under warm but not so humid climate represented by Kamthi. It can be seen that arborescence or tree habit, production of spore/ pollen and development of dispersal mechanism, production of seeds and their dispersal mechanism and wide varieties of plant communities to grow under varied ecological conditions all developed steadily and simultaneously throughout the Lower Gondwana (Chandra, 1992).

Lower Gondwana Flora of Kashmir

The Permian Gondwana of Kashmir region, laid under terrestrial lakes and lagoons, is stratigraphically known as *Gangamopteris* beds. It includes five different floral and stratigraphical beds, viz., Nishatbagh, Vihi, Marahom, Munda and Mamal. These floral beds correlate with the Talchir, Karharbari and the Barakar formations of the Peninsular India. The flora comprises (Table 3) *Glossopteris, Gangamopteris, Pantophyllum (=Noeggerathiopsis), Palmatopteris, Cordaites, Neomariopteris* and *Schizoneura* and exclusive forms like *Gondwanophyton, Kashmiropteris, Kawizophyllum, Psygmophyllum* and *Lepidostrobus* (Kapoor, 1977; Bajpai & Maheshwari, 1987, 1995; Maheshwari, 1992). Like Peninsular India cool to warm and humid climatic conditions are presumed during Permian Gondwana times in Kashmir.

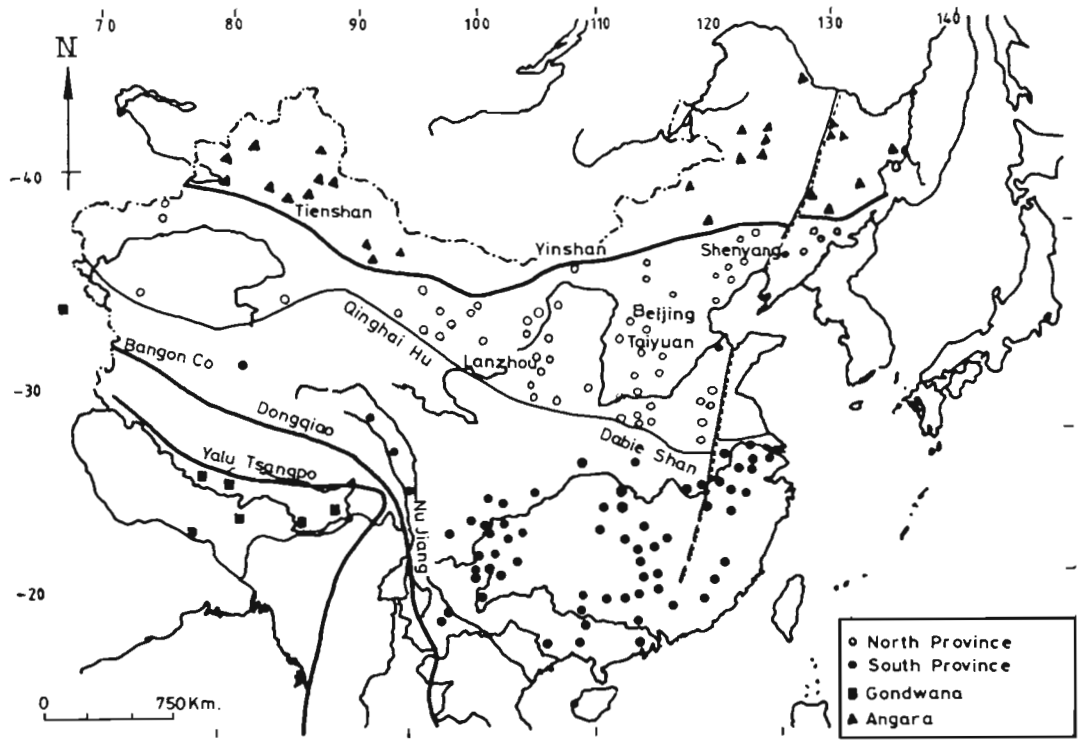
Table 3—Lower Gondwana flora from Kashmir

Exclusive Forms	
Glossopteris	*Gondwanophyton*
Gangamopteris	*Kashmiropteris*
Pantophyllum	*Kawizophyllum*
Palmatopteris	*Psygmophyllum*
Ceraites	*Lepidostrobus*
Neomariopteris	
Schizoneura	

Singh *et al.* (1982) and Pant *et al.* (1984) have reported a number of Cathaysian elements in the Permian of the Kashmir Valley. They are *Lobatannularia ensifolia, Paracalamophyllum thonii* var. *minor (=Sphenophyllum thonii* var. *minor), Rajahia mamalensis, Lobatannularia lingulata, Lobatannularia sinensis* var. *curvifolia, Sphenophyllum thonii* var. *archangelskyii* and *Sphenophyllum thonii* var. *waltonii*.

CATHAYSIA FLORA OF CHINA

The term Cathaysia flora was proposed by Halle (1935) for the entire Carboniferous and Permian plant succession in East Asia. China is one of the



Map 2—Northern and southern Permian subprovinces of China (after Li Xingxue & Yao Zhaoqi, 1985),

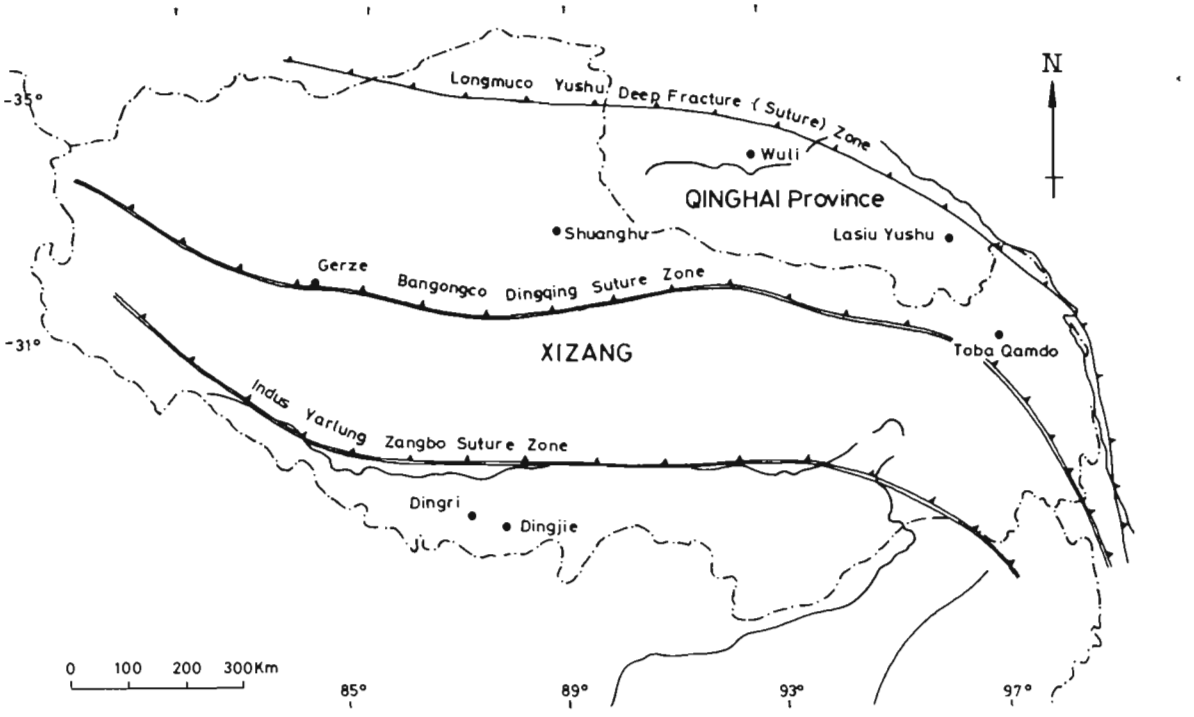
most important and significant location for the Cathaysia flora in Asia. The Chinese Cathaysian floral province is divided into northern and southern subprovinces (Map 2) with a geographical boundary along the Kunlun-Qinling Mountains (Li Xingxue & Yao Zhaoqi, 1985). The northern floral subprovince was located in an equatorial position and had a tropical climate during the Carboniferous and Permian. Fossil plants of north subprovince occur extensively through North China and are widely distributed in a number of major coalfields namely Hebei, Shanxi, Shandong and Inner Mongolia, etc. The Permo-Carboniferous section near Taiyuan is well exposed, rich in both animal and plant fossils

Table 4—Distribution of common fossil plants of the Permian in North China

SPECIES	EARLY PERMIAN		LATE PERMIAN	
	Lower Part	Upper part	Lower Part	Upper Part
Cathaysiodendron acutangulum	+			
Cathaysiodendron incertum	+			
Lepidodendron posthumii	+			
Lepidodendron oculus-felis	+	+	+	
Stigmaria ficoides	+	+		
Stigmaria rugulosa	+			
Sphenophyllum costa	+	+		
Sphenophyllum emarginatum	+	+	+	
Sphenophyllum kawasakii	+	+	+	
Sphenophyllum minor	+	+	+	
Sphenophyllum neofimbriatum		+		
Sphenophyllum oblongifolium	+	+		
Sphenophyllum rotundatum			+	

Contd.

Sphenophyllum sino-coreanum			
Sphenophyllum spathulatum	+		
Sphenophyllum thonii	+	+	
Sphenophyllum verticillatum	+	+	
Bowmanites laxus		+	+
Calamites cistii	+	+	
Calamites suckowii	+	+	
Annularia gracilescens	+	+	
Annularia mucronata		+	+
Annularia orientalis	+	+	+
Annularia stellata	+	+	
Lobatannularia ensifolia		+	+
Lobatannularia heianensis			+
Lobatannularia lingulata		+	+
Lobatannularia sinensis	+		
Tingia carbonica	+	+	
Tingia hamaguchii	+	+	
Tingia partita			+
Plagiozamites oblongifolius			+
Sphenopteris firma		+	+
Sphenopteris gothanii		+	+
Sphenopteris tenuis	+	+	
Pecopteris arborescens	+	+	+
Pecopteris candollioides	+		
Pecopteris hemitellioides	+	+	+
Pecopteris hirta		+	+
Pecopteris lativenosa	+	+	
Pecopteris norinii	+	+	
Pecopteris orientalis	+	+	
Pecopteris polymorpha	+		
Pecopteris taiyuanensis		+	
Pecopteris unita	+	+	
Fascipteris hallei		+	
Alethopteris norinii	+	+	+
Protoblechnum wongii		+	
Odontopteris chui	+	+	
Odontopteris subcrenulata	+	+	
Mariopteris hallei	+	+	+
Callipteridium kuraiense	+	+	
Emplectopteris triangularis	+	+	
Emplectopteridium alatum	+	+	
Cathaysiopteris whitei	+	+	
Gigantonoclea hallei			+
Taeniopteris angustifolia			+
Taeniopteris mucronata	+	+	
Taeniopteris multinervis	+	+	
Taeniopteris norinii		+	+
Taeniopteris schenkii	+	+	
Taeniopteris shansiensis		+	
Pterophyllum daiboense	+	+	+
Psygmophyllum multipartitum			+
Cordaites principalis	+	+	+
Cordaites schenkii	+	+	



Map 3—Localities of mixed Gondwana and Cathaysian elements in China (after Li Xingxue & Xinyuan, 1994).

and has been considered as the stratotype for the Late Palaeozoic in North China. It is the type section for the Cathaysia flora. The Permian common plants in the northern floral subprovince are listed in Table 4. In South China the Upper Carboniferous is mostly marine with no evidence of reliable plant fossils and during the Permian there were frequent changes in sea and land and volcanic erruptions. The marine and non-marine alternating coal-bearing deposits are mainly distributed in Hunan, Fujian, Jiangxi, Guangdong, Jiangsu, Yunnan, Ghizhou and Sichan, etc. The southern floral subprovince is characterised by *Otofolium, Rajahia, Annularia ptngloensis*(Sze), *Pecopteris echinata* Gu & Zhi, *Gigantopteris nicotianaefolia* (Schenpz), *Gigantonoclea acunminatiloba*(Shin), *Gigantonoclea gutzhouensis* Gu & Zhi, *Ulmania* cf. *bronnii* Goeppert and some peculiar fertile genera including *Pectinangium, Gigantonomia, Gigantotheca* and *Distchotheca* (Li Xingxue *et al.*, 1995) and none of which have been found in the northern floral subprovince, some peculiar organ genera are commonly known in North China such as *Nystroenia, Astrocupulites* and some unique plants like *Pseudorhiptdopsis, Procycas,* etc. which are not known in the southern floral subprovince. It is noteworthy that *Otofolium* and *Rajahia* have been recorded in the northern subprovince (Shen Guanglong, 1995). It is worth emphasizing that some typical Cathaysian genera, such as *Gigantopteris, Otofolium* and *Rajahia* are of very rare occurrences in the northern floral subprovince, while *Emplecopteris* and *Yuania* are restricted to rare appearance in the southern floral subprovince. So far, *Emplectopteridium* has never been recorded in the southern floral subprovince. Minor differences between the northern floral subprovince and southern floral subprovince reflect variations in floristic composition and terrestrial ecosystem in time and space.

The common plant species between south and north China are *Fascipteris* spp., *Lobatannularia multifolia* Konno & Assama, *Annularia shirakii* Kaw, *Gigantonoclea lagrelii* (Halle), *Cladophlebis permica* Lee & Wang, *Plaziozamites oblongifolius* Halle and *Pterophyllum eratum* Gu & Zhi. The

Table 5—Flora from Qinghai-Xizang Plateau

Shuanghu District, Northern Xizang (Li *et al.*, 1982)
Lobatannularia sp.
Annularia pingloensis (Sze) Gu & Zhi
Rajahia (Pecopteris) calceiformis Li & Yao
Pecopteris shuanghuensis Li & Yao
Gigantonoclea guizhouensis Gu & Zhi
Gigantonoclea meridionalis Li & Yao
Rhizomopsis gmmifera Gothan & Sze
Compsopteris contracta Gu & Zhi var. *Punctinervis* Li & Yao
Toba in Qamdo, eastern Xizang (Li *et al.*, 1982a).
Lepidodendron oculis-felis (Abbado) Zeiller
Sphenophyllum koboense Kobatake
Sphenophyllum cf. *sino-coreanum* Yabe
Paracalamites stenocostatus Gu & Zhi
Annularia pingloensis (Sze) Gu & Zhi
Lobatannularia multifolia Konno & Asama
Schizoneura manchuriensis Konno
Rajahia (Pecopteris) calceiformis Li & Yao
Rajahia (Pecopteris) pseudohemitelioides Konno
Rajahia (Pecopteris) qamdoensis Li, Yao & Deng
Pecopteris andersonii Halle
Fascipteris (Ptychocarpus) densata Gu & Zhi
Fascipteris stena Gu & Zhi
Compsopteris contracta Gu & Zhi
Gigantopteris dictyophylloides Gu & Zhi
Gigantopteris cf. *nicotiannaefolia* Schenk
Gigantonoclea miridionalis Li & Yao
Gigantonoclea spp.
Rhizomopsis gemmifera Gothan & Sze
Rhipidopsis pani Chow
Lasiu of Yushu, Southern Qinghai (Li & Yao 1981)
Lobatannularia multifolia Konno & Asama
Annularia cf. *pingloensis* (Sze) Gu & Zhi
Rajahia (Pecopteris) calceiformis Li & Yao
Compsopteris cf. *contracta* Gu & Zhi etc.
Wuli Southwestern Qinghai (Li 1988)
Rajahia (Pecopteris) calceiformis Li & Yao
Gigantonoclea spp.
Pecopteris sp. etc.
Dingri and Dingjie districts, South Xizang (Li *et al.*, 1991), Mixed Cathaysia Gondwana elements
Trizygia speciosa Royle
**Austroannularia qubuensis* (Hsü) Rigby
Paracalamites australis Rigby
Sphenophyllum thonii var. *minor* Sterzel
Asterotheca sp.
Pecopteris unita Brongniart
Cladophlebis qubuensis (Hsii) Li
Glossopteris communis Feistmantel
G. dingriensis Rigby
G. indica Schimper
G. intermittens (Feistmantel)
Vertebraria indica Royle
Scale leaf
Gerze District, Xiagangjiang
Strongly ribbed arthrophytes (e.g. *Phyllotheca*)
Cordaitean leaf-imprints (e.g. *Noggerathiopsis*)
Pecopteris aff. *arcuata* Halle
? Plagiozamites oblongifolius Halle
Kashmir Valley (Singh *et al.*, 1982 & Pant *et al.*, 1984)—Mixed Gondwana Cathaysia elements
Lobatannularia ensifolia
Lobatannularia lingulata
Lobatannularia sinensis var. *curvifolia*
Parasphenophyllum thonii var. *minor*
Rajahia mamalensis
Sphenophyllum thonii var. *archangelskyii*
Sphenophyllum thonii var. *minor*
Sphenophyllum thonii var. *waltonii*

Cathaysia flora is thus mainly composed of lycopods, sphenopsids, ferns, pteridosperms and cordaitean gymnosperms.

Qinghai-Xizang (Tibet) Flora

The palaeobotanical studies of the Permian plants in Qinghai-Xizang plateau have been made during past two decades. The Permian localities situated to the north of the Bangongco-Dengquen (Dingquine) suture of central Xizang are characterised by Cathaysian elements and belong to the South China province Map 3. The important Cathaysian elements found in the Shuanghu District in northern Xizang (Li *et al.*, 1982a), Toba in Qamdo eastern Xizang (Li *et al.*, 1982), Lasiu Yushu southern Xizang (Li & Yao, 1981) and Wuli of south eastern Qinghai (Li, 1986) are listed (Table 5).

Another flora in Xiagangiang of Gerze District is dominated by many strongly ribbed stem casts or

arthrophytes (e.g., *Phyllotheca*) and cordaitean leaf imprints (*Noeggerathiopsis*) a feature rarely known in the Cathaysian flora, resembling rather closely plant forms of Gondwana. The flora is also associated with some forms of Cathaysian flora such as *Pecopteris* aff. *arcuata* Halle, *?Plagiozamites oblongifolius* Halle. Therefore Xiagangiang flora is considered as a mixed flora of Cathaysian-Gondwana affinity by the Chinese palaeobotanists, though the flora is poorly preserved to be identified even up to generic level.

The most important and significant Permian flora of Gondwana affinities is that from the Qubu Formation recorded in the Dingri and Dingjie districts of South Xizang during last two decades (Hsü, 1973, 1976, 1978; Li, 1983; Li *et al.*, 1991). The final list of plant types include *Trizygia spectosa* Royle, *Austroannularia qubuensis* (Hsü) Rigby *(=Lobatannularia), Paracalamites australis* Rigby, *Sphenophyllum thonii* var. *minor* Sterzel, *Asterotheca* sp., *Pecopteris unita* Brongniart, *Cladophlebis qubuensis* (Hsü) Li, *Glossopteris communis* Feistmantel, *Glossopteris dingriensis, Glossopteris indica* Schimper, *Glossopteris intermittens* Feistmantel, *Vertebraria indica* Royle, scale leaf and stem. Accordingly, the Qubu flora is correlated with the Early Permian Barakar (Li *et al.*, 1991) or Karharbari Formations (Hsü *et al.*, 1990).

The reports of the mixed occurrence of Gondwana and Cathaysian elements in Kashmir and Qinghai-Xizang (Tibet) plateau in recent years have created much rethinking about the concept of Gondwanaland. Crawford (1974) suggested a modified concept of "Greater Gondwanaland" based on finds of index fossils in the Triassic of Tibet like *Daphnlopsis* and *Lystosaurus*. Accordingly he stretched the boundary not only into Tibet but further north up to Tarim Basin block and the north western part of China. Supposed finds of *Glossopteris* (Hsü, 1973, 1976, 1978; Li, 1983; Li *et al.*, 1991; Hsü *et al.*, 1990) in South Xizang supported Crawford's ideas. Geological data by Stocklin (1981) also strengthened this idea based on his belief about the non-existence of an ocean between Xizang and India during Permian and accordingly the Tethyan oceanic trough between India and Xizang appeared only in the Mesozoic. The Indian scientists (Pant *et al.*, 1984; Maheshwari & Bajpai, 1987; Bajpai & Maheshwari, 1995) believe that the northern boundary of Gondwana did not reach beyond the Indus-Yarlung-Zangbo suture line during the Permian. According to them the mixing of the two floras should have been on more uniform basis which is not so far reported. In the absence of reproductive structures it is also difficult to believe that the same plants were growing in southern Xizang as in Gondwana territory.

There is no doubt that based on the present evidences from Qubu flora in southern Xizang and Mammal flora from Kashmir some kind of intermixing of Cathaysian and Gondwana elements has taken place. Some of the arguments put forward by various authors explain that :

1. The mixing of the Gondwana elements in Cathaysia flora and Cathaysian elements in Gondwana flora is because of migrants from either side (Sahni, 1935; Wagner, 1962; Konno, 1966; Ahmad, 1978).
2. The mixing of such foreign elements in the pure floras may not be really related but they could represent similar looking homoplastic forms (Plumstead, 1973; Asama, 1967; Meyen, 1967; Pant, 1975).
3. The mixing is partly because of migrants and partly due to homoplasy (Meyen, 1967; Lacey, 1975).
4. The mixing is probably because of scattered islands between the Indian and the Tibetan plateau giving way to intermixing but not uniformly and therefore few elements of either side could make it to the other side (Nakazawa & Kapoor, 1977).
5. This mixing is controlled by climatic conditions, continental positions and plate tectonics.

It is premature to draw the northern limit of Gondwana on the basis of (i) few, fragmentary, ill preserved specimens from only few localities in Xizang or Kashmir; (ii) in the absence of structural

details and reproductive parts in similar looking forms; (iii) in the possibility of inaccurate identifications of the floristic elements; (iv) in the absence of other parameters, like palaeontological, palynological and detailed sedimentological data.

ORIGIN OF CATHAYSIA AND GONDWANA FLORAS

The Cathaysia flora is mainly composed of lycopods, sphenopsids, ferns, pteridosperms and cordaitean gymnosperms as is obvious from the list of fossil plants from north China province. The Cathaysia flora was located in the equatorial region under a tropical climate during the Carboniferous and Permian. Sun Keqin (1995, 1996) put forward that some obvious changes in floral components of the Cathaysia area occurred during the transition from the Early Carboniferous to Late Carboniferous which resulted in extinctions of many typical plant elements of the Lepidodendropsis flora and occurrences of a number of forerunners of the Cathaysia flora. Therefore, the Cathaysia flora did not originate from the Euramerica flora but it is derived from the globally identical Lepidodendropsis flora of the Early Carboniferous. From the beginning of the Namurian A, the Cathaysia flora gradually separates from the Lepidodendropsis flora. The Cathaysia flora can be recognized as an independent flora in the Early Late Carboniferous (Namurian B to C), belonging to the Early Cathaysia flora. The flora is characterised by a variety of oriental species of lycopods and many characteristic elements of ferns and pteridosperms, etc. The range of the Cathaysia flora is generally agreed upon from the beginning of the early Late Carboniferous to the end of the Permian in age. The most obvious changes of dry climate and tectonic movements caused extinction of the Cathaysia flora by the end of the Late Permian (Sun Keqin, 1996).

The origin of Gondwana flora is still not well understood as there are few records prior to Permian. The ancestors of this flora and their geographical situation are still controversial. The ancestors of Gondwana flora cannot be traced back in Carboniferous or older strata as there are serious gaps in our knowledge. Plumstead (1973) believed that the protoglossopterideae, whose remains were found from the Carboniferous beds of South Africa, were the ancestors of glossopterids of the post glacial coal-bearing Gondwana strata. The idea was discarded by many workers as these Protoglossopterid plants were actually smaller forms of *Glossopteris* and recovered from the same beds as others. Sahni (1939) believed that almost sudden and enigmatic arrival and spread of the Glossopteris flora is deeply rooted in the glacial episode itself which presumably might have triggered genetic changes of rapid evolutionary significance. Accordingly there might have been mass mutational changes in the then existing Carboniferous flora giving rise to *Glossopteris* and allied forms. Unfortunately, fossil history cannot substantiate Sahni's contention atleast in India as there are no reports of Late Carboniferous depositions and fossil plants. The extinction of the Glossopteris flora was gradual as many of its elements lingered on in the Triassic. Pant (1987) considered that mutational changes might have been responsible for the coming of new elements along with migrants from other parts.

CONCLUSION

Summarising the comparison between the Gondwana and the Cathaysia floras :

1. Both the flora are represented by major group of plants like lycophytes, arthrophytes, filicophytes and gymnosperms. At generic and specific level the two floras have characteristic and exclusive forms.

2. Some intermixing has taken place perhaps at generic level.

3. The two floras have originated from the globally identical Early Carboniferous floras.

4. A typical Gondwana flora is of Early Permian to Late Triassic in age. The Cathaysia flora is early Late Carboniferous to Permian in age.

5. The climate of Gondwana flora was essentially cool to warm temperate gradually ameliorating while that of Cathaysia was tropical as it was

located at equatorial region during the Carboniferous and Permian.

6. The extinction of the Glossopteris flora is gradual as some of the forms linger on in the Triassic. The Cathaysia flora, due to dry climate and tectonic movements, vanished by the end of the Late Permian.

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