Stratigraphic and phytogeographic palynology of late Paleozoic sediments in western Yunnan, China

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Abstract

This long paper is about the palynological studies of late Paleozoic rocks of western Yunnan, SW China, especially about the stratigraphy, phytogeography and tectonic, based upon the palynomorphs contents. Such kind of study will, hopefully, be applicable to the Japanese Paleozoic sediments, which were deposited in a similar tectonic background as western Yunnan.

Keywords: late Paleozoic, palynology, phytogeography, tectonic, western Yunnan, SW China.

Contents

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Foreword

During my stay in the Department of Geology, Faculty of Science, Niigata University from March 1998 to March 2000 to carry out a joint research entitled " Carboniferous and Permian biota comparative studies and their tectonic implication in between China and Japan" . I have been encouraged and assisted by Prof. Jun-ichi Tazawa of the Department to publish this special paper. It documents the palynological studies of the late Paleozoic rocks in western Yunnan, China, and will help the Japanese colleagues to understand the importance of the palynological study in a Paleozoic paleosuture zone between Gondwana and Laurasia where macrofossils are very poor or absent.

The study of Paleozoic palynology, especially spores and pollen of late Paleozoic has a long history. It became important in the coal industry in the 19th century and continued to dominate research until the late 1950s when palynology for oil exploration became more important. Well-documented palynological sequences have been established for the Devonian to Triassic; they are especially important in the latest Devonian, early Carboniferous, early Permian, throughout much of the world. However, the importance of palynology was slow to be recognized in Asia where many late Paleozoic rocks yield fusulinids, other faunas and plants. For this reason, palynology has not played an important role in the study of late Paleozoic biostratigraphy and paleobiogeography in Asia.

The biostratigraphy and paleobiogeography of most of the platform areas in Asia have been exhaustively studied. In contrast, most of the paleosuture zones contain few macrofossils and the microfossils (spores and pollen) are more biostratigraphically and paleobiogeographically useful.

This microfloral study of late Paleozoic in western Yunnan will optimistically be applicable to the Japanese Paleozoic rocks, which were deposited in a similar tectonic setting in which stratigraphically useful plant data are rare.

1. Introduction

1.1 Geological setting and the history of the Gondwanan geology in Asia

Due to its important paleogeographic and tectonic location and the finding of biota with the Gondwanan affinity in western Yunnan, the geology, especially the paleontology and paleobiogeography, in western Yunnan would be one of the key and interesting areas in Asia, especially in SE Asia, to clarify the geological evolutionary history of east Tethys and the relationship of Laurasia and Gondwana.

1.1.1 Geological setting of western Yunnan

Western Yunnan lies on the eastern side of the collision zone between the Indian and the Eurasian plates, within the Tethys-Himalayan folding system (Wang *et al.*, 1984). The following three lithological groups are recognised: **(1)** the Ailaoshan Groups in the east zone, which is also called **geological block I** in this paper, composed of the following groups, the Shuanggou Group, the Chongshan Group, and the Damenglong Group; **(2)** the Lancang Jiang Groups in the middle zone (also named as **geological block III**), subdivisible into the Lancang group, the Mengtong Group, and the Ximeng Group; and **(3)** the Gongyanghe Group and the Gaoligongshan Group in the west zone (also referred to **geological blocks VI & V**) (Fig.1). All of these groups make up the basement rocks in western Yunnan. After the Jinning movement, the ocean crust of Yunnan transformed into continental crust both in eastern and western Yunnan. Since then eastern Yunnan had become continent while western Yunnan still remained an ocean.

In the Three Rivers (Jinshajiang, Lancangjiang/Meekng, Nujiang/Salween rivers) region of western Yunnan, based upon the distribution and development of the strata and fossils, together with the presence of deep faults (the main three rivers mentioned in above), the following tectonic units can be recognised from east to west, they are the Yangtze Microcontinent, the Mojiang (Ailaoshan-Tengtiaohe) Oceanic Basin, the Simao Massif (yielding Lincang Terrane), the Changning-Menglian Oceanic Basin, the Baoshan-Gengma Massif, the Luxi Trough and the Tengchong Massif (Liu *et al.*, 1996). In general, three basic zones in terms of stratigraphic regionalization in western Yunnan can be outlined (Fig.1).

(1) The east zone (geological block I): The Mesozoic strata are extensively distributed in the most area of this zone. Some late Palaeozoic strata are also present in its west margin close to the Lincang granite (**geological block II**) and its east margin as well.

This zone is also named by some people as the Lanping-Puer (or Simao) Massif, which lies between the Yuanjiang and the Lancangjiang Fault Zones, extending from NW to SE. The remarkable red beds of Jurassic to Eocene age are widely distributed in this zone. The oldest strata dated back to Silurian flysch-like deposits consisting of graptolite shale, siltstone and siliceous deposits in the eastern margin of this zone. The Devonian System is represented by siliciclastic deposits and limestone. During the Carboniferous and Permian periods lithofacies differentiation became apparent. Carbonates and fine clastics, on one hand, were deposited in stable basins; intermediate-basic volcanics and flysch sequences, on the other hand, were developed in mobile regions. Middle and late Triassic deposits varied from volcanics, carbonates and thick clastic sequences with purplish red beds. Indosinian orogeny strongly affected this region and terminated the marine envi-

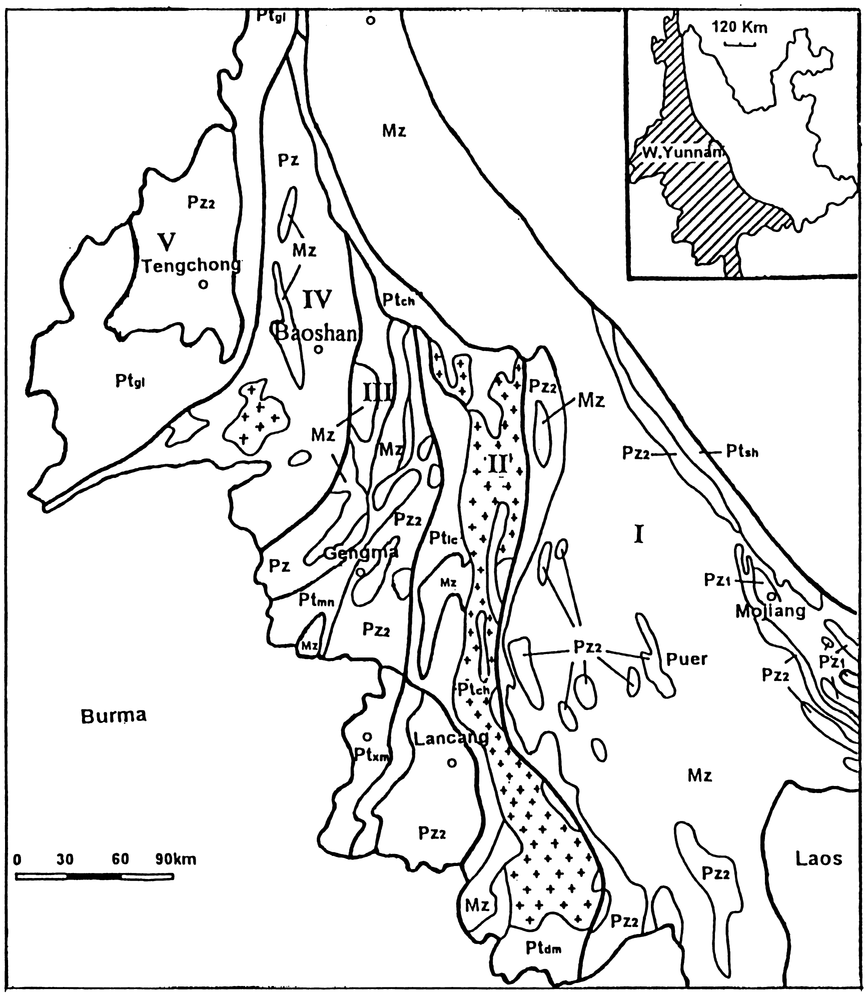

Fig. 1. The simplified geological map of western Yunnan, S.W.China.
Mz-Mesozoic; Pz-Palaeozoic; Pz2-Upper Palaeozoic; Pz1-Lower Palaeozoic; Pt-Proterozoic; Ptgl-Gaoligongshan Gr.; Ptmn-Mengtong Gr.; Ptxm-Ximeng Gr.; Ptlc-Lancang Gr.; Ptch-Chongshan Gr.; Ptdm-Damenlong Gr.; Ptsh-Shuanggou Gr.; r-Granite; I-Lanping-Puer massif; II-Lincang Granite; III-Changning-Menglian Belt; IV-Baoshan massif; V-Tengchong massif.

ronment. From Jurassic to Eocene this region subsided continuously with accumulation of huge red beds which were often folded during the Himalayan Orogeny in late Eocene.

(2) The middle zone (geological block III): In brief, the middle zone or **the Changning-Menglian Belt** in terms of tectonopaleogeography is generally dominated by the late Paleozoic strata,. In this belt late Paleozoic strata yielded very abundant and widespread fossils, and lower Triassic sediments and fossils were also discovered recently.

The Changning-Menglian Belt is confined by the Lancangjiang Fault Zone on the east and the Kejie-Nandinghe Fault on the west, which normally refers to the part between the Lincang Batholith and the Kejie-Nandinghe Fault. The oldest strata are the metamorphosed Precambrian flysch and volcanic formations, probably belonging to the Middle Proterozoic. Early Paleozoic strata are also slightly metamorphosed. The Ordovician System consists of siliciclastics and carbonates while the age of fossils-barren sequence below remains a problem and is thought to be of Cambrian age (Bureau, 1990). Devonian sediments with a huge thickness rest disconformably on the lower Paleozoic and consist of fine graptolite-bearing clastics, siliceous shale and chert. During the Permo-Carboniferous period, two different lithological successions were developed. One succession, mainly in the eastern part and some places in the western part of this region, is represented by thick and continuously fine siliciclastic and bedded chert. Liu Benpei *et al.* thought that they were deposited in a continental slope environment. The other one is presented by fossiliferous limestone in the central part of this region on which overlies the Lower Carboniferous Yiliu Formation consisting of basaltic volcanics and limestone intercalation indicating Tournaisian age. A continuous Devonian to Anisian chert succession with the finding of radiolaria were claimed by Liu *et al.* (1993) in the south of Menglian county. Early Triassic sediments are not widely distributed. Late Triassic to middle Jurassic sequences represent molasse deposits, comprising lacustrine and fluviatile strata and lagoobal red evaporites.

Further more three subdivisions of this belt can be made according to the stratigraphic sequences and sedimentary facies.

(1) East Area: The huge thickness (more than 2,000 m) and complicated association of arkosic arenite, quartz graywacke, argillaceous rocks, bioclastic marl and silicate rocks (Nanduan Formmation and Laba Group) developed very well in this area, ranging in age from Devonian (?), Carboniferous and Permian, all of which conformably overlie the lower Paleozoic basement. On the analysis of sedimentary facies and data of petrochemistry, this area could represent the upper slope of a passive continental margin to CCD surface and even much deeper sedimentary sequences. The Lincang granite (**geological block II**) outcrop in east of this area is connected to the east zone. Some Visean miospores have been extracted from the top of the Nanduan Formation.

(2) Middle Area: The basement rocks are rare or covered in this much narrowed zone. However, the most completely stratigraphic sequences and complicated deposit types are exposed very excellently in this area. From the multidisciplinal synthesis a new knowledge of the stratigraphic frame in this region was obtained. There are by the current investigation abundant deep water radiolarian-bearing silicate rocks ranging in age from early Devonian to middle Triassic, and nine radiolarian assemblages have been established. Especially, the discovery of radiolarians in early Devonian, the end of Permian and the early-middle Triassic is extremely significant to the understanding of the evolution of the Paleo-Tethys.

(3) West Area: Once more the association of quartz graywackes, argillaceous rocks and silicate rocks (Jialaba Formation and Nanpiehe Formation) occur in this west area. The extraction of miospores from rocks both in Xiaolaba, Lanchang and in Nanpiehe, Gengma shows their ages back to late Devonian and Carboniferous rather than late Permian in which the finding of plant fragments is doubtful. The possible sedimentary environments are quite the same as the east area-upper slope of continental margin, which belongs to the Baoshan-Tengchong Massifs in the west.

(3)The west zone: In brief, the Baoshan-Tengchong Massifs show particularly well exposed Paleozoic outcrops. However, the late Paleozoic dominating in the Tengchong Massif is termed as **geological block V** close to Burma, while the remaining part of this zone is the Baoshan Massif in the east (**geological block IV**).

Since 1970s, the late Paleozoic, especially the late Carboniferous and early Permian sequences in western Yunnan have been recognised sharing some common features with the sequences in Salt Range, Kashmir, Tibet, eastern and peninsular Burma, western Malaysia, mainly in two aspects of "pebbly mudstone" and "cold water fauna" . So far only the Tengchong and the Baoshan Massifs in western Yunnan were once claimed with the occurrence of the above mentioned "pebbly mudstone" and "cold water fauna" In the Tengchong Massif, the late Carboniferous and early Permian Menghong Group consists of about 2,000m clastic sediments. About one-third of this above sequence is predominant diamictite and pebbly mudstone. The late Carboniferous and early Permian "pebbly mudston" in the Baoshan Massif is the Dingjiazhai Formation which contains in its lower part about 15-20m diamictite and coarse clastics. Both Wang (1983) and Cao (1986) compared the Menghong Group in Tengchong and the Dingjiazhai Formation in Baoshan with the Horpatso Group in northwestern Tibet, the Yongzhu Group near Xainza in central Tibet, the Phuket Series in Thailand and the Mergui Series in Burma. Then they concluded that the "pebbly mudstone" distributed in the above mentioned areas might have deposited in a glacio-marine environment somewhere at the northern margin of Gondwana.

The Tengchong Massif lies west of the Nujiang/Salween Faults. The oldest strata in wide distribution are the middle Proterozoic metamorphics, i.e. the Gaoligongshan Group, being most granulites. The oldest sediments known so far belong to the lower Devonian carbonates and siliciclastics. No middle and upper Devonian exposed in this region. The Carboniferous System is mainly represented by the Menghong Group. The lower part of this group consists of rather monotonous siltstone and mudstone (or shale) in the southern part and sandstone in the northern part. The middle is dominantly composed of diamictite and pebbly mudstone. The upper is mainly dark and black shale and siltstone with some irregular argillaceous limestone beds. The Menghong Group is then overlain by the Permian limestone, dolomitic limestone and marble of the Dadongchang Formation, which extends up to the upper Maokou (lower Tatarian). The top part of the Permian is unknown.

The Baoshan Massif lies east close to the Tengchong Massif and bounded by the Lancangjiang Fault Zone and the Kejie-Nandinghe Fault on the east and the Nujiang Zone on the west. As mentioned before this is the first locality in which the most remarkable glacigene sequence has been considered and reported in 1980s. The oldest part of the stratigraphic sequences in Baoshan are the Gongyanghe Group of Sinian to middle Cambrian in age, which extends southwards to Shan States in a name of Chaung Magyi Group. The Gongyanghe Group is a flysch sequence consisting of siliciclastics and a few silicerous shale and carbonates. Some trilobites from the upper Cambrian of the Bashan Massif show similarities to those found in North China. The fossiliferous siliciclastics and some argillaceous limestone of Ordovician represents a relatively stable environment. The lower Silurian is dominated by graptolite-bearing shale. The middle and upper Silurian are mainly fossiliferous argillaceous limestone. The Devonian starts with fine siliciclastics and some argillaceous limestone intercalations containing tentaculids and conodonts. From middle Devonian to early Carboniferous are prevailed by fossiliferous carbonates. Then the whole massif emerged. The lower Permian Dingjiazhai Formation lies unconformably on early Carboniferous or older

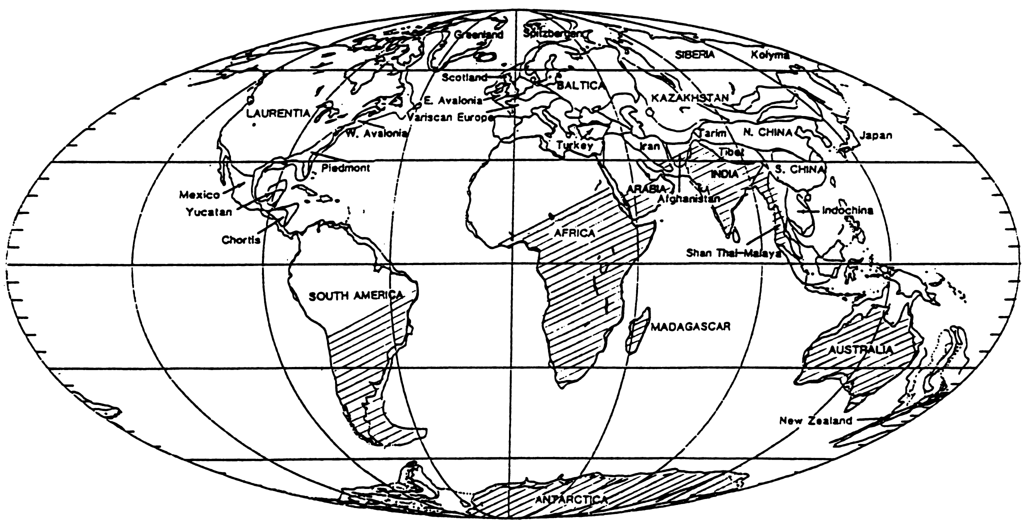

Fig.2. The shadows showing the possible Gondwanaland on the present day continents map (modified from Ziegler *et al.* 1977a,b and Scotese,1979).

sequences, which consists of two parts. The lower part of the Dingjiazhai Formation consists of diamictite, pebbly mudstone, slumped and slurried diamictite, turbidite, conglomeratic sandstone and siltstone. The upper part comprises laminite, black mudstone and siltstone claimed by Jin (1994). The Dingjiazhai Formation then is overlay by Woniusi Basalts. The spores and pollen found in this paper came from the black mudstone at the bottom of the upper part of the Dingjiazhai Formation.

1.1.2 The history of the Gondwanan geology in Asia

The history of the Gondwanan geology in Asia was back to the proposal of Gondwana-Land including India subcontinent by Suess. In 1885 he first claimed that the restricted occurrence of the *Glossopteris* flora in the Peninsular India, southern and middle Africa and Madagascar pointed to a continuous landmass-Gondwana-Land. Later authors, Wegener (1915) and Du Toit (1937) extend the landmass to the rest of Africa, Arabia, South America, Antarctica and Australia, and shortened its name to Gondwanaland. Others have since truncated it to Gondwana (Schwarzbach, 1981), and still others have restored it to Gondwanaland (Sengor, 1983) (Fig. 2).

Up to 1970s, a part of SE Asia was considered by many geologists to be a part of Gondwanaland. For instance, after the stratigraphic analysis, Ridd concluded in 1971 that the whole SE Asia once could be a part of Gondwanaland and claimed again in 1980 that Thailand-Malaysia Peninsular (excluding Indochina) could split from Gondwana in Devonian and collided with South China block by the end of Permian. Furthermore, in 1983 Stauffer once predicted that the tectonic feature of SE Asia look like "mosaic" to him. The westmost part of this "mosaic", i.e., from south Sumatra to Southwest China harboured in the vicinity of the north margin of Gondwanaland. After a series of collision, all these fragments in SE Asia united together as a whole in Triassic. In the discussion about the evolution of Tethys, Sengör (1984,1985,1988) proposed a concept of Cimmerian to represent a continent, which in his opinion split from north

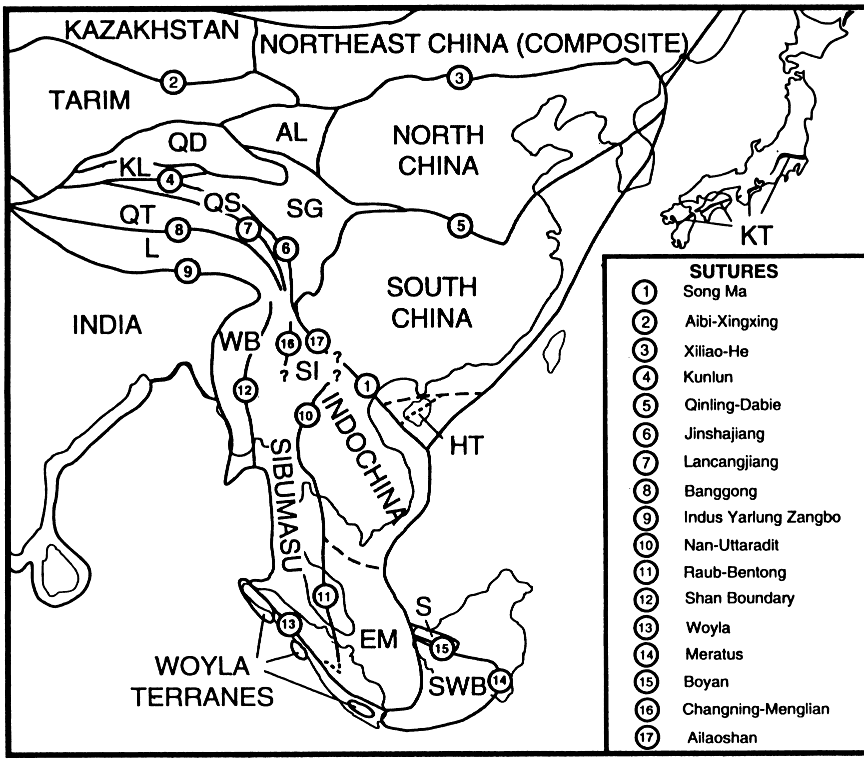

Fig.3. The distribution of principal continental terranes and suture of East and SE Asia. EM = East Malaya; WB = West Burma; SWB = South West Borneo; S = Semitau Terrane; HT = Hainan Island terranes; L = Lhasa Terrane; QT = Qiangtang Terrane; QS = Qamdo-Simao Terrane; SI =Simao Terrane; SG = Songpan Ganzi accretionary complex; KL = Kunlun Terrane; QD = Qaidam Terrane; AL = Ala Shan Terrane; KT = Kurosegawa Terrane (after Metcalfe, 1996).

margin of Gondwanaland in long strip and drifted northwards and then finally collided with Asia continent. Therefore, Tibet, western Yunnan in China and a part of SE Asia should be included in his Cimmerian. However, an Australian geologist Metcalfe introduced another name of Sibumasu while discussing the Carboniferous stratigraphy, paleontology and paleogeography in SE Asia in 1984 (Fig.3).

The Sibumasu includes the Shan Staes in Burma, Northwest Thailand, Burma Peninsula, Thailand, West Malaysia and Sumatra. After careful examination about the stratigraphic sequences and paleontological data in these SE Asia blocks, he astonished to have found the remarkable similarity of late Paleozoic stratigraphic sequences in between this Sibumasu block and northwest Australia. He concluded further that the Sibumasu split from Gondwana in early Early Permian and then drifted northwards and collided with South China block in late Triassic.

1.2 The finding of the Gondwanan facies in China (Tibet, western Yunnan)

So far, only in Tibet and western Yunnan has been claimed the finding of the Gondwanan facies strata although there are still some controversy about these, especially about the relevant sequences in western Yunnan.

1.2.1 The finding of the Gondwanan facies in Tibet

In China, back to 1950s, Lipo first reported in 1955 the finding of pebbly-slate or debris-slate, which is now called diamictite, from the Permo-Carboniferous strata in the region of Linzhou and Bomi in Tibet. In 1976, the first finding of the Gondwanan facies strata and the *Glossopteris* flora were reported by Yin and Guo (1976) and Xu (1976) respectively in the northern slope of Mt. Everest in Tibet. Since then, the Permo-Carboniferous strata in Linzhou and Bomi area had been quoted as the Gondwanan facies strata in the Lasa block. In the west part of Qiangtang block north to the Lasa block, there developed a series of rock suites of late Paleozoic named by Norin (1946) as the Horpatso Series. This series also had once been treated as the Gondwanan facies strata and could be correlated with the one in Kashmir.

The cold water *Eurydesma* fauna has been found by Liu *et al.* (1983) from the middle part of the Woerbacuo Formation (former Zhanjin Formation) ir the west part of Qiangtang block and possible from the diamictite in the Xiagangjiang region in the Lasa block (Rao *et al.*, 1983). The *Glossopteris* flora dated as early Chihsian was discovered by Xu (1973, 1976, 1990) from the Qubu Formation in the northern slope of Mt. Everest in the south of Yaluzhangbu River in China.

1.2.2 The finding of the Gondwanan facies in western Yunnan

With the finding of the Gondwanan facies strata and the *Glossopteris* flora in Tibet, some geologists began to concern about the late Paleozoic geology in western Yunnan, which is supposed to have strong links with Tibet in tectonic. In the late 1970s, a few geologists mainly from geological survey teams belonging to Geological Survey of Yunnan Province once noticed the possible existence of the Gondwanan facies strata and its biota while doing geological mapping in western Yunnan. Until the early 1980s, Wang (1983) first published this kind of finding in western Yunnan. And he described that Tengchong was a glacio-marine environment while Baoshan a normal shallow marine beyond glacio-marine. Both Tengchong and Baoshan could be correlated with the lower Gondwanan Series in Himalayas and India. However, Cao believed in 1986 that both the Dingjiazhai Formation in Baoshan and the Menghong Group in Tengchong belong to glacio-marine strata. In both Tengchong and Baoshan, there were some claims about the finding of cold-water fauna and even the *Glossopteris* flora in the supposed glacigene sequences, e.g., *Stepanoviella*? *gracilis*, *Eurydesma sinensis* Lin (unpublished and diagnosed by Lin Mingji) from the Dingjiazhai Formation(Duan, 1983); *Spiriferellina cristata, Marginifera* sp. from the lower Menghong Group (Cao, 1986). In the younger horizons above this glacigene horizon, there also claimed some cold water *Costiferina-Waagenites* fauna by Fang (1983) from the Xiaoxinzhai Formation (probably Kungurian or even younger) and *Glossopteris* ? sp (unpublished) from the Yongde Formation (Kungurian or even younger).

Both Wang (1983) and Cao (1986) connected and correlated the above strata in Tengchong and Baoshan with the Zhadari diamictite in Quzong district of Qubu, Tibet (Yin,1976); the Angjie Formation of the Yongzhu Group in Linzhou and Shenzha district in Tibet (Han *et al.*, 1983); the Laigu Group in Basu, Tibet (Chen, 1987) and the Phuket Group in Thailand (Mitchell *et al.*, 1970; Ridd, 1971). Fig. 4 is showing the distribution of Permo-Carboniferous glacio-marine deposits in southwestern China and SE Asia. Since then, the diamictite or pebbly mudstone as well as the above fauna and the flora in Tengchong and Baoshan have been quoted with little doubt as glacio-

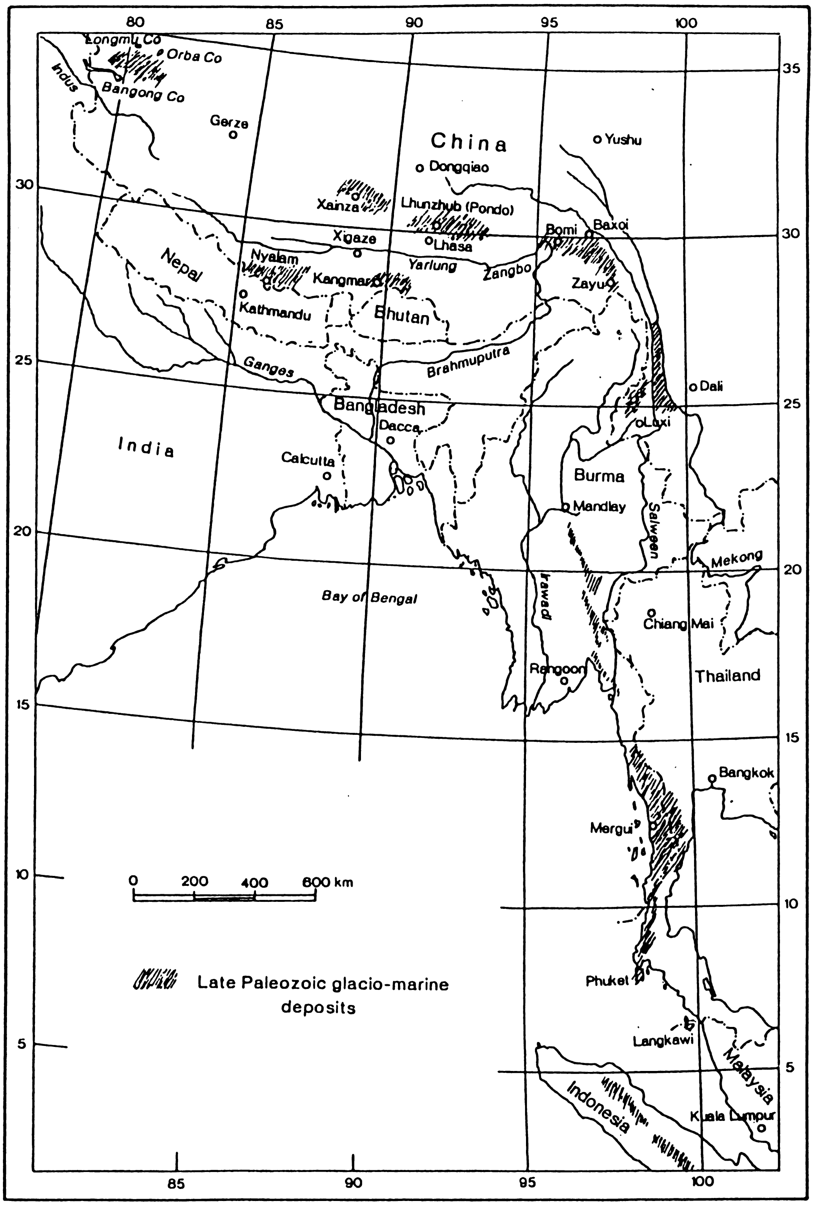

Fig.4. Distribution of Permo-Carboniferous glacio-marine deposits in south-western China and Southeast Asia (after Jin, 1994).

marine deposits or tilloid, cold water fauna and Gondwana related flora by many geologists (Wang, 1985; Huang Jiqing and Chen Bingwei, 1987; Xiao Xuchang *et al.*, 1988; Yang Jiawen and Yan Pingxing, 1990; Bureau, 1990, etc.). Subsequently, all of these have been used the evidences to support the hypothesis that western Yunnan was of Gondwana provenance in tectonic.

1.3 The rise of suspicion about the Gondwanan facies in western Yunnan in the early 1990s

In the early 1990s, the above supposed evidences were provoked by some geologists since the claimed fossils are either ill preserved or wrong-identified. Zhou and Fang (1990), Duan Lilan (1991) and Fang (1991) successively began to doubt the glacio-marine nature of the "pebbly mudstone" and reject the idea of the presence of cold water fauna in western Yunnan. After the carbonate microfacies study from the upper Pumenqian Formation to the Dingjiazhai Formation at Youwang section in Baoshan, Zhou and Fang considered that the pebbly strata in the lower Dingjiazhai Formation could be some kind of debris flow deposits rather than ice-rafted boulder or debris. The unpublished *Eurydesma* from the Dingjiazhai Formation was rejected by Fang and modified to be the genus of *Schizodus* because the above specimen are smaller and thinner than those from Australia. Additionally, the plant specimens *Glossopteris* found in Yongde was also cast a question mark by Li Xingxue due to the incompleteness of specimens themselves (Fang, 1991). With the successive negation of tillite and cold water fauna in Baoshan, therefore, Zhou and Fang concluded that the hypothesis of Baoshan Massif being of Gondwana provenance lose its necessary supporting. In their opinion, the Baoshan Massif exhibits some kind of transitional type. In the paper of "Sibumasu biotic province and its position in paleotethy" , Fang discussed this issue again in more details. His main arguments are that Sibumasu was neither a part of the Gondwanan realm nor Cathaysian realm and an independent province instead, which could be attributed into Tethyan realm. In other words, he doubts about or denies the existence of the Gondwanan facies strata and the Gondwanan type cold-water fauna in Baoshan. His arguments were mainly based upon the following claims. First, the so-called *Eurydesma* and tillite from the lower Dingjiazhai Formation had been respectively modified and rejected. The age of this Dingjiazhai Formation should be late Carboniferous (Gzelian stage). So it has no relation with the glaciation mainly from Asselian to Sakmarian in Gondwanaland. Second, he described the possible difference of ice-rafted pebble and pebbly mudstone in between Thailand-Malaysia Peninsula, India, Arabian Peninsula and northwest Australia. Third, the claims of *Costiferina-Waagenites* to be cold-water fauna by Fang Runsen had nothing related to the typical cold-water fauna (mainly from Asselian to Sakmarian) in Gondwanaland since this *Costiferina-Waagenites* horizon is much younger (probably Kungurian or even younger, also see Table 14).

1.4 The goal of this palynological study in western Yunnan

The geological configuration of western Yunnan, SE China has been puzzled in geological circle for a long time. So far, various documented information demonstrates that the Phanerozoic geological history of Asia-Australia-the pacific region is actually the history of the Gondwana dispersion and the formation of the Asian continent. The Asian continent is, instead of being a simple continent cored by a huge Precambrian craton, an integrated one by many micro-continental blocks in varying sizes, that were welded to Siberia (or Angara) after their separation from the Pan-Gondwana continent. The most conspicuous in this region is the intersection of the Circum-Pacific and the (eastern) Tethyan tectonic belts in eastern Asia. We target one of the most important geological belts, the Changning-Menglian Belt, which is the key area within the Tethys-Himalayan folding system.

Due to the lack of sufficient megafossils data in both fauna and flora at some critical time periods, the biostratigraphy (strata dating) and paleobiogeography (biotic provincialism) in west-

Table 1. The table showing the palynological sampling in the different areas in western Yunnan.

Stratigraphic Regions			Sec. No.	Section Symbol	Sections Localities	Samples Amount
Tibet		East Tibet	(1)	SL*	Songlen, E.Tibet	20
			(2)	ZW	Zhuwagen, E.Tibet	89
Western Yunnan	West Zone	Tengchong Massif V	(3)	TKI, TKIII*, TKIV	Kongshuhe, Tengchong	16
			(4)	TDI	Dayunshan, Tengchong	7
			(5)	LDI---LQ	Dashuigou---Qiaotou	10,20
			(6)	SSI,SSII*,SSIII,SSIV	Siguangping, Lianghe	44
		Baoshan Massif IV	(7)	CYK*	Kongsongzhai, Yongde	18
			(8)	YA*	Anpaitian, Yongde	14
			(9)	BWII, 90BW*, JJ*	Woniusi, Baoshan	12,
			(10)	DSI*	Dongshansi, Baoshan	14,32
	Middle Zone	Changning-Menglian Belt III	(11)	SPS,NPI,NPII,NPIII***	Sipaishan, Gengma	18
			(12)	XHS*	Xinheishan, Gengma	15, 76
			(13)	GN*	Nanpiqiao, Gengma	8,
			(14)	JL*	Jinglie, Gengma	17,
			(15)	AN,ANII,ANIII,AL**	Ali,Nanduan, Lancang	13, 7
			(16)	XLB*	Xiaolaba, Lancang	56
			(17)	MYII*	Muyinhe, Lancang	14
			(18)	LL,LLII*	Laba, Lancang	12
			(19)	AH*	Ali,Haibang	21
	East Zone	Lanping-Puer Massif	(20)	SL, RS*	Silan-Gonglu, Lancang	11
			(21)	MX, NMT*	Xumuchang, Namutian	32
			(22)	MD*	Dengkong, Mojiang	10,7
			(23)	MXD	Xiamidi, Mojiang	8
						13

ern Yunnan could not have been achieved so satisfied. And the more convincible tectonic implication can not be made either. The following palynological study aims at the more detailed analysis of the phytogeographic relationship in this above suture zone area in between Gondwana and Laurasia, based upon comparative studies of microfloral assemblages. It aims tentatively to establish the biostratigraphic sequences in this palynologically uninvestigated area. The spore / pollen content of these rocks have proved to be a major contribution to unravelling the late Paleozoic phytogeography of this relatively unknown and tectonically critical region.

2. Late Paleozoic palynostratigraphy in western Yunnan

2.1 Stratigraphy and palynological sampling of late Paleozoic sediments in western Yunnan

Many geological field trips to western Yunnan have been carried out and a total amount of 634 samples have been collected since 1988 (Table 1). Fig. 5 is the location map of the palynological sampling in western Yunnan. The first trip in 1988 was a tentatively palynological investigation, in which we tried to cover all the different zones in western Yunnan, in other words, collecting the most sections of late Paleozoic rocks from the three major zones, the east Lanping-Puer zone, the middle Changning-Menglian Belt, and the west Baoshan-Tengchong zone. After the samples have been processed in the laboratory, we turned our interests onto the middle zone- the Changning-Menglian Belt. Then I brought some samples to visit the Center for Palynological Studies, Sheffield University, U.K., where we made an interesting finding of *Retispora lepidophyta* microflora from Gengma. So I made the third trip to western Yunnan in 1992 to collect more samples.

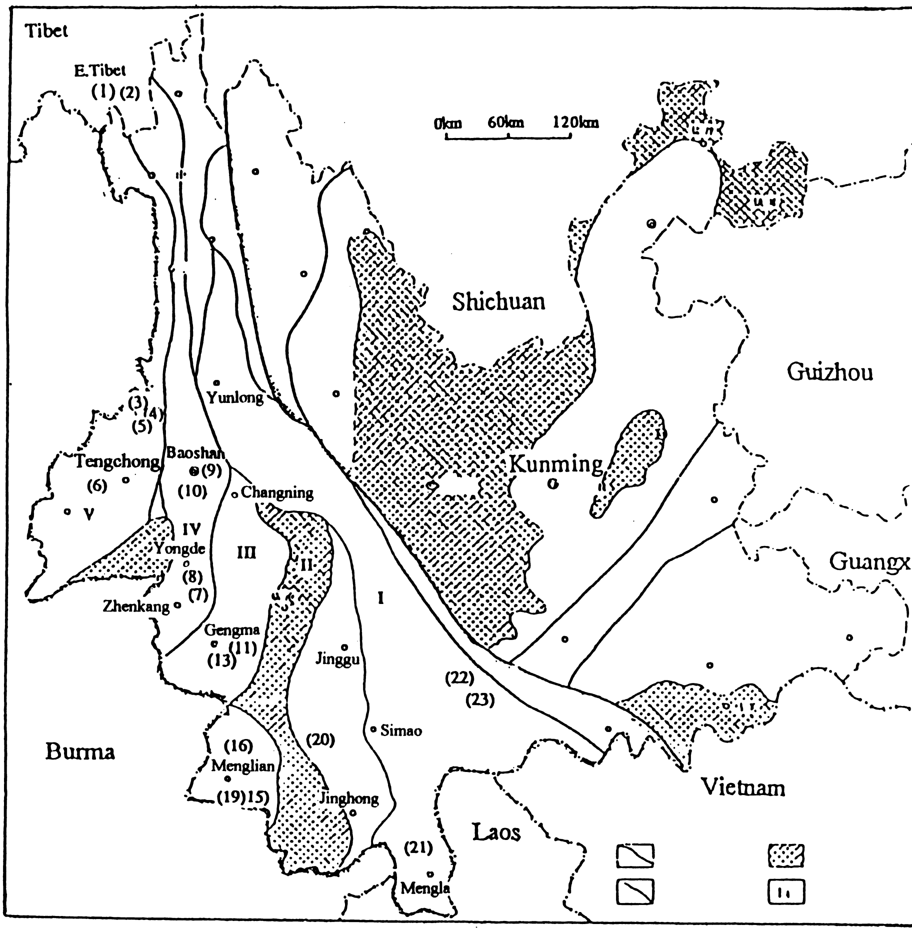

Fig.5. The distribution of sections collecting the palynological samples from western Yunnan. (1)Shonglen, E.Tibet; (2) Zhuwagen, E.Tibet; (3) Kongshuhe, Tengchong; (4) Dayunshan, Tengchong; (5) Dashuigou-Qiaotou; (6) Siguangping, Lianghe; (7) Kongsongzhai, Yongde; (8) Anpaitian, Yongde; (9) Woniusi, Baoshan; (10) Dongshansi, Baoshan; (11) Sipaishan, Gengma; (13) Nanpiqiao, Gengma; (15) Ali Nanduan, Lancang; (16) Xiaolaba, Lancang; (19) Ali Haibang, Menglian; (20) Silan-Gonglu, Lancang; (21) Xumuchang, Namutian; (22) Dengkong, Mojiang; (23) Xiamidi, Mojiang.

Again I made the most interesting finding of *Microbaculispora tentula-Jayantisporites pseudozonatus*, a typically Gondwanan assemblage of the lowermost Permian from the supposed glacigene sequence in Tengchong in 1994. And in 1997 I found again the lower Permian palynological Oppel-Zone *Pseudoreticulatispora confluens* in Baoshan, which was originally established in Australia (Foster *et al.*, 1988). Table 2 displays the late Paleozoic palynomorphs sequences extracted and established so far in western Yunnan.

For some reasons I was not able to process all these samples. The samples processed are shown with asterisk marks in Table 1. Some sections yielded very abundant spores and pollen while some others very few or even rare. The following displays the samples horizons in sections from which the most important and interesting spores and pollen have been extracted, especially the sections yielded the above mentioned assemblages from the middle zone - the Changning-Menglian Belt

Table 2. Some late Paleozoic palynological sequences established for western Yunnan.

	West Zone		Middle zone		East Zone	
			Changning–Menglian		Lanping–Puer	
	Tengchong	Baoshan	Gengma	Ali Haibang	Namutian	Dengkong
P2						*Jansoniuspollenites ovatus* *Alisporites taeniolis* *A. ovatus*
P1	*Primuspollenites levis* *Scheuringipollenites maximus* *Microbaculispora tentula* *Jayantisporites pseudozonatus*	*Pseudoreticulatispora confluens*		*Striatopodocarpites cancellatus* *Striatoabietites multistriatus* *Florinites ovalis*	*Florinites mediapudens* *Laevigatosporites perminutus*	
C2				*Florinites minutus* *Laevigatosporites vulgaris*	*Lycospora rotunda*	
C1			*Lycospora pusilla* *Grandispora spiculifera*	*Cristatisporites menendezii* *Granulatisporites frustulentus* *Tricidarisporites phippsae*		
D3			*Retispora lepidophyta*			

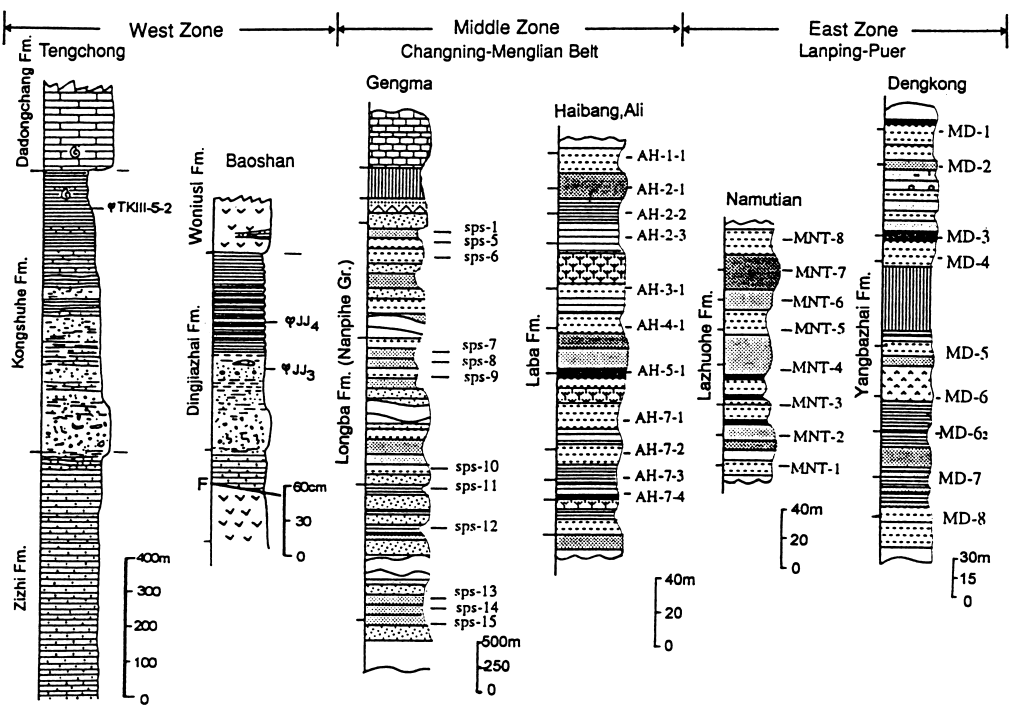

Fig.6. The lithology of upper Paleozoic from which the palynomorphs extracted in western Yunnan.

and from the west zone-the Tengchong and Baoshan Massifs. Some sections containing palynomorphs from the east zone are also provided in brief.

The most interesting and significant palynomorphs, which ranged from latest Devonian to late Permian and distributed from west to east in the Tengchong Massif, the Baoshan Massif, the Changning-Menglian Belt, and the Lanping-Puer Massif, had been obtained so far from the late Paleozoic rocks of more than six localities in western Yunnan. The stratigraphy of these six localities is shown in Fig. 6. The following is a introduction one by one about the main palynostratigraphic sequences of late Paleozoic established in western Yunnan.

2.2 Latest Devonian to early Carboniferous miospores assemblages

So far, the latest Devonian and early Carboniferous assemblages from Gengma, in the west area of the middle zone (geological block III), are the oldest palynomorphs of this palynological investigation in western Yunnan. This palynological data modified the age of the original formation (Lower Nanpihe Fm.) from late Permian to latest Devonian and early Carboniferous, and also even the environments of this formation from paralic environments to a continental slope together with the petrologic study (Yang *et al.*,1995).

2.2.1 General features

The microflora of the Longba Formation, or at least that portion studied here, is a well-preserved and diversified one in which more than one hundred and thirty species have be recognized and are referable to the previously instituted form genera. With the exception of two species, *Grandispora praecipua* and *Retusotriletes digressus* that display tendencies towards dilete or monolete apertural characteristics and towards a bilateral symmetry. The miospores exines display some kind of sculptural and structural diversity that is consonant with the late Devonian-early Carboniferous palynofloras. Exines (or exoexines) of the large majority of the species show some forms of sculptural and structural modification. This varies among granulate, verrucate, spinose, conate, baculate, pilate, rugulate, and reticulate. Constructional variation shows acamerate (same as acavate), slightly camerate (cavate), crassitudinous, cingulicamerate, and pseudosaccate. Both single and double-layered (most camerate) are represented, sometimes layered eoexine (two-layer eoexine) is also encountered. Equatorial modifications include cingula zones and crassitudes. No fundamentally monolete or saccate miospores occur in these late Devonian and early Carboniferous assemblages.

2.2.2 Miospores assemblages from Sipaishan in the Changning-Menglian Belt

Three miospore assemblages have been roughly distinguished from the uppermost Devonian and lower Carboniferous sediments of Gengma. They are based upon concurrent ranges of selected miospore species, which form an Oppel-Zone, because it was often necessary to recognize the presence of the zone when not all the diagnostic species were present.

(a) Retispora lepidophyta assemblage

This oldest assemblage obtained in this palynological investigation was from a gray, fine-grained siltstone and silty shale (sample SPS-12) in Shipaishan section and was completely dominated by the latest Devonian marker *Retispora lepidophyta* (Kedo) Playford, taking up about 30-40 % of the overall assemblage. Species of *Spelaeotriletes* were distinctive and frequently encountered. The other common species include *Grandispora praecipua, G. echinata, G. notensis, G. clandestina, Apiculatisporis morbosus, Hymenozonotriletes explanus, Auroraspora macra, Microreticulatisporites araneum, Retusotriletes triangulatus, Retusotriletes digressus, Neoraistrickia* sp, *Diducites mucronatus, Discernisporites micromanifestus, Punctatisporites minutus, Punctatisporites planus, Punctatisporites irrasus, Leiotriletes trivalis, Calamospora perrugosa, Basaudaspora collicura, Apiculiretusispora granulata,* and *Cyclogranisporites* cf. *commodus.*

Above all, most species are of latest Devonian to early Carboniferous age. Only the following species are limited in age range, such as *Retispora lepidophyta, Grandispora praecipua, Grandispora clandestina,* and *Apiculatisporis morbusus,* which were exclusively found in the uppermost Devonian in western Australia (Playford, 1983).

In the dark, yellow, slightly metamorphosed, fine-grained siltstone of the sample SPS-13, *Retispora lepidophyta* occurs again around 6-8 % of the assemblage. The preservation of *Retispora lepidophyta* from the sample SPS-13 was not so good as the sample SPS-12. Most specimens of *Retispora lepidophyta* were broken or damaged and even the structure of the spores appears to be a little difference in between these two samples. Generally, they tend to be smaller in overall size, with a smaller intexinal (inner) body, and commonly fewer lumens than the normal one. On the other hand, various types of the specimens of *Retispora lepidophyta* also have been observed. It possibly means a result of reworking because many species are the representatives of the younger assemblage, such as, *Grandispora spiculifera, Schopfites delicatus, Kraeuselisporites fasciatus, Anapiculatisporites austrinus, Raistrickia* cf. *condylosa, Spelaeotriletes* cf. *balteatus, Verrucosisporites irregularis,* ? *Triangulatisporites* sp, *Convolutispora major, Radizonates mirabilis,* and *Baculatisporites fusticulus,* however, there is still many members, which seem to be late Devonian: *Rugospora flexuosa, Grandispora praecipua, Grandispora clandestina. Teichertospora torquata, Apiculatisporis morbosus, Hystricosporites porrectus, Hymenozonotriletes scorpius, Ancyrospora* sp., and *Videospora glabrimaginata.* The assemblage of the sample SPS-13 appears to be somewhat mixed (in term of reworking) or shows a transitional nature around the Devonian / Carboniferous boundary.

(b) Grandispora spiculifera assemblage

The Longba Formation, in fact, is dominated by the *Grandispora spiculifera* assemblage, which could be found in many sections around Gengma County. In this paper this assemblage has been encountered in the SPS section, the GN section, and the NPIII section. The *G. spiculifera* assemblage was originally discovered in the Australian lower Carboniferous (Tournaisian in West Europe) and described by Playford (1976). Although not all the representatives of the current assemblage are the same as those in Australia, they are quite comparable.

The *Grandispora spiculifera* made its first appearance a little earlier in western Yunnan than in Australia. It could occur less consistently before Carboniferous, but only in a smaller number. It also concurs with *Retispora lepidophyta* rarely in the sample SPS-12. However, it became abundant after the disappearance of *Retispora lepidophyta.* The commonly concurrent representatives are: *Spelaeotriletes balteatus, Baculatisporites fusticulus, Grandispora notensis, Granulatisporites frustulentus, Vallatisporites verrucosus, Velamisporites caperatus,* *Lophozonotriletes* sp., *Densosporites* cf. *spitzbergensis, Retusotriletes witneyanus, Raistrickia* cf. *condylosa, Endoculeospora vargranulata, Kraeuselisporites* sp., *Neoraistrickia* sp., *Retusotriletes crassus, Retusotriletes incohatus, Punctatisporites planus, Punctatisporites irrasus, Rugospora flexuosa, Calamospora nigrata, Hymenozonotriletes explanatus, Baculatisporites fusticulus, Discernisporites* sp, *Anaplanisporites baccatus, Anapiculatisporites austrinus, Auroraspora macra, Auroraspora asperella, Spelaeotriletes crustatus,* and *Spelaeotriletes obtusus*. In the sample SPS-11, the following species could also be included in the *Grandispora spiculifera* assemblage: *Dictyotriletes submarginatus Hymenozonotriletes scorpius, Schopfites delicatus, Leiotriletes trivalis,* and *Umbonatisporites abstrusus*. Judging only from these species, they are also quite comparable to the ones in West Europe.

(c) Lycospora pusilla assemblage

This assemblage is characterized by the first presence of *Lycospora pusilla*. In the current investigation, *Lycospora pusilla* has been found in the following three sections: the GN section (13), the SPS section (11A), and the NPIII section (11B).

Only one sample (NPIII-44) in the NPIII section contains very well preserved *Lycospora pusilla*, and the concurrent species include *Schopfites* cf. *delicatus, Umbonatisporites* sp, *Kraeuselisporites hibernicus, Anapiculatisporites austrinus, Grandispora notensis,* and *Cymbosporites magnificus*. Some new forms are also present in this assemblage.

In the sample SPS-7, *Lycospora pusilla* was more common and associated with *Anapiculatisporites austrinus, Anapiculatisporites hystricosus, Anapiculatisporites largus, Anapiculatisporites semisentus, Apiculatisporis morbosus, Grandispora spiculifera, Grandispora notensis, Granulatisporites frustulentus, Planisporites conspersus, Spelaeotriletes pretiosus, Schopfites* sp., *Tumulispora* sp., *Spelaeotriletes obtusus* and commonly some new species of the genus *Neoraistrickia*. *Lycospora pusilla* in the sample SPS-9 is about 5% of overall sporomorphs, and the components of the miospores are quite comparable to the other samples producing *Lycospora pusilla*. *Anapiculatisporites largus*, and *Planisporites conspersus* in the sample GN 482.60 are the typical members of the *Anapiculatisporites largus* assemblage of Visean age in Australia described by Playford (1983, 1985), which have also been found in this area in western Yunnan. It confirms the Visean age of the strata containing *Lycospora pusilla*.

2.2.3 Stratigraphic distribution of palynomorphs in the studied sections

The distribution of the determined miospores species of the uppermost Devonian and lower Carboniferous is not shown in this paper. But some important taxa are listed on their appearance at their stratigraphical horizons in Tables 3, 4, and 5. There are totally about 70 genera and 130 species, of which have been diagnosed from the above three Devonian-Carboniferous sections. Among them the NPIII section produces about 140 palynomorphs taxa. They include 71 determined species, a few acritarchs and 16 new miospore forms or species. The NPIII section shows the repeated sequences due to the local strata folds. In term of miospores zones, the section ranges from RL (*Retispora lepidophyta*), to GS (*Grandispora spiculifera*), and probably Pu (*Lycospora pusilla*) zones, and again the RL, GS, possible Pu and GS zones from the sample NPIII-55-2 to the sample NPIII-22. (see Table 3).

The most diversified miospores occur in the SPS section and contain about 243 palynomorphs,

Table 3. Some important spore taxa distribution in the NPIII section.

Species \ Samples: NPIII-	22	25	26	27	28	29	30	32	33	35	36	37
Anapiculatisporites austrinus	+		+		+	+	+		+		+	+
Auroraspora corporiga							+		+			
Auroraspora macra	+	++	+		++	+	++		+		++	+
Convolutispora major			+									
Diducites mucronatus		?							+		+	
Grandispora echinata	+	+				+	+	+	+			+
Grandispora notensis				+	+	+						+
Grandispora praecipua		+			+	+			+			
Grandispora spiculifera					+	+			++		+	
Granulatisporites frustulentus					+	+			+		++	+
Granulatisporites micrograniféra	+											
Hymenozonotriletes explanatus					+	+					+	
Hymenozonotriletes scorpinus				+								
Kraeuselisporites hibernicus						+						
Lycospora pusilla										+		
Neoraistrickia spp. nov								+	+			
Raistrickia condylosa									+			+
Retusotriletes incohatus		+	+	+	+	+		+	+		+	+
Retusotriletes crassus	+		+		+	+			+		+	
Ruospora flexuosa		+		+		+					+	
? Teichertospora torquota									?		+	
Verrucosisporites nitidus											+	
Videospora glabrimaginata											+	
Miospore biozones				G	S					Pu	G	S

Table 3. Some important spore taxa distribution in the NPIII section (continue).

Taxa Samples :NPIII-	38	39	41	42	44	46	47	50	52	54	55	56
Anapiculatisporites austrinus					+			+			+	
Anapiculatisporites hystricosus	+											
Auroraspora corporiga	+	+										
Auroraspora macra	+	++		+	+	+	+	+		+	+	+
Crassispora catenata					+							
Densosporites spitsbergensis							+					
Diducites mucronatus		+								+		
Grandispora echinata		+	+	+			+	+		+	+	
Grandispora praecipua		+			+					++	+	
Grandispora spiculifera		+									+	
Granulatisporites frustulentus		+	+	+			+			++		+
Hymenozonotriletes cf. explanatus		+									+	
Hymenozonotriletes scorpinus				+	+						+	
Kraeuselisporites hibernicus					+		+					
Lycospora pusilla					+?							
Plicatispora scolecophora								+			+	
Retispora lepidophyta			+?	+?								+?
Retusotriletes crassus		+					+	+				
Retusotriletes incohatus	+	+	+		+		+	+		+	+	
Retusotriletes witneynus						+						
Rugospora flexuosa					+		+			+	++	+
Schopfites claviger							+					
Schopfites delicatus					+					+		
Spelaeotriletes obtusus				+								
Velamisporites caperatus											+	
Verrucosisporites nitidus					+							
Verrucosisporites gibberosus									+			
Verrucosisporites scurrus									+			
Videospora glabrimarginata						+					+	
Miospore biozones	G	S	R	L	?Pu		G	S				Rl

Table 4. Some important spore taxa distribution in the SPS section.

Taxa \ Samples-SPS-	**1**	**5**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Anapiculatisporites austrinus			+	+	+	+			+	+	+
Apiculatisporis morbosus								+	+	+	
Auroraspora corporiga				+	+		+	+	+	+	
Baculatisporites fusticulus	+					+					
Crassispora catenata								+			+
Crassispora maculosa							+				
Dictyotriletes flavus		+									
Diducites mucronatus			+		+	+	+		+	+	
Grandispora notensis			+	+	+	+		+	+		
Grandispora echinata			+	+	+	+	+	+	+	+	+
Grandispora praecipua			+	+	+	+	+	+	+	+	+
Grandispora spiculifera				+	+	++	+	+	++		
Granulatisporites frustulentus			+		+	+			+	+	
Hymenozonotriletes explanatus						+		+	+	+	+
Hymenozonotriletes scorpius			+				+		+		
Hystricosporites porrectus									+	+	
Lycospora pusilla		+	+		+						
Raistrickia condylosa				+		+	+		+	+	
Retispora lepidophyta								++	+	?	
Retusotriletes incohatus	+				+	+	+	+	+	+	+
Rugospora flexuosa				+	+	+			+	+	+
Rugospora polyptycha			+				+				
Schopfites delicatus							+		+		
Spelaeotriletes balteatus	+		+	+		+	+				
Spelaeotriletes pretiocus				+							
Teichertospora torquata							?		+	+	+
Tumulispora sp						+					
Umbonatisporites abstrusus							+	+			
Umbonatisporites cf. *distinctus*					+						
Vallatisporites verrucosus						+					
Verrucosisporites cf. *nitidus*	+		+								+
Videospora glabrimarginata									+		
Miospore Biozones	P u					G s		Rl	Gs	Rl	

showing the great abundance and diversity of this latest Devonian-early Carboniferous miospores assemblage. There are 152 determined species, a few acritarchs, a few chitinozoans and 24 new miospore forms or species. The geological age of the SPS section based on the miospores suggests from Strunian to Tournaisian and Visean. This section seems to be repeated again from Strunian to Tournaisian due to the local folds, that is, from RL miospores zone to GS and, then repeating again the RL, GS and Pu biozones from the sample 15 to the sample 1 (see Table 4).

About 167 palynomorphs taxa recorded in the GN section. Among them 115 species have been determined. And a few scolecodont was also recorded. Based on the stratigraphical distribution of some important taxa, most strata in the GN section could be Visean age (see Table 5).

2.2.4 Latest Devonian and early Carboniferous miospores zonation scheme and a tentative inter-continental correlation

(a) Introduction

The first comprehensive scheme of miospores zonation for the British Dinantian was described

Table 5. Some important spore taxa distribution in the GN section.

Taxa \ Samples: GN-	481.3	481.3	481.3	481.8	481.8	481.8	481.8	491.9	481.9	482.5	482.6	482.8
Anapiculatisporites hystricosus	+										+	
Anapiculatisporites largus							+					+
Anapiculatisporites austrinus									+	+	+	+
Apiculiretusispora fructicosa			+									
Archaeozonotriletes incrassatus				+		+		+				
Auroraspora macra	+		+					+	+	+	+	+
Baculatisporites cf. *fusticulus*									+			
Crassispora drucei	+			+								
Crassispora cf. *trychera*	+										+	
Cristatisporites indolatus								+				+
Convolutispora major											+	
Dibolisporites cf. *microspicatus*	+											
Diducites mucronatus	+										+	
Gorgonisporites multiplicabilis								+				
Grandispora cornuta			+	+	+	+		+		+	+	+
Grandispora echinata			+			+			+	+	+	+
Grandispora spiculifera	+					+		?			+	
Granulatisporites frustulentus	+								+		+	+
Hymenozonotriletes explanatus	+							+	+	+	+	
Kraeuselisporites hibernicus										+	+	
Lycospora pusilla		+					+	+		+	+	
Neoraistrickia spp nov.									+		+	
cf. *Radiizonates* cf. *mirabilis*			+									
Raistrickia condylosa			+						+		+	
Retusotriletes leptocentrum											+	
Retusotriletes incohatus	+		+	+	+	+			+	+	+	+
Rugospora flexuosa										+	+	+
Schopfites delicatus	+										+	
Spelaeotriletes obsolutus	+								+	+		
cf. *Tricidarisporites mixtus*							+					
Tumulispora dentata								+	+			
Umbonatisporites abstrusus												+
Vallatisporites cf. *microspinosus*							+					
Verrucosisporites nitidus								+		+		
Waltzispora sp.			+									+
Miospore biozones	P u											

by Neves *et al.* in 1972. The original scheme comprised eight concurrent range zones. The lower two were described from lower to middle Tournaisian sections in south-west Britain and the succeeding six zones of upper Tournaisian and Visean age were described from sections and boreholes from Northern England and the middle Valley of Scotland. The bases of the zones were consistently defined by the first appearance of distinctive associations of miospores taxa; normally two taxa were selected as index species in naming the zones.

Neves (1972) proposed three zones for the Tournaisian. The lowermost of these was the PL zone, and in Southwest Britain this zone was succeeded by the NV zone towards the top of the Old Red Sandstone facies. The NV zone appeared to be succeeded by the CM zone which, however, had not been recorded from the upper Tournaisian strata of the Midland Valley of Scotland. Since then, the Tournaisian part of the scheme in British Isles has been progressively modified by the

Table 6. The development of zonation scheme for the Tournaisian rocks in British Isles (after Higgs *et al.* 1988).

<table>
<tr><th>Neves et al 1972</th><th colspan="2">Clayton et al 1974</th><th colspan="2">Clayton et al 1978</th><th>Higgs et al 1988</th><th colspan="2">Stratigraphy</th></tr>
<tr><td>CM</td><td colspan="2">CM</td><td colspan="2">CM</td><td>CM</td><td rowspan="2">Tn3</td><td rowspan="6">C</td></tr>
<tr><td>//////////</td><td colspan="2">///// //////</td><td colspan="2">///// //////</td><td>----------</td></tr>
<tr><td rowspan="4">NV</td><td rowspan="4">VI</td><td rowspan="5">NV</td><td colspan="2">PC</td><td>PC</td><td rowspan="3">Tn2</td></tr>
<tr><td rowspan="3">VI</td><td rowspan="4">NV</td><td>BP</td></tr>
<tr><td>HD</td></tr>
<tr><td>VI</td><td rowspan="4">Tn1</td></tr>
<tr><td>//////////</td><td>LN</td><td>LN</td><td>LN</td><td rowspan="3">D</td></tr>
<tr><td rowspan="2">PL</td><td colspan="2" rowspan="2">PL</td><td>LE</td><td rowspan="2">PL</td><td>LE</td></tr>
<tr><td>LL</td><td>LL</td></tr>
</table>

detailed studies in the late Devonian and Dinantian of southern Ireland (Clayton *et al.*, 1974,1978). The culmination of this research has led to the erection of a new zonal scheme for the Irish Tournaisian (Clayton, 1985; Higgs *et al.*, 1988) (see Table 6). This scheme comprises eight biozones, three of which are of latest Devonian (Strunian) age and five are of Dinantian age.

However, the succeeding Visean part of the original zonation scheme has by comparison with the Tournaisian part received very little modification. In 1988, Higgs *et al.* has modified slightly the zonation scheme by the study of new information from the uppermost Tournaisian and lower Visean. The Pu biozone has informally been divided into two parts, a lower division containing rare *Lycospora pusilla* and an upper division with abundant representatives of this species.

(b) Western Europe

GREAT BRITAIN: Dr. G. Dorby supervised by Dr. R. Neves in England is the first one who dealt with palynological study of the upper Devonian and lower Carboniferous deposits in Great Britain. Higgs *et al.* (1988) illustrated the distribution of the British upper Devonian and lower Carboniferous sections that have been palynologically investigated. (see Higgs *et al.*, Fig-26, 1988). There are totally 17 localities in Great Britain where more than 17 authors did their palynological investigation of late Devonian and early Carboniferous in Great Britain. They are Dolby (1970), Neves (1970,1973), Neves *et al.* (1973), Neves and Ioannides (1974), B.Owens (1973, 1983), Clayton (1971), Sullivan (1960, 1968), Marshall (1971), Holliday (1979), Welsh (1979, 1983), Llewellyn *et al.* (1969), Mortimer *et al.* (1970), Bassett and Jenkins (1977), Gayer *et al.* (1973), Utting and Neves (1970), Mitchell (1982), and Higgs and Clayton (1983). Only in the southwest of England the continuous succession could be exposed. Among them only in Cannington Park and Burrington Combe exposed LN and VI, which means a continuous deposition between Devonian and Carboniferous. This means that a continuous zonal sequence for the Tournaisian has not been completely recorded from any one region.

Clayton (1985) assigned the BP-TS zones to the *Vallatisporites* microflora, the TC-NC zones

Table 7. The zonation scheme correlation between British Isles and Belgium (after Paproth and Streel 1970; Streel 1973; Higgs and Streel, 1992).

<table>
<tr><td colspan="2" rowspan="2"></td><td rowspan="2"></td><td colspan="2" rowspan="2">Belgium</td><td>England</td></tr>
<tr><td>PC</td></tr>
<tr><td rowspan="3">C</td><td rowspan="3">Hastarian</td><td>Tn2a</td><td colspan="2" rowspan="2">TE</td><td>BP
HD</td></tr>
<tr><td rowspan="3">Tn1b</td><td>VI</td></tr>
<tr><td colspan="2">//////// ////</td><td>////////////////</td></tr>
<tr><td rowspan="4">D</td><td rowspan="2">Strunian</td><td colspan="2">Pls2</td><td>LL</td></tr>
<tr><td>Tn1a</td><td rowspan="2">Pls1
Plm
Pli</td><td rowspan="2">LV</td><td rowspan="3"></td></tr>
<tr><td rowspan="2">Famen nian</td><td rowspan="2">Fa2d
Fa2c</td></tr>
<tr><td></td><td>VCo</td></tr>
</table>

to the *Grandispora* microflora. The VI and HD zones contain many taxa typical of the *Lophozonotriletes* microflora, as do Tn1b/ Tn2a assemblages from other areas.

IRELAND: Compared to Great Britain, Tournaisian strata are extensively developed in Ireland and comprise a wide range of clastics and carbonates. Higgs *et al.* (1988) has divided them into four geological provinces, the South Munster Basin, the South Midlands, the North Midlands and the Northwest. The South Munster Basin is the best province where the Tournaisian miospores assemblages occurred very abundantly and completely. All the seven biozones could be recorded in this area, such as in the Old Head of Kinsale and the North Ringabella sections. Higgs, Clayton and Keegan have been doing most of the palynological investigation of the Tournaisian rocks of Ireland. And they also provided an excellent synthesis of numerous palynological investigation of the Irish Tournaisian succession undertaken from 1973 to 1985. A comprehensive miospore zonation has been established in their paper (Higgs *et al.*, 1988) for the succession which currently serves as a standard for Western Europe.

BELGIUM: In the European continent, palynology of late Devonian and lower Carboniferous has been studied traditionally and exhaustedly. In Belgium, the palynology of late Devonian and lower Carboniferous has been recorded by Paproth and Streel (1970), Streel (1970, 1973), Paproth *et al.* (1983), and Higgs and Streel (1992). No LE and LN biozonal assemblages have been recorded from Belgium (see Table 7), mainly due to the presence of palynologically unfavourable lithologies and to possible non-sequences within this stratigraphical interval. Higgs and Streel (1992) first detailed palynostratigraphy of the Hastarian Stage, which span the Tn1b and Tn2 lithostratigraphical units. The four biozones (VI, HD, BP, and PC) were successfully established in the western part of the Namur Synclinorium, where the Hastarian succession is represented by a mixed sequence of marine clastics and carbonate rocks.

WEST GERMANY: Higgs and Streel (1984) did their palynological study in the type area of

Table 8. The zonation scheme correlation between British Isles and East Germany and Poland (after Burman, 1975; Turnau, 1978; and Higgs *et al* 1988).

East Germany	British Isles
CM	CM
RM	PC

ND	HD
NRH	VI
PA	---------
Retispora	LN
lepidophyta	LL

Poland	British Isles
CI	CM
	PC
MA	
	HD
//////////	//////////
//////////	//////////
	LN
RA	
LU	LL

the northern " Rheinisches Schiefergebirge" of Sauerland and suggested LL and LE biozonal assemblages characterising the upper part of the Wocklum Limestone and the lower part of the overlying Hangenberg Shales. And LN biozonal assemblage is represented in the upper part of the Hangenberg Shales. The VI biozone has been recorded from the very top of these shales, with the LN/VI biozonal boundary being pinpointed at 14cm below the base of the Hangenberg Limestone (the traditional base of the Carboniferous System in Germany). Basal VI biozonal assemblage occurs in the lowermost part of the Hangenberg Limestone where they are associated with conodonts *Siphonodella sulcata* fauna. A HD biozonal assemblage was recorded from the base of the overlying shales of the Liegende Alaunschiefer (Alum Shales) in the Oberrodinghausen section, which is associated with conodont fauna of the lower *Siphonodella crenulata* zone.

(c) Eastern Europe (East Germany, Poland, Former U.S.S.R)

EAST GERMANY: The palynological assemblages of late Devonian and early Carboniferous have been well recorded in the Baltic Island of Rugen in East Germany. Burmann (1975) described one sequence of miospores zones for the Tournaisian deposits, where he established six biozones, using *Retispora lepidophyta*, PA, NRH, ND, RM, and CM respectively. Higgs *et al.* (1988) has attempted to correlate them with Irish zonation (see Table 8).

POLAND: In 1978, Turnau presented a miospores zonation scheme for the late Devonian and early Carboniferous sediments of west Pomeramia, northern Poland. She established four biozones within this sequence, (Lu) *Grandispora lupata,* (Ra) *Tumulispora rarituberculata* for the late Devonian assemblages, and (Ma) *Convolutispora major* and (Cl) *Prolycospora claytonii* for the early Carboniferous. The correlation between Polish biozones and Irish ones has been suggested by Higgs *et al.* (1988) (see Table 8). One thing should be noted that the miospores assemblage of (Cl) zone shows many compositional similarities with the CM biozone of Britain and Ireland, except for the infrequent presence of *Lycospora pusilla* throughout the Cl zone which is somehow similar to the present record in western Yunnan.

Above the Cl zone, three more zones were recognised in the Visean of Pomerania (Turnau,

Table 9. The zonation scheme correlation between British Isles and former USSR (after Avchimovitch *et al.* 1988).

Stratigraphy	USSR	Selected important species	West Europe
			HD
Carboniferous	M	*Tumulispora malevkensis*	VI
	P PMi	*Vallatis. pusillites - Bascaudas. mischkinensis*	possible VI
Devonian	PM	*Vallatis. pusillites - Tumulispora malevkensis*	LCr
	P PLE	*Vallatis. pusillites - R.lepidophyta, H. explanatus*	LN
	LE	*R. lepidophyta - H.explanatus, - Cymbosp. minutus*	LE
		or V. hystricosus - V. pusillites - H. explanatus	LE
	Ltn LMb	*R. lepidophyta-tenera, -- Tholisporites mirabilis*	LL
	LL	*R. lepidophyta - Knoxisporites literatus*	LL
	Lty LF	*R. lepidophyta - typica -- Grandispora facilis*	LV
	LV	*R. lepidophyta - Apiculiretusispora verrucosa*	LV

1979). The Pu zone (*Lycospora pusilla*) is V1 - V2 in age and is correlated with the upper part of the Pu Zone in the British Isles. The base of the Ca zone approximately at the V2 / V3 boundary is defined by the incoming of *Schulzospora campyloptera* and *Waltzispora planiangulata* also appears at this level. The Pa zone (highest Visean) contains *Murospora margodentata* and *Potoniespores delicatus*, which are the common taxa in the British Isles at this level. The Ca and Pa zones of Pomerania probably correlate with the TC and NM zones respectively in the British Isles (Clayton, 1985).

FORMER USSR: The following several important palynological publications have dealt with the Devonian / Carboniferous transition beds in the western part of the U.S.S.R, especially the Pripyat Depression, Byelorussia, the Moscow area and the Volga-Urals area, e.g., Byvscheva (1971), Kedo (1963), and Naumova (1953). Significant improvement has been made by joint studies of exchange palynological material between Russian and Western palynologists, e.g., Owens *et al.*(1978), Byvscheva, Higgs and Streel (1984), Avchimovitch, Byvscheva, Higgs, Streel and Umnova (1988). The five established biozones are illustrated in Table 9.

The most significant changes of the palynological assemblages during the Devonian-Carboniferous transition took place at two levels, (1) at the base of P zone (Russian Platform) or LN zone (western Europe), and (2) at the base of M zone or PMi subzone (Russian Platform) equivalent to VI zone (western Europe) or within the similar interval at the top of PM subzone (Byelorussia) or LN (LCr) zone (western Europe) (Avchimovitch *et al.*, 1988). Owens *et al.* (1978) has published a very detailed comparison of the Dinantian miospore succession of the Donetz Basin and West Europe. The paper revealed close similarities between these two areas. Three zones have been established in the Donetz Basin, one covering the Tournaisian, and two in the Visean. LR zone (Tournaisan) includes the taxa typical of the *Lophozonotriletes* microflora, such as

Lophozonotriletes triangulatus, which has been found in the association with forms characteristic of the *Vallatisporites* microflora such as *Auroraspora macra* and *Raistrickia clavata*. The first occurrence of *Schopfites claviger* in the late Tournaisian permits correlation at this level with those in the Baltic area and the British Isles. A microflora transition from the *Monilospora* microflora to the *Grandispora* microflora is seen in the Visean of the Donetz Basin. Ma zone is marked by the first appearance of *Murospora aurita* and *Tripartites inciso-trilobus* from the *Monilospora* microflora, together with ubiquitous taxa such as *Lycospora pusilla* and *Potoniespores delicatus*. In the higher Visean MR-MD zones are typical of the *Grandispora* microflora such as *Grandispora spinosa*, *Rotaspora ergonulii*, *R. fracta*, *R. knoxi* and *Tripartites vetustus*.

(d) North America

UNITED STATES OF AMERICA: In America, few published records dealt with the Devonian/ Mississipian (lower Carboniferous) boundary. Many of them are probably Namurian.

Winslow (1962), Evans (1968) described some basal Mississippian miospores assemblages from the lower part of the Cuyahoga Group in Ohio. Warg and Traverse (1973), Streel and Traverse (1978) recorded some early Mississippian miospores assemblages as well from the Pocono Formation in Pennsylvanian. All these assemblages are quite restricted in composition, but collectively contain *Hymenozonotriletes explanatus*, *Lophozonotriletes cristifer*, *L. triangulatus*, *Umbonatisporites distinctus*, *Vallatisporites vallatus*, and *Verrucosisporites nitidus*.

Coleman (1983) once communicated with G. Clayton about a mid-Tournaisian assemblage, which is comparable with the assemblage from the PC zone in central Ireland, from the Henley Bed of Kentucky, including *Spelaeotriletes pretiosus*, *Umbonatisporites distinctus*, *Vallatisporites vallatus* and *Verrucosisporites nitidus*.

Horowitz *et al.* (1979) described a miospores assemblage from a borehole core ranging in age from Osagian to early Pennsylvanian. One of these miospores (lower interval) assigned to the mid-Visean TC zone of the British Isles, containing *Lycospora pusilla* and *Densosporites* spp. without forms typical of the TC zone in the British Isles, such as *Perotrilites tessellatus*, *Schulzospora* spp. However, the other miospores assemblages (upper interval) assigned to the NC zone comprises many forms typical of the Visean and early Namurian of the British Isles including *Crassispora maculosa*, *Florinites* spp, *Grandispora spinosa*, *Savitrisporites nux*, *Tripartites distinctus*, *T. vetustus*, *Triquitrites marginatus* and some doubtfully reworked material containing *Auroraspora macra*, *Baculatisporites fusticulus*, and *Crassispora trychera*.

All the described assemblages can be assigned either to the *Vallatisporites* or to the *Grandispora* microflora (Clayton, 1985).

EASTERN CANADA: Both Hacquebard (1957) and Playford (1964) described in detail the assemblages from the Dinantian Horton Group in Nova Scotia and New Brunswick. Assemblages from the Horton Bluff and Cheverie Formations of the Horton Group contain many taxa in common with the mid-late Tournaisian ones of Western Europe. These are *Discrenisporites crenalatus*, *Raistrickia clavata*, *Spelaeotriletes pretiosus*, *Vallatisporites vallatus*, *V.verrucosus*, and *Verrucosisporites nitidus*. Dr. Utting subsequently recorded the presence of *Schopfites claviger* from the Cheverie Formation, and *Umbonatisporites distinctus* from the Horton Group.

Uttintg (1977, 1978, and 1980) and Neves and Belt (1970) worked on the Windsor and Canso

Groups from eastern Canada concerning Visean miospore assemblages (see the Dinantian miospores zonation of eastern Canada). The Spore Zone I compared closely with the Pu and TS biozones of West Europe. However, the Spore Zone II and III are difficult to correlate with those in West Europe. Nevertheless, Clayton (1985) still insisted that the Tournaisian and Visean assemblages in eastern Canada should be assigned to the *Vallatisporites* and *Grandispora* microflora respectively.

WESTERN CANADA: Tournaisian miospore assemblages in western Canada have been described from the Northwest Territories (Utting, 1983). It includes *Auroraspora macra*, *Densosporites spitsbergensis*, *Knoxisporites literatus*, *Lophozonotriletes cristifer*, *L. triangulatus* and *Umbonatisporites distinctus*. *Vallatisporites vallatus* and *Tripartites inciso-trilobus* first appear from the late Tournaisian Clausen Formation.

Assemblages of Visean from the same area are recorded by Hacquebard and Barss (1957), Sullivan (1965), Braman & Hills (1977), and Utting (1983). Assemblages from the late Visean Golata and Mattson Formations reported by Staplin (1960) include *Lycospora pusilla*, *Murospora aurita*, *Rotaspora fracta*, *Tripartites inciso-trilobus* and *Triquitrites* spp. *Schulzospora* spp. first appears towards the top of the Visean in the Mattson Formation.

According to the study of Clayton (1985), the Dinantian assemblages from western Canada can be assigned to the *Lophozonotriletes* and *Monilospora* microfloras.

(e) The Arctic Region

The miospores succession in Spitsbergen is the most diverse and complete one from the Arctic region. Playford (1963) recognised in the Spitsbergen Clum sequence two assemblage-types. They are ' *Rarituberculatus* Assemblage' which he considered to be Tournaisian, and the other ' Aurita Assembnlage' which was thought to be Visean and possibly, in part, early Namurian. In 1962 Playford noticed the striking similarity of the palynological assemblages among Spitsbergen, western Canada and the Russian Platform.

(f) North Africa

Lanzoni and Magloire's (1969) paper on the Illizi Basin, Algerian Sahara established the first palynological zonation in North Africa. Attar *et al.* (1980) erected a simpler, but better substantiated zonal scheme comprising two zones in late Devonian and three zones in Dinantian compared with the six zones / subzones of Lazoni and Magloire. The scheme established by Massa *et al.* (1980) in the Rhadames Basin, western Libya, comprises seven palynozones in the interval between the uppermost Devonian and middle Carboniferous.

WESTERN LIBYA: In the M'Rar and Assedjefar Formation of the Rhadames Basin, the lowest zone of Massa *et al.*'s zonation scheme is Palynozone XI (Strunian). It is characterised by *Retispora (Spelaeotriletes) lepidophyta*. More species include *Discernisporites (Endosporites) micromanifestus*, *Verruciretusispora magnifica*, *V. (Hymenozonotriletes) famenensis*, *Pustulatisporites giberous*, *Dictyotriletes fimbriatus*, *Emphanisporites* cf. *rotatus*, *Lophozonotriletes rarituberculatus*, *Lagenicula* etc. Acritarchs, *Gorgonisphaeridium winslowii*, *Veryachium* sp, and *Stellinium octoaster*. It is noted that some Gondwanan members also occur in this assemblage such as: *Apiculiretusispora (Anapiculatisporites) semisenta*, *Grandispora balteata*, and *Cristatisporites* sp..

Palynozone XII (upper Tournaisian): This zone is characterised by the following members: *Vallatisporites vallatus*, and *Spelaeotriletes pretiosus* (Playford), some more spores like *Densosporites variomarginatus*, *Radiizonates genuinus*, *Cirratriradites elegans* emd, *Colatisporites denticulatus-decorus,* and some *Apiculiretusispora semisenta, Dictyotriletes fimbriatus* and *Knoxisporites literatus-pristinus*. A quite rare and probably reworked *Retispora lepidophyta* occurred at the exact base of the M'Rar Formation (carotte 8 de C1-49). In the middle part of Upper Tournaisian the earlier *Diatomozonotriletes fragilis* appeared. The base of the Dinantian in the Illizi Basin (= base of Palynozone III) is defined at the first appearance of *Spelaeotriletes balteatus*, *S. pretiosus* and *Vallatisporites vallatus*, and the disappearance of *Retispora lepidophyta*.

Palynozone IV V (Visean): The base of the Visean is coincident with the base of Palynozone IV, and is defined by the first appearance of a group of taxa which include *Cingulizonates bialatus* and *Radiizonates genuinus*, and the increased abundance of *S. balteatus*. This last-named taxon commonly includes monolete variants whose first appearance (as <spore monolete zonale no. 2874>) was noted also by Lanzoni and Magloire at the base of the Visean. Although *S. balteatus* is a very common constituent of mid-late Tournaisian assemblage in Western Europe, monolete variants do not occur, lending some support to Lanzoni and Magloire's view that the monolete and trilete forms constitute separate species. The base of Palynozone V in the late Visean is defined by the first appearance of *Lycospora pusilla*. At the same level there is a significant decrease in the number of *Densosporites variomarginatus, S. balteatus* and *S. owensi*.

ALGERIA: Attar *et al.* (1980) erected six palynozones in the Issendjel and Assekaifaf Formations of the Illizi Basin, Algeria. Palynozone I and II are the late Devonian miospores assemblages.

Palynozone I (Famennian): Only some genera, *Verruciretusispora* Owens, *Perotriletes* Erdtmann, and *Lophozonotriletes* (Naumova) Potonie are provided. The following elements *Archaeozonotriletes famenensis, Dictyotriletes fimbriatus, Ancyrospora capillata, Hymenozonotriletes domanicus, Trachytriletes radiatus, Emphanisporites,* and *Leiotriletres*. *Endosporites* are also very common.

Palynozone II (Strunian): This biozone is characterised by the presence of *Retispora (Spelaeotriletes) lepidophyta*, which reaches to a percentage of 20%. Spores and microplankton are rich in this zone which shows the same palynological composition as Palynozone I.

Palynozone III (Tournaisian): *Vallatisporites vallatus* and *Spelaeotriletes pretiosus* are the characteristic constituents of this Palynozone III. It is to be noted that some spores such as, *Grandispora balteatus*, *Densosporites variomarginatus*, *Lophozonotriletes*, *Perotriletes*, *Endosporites, Archaeozonotriletes*, and *Dictyotriletes fimbriatus* also occur in this zone. At the base of the zone, some rare probably reworked *Retispora lepidophyta* is also observed. *Hymenozonotriletes explanatus* ranges from the preceding zone.

Palynozone IV (Visean): It is characterised by the great abundance of *Grandispora balteata* (up to 25%). *Densosporites variomarginatus* is also common in all of the IV Palynozone. Some other forms are *Radiizonates genuinus*, *Spelaeotriletes owensi*, *Vallatisporites agadesi*, *Spelaeotriletes triangulus*, and *Vallatisporites ciliaris*.

In the same area in North Africa, assemblages described from less extensive sections in the

Table 10. A tentative correlation chart of Devonian-Carboniferous miospores assemblages in China (after Yang, 1997)

Stratigraphy		West Europe (Higgs *et al.*, 1988)	Tibet (Gao,L. 1988)		Central Hunan (Yang,Y 1987)		Central Hunan (Gao,L. 1990)		W.Hubei NW Hunan (Gao,L. 1992)		SE Guizhou (Gao,L. 1991)		Baoying Jiangsu (Ouyang *et.al.* 1987)	
Carboniferous	Tn2b-c	PC		BM				FM		PC	Tangbagou Fm.	TM	Jinling Fm.	
		BP			Manlanbian Fm.									
	Tn2a	HD	Yali Fm.	VI			Menggongao Fm.	VI	Changyang Fm.		Upper Gelaohe Fm.	VI		DM
	Tn1b	VI				NV							Leigutai Member	
Devonian		LN		LN				LN		LN		PN		
		LE	Zhangdong Fm.	PL	Menggongao Fm.	PL	Shaodong Fm.	LE	Tizikou Fm.	LE	Lower Gelaohe Fm.			
	Tn1a-b	LL						LL						LH

Stratigraphy		Jurong Jiangsu (Ouyang *et.al.* 1987)		Lower Yangtz (Ouyang *et.al.* 1989)		Lower Yangtz (Gao,L. 1991)		W. Zhejiang (He,*et.el.* 1993)		Quannan Jiangxi (Wen, *et al.*, 1993)		N. Talimu (Gao,L. 1991)		W. Yunnan (Yang,W 1993, 1997)		Guilin (This Paper)	
Carboniferous	Tn2b-c / PC	Jinling Fm.		Jinling Fm.	DP								PC		PC		
	BP				MD		BP			Liujiatang Fm.					BP		
	Tn2a / HD		DC				VI		DP		TT	Sand Well No.10	HD	Longba Fm.			
	Tn1b / VI	Leigutai Member		Leigutai Member				Hsihu Fm.		Huangtang Fm.			VI			1st member of Luzhai Fm.	
Devonian	LN		LC		LC		PL		LC								Pml Pmr
	LE					Leigutai Member				Fanxia Fm.	MX				LE		
	Tn1a-b / LL		LH		LH		LL		LH								

Agades Basin of Niger (Loboziak and Alpern, 1978), Jebilet, Morocco (Clayton and Graham unpublished data) and the Elburz area of northeast Iran (Coquel *et al.*, 1977) are generally similar to those from Algeria and Libya (Clayton, 1985). Clayton proposed to assign the North African (and Iranian) Dinantian assemblage to a < *Spelaeotriletes balteatus* microflora > distinct from the *Vallatisporites* and *Grandispora* microfloras.

(g) Far East

CHINA: A detailed comparison of the Chinese Devonian-Carboniferous miospores had been worked out by Yang Weiping in 1997 based upon some previous works from Gao (1990, 1991, 1993), He (1985), Yang,Y (1987), Ouyang (1987, 1989, 1993), Wen and Lu (1993), Yang Weiping (1991,1997) (Table-10).

The Leigutai Formation of the Wutong Group in Jiangsu contains plant fossils *(Leptophloeum rhombicum* and *Sublepidodendron mirable)* and fish fossils *(Sinolepis macrophala, Asterolepis sinensis),* miospores *(Retispora lepidophyta* and *Aneurospora greggsii)* and some common members such as *Cymbosporites scabellus, Lophozonotriletes curratus, Lophotriletes macrogrumosus* and *Apiculiretusispora* spp.

Spores from the black shales in the Xikuangshan Formation, Hunan, are rich and also contains *Retispora lepidophyta, Calamospora microrugosa, Cymbosporites lasius* var.*minor, Geminospora parvibasilaris, Dibolisporites* sp., *Stenozonotriletes* sp., *Lophozonotriletes* sp., *Granulatisporites* sp., *Verrucosisporites* sp., and *Aneurospora graggsii.*

Retispora lepidophyta, Hymenozonotriletes explanatus and *Grandispora echinata,* *Aneurospora grggsii* have been found from the upper part of the Wangjiadian Formation of the Lower Carboniferous in Zhangxian county, Gansu Province, where also yielded some plant fossils (*Leptophloeum rhombicum*).

The occurrence of LE has also been reported from the Zhangdong Formation in Tibet (Gao, 1983). The original one was named by Gao as the *Retispora lepidophyta-Vallatisporites pusillites* assemblage, which includes more spores, such as *Grandispora echinata, G. cornuta, Vallatisporites verrucosus, V. vallatus, Discernisporites micromanifestus, Cristatisporites hacquebardii, Apiculiretusispora granulata, A. nitida, Pulvinispora depressa, Acanthotriletes spinellosus, Cymbosporites formosus, Geminospora parviasilaris, G. nanus,* and *Archaeozonotriletes variabilis*.

In the early Carboniferous, Gao (1980) established four zones. Zone II obtained from the Qianheishan Formation includes *Auroraspora macra, Hymenozonotriletes explanatus, Lophozonotriletes malevkensis, L. triangulatus, Schopfites claviger*? and *Umbonatisporites distinctus*. This might represent the whole of the Dinantian (Tournaisian). And this assemblage could be assigned to the *Vallatisporites* microflora.

Zones III and IV from the Chouniugou Formation mostly contain taxa like *Crassispora maculosa, Rotaspora knoxi, Savitrisporites nux, Spencerisporites radiatus, Tripartites vetustus* and *Triquitrites marginatus* that are typical of the *Grandispora* microflora.

Of special interest is the abundance in the Dinantian of *Lophozonotriletes triangulatus* and *Granulatisporites frustulentus*. The composition of this assemblage suggests, however, that persistent links existed in Dinantian times with the *Lophozonotriletes* and *Monilospora* microfloras to the north, and with the *Granulatisporites frustulentus* microflora, presumably to the south.

(h) Southern Hemisphere

AUSTRALIA: The latest Devonian and early Carboniferous (Dinantian) palynostratigraphy of Australia is well summarised by Playford and Helby in Kemp *et al.* (1977) and Playford (1985). The miospores assemblages in Australia seem to be quite different from those in Western Europe although the Dinantian palaeo-latitudes of the two regions were similar.

The latest Devonian assemblage is called *Retispora lepidophyta* assemblage (Strunian) recorded from the upper part of the shallow marine, Famennian-Tournaisian, of the Fairfield Group, and from the Bonaparte Gulf Basin. This assemblage is characterised by numerous species that do not persist into the lower Carboniferous ones. They chiefly include *Retispora lepidophyta, Brochotriletes textilis, Apiculatisporites morbosus, Grandispora clandestina, Grandispora praecipua, Hystricosporites porrectus, Hymenozonotriletes scorpius, Cirratriradites impensus, Leiotriletes laurelensis,* and *Reticulatisporites ancoralis.*

Grandispora spiculifera assemblage (Tournaisian): This palynostratigraphic unit, the lower of the two constituting the *Granulatisporites frustulentus* microflora, was originally known from the subsurface marine sediments belonging to the upper part of the Fairfield Group in the northern Canning Basin, Western Australia. The following taxa are noteworthy in this assemblage, *Grandispora spiculifera, Knoxisporites pristinus, Lophozonotriletes triangulatus, Crassispora drucei, Dibolisporites medaensis, Dibolisporites montuosus,* and *Raistrickia strumosa.* For further subdivision inside this assemblage, the respective incoming of *Cristatisporites colliculus,* *Punctatisporites subvaricosus, Acanthotriletes intonsus, A. acritarchus, Knoxisporites* sp. cf. *K.ruhlandii* and *Crassispora invicta* could be of considerable significance.

Anapiculatisporites largus assemblage (Visean): This miospores assemblage spanning much of the Visean was originally known from the Bonaparte Formation in the Bonaparte Gulf basin. The following species are important and distributed more or less consistently through the assemblage' host strata, *Foveosporites appositus, Grandispora debilis, Diademaspora acuminata, Acanthotriletes acritarchus, Knoxisporites* sp. cf. *K.ruhlandii, Acinosporites spiritensis, Crassispora invicta, Dictyotriletes proprius, Convolutispora rimulosa, Convolutispora balmei, Planisporites conspersus, Secarisporites undatus, Grumosisporites ruginosus,* and *Diatomozonotriletes* spp.

BRAZIL: Loboziak, Streel, Caputo, and Melo *et al.* (1991) reported the latest Devonian and early Carboniferous miospores zones from a borehole in the Amazonas Basin in Brazil. They range with some discontinuity from the uppermost Famennian to the lowermost Visean. The lowermost sample (core 55: 2485,00/2483,80 m) contains some spores such as *Retispora lepidophyta, Hymenozonotriletes explanatus* and *Rugospora radiata.* They are correlated to LE biozone in West Europe of latest Famennian age. The miospores in the next two productive samples (cores 52 and 51 at 2256,80/ 2252,00 m) are characterised by *Spelaeotriletes balteatus* typical of BP biozone of Middle Tournaisian age in West Europe. Below core 24, *Crassispora trychera*, a characteristic taxon of the upper part of the older PC biozone in British Isles, is nearly always present. The miospores from core 24 (at 2180,20/2180,10 m) yields *Schopfites claviger* which indicates the base of the CM (*S.claviger- A.macra*) biozone in this basin. The first occurrence of *Lycospora* spp. from core 16 (at 2159,90/2156,60 m) shows the presence of the base of the Pu (*Lycospora pusilla*) biozone. Therefore, the strata investigated palynologically by Loboziak *et al* span from the upper part of the older PC biozone to the lower part of the Pu biozone, covering most of the upper Tournaisian and part of the lower Visean.

Some Gondwanan species identified in this region as *Arastrisporites saharaensis, Vallatisporites agadesi,* and *Spelaeotriletes owensii* which were originally reported from North Africa (Loboziak and Alpern 1978, Loboziak *et al.*, 1986) and *Granulatisporites frustulentus*, and *Grandispora spiculifera* which were originally described from Australia (Balme and Hassel, 1962; Playford, 1976).

(i) Western Yunnan, S.W. China

The miospores assemblages obtained from Gengma County in western Yunnan, SW China can be roughly correlated with the ones recorded in Australia [see Table 11]. The *Retispora lepidophyta* assemblage for the uppermost Devonian, the *Grandispora spiculifera* assemblage for the Tournaisian, and the *Anapiculatisporites largus* assemblage for the Visean, respectively. However, there are still a lot of miospores, which are the common members in West Europe and Northern Hemisphere. As a sophisticated miospores zonation scheme has been erected by Higgs, Clayton and Kegan in 1988, an attempt has been made to correlate the Yunnan assemblages to the standard West Europe miospores zones. The correlation seems to be optimistical and useful. The lowermost sample SPS-12 in sense of biozones produces some miospores such as *Retispora lepidophyta*, and *Hymenozonotriletes explanatus*. Therefore, they could be correlated to the latest

Table 11. The correlation chart showing the occurrence of some important taxa in Australia, western Yunnan, and West Europe.

Age	Australia	Western Yunnan	W. Europe
Visean	*Anapiculatisporites largus* *Foveosporites appositus* *Diatomozonotriletes spp* *Planisporites conspersus* *Convolutispora rimubsa* *C. balmei* *Granualtisp. frustulentus*	*Lycospora pusilla* *Granu. Frustulentus* *Anapiculatisporites largus* *Grandispora notensis* *Kraeuselisp.hibernicus* *Grandispora spiculifer ?* *Planisporites conspersus* *Spelaeotriletes pretiosus ?*	*Lycospora pusilla* (Pu)
Tournaisian	*Grandispora spiculifera* *Lophozonotri. triangulatus* *Crassispora drucei* *Raistrickia strumosa* *Acanthotriletes acritarchus* *Granulatisp. frustulentus*	*Grandispora spiculifera* *Spelaeotriletes balteatus* *Grandispora notensis* *Granulatisp. Frustulentus* *Umbonatisporites abstrusu* *Schopfites delicatus* *Anapiculatisp. austrinus* *Rugospora flexuosa* *Raistrickia* cf. *condylosa* *Retusotriletes incohatus*	*Schopfites claviger-* *Auroraspora macra* (CM) *Spelaeotriletes pretiosus* *Raistrickia clavata* (PC) *Spelaeotriletes balteatus* *Rugospora polyptycha* *Kraeuselispor.hibernicus* *Umbonati. distinctus* (HD) *Retusotriletes incohatus* *Verrucosis. verrucos (VI)*
Strunian	*Retispora lepidophyta* *Apiculatisporis morbosus* *Grandispora clandestina* *Grandispora praecipua* *Hymenozonotriletes scorpius*	*Retispora lepidophyta* *Grandispora praecipua* *Grandispora clandestina* *Apiculatisporis morbosus* *Hymenozono. explanatus* *Diducites mucronatus*	*Retispora lepidophyta* *Verrucosi. nitidus* (LN) *Retispora lepidophyta* *Hymeno. explanatus* (LE) *Retispora lepidophyta* *Knoxisp.literatus* (LL)

Famennian LE biozone in West Europe. The abundance of *Grandispora spiculifera* from the Longba Formation indicates that the major of this formaton should be Tournaisian age and could be correlated with Australian lower Carboniferous miospore assemblage (see Table 11). The presence of *Kraeuselisporites hibernicus, Rugospora polyptycha, Spelaeotriletes balteatus, S. pretiosus,* and *Auroraspora macra* allow the correlation with BP, PC biozones of West Europe.

The occurrence of *Spelaeotriletes pretiosus* in the sample SPS-8 could mean the existence of Middle Tournaisian PC biozone (Tn2b-Tn2c) in western Yunnan. Some other species from this sample such as *Schopfites delicatus, Spelaeotriletes obtusus, Spelaeotriletes resolutus, Crassispora trychera, Crassispora maculosa, Raistrickia clavata,* and *Raistrickia condylosa* are characteristic taxa of middle to upper Tournaisian age in West Europe. The occurrence of *Lycospora pusilla* from the samples NPIII-35, GN482.60, SPS-5, SPS-7, SPS-9 could mean the existence of Pu biozone of the lowermost Visean age in western Yunnan. Above all, the strata from Gengma investigated in this paper cover a record from the uppermost Devonian (Strunian) to the middle and upper Tournaisian and even into the lower part of the lower Visean.

2.2.5 Early Carboniferous miospores assemblage from Nanduan, ALI in the Changning-Menglian Belt

(1) General features

Besides the above excellent assemblages of Sipaishan, Gengma there is another lower Carboniferous miospores assemblage in this same Changning-Menglian Belt. A section located in ALI village, Menglian county (see Fig.5, section 15) in the southernmost of the Changning-Menglian Belt yielded a very good miospores assemblage. The upper Paleozoic (from Devonian to Permian) is distributed widely in this area. Among them, the Devonian and lower Carboniferous sequence is worthy to mention here, which is dominated by the spectacular deposits with a huge thickness (more than 2,000 m) of abundant arkosic arenite and graywacke rock suit. The previous geological survey once recorded the finding of some goniatites: *Kazakhoceras* sp., *Acrocanites* sp., which suggest a Visean age, from a horizon at the middle part of Upper Nanduan formation.

Totally, 56 pieces of samples from 4 sections have been collected from this Nanduan Formation. And half of these samples had been processed. The production of palynomorphs in this formation is not as good as the ones from Sipaishan. Finally and fortunately, we did find some early Carboniferous miospores.

(2) Miospore assemblage

A sample in section 15, which collected by Liu and diagnosed by Gao, provided the following miospores species: *Vallatisporites cilaris*, *Diatomozonotriletes* sp, *Waltzispora* sp, *Convolutispora venusta, Punctatisporites ornatus, Leiotriletes tumidus, Verrucosisporites nitidus, Convolutispora florida, Colatisporites denticulatus, Retusotriletes mirabilis, Laevigatosporites vulgaris, Lycospora pusilla,* and *Baculatisporites fusticulus*. And the following seem to be only distributed in Southern Hemisphere such as *Cristatisporites menendezii, Granulatisporites frustulentus, Anapiculatisporites redactus, Tricidarisporites phippsae,* and *Racemospora cumulata*. Gao suggested a Visean age, which appear to coincide with the dating of ammonite.

Based upon the above list, it is not difficult to say Visean age. However, some species of the above list could go up. So it is still open to the age of the Nanduan Formation in palynology since the samples mainly collected from the top horizon of the Nanduan Formation.

2.3 Late Carboniferous (?Permian) spores and pollen assemblages

The following is an uncertain part of palynostratigraphy in western Yunnan. In other words, they are lack of index fossils of spores and pollen and therefore the palynostratigraphy is open to be argued for these parts.

2.3.1 General features

As stated early in 2.2, during the last thirty years the activities of the C I M P working group concerned with stratigraphical palynology have contributed to the compilation of data relating to the stratigraphical distribution of miospores within the Carboniferous. The following palynologists who made their contributions to the palynological subdivision of parts of the Carboniferous System are noteworthy: The Tournaisian introduced in 2.2; Namurian by Neves (1961), Owens *et al.* (1977) and Jachowicz (1968); Westphalian by Smith and Butterworth (1967) and Loboziak (1974) etc; Stephanian by Liabeuf *et al.* (1967), Alpern and Liabeuf (1967) and Alpern *et al.* (1969). Clayton *et al.* (1977) contributed this approach in their book of Carboniferous miospores of West Europe, illustration and zonation.

The palynomorphs obtained from the Xiaolaba section and the Namutian section are indefinite in age due to the lack of index fossils and low production of palynomorphs. They could be attributed to Permian based upon the regional geology, mainly the previous biostratigraphy of these two formations. However, the Xiaolaba section and the Namutian section are the two sections mainly yielding late Carboniferous spores and pollen, which many species also can go upwards to Permian.

2.3.2 Spores and pollen assemblage from Xiaolaba in the Changning-Menglian Belt

The Xiaolaba section (see fig.5, section 16) is located in the Xiaolaba village of Lancang County, which is also within the Changning-Menglian Belt (Geological Block III). This geological belt was claimed by Liu (1993) belonging to the fore-arc of the Lin-cang marginal arc, the westernmost border of the South China plate during the Hercynian-Indosinian Stage. Late Paleozoic strata yielding abundant fossils are widely distributed in this belt. And even some lower Triassic sediments and fossils have also been discovered recently (Feng, 1996). The Laba Formation in the area nearby the Xiaolaba section is much more complicated. The author prefers to use "the Laba Group" instead of " the Laba Formation" because of which is the major exposure in this area. The rocks are more fossiliferous with ill-preserved fusulinids and bryozoans recorded in the bioclastic marl. Some of these fusulinids are of age significance. They are *Neoschwagerina, Sumatrina* and *Verbeekina*, which are typical of middle Permian in age. However, some typical late Carboniferous members are also recovered recently, such as *Triticites* and *Schwagerina*. Consequently the previous geological survey of the Laba Formation in this area showed its geological age ranging from late Carboniferous to late Permian.

The lithology of the Laba Formation consists of quartz graywacke, and argillaceous silicalite. Fortunately, the rocks of grey and dark carbonate shales, slates and muddy silicalite in the Xiaolaba locality have yielded a very interesting miospores assemblage. The miospores were mainly obtained from two samples (XLB-sp-2, XLB-6-1) in section 16. The palynomorphs were dominated by the following species: *Convolutispora tesselata, Laevigatosporites vulgaris, Punctatisporites punctatus, P. rotundus, Florinites ovalis, F. minutus, Schopfipollenites* sp., *Lophotriletes* sp., *Microreticulatisporites* sp, *Pityosporites* sp., *Foveolatisporiotes* sp., *Acanthotriletes* sp., *Dictyotriletes* sp., *Cyclogranisporites* sp., *Verrucosisporites* sp., *Calamospora pullida, Lycospora rotunda, Granulatisporites granulatus,* and *Cristatisporites* sp.. This assemblage was distinctive in that *Florinites ovalis, Florinites minutus. Schopfipollenites* sp., and *Laevigatosporites vulgaris* were also present and therefore its geological age could not be older than Westphalian.

2.3.3 Spores and pollen assemblage from Namutian in the Lanping-Puer Massif

The Lazhuohe Formation in the area around the Namutian section (fig.5, section 21) is located in a small village called Namutian in Mengla County. The lithology of the Lazhuohe Formation is a rock suit of grey, black sandstone, shales, silicate nodule, bioclast limestone, silicalite and some volcanic rocks. The thickness of this formation ranges from 230 to 771m. The reported fossils in the book of Regional Geology of Yunnan Province (1990) are fusulinids *Neomisellina lepida, Sumatrina longssima,* and *Yabeina* etc. Based upon the above fossils, it is no doubt that this formation should be late Early Permian (Maokouan) in age.

The sample NMT-6 yielded the following interesting miospores: *Limitisporites* sp., *Calamospora microrugosa, Crassispora trychera, Florinites mediapudens, Laevigatosporites vulgaris, L. perminutus, Punctatisporites aerarius, P. minutus, Waltzispora* sp., *Verrucosisporites microtubercosus, Lycospora pusilla,* and *L. rotunda.* It is somehow strange for this supposed Permian assemblage that many species are of Carboniferous and lack of disaccate pollen. The main reason is the insufficient sampling and low production of palynomorphs in this formation. Obviously, no further palynostratigraphic refinement could be made from this one single sample.

2.3.4 Correlation

It is not easy to correlate the spores and pollen assemblages from the Xiaolaba section and the Namutian section with the previously established biozones due to the lack of sufficient index fossils and low production of palynomorphs, in particular disaccate pollen. However, some broad correlation still can be attempted based upon the geological ranges of some fundamental species. In the Xiaolaba section, *Laevigatosporites vulgaris* mainly ranges from Westphalian to Autunian (lower Permian). In South China it can go down to lower Carboniferous (Tournaisian). And in India, Australia, Antarctica, South Africa, it also can go up to upper Permian and even lower Triassic (Queensland in Australia). The two distinctive species *Florinites ovalis, F. minutus* are also within the range from upper Westphalian to Stephalian and even lower Permian in North China (Gao, 1985). Therefore, the palynological assemblage in Xiaolaba could range from uppermost Carboniferous to lower Permian incorporating with the fusulinids data.

In the Namutian section, although many species are of Carboniferous age, the following *Latosporites minutus (Laevigatosporites perminutus), Lycospora rotunda, Punctatisporites aerarius,* and *Florinites mediapudens* are somehow bounded to Permian in China. For example, *Florinites ovali Florinites mediapudens* mainly occurred in the upper Permian in Hunan (Jiang and Hu, 1982), South and Central China (Lin *et al.*, 1978), East Yunnan (Ouyang, 1986), and Xinjiang (Zhang, 1990). *Laevigatosporites perminutus* quite often distributed from upper Carboniferous to upper Permian in North China (Gao and Wang, 1984; Gao, 1985). *Lycospora rotunda* is distributed in the upper Carboniferous in North China while in the Permian in South and Central China (Lin *et al.*, 1978) and even in the upper Permian in Hunan in South China (Jiang and Hu, 1982). So the Namutian palynological assemblage could be dated as early Late Permian together with the other paleontological data previously found in this area.

2.4 Early Permian spores and pollen assemblages

In contrast to the previous part, the following is much more certain and significant in palynostratigraphy and even phytogeography in western Yunnan.

2.4.1 General features

Some definite Permian spores and pollen have been extracted from the glacigene sequences in West Zone (geological block IV, V in Fig.1), which is the geological unit lying west of the Changning-Menglian Belt, and even from the Laba Formation in the East Area of the Changning-Menglian Belt. The targets mainly aimed at the remarkable glacigene deposits in both Tengchong and Baoshan. It is not so easy to do a palynological extraction from these mentioned glacigene sequences in western Yunnan. Fortunately and finally, some typical lower Permian Gondwanan spores and pollen assemblages were discovered from Tengchong in 1996, from Baoshan in 1997 and even from the Changning-Menglian Belt in 1994. The major of these assemblages in both Tengchong and Baoshan is only comparable to the ones in Australia and even the whole Southern Hemisphere.

The palynological sampling has been intensively made from the supposed glacigene sequences in western Yunnan, mainly from sections 3, 5, and 9 in Fig.5 and Table 1. However, only some spores and pollen have been recovered from the Kongshuhe TKIII section (section 3) and the Liujiazai-Qiaodou section (section 5) in Tengchong and also from the Jinji section (section 9) in Baoshan as well as from the Laba Formation in Ali Haibang (section 19) in the Changning-Menglian Belt. The following is the main introduction of the lower Permian palynostratigraphy in western Yunnan.

2.4.2 Spores and pollen assemblages from Kongshuhe and Qiaotou in the Tengchong Massif

(1) General features

The palynological attention has been mainly paid to the supposed glacigene sequences, which is originally called the Menghong Group and shows Carboniferous features due to the finding of brachiopods and bivalves from mudstones and shale in the upper part of the Menghong Group. In general, the Permo-Carboniferous succession of the Tengchong Massif consists of two parts, a lower clastic part and an upper carbonate part. The clastic part of the Permo-Carboniferous succession was first named to be the Menghong Group by Fang Zhongjing in 1962 from the village of Menghong, about 20km southwest of Tengchong town. The section exposed there is composed of slightly metamorphosed slate and pebbly slate about 600m thick. And he correlated the Menghong Group with the Chaung Magyi Series in Burma and thought that it belonged to the Sinian or the Cambrian. In 1994 Jin redefined the Permo-Carboniferous succession in the northern part of the Tengchong Massif into three formations. They are in ascending order: the Zizhi Formation, the Kongshuhe Formation and the Dadongchang Formation. The lower two formations are only parts of the Menghong Group, which is mainly clastic while carbonates overlying the clastic sequence are included in the Dadongchang Formation. The spores and pollen came from the black mudstone of the upper part of the Menghong Group.

The age of the Menghong Group is somewhat problematic due to the scarcity of fossils. The brachiopods from the dark fine clastics in the upper part of this group show a Permo-Carboniferous age, while fusulinids from the overlying limestone indicate a late Stephanian to Asselian age. Nie *et al.* (1993) once claimed that the age of the Menghong Group in the Tengchong Massif and the Dingjiazhai Formation in the Baoshan Massif mainly submitted to fusulinids was totally wrong. They asserted that the Menghong Group and the Dingjiazhai Formation were temporally equivalent sequences of the typical Gondwanan sequences in Australia and India. Due to these Gondwanan sequences had been dated as Early Permian, the Menghong Group and the Dingjiazhai Formation, should also be assigned an Early Permian. They also developed an idea of redepositing to explain the controversy in between the brachiopods dating and the fusulinids dating. But the palynomorphs seem to be able to solve this problem (Yang *et al.*, 1996).

(2) Spores and pollen assemblage from Kongshuhe

Some extracted from the grey, dark grey silicate mudstone of the Kongshuhe Formation, had been reported in 1996 by YWP and listed as follows: *Jayantisporites pesudozonatus, Microbaculispora tentula, M.* cf. *trisina, Punctatisporites gretensis, P.* sp., *Verrucosisporites subsaccata, Vittatina* cf. *fasciolata, Horridotriletes tereteangulatus, Protohaploxypinus* sp, *Propinguispora praetholus, Altitriletes densus, Brevitriletes* sp., *Cordaitina* sp, *Spelaeotriletes sp, and Retusotriletes* sp. This above assemblage has been dated as early Permian (Asselian) and correlated with stage 2 and probably part of *Pseudoreticulatispora confluens* Oppel zone in Australia (Yang *et al.*, 1996). And the fusulinids from the limestone above this palynological assemblage has been suggested to be *Pseudoschwagerina* zone of Sakmarian instead of the *Triticites* zone of Gzelian by a fusulinids specialist Dr. Wang Yujing (Yang *et al.*, 1996).

(3) Spores and pollen assemblage from Qiaotou

A sample QD-35 from the Kongshuhe Formation in section 3 in this Tengchong Massif as well, which was provided by colleagues and diagnosed by Gao, yielded the following lower Permian spores and pollen species: *Calamospora microrugosa, Leiotriletes* sp., *Verrucosisporites* sp., *Granulatisporites* sp., *Cyclogranisporites* sp., *Punctatisporites* sp., *Laevigatosporites vulgaris, Protohaploxypinus samoilovichii, P.* sp., *Vittatina* sp., *Florinites ovalis, F. pumicosus, Vitreisporites signatus, Primuspollenites levis, Labiisporites* sp., *Scheuringipollenites maximus, Protopodocarpites* sp., *Anticapipollis gansus, Weylandites lucifer, Alisporites* sp, and *Wilsonites* sp. Among them, *Primuspollenites levis* was mainly reported from the Carboniferous and the Permian in India (Tiwari, 1964, 1968; Saksena, 1971; Bharadwaj and Dwivedi, 1981; Prasad and Maithy, 1990). Gao and Wang (1984) once documented this species from the upper Permian in North China. *Scheuringipollenites maximus* is a much wide-distributed species mainly in Southern Hemisphere. For example, it had been once reported from the Permian in South Africa (Anderson, 1977); in W.Australia (Backhouse, 1991; Foster, Palmieri and Fleming, 1985; Gilby and Foster, 1988); in Antarctica (Balme and Playford, 1967; Playford, 1990); in India (Das, Karmarkar & Roy, 1989; Tiwari, 1968). *Weylandites lucifer, Laevigatosporites vulgaris, Protohaploxypinus samoilovichi* are also Permian worldwide species. Due to the occurrence of *P. samoilovichi*, this assemblage should be much younger than the TP assemblage from Kongshuhe.

2.4.3 Spores and pollen assemblage from Jinji in the Baoshan Massif

(1) General features

The palynological investigation into the glacigene sequences in the Baoshan Massif had been made many times. Eventually, two samples collected by Zhou Zicheng and Fang Zongjie from the Dingjiazhai Formation in Baoshan did produce a rich and very important palynological assemblage. The Dingjiazhai Formation is widely distributed in the Baoshan Massif, which was named by the Geological Survey in 1980 based upon the section beside the small village of Dingjiazhai, about 30km south of Baoshan town. In general, this formation is clastic and consists of shale, siltstone and sandstone alternations with a general tread of fining up. Some bioclastic limestone lenses are interbedded in the middle and top parts. The so-called pebbly mudstones, 15 to 20 m thick, are found from the lower part of the formation. The palynomorphs mainly came from the black and grey mudstones above the pebbly mudstones in the Dingjiazhai Formation.

(2) Spores and pollen assemblage from Jinji

Some significant Gondwanan type spores and pollen have recently been extracted from the Dingjiazhai Formation in Jinji, which is the main glacigene sequences in the Baoshan Massif. The age of this palynological assemblage found from Baoshan might be slightly younger than the one from Tengchong. The important members are included as follows: *Microbaculispora tentula, M. trisina, Pseudoreticulatispora confluens, Jayantisporites variabilis, Horriditriletes* cf. *tereteangulatus, Indotriradites niger, Vittatina fasciolata, Weylandites lucifer, W. magmus, Protohaploxypinus limpidus, P. amplus, P.* cf. *rugatus, Striatopodocarpites cancellatus, S. fusus, Striatoabietites multistriatus, Retusotriletes diversiformis, R.* sp., *Verrucosisporites* cf. *andersonii, Calamospora microrugosa, Limitisporites* cf. *rectus, Converrucosisporites* sp., *Plicatipollenites* spp., *Auroraspora* sp., *Dictyotriletes* sp., *Interradispora* sp., and *Sahnites* spp. Among them, *Pseudoreticulatispora confluens* is the index fossil for the *Pseudoreticulatispora confluens* Oppel-Zone in Australia (Foster and Backhouse, 1988). Due to the coexistence of *Microbaculispora tentula, Horriditriletes tereteangulatus, Striatoabieites multistriatus,* and *Plicatipollenites* spp., this above palynomorphs assemblage from Baoshan could be called *Pseudoreticulatispora confluens* comparable zone in terms of Foster ´ s definition (1988). Therefore, the age of this assemblage could be dated as latest Asselian and probable Sakmarian.

2.4.4 Spores and pollen assemblage from ALI, Haibang in the Changning-Menglian Belt

(1) General features

This section (see Fig.5, section 19) yielding miospores is also located in the above geological belt, the Changning -Menglian Belt, however, a little bit southward to the border between China and Burma in terms of geography. The most widely distributed strata are the late Palaeozoic. From the geological map we may predict that this area is the southernmost end of the Laba Formation extending from the north. However, there is still some slight difference in rock contents. The lithology of the Laba Formation in HaiBang, ALI locality are of grey, grey-green muddy siltstone, muddy slates interbedded with black shales and silicalites.

(2) Spores and pollen assemblages

Some interesting lower Permian spores and pollen were extracted from the Laba Formation in Haibang, Ali. These palynomorphs are composed of the dominant Eurasian members and some Gondwanan elements as well. The Eurasian species (or the Northern Hemisphere) are *Laevigatosporites vulgaris, L. minor, Lundbladispora* cf. *gigantea, Columinisporites peppersii, Florinites* cf. *occultus, Vittatina* cf. *fasciolata, Punctatisporites minutus, P. greatensis, Cordaitina* sp., *Cycadopites* sp., *Densosporites* sp., *Prorohaploxypinus* sp., *Pityosporites* sp., and *Lycospora* sp. The following mainly occurred in western Australia are also present in this assemblage, *Striatopodocarpites cancellatus* and *Striatoabietites multistriatus*. The age of this mixed assemblage could be dated as early Permian solely based upon palynomorphs. However, together with the other evidence of fossils, such as radiolaria *Follicuculus schlacolatus* in the slightly above horizons in the same section. Therefore, this palynological assemblage from Haibang could be regarded as Artinskian.

In fact, two miospores assemblages were extracted from section 19 at this HaiBang, ALI locality. The sample 90-AH-7-4 was collected from a grey black muddy carbonate slate and produced the following miospores species: *Calamospora* cf. *liquida, Brevitriletes* sp., *Cycadopites* sp., *Laevigatosporites vulgaris, L. minor, Lundbladispora* cf. *gigantea, Columinisporites peppersii, Densosporites* sp., *Florinites* cf. *occultus, Verrucosisporites* sp., *Protohaploxypinus* sp., *Granulatisporites granulatus, Pityosporites* sp., *Leiotriletes* sp., *Lycospora sp., Punctatisporites gretensis, Cordaitina* sp., and *Vittatina* cf. *fasciolata.*

The more interesting assemblage was extracted from the sample 90-AH-7-3, grey-green muddy slate and muddy shale. It is remarkably represented by striate bisaccate and monosaccate pollen, such as *Striatopodocarpites cacellatus, Protohaploxypinus limpidus, and Weylandites magmus.* The quite common encountered species are as follow: *Florinites* cf. *occultus, F.* sp, *Verrucosisporites* sp., *Columinisporites* cf. *peppersii, Lundbladispora* sp., *Leiotriletes lukugaensis, L.* sp., *Calamospora* sp., *Crassispora* sp., *Gondispora* cf. *tenuispina, Indotriradites (Kraeuselisporites)* cf. *niger, Pityosporites ovatus, Anapiculatisporites* sp., *Planisporites granifer, Alatisporites* sp., *Microreticulatisporites* sp., *Aratrisporites* sp., *Spelaeotriletes* sp., *Laevigatosporites minor, L. vulgaris, Horriditriletes* sp., *Retusotriletes planus, R. triangulatus, Sulcatisporites* sp., *Alisporites* spp., *Protohaploxypinus limpidus, Vittatina fasciolata, Striatopodocarpites cancellatus,* and *Striatoabieites multistriatus.*

The age of the strata from which the sample AH-7-4 collected could be latest Carboniferous (Stephanian) and early Permian (Autunian). And the age of the strata of the sample AH-7-3 should be early Permian (Asselian to Kungurian). Therefore, together, the geological age of the Laba Formation should be latest Carboniferous and early Permian in terms of palynology.

2.4.5 Tentative correlation with the Gondwanan assemblages

Due to the excellent Permian palynostratigraphy study has been made in Australia, it makes an easy and convenient way for the assemblages from western Yunnan to be compared with. In Australia, the history of Carboniferous and Permian palynological study is closely linked with the development of economic, particularly coal energy resources (Kemp, *et al.*, 1977). During this stage, the binomial nomenclature was applied to the dispersed fossil forms in a series of systematic papers (Balme and Hennely, 1955, 1956a, b; Hennelly, 1959). In the early 1960s, with the acceleration of oil exploration activity in Australia the palynological research is much emphasised on biostratigraphy instead of morphology of spores and pollen. The palynostratigraphic schemes encompassing the late Carboniferous and Permian were established subsequently and independently in western and eastern Australia. These have been proved to be some very useful schemes in Gondwanaland. Among them, the following should be mentioned herein. The eastern Australian palynostratigraphic scheme of Carboniferous and Permian was established mainly on the works of Evans (1967, 1969), Kemp *et al.* (1977) as well as Price (1983) and is thought to be the most well known scheme in Gondwanaland. The western Australian late Carboniferous and early Permian palynostratigraphy is mainly based upon the studies made by Balme (1964), Segroves (1970), Foster and Waterhouse (1988), and Backhouse (1991, 1993).

In Antarctica, early Permian palynofloras have been separately reported from South Victoria Land (Kyle, 1977), the Transantarctic Mountains (Kyle and Schopf, 1982) and the northern Heimefrontfjella mountain-range, Dronning Maud Land (Lindström, 1995).

Besides in Australia and Antarctica, Hart (1965) might be the first palynologists who studied the palynology of Africa Permian strata. Then, Anderson (1977) made his most comprehensive

Table 12. Lower Permian palynological correlation between western Yunnan and elsewhere in Gondwana.

Stage Substage	Antarctica South Victoria land, Kyle,1977	South Africa Karoo Basin Anderson, 1977	Eastern Australia: Kemp *et.al.* 1977	Eastern Australia: Collie Basin Backhouse 1991	Western Australia Canning Basin, Kemp *et.al.* 1977	India Damodar & Rajmahal Basins Tiwari & Tripathi 1992	S.W.China Western Yunnan: Tengchong Yang *et.al.* 1996	S.W.China Western Yunnan: Baoshan Yang 1997
Baigend-zhinian		3c	U.Stage 4a	*P.sinuosus*	Unit VI	Zone V		
		3b	L.Stage 4		Unit V			
Aktastinian	*Protohaploxypinus zone*	3a	Stage 3b	*M.trisina*		*Crucisaccites monoletus*		
Sterlita-makian		2d 2c	Stage 3a	*S.fusus*	Unit IV	Zone IV		
		2b 2a		*P.pseudo-reticulata*	Unit III	*P.korbaensis* Zone III		
Tastubian								
Asselian	*Parasaccites* zone	1	Stage 2	*P.confluens* Stage 2	Unit II	*P.gondwanensis* Zone II	TP zone	*P.confluens* comparable zone
295ma								

Permian palynological study in South Africa. Manum and Tien (1973), Utting (1976, 1978) made their contributions to the African Permian palynostratigraphy as well in Tanzania and Zambia independently.

The palynostratigraphy of the lower Gondwanan sediments in India were studied by Tiwari (1975), Banerjee and DíRozario (1990), Tiwari and Tripathi (1992).

In South America, Archangelsky *et al.* (1979, 1980), Gamerro and Archangelsky (1981) summarised the Carboniferous and Permian palynostratigraphic scheme for South America. Azcuy (1979) made a review of the early Gondwanan palynology of Argentina and South America.

Many efforts to the correlation of these late Carboniferous and early Permian palynological assemblages among these above Gondwanan continents have been achieved by Kempt *et al.* (1977), Truswell (1980), Foster and Waterhouse (1988), Backhouse (1991, 1993) and Lindström (1995). All of these are the most important fundamentals with that allow the assemblages from western Yunnan to be compared.

Although the palynological assemblages found in Tengchong and Baoshan are not so rich or abundant. It seems to be not difficult to correlate these assemblages from both Tengchong and Baoshan with the *P. confluens* comparable assemblage in Australia and even the whole Gondwanaland based upon some key taxa (see Table 19). The age of the Baoshan assemblage might be slightly younger than the one from Tengchong. This is because of the finding of *P. confluens* from Baoshan, which allows more confirm correlation in between Baoshan and Australia.

So far, the palynological assemblages found from the Kongshuhe section in Tengchong and the

Jinji section in Baoshan can solely be compared with those in Gondwana (see Table 12).

Microbaculispora tentula was originally established by Tiwari (1964) from the Talchir Formation and the Bap Formation of lower Permian Barakar stage of lower Gondwanan Series in India. It was subsequently reported to occur in the lower Permian Dwyka Tillite of Karoo Basin from South Africa (Anderson, 1977), Tazania, and Zimabwe (Falcon, 1975); at the bottom of the Ewington member of the Lower Permian Stockton Formation of the Collie Basin (Backhouse, 1991), the Grant Formation of the Canning Basin as well as the Bonaparte and Troubridge Basins in Western Australia (Foster and Waterhouse, 1988); various Late Palaeozoic tillitic sequences in Transantarctic Mountains such as in the Locality A and Lidkvarvet of the northern Hemiefrontfiella mountain-range, Dronning Maud land, Antarctica (Lindstrom,1995). All these horizons yielding *M. tentula* are just on the top of glacigene strata or the upgrading strata.

Jayantisporites pseudozonatus had been recognised in Africa, South America, India and Australia and assigned at least six different specific names, involving four distinct genera (Foster and Waterhouse, 1988, p.144). As his remarks in Appendix 1, Foster selected the following synonymies for *Jayantisporites pseudozonatus* Lele and Makada, 1972. These are *Zinjisporites zonalis* Hart (?) 1965, *Dentatispora pseudoreticulata* Bose and Maheshwari, 1968, *Cristatisporites solaris auct.non* (Balme) Butterworth *et al* - Maheshawari (?), 1969, *Dentatispora superba* Maheshwari (?), 1969, *Dentatispora* sp. Maheshwari 1969, *Zinjispora (sic) zonalis (?) auct.non* Hart-Manum and Duc Tien, 1973, *Zinjisporites spinosus* (*auct. non* Kar and Bose) Anderson, *pars* 1977. *Cristatisporites* sp.B Archangelsky & Gamerro (?) 1979, and *Cristatisporites* sp., 1983. The current author basically agree with Foster′ s consideration and appreciate his preliminary contribution to the correlation of *Granulatisporites confluens* zone with the comparable assemblages within the Gondwana. In spite of *Jayantisporites pseudozonatus* once reported to present in the slightly lower horizon in India, It mostly distributed in the quite same horizons associated with *M. tentula* in the Canning, the Bonaparte, and the Troubridge Basins from Australia; in the Chaco-Parana, the Paganzo, the Parana, the Colorado, and the Central Patagonian Basins from Argentina and Brazil as well in South America; in the Talchir Formation and the Bap Formation from India; in the Dwyka Tillite from South Africa, Tazania and Zimbabwe in Africa; in the Locality A and Lidkvarvet of the northern Hemiefrontfiella mountain-range Dronning Maud land, Antarctica. *Horriditriletes tereteangulatus* was one of the most distinctive and important elements of Powis (1984) refinement stage 2. Therefore, together with *Procoronaspora spinosa, Propinguispora praetholus, Vittatina fasciolata,* the above TP zone from Tengchong and *P.confluens* comparable assemblage from Baoshan could be correlated with *P. confluens* Oppel Zone in western Australia, stage 2 of Kemp *et al.*, 1977 or the top of zone 1 and zone 2a in the Karoo Basin of South Africa and was dated as late Asselian and early Sakmarian (see Table 12).

With respect to the current palynomorphs horizons, the Kongshuhe Formation is now subdivided lithologically by Jin (1994) into three parts, diamictites, pebbly mudstone and black mudstone and siltstone. A transitional sequence consisting of siltstone, sandstone and marls above the black mudstone unit is also included within the Kongshuhe Formation. In the Kongshuhe section, fusulinids was once reported by Fang *et al.*, (1991) from this transitional sequence with the occurrence of *Triticites parvulus, T. ohioensis, Hemifusulina pseudosimplex, Schwagerina pararegaria,* and *S. gragaria,* mainly from the fossiliferous argillaceous limestone of the upper part of the Kongshuhe Formation. In the calcareous mudstone, brachiopods, *Pseudomarginifera* cf. *kolymaensis, Spiriferella rojah, Costiferina alata, Calliomargintia* cf. *himalayensis, Stepanoviella* aff. *gracilis, Waagenities* cf. *sureshanensis,* and *Athyris* sp. and bryozoans, *Fenestella elusa,* and *F. supravischerensis* were also once found in the previous geological survey. The fusulinids assemblage had been dated by Fang (1991) as Gzelian. After serious observation of the description and exhibition of these fusulinids fossils, Dr. Wang Yujing modified the above species and reconsidered the age of this fusulinids assemblage from Gzelian to Sakmarian (Yang *et al.*, 1996). Therefore, the reconsideration of fusulinids supported the palynological dating.

Pseudoreticulatispora confluens was originally established by Archangelsky and Gamerro (1979) in South America into the genus of *Granulatisporites.* In 1991 Backhouse changed it to the current genus. In 1988 Foster and Waterhouse used it to be the index fossils of their *P. confluens* Oppel Zone in West Australia. So far this species has been reported in a wide distribution from Australia, South America, India, Africa and SW China with a very restricted stratigraphic range from Asselian to Sakmarian. *Horriditriletes tereteangulatus* has been recorded in a more wide distribution, mainly from lower Permian in Pakistan, Australia, Algeria, India, Wales, Antarctica, Tanzania, Zambia, Germany etc.. Due to its occurrence to the upper Permian and even Mesozoic, this makes it in an even more wide distribution. *Striatoabietites multistriatus* is the similar species to *H. tereteangulatus* in their geographic distribution and stratigraphic range. *S. multistriatus* has mostly been reported also from the lower Permian in South Africa, Australia, Bolivia, Brazial, Peru, Argentina, India, Xinjiang in China, and Spitsbergen. Therefore, together with *M. tentula* and some other species, this palynological assemblage from Jinji, Baoshan could be a quite similar one to the *P. confluens* Oppel zone in Australia. By the way, there are also some brachiopods from the limestone above this palynomorphs horizon. Shi *et al.* (1996) described an early Permian brachiopod fauna from the upper part of the type Dingjiazhai Formation. The brachiopod fauna is dominated by *Stenoscisma* sp. and *Elivina yunnanensis*. Based on their correlation, a late Sakmarian age is proposed for the Dingjiazhai brachiopod fauna which support the current palynological dating of this same Dingjiazhai Formation in Baoshan (see Table 14).

2.5 Late Permian spores and pollen assemblages

In this palynological investigation in western Yunnan, the late Permian spores and pollen only extracted from the Lanping-Puer Massif, which are typical Cathyasian types.

2.5.1 General features

Till Permian period, the Mojiang district become apparent different from the rest of the Lanping-Puer Massif. In this Mojiang district developed very well Permian succession. In Chihsian (equivalent to Kunggurian and Roadian, Jin *et al.*, 1997), some stable deposits of limestone yielding fusulinids (*Misellina claudiae*) outcrops in the western part of this Mojiang district while in the eastern part is somehow mobile sediments including quartz-sandstone, silty shales, andesite, basalt, volcanic breccia and tuff. Some brachiopods and bryozoan have once been found in the above sequence. In Maokouan (equivalen to Wordian and Capitanian, Jin *et al.*, 1997), in the western part, the Baliu Formation is the main deposition for this period and consists of sandstone, sandy mudstone, silicate bioclast limestone interbedded with some tuff. Some fusulinids *Neowchwagerina simplex*, *Sumatrina longissima*, and brachiopods yielded from the limestone. In Wuchiapingian, the Yangbazhai Formation in the Mojiang district is characterised by grey black, grey yellow sandstone and shales, silicalite, tuff, andesite and basalt interbedded with some coal seam, in which yielded many fossils including brachiopods, trilobite, plants and fusulinids. In Changhsingian, volcanic breccia, tuff, andesite and limestone lenticle with fusulinids *Palaeofusulina* distributed in this area.

The following Dengkong section (section 22) yielding spores and pollen is located in the east margin of this Lanping-Puer Massif.

2.5.2 Spores and pollen assemblage from Dengkong in the Lanping-Puer Massif

The strata of grey black, grey yellow sandstone, shales and coal seam yielding megaplant and microflora is the Yangbazhai Formation in this Mojiang district. The megafossils collected from this formation and diagnosed by Yunnan Geological Survey are brachiopods, *Oldhamina* and *Leptodus tenus,* plants, *Gigantopteris nicotianaefolia, Lepidodendron acutangulum,* trilobite, *Pseudophillipis chongqingensis;* Fusulinids, *Codonofusiella.* The sample MD-7 from the yellow shales in the Yangbazhai Formation yielded some interesting miospores. They are *Jansoniuspollenites ovatus, J.* cf. *J. ovatus, Limitisporites* sp., *Piceopollenites* sp., *Alisporites taenialis, A. ovatus, Cordaitina* sp. and *Protohaploxypinus* spp. The sample MD-7 could be late Permian in age. Further detailed zonation could not be done in this investigation because of the insufficient materials.

3. Phytogeography and tectonic implication in western Yunnan

3.1 Review of paleobiogeography in western Yunnan

The study of paleobiogeography in western Yunnan could link with the finding of the Gondwanan facies in Tengchong and Baoshan in 1980s. Since Fang Runsen (1983) described a late Early Permian brachiopod fauna with the Gondwanan affinity from the Yongde Formation in the southern Baoshan Massif in a publication titled "Early Permian Brachiopod from Xiao Xin Zhai of Gengma, Yunnan and its geological significance" , many research have been undertaken over the last decade in an attempt to reveal the late Paleozoic paleobiogeography of western Yunnan and its vicinity. The following mainly focus on the history of paleontological and paleobiogeographical studies in western Yunnan in both published data and unpublished data (non-official publication) in order to provide a historical review on this issue. Due to the chaos existed in both unpublished data and rough paleontological work in western Yunnan, it puzzled the geological circle for a long time to know what is the real paleobiogeographic configuration in western Yunnan. Therefore, the incoming review is only based on my collection and knowledge about the late Paleozoic paleobiogeography in western Yunnan as many as I can cover the available data so far.

The most sensitive fossils in paleobiogeography of western Yunnan were Gondwana-related fauna (cold fauna, or some cold-warm fauna) and the *Glossopteris* flora.

In the same year of 1983, Duan Xinhua once claimed in an unpublished report about the finding

Table 13. The characteristic bivalve fauna distribution of early Permian in Gondwanan-Indian regions (modified from Yin, 1997).

age	P1				P2	
	P1a	P1s	P1q	P1m	P2w	P2c
	1 2 3 4 *Eurydesma* zone					
		1 4 6 *Schizodus-Oriocrassatella* assemblage				
			2 5 *Astartella, Kolyclopecten* *Atomodesma*			
				5 *Nuculopsis, Aviculopecten*		
1-India; 2-Salt Range, Pakistan; 3-Lesser Himalayan; 4-Kashimir; 5-Mount Everest; 6-Gengma,						

of typical Gondwanan bivalve fauna *Eurydesma sinensis* Lin (unpublished, diagnosed by Lin Minji) from the Dingjiazhai Formation in Xiaoxinzhai of Gengma although it has been in later turn down by fang Zongjie *et al.* (1990). This might be the first report of the earliest Permian Gondwana-related fauna or so called cold water fauna in western Yunnan. But later in 1991 Fang Zongjie rejected this *Eurydesma* claimed by Lin Mingji and modified it to be the genus of *Schizodus* after he restudied this specimen. He thought these specimens are smaller and thinner than those from Australia. From Table 13, you might find that the *Eurydesma* zone was mainly distributed from Asselian to the lower part of Sakmarian in India, Pakistan, lower Himalayan region and Kashimir. Obviously the bivalve fauna found from Gengma is in a higher horizon (upper Sakmarian to lower Chihsian (P1q) equivalent to Kungurian). Then the *Schizodus* fauna from Gengma, western Yunnan is still comparable to the equivalent fauna in India and Kashmir. In 1986, Cao Runguan also once provided some fauna list from both Tengchong and Baoshan, which has been claimed to be cold water fauna or cold-warm water fauna. Some brachiopods *Stepanoviella* ? *glacilis*, etc. once documented by Cao Runguan (1986) from the glacio-marine facies of the Dingjiazhai Formation in Baoshan. And some *Spiriferellina cristata, Marginifera* sp., etc. from the middle part of the Menghong Group in Tengchong was also claimed by the Regional Geology Survey Team of Yunnan Province. In 1993, Nie Zetong *et al.* reported the abundance of brachiopods from both the Dingjiazhai Formation in Baoshan and the Kongshuhe Formation in Tengchong. These two formations share the similar elements such as *Globiella* (*G. gracilis* (Jin)) and *Brachithyrinella* (*B.* cf. *narsarhensis* (Reed)). Furthermore, more recent paleontological work seems to support to some degree the existence of Gondwanan affinity fauna in West Yunnan. In 1996, Shi *et al.* described an early Permian brachiopod fauna (*Stenoscisma, Elivina, and Globiella*) of Gondwanan affinity from the Baoshan block, western Yunnan, China (see table 14). Back to 1983, Fang Runsen once claimed the finding of cold water brachiopods from the lower

Table 14. The characteristic distribution of Permian brachiopods in the South part of the Intermediate Transitional Block (modified from Yin, 1997).

age	P1: P1a, P1s, P1q, P1m; P2: P2w, P2c
1	*Globiella* assemblage
	'*Taeniothaerus* assemblage'
	Karavankina-Marginifera typica assemblage
2	*Martinia camongensis* - *Ambikella* assemblage
	Neospirifer fasciger - *Subansiria ranganensis* assemblage
	Stenoscisma ornata - *Costiferina sinensis* assemblage
	Paraderbyia doumaensis-Jipuproductus jipuensis assemblage
	Neoplicatifera-Marginifera assemblage
	Leptodus-Squamularia
3	*Bandoproductus-Trigonotreta* assemblage
	Neospirifer-Globiella assemblage
	Costiferina-Stenoscisma gigantea assemblage
	Pseudoantiquitonia assemblage
	Crenispirifer-Spinomarginifera-Transennatia
4	*Globiella* assemblage
	Stenoscisma-Elivina Globiella
	Costiferina assemblage
	Waagenites assemblage
5	*Komukia-Sulciplica* assemblage
	Spinomartinia prolifica assemblage

1-middle Afganistain; 2-M&W,Qiangtang; 3-Lasha; 4-Tengchong-Baoshan; 5-Burmese-Thai-Malayan

Permian in Xiaoxinzhai of Gengma. He further divided these brachiopods into two assemblages, the lower *Costiferina* assemblage and the upper *Waagenites* assemblage, which in fact yielded from the Xiaoxinzhai Formation, a horizon much higher than the Dingjiazhai Formation or the Kongshuhe Formation (see Table 14).

One more so-called cold water or cold-warm water fauna is *Monodiexodina*, which was a bipolar distributive genus in Permian. Han Nairen (1991) once claimed the finding of *Monodiexodina* in Laochang of Lancang county in western Yunnan although Nie Zetong once disagreed with this found specimen to be *Monodiexodina*. Table 15 provides a more wide-area distribution of fusulinids in the vicinity of western Yunnan.

With respect to the plant fossils, especially the *Glossopteris* flora in western Yunnan, Li

Table 15. A more wide-area distribution of Permian fusulinids in the South part of the Intermediate Transitional Block (after Yin, 1997).

age	West	Middle			Southeast		
	E.Karakurun	Lasha	W.Qiangtang	M.Qiangtang	Baoshan	S.Thailand	W.Malaysia
P_2c			*Palaeofusulina*	*Palaeofusulina*	*Palaeofusulina*		
P_2w			*Codonofusiella* *Sphaerulina*				
P_1m	*Neoschwagerina*	*Neoschwagerina*	*Neoschwagerina*	*Neoschwagerina* *Polydiexodina*	*Neoschwagerina*	*Neoschwagerina simplex*	*Nankinella* *Chusenella* *Schwagerina*
P_1q	*Misellina* *Monodiexodina*	*Parafusulina*	*Monodiexodina*	*Parafusulina-Monodiexodina*	*Monodiexodina*	*Misellina confragaspira* *Monodiexodina*	
P_1s			*Pamirina-Eoparafusulina*		*Triticites* *Quasifusulina*		
P_1a							

Xinxue once made a summary about the late Paleozoic flora in SE Asia. Again the most sensitive fossil is *Glossopteris*. In Li′s summary, this genus was once reported with question mark from many places in western Yunnan. For example, in Taiping Chang of Yunnan, the specimen of *Glossopteris* sp. is only a fragment, which cannot be identified at al. And the other specimens originally determined by Zeiller as *G. india, G. angustifolia* also have successively been modified to the genus of *Sagenopteris*. Recently, Li *et al.* made some progress on these. He reported the two localities from Gengma and Yongde districts in which *Glossopteris* ? sp. has been identified (see chapter 3.2).

Recent palynological studies in both Tengchong and Baoshan even exhibit more strong links with Gondwanan microflora. So these are all the paleontological data so far available from western Yunnan. Further detailed explanation related to paleobiogeography, especially the evolutionary paleobiogeography in western Yunnan will be first discussed in the later part of this paper in order to sort out the chaos and make a new effort to the understanding of late Paleozoic paleobiogeography in western Yunnan.

3.2 Phytogeographical delimitation of megaplant fossils in western Yunnan

The paleobotanical study in western Yunnan was back to the early 20th century, Zeller (1902) first described the plant fossils of *Glossopteris indica* Schimper, *G. angustifolia* Brongn from Taiping Chang in Yunnan although they have been modified to be *Sagenopteris* by Hsu *et al.* (1970) and Sze *et al.* (1963). And in 1906, Yakoyama also once documented *Glossopteris* ? sp. in Yunnan. Till 1990s Li Xingxue had a chance to diagnose some plant fossils from western Yunnan.

Table 16. The possible plant fossils of late Paleozoic in western Yunnan.

	Teng-Chong	Baoshan	Yongde	Gengma	Lincang	Lanping-Puer (Simao)
P_2				Sipaishan ?*Lobatanularia* sp		Dengkong, Mojiang *Gigantopteris* sp.
P_1	Kongshuhe	Dingjiazhai	Anpaitian *Glossopteris* ? sp.	Xiaodingxi *Glossopteris* ? sp	Laba Fm. plant fragments	Lazhuohe *Cladophlebis*
C_2						*C.*sp. *Tingia* sp. Baliu, Mojiang *Pecopteris*
C_1					Naduan Fm. *Calamites*	Mengla *Neuropteris*
D_3			*Leptophleum rhombicum* *Zosterophyllum*			*Sublepidodendron*

Calamites cf. *suckowu* Brongn was recognised by Li from Ali of the Menglian district in southwestern Yunnan within this Changning-Menglian Belt, which is supposed to be the early Carboniferous flora. And Li also recorded *Pecopteris* spp., *Glossopteris* ? sp., *Paracalamites* ? sp. and *Carpolithus* sp. from the Permian of the Gengma district which is located in the southwest of the Shuangjiang Line. *Glossopteris* ? sp. was again identified from the lower Permian Yongde Formation near the Yongde county, which is about 80 km northwest of Gengma. In Li′ s opinion, the plant assemblages from these three above-mentioned localities contain few plants, mostly in a form of fossil fragments. Therefore, it is not easy to determine definitely this significant genus *Glossopteris* in the above localities. But he still declines to the appearance of the questionable *Glossopteris* in both Gengma and Yongde.

Table 16 is showing all the probable plant fossils claimed to have been found in western Yunnan by the Regional Geology Survey Team in Yunnan although no guarantee can be given to the accuracy of the diagnosis. However, it might present the general background of plant fossils from western Yunnan in terms of phytogeography. However, Li Xingxue *et al.* (1996) drew his phytogeographic line through Baoshan-Shuangjiang-Menglian, with somewhat different Permian biota and lithofacies on the east compared with the west side, and might belong to the Cathaysian or Euro-Cathaysian Floral Province and the Gondwanan (*Glosspoteris*) Floral Province, respectively. It becomes obvious now that the east sides of this line should belong to the Cathaysian Floral Province due to the appearance of gigantopterids at many localities although there was some reports on the finding of *Glossopteris* sp. in the east sides of this line. But the *Glossopteris* ? sp

Table 17. The possible Permian plant fossils distribution in SE Asia.

		West Yunnan China	Thailand	Vietnam Laos	Malaysia	Indonesia	
						Sumatra	W. New Guinea
Cathaysian Floras	P2	**Mojiang** *Gigantopteris*					
	P_2^1		**Phetchabun** Flora **Loei** Flora	**Phong Saly** *Protoblechnum*	**Linggiu** Flora		
	P_1^2				**Jengka** Flora		
	P_1^1					**Djambi** Flora	**Locality 1**
Mixed Floras	P2						
	P_2^1						
	P_1^2	**Gengma** *Glossopteris ?sp*					**Locality 2 ? 3**
	P_1^1						
Gondwanan Floras	P2						
	P_2^1						
	P_1^2						**Locality 4**
	P_1^1						

documented by Yokoyama (1906) from the area to the east of this boundary line has been turn down by Li Xingxue *et al.* And the specimens originally diagnosed by Zeiller as *G. indica*, *G. angustifolia* also had successively been reassigned to the genus *Sagenopteris* (Sze *et al.*, 1963, p135). However, the area to the west of this line is still not so convincible since the plant assemblages from both Gengma and Yongde are not strong enough to declare its affirmative provincialism of Gondwana. But Li *et al.* declined these above-mentioned Gengma and Yongde districts to be drawn within the Gondwanan floral (*Glossopteris*) Realm.

In Table 17, the author tries to make a simple correlation of plant assemblages in SE Asia documented by Li Xingxue *et al.* in 1996. The phytogeographic provinces of the whole SE Asia have also been provided by Li *et al.* (Fig.7)

Based upon Li′ s summary, there is only one locality — the locality 4 in west New Guinea in which has been confirmly claimed to find the typical Gondwanan elements *Glossopteris* including *Glossopteris* sp. cf. *G. indica* Schimper, *Glossopteris* sp. cf. *G. retifera* Feistmental, *Vertebraria,* the later one is the only one species found in the locality 2. The locality 3 in west New Guinea and Gengma, Yongde in western Yunnan might be the representative areas so far found the mixed floras of Cathaysian and Gondwana in spite of the crucial element *Glossopteris* with a question mark. In locality 3, only one species *Glossopteris* cf.*G.browniana* Brongniart supposed to link with Gondwanan elements while the rest species are *Trizygia* sp. cf. *T. speciosa* Royle, *Cladophlebis* sp. cf. *C. australis* Morris, *Pecopteris unita* Brongniart, *Validopteris* sp. In Gengma of western Yunnan, Li recorded *Pecopteris* spp., *Glossopteris* ? sp., *Paracalamites* ? sp. and *Carpolithus* sp. However, the majority of SE Asia belongs to the realm of the Cathaysian flora (see Fig.7).

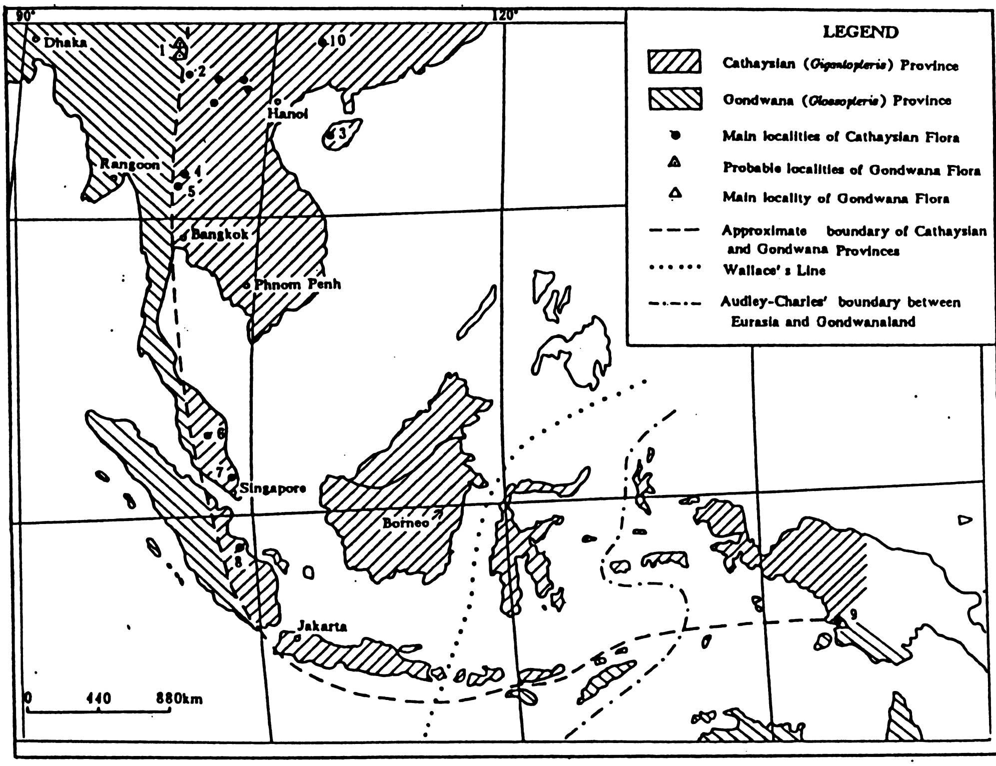

Fig.7. Sketch map showing the phytogeographic provinces of the Permian floras and their significant localities in S.E.Asia (after Li et al., 1996).The Location of floras: 1- Gengma and Yongde of western Yunnan, China; 2- Ali, Menglian of western Yunnan, China; 3- Dongfang of Hainan, China; 4- Loei Flora in Thailand; 5- Phetchabun in Thailand; 6- Jengka Flora in Malaysia; 7- Linggiu Flora in Malaysia; 8- Djambi Flora in Sumatra, Indonesia; 9- W.New Guinea, Indonesia; 10- Laibing in Guangxi, China.

3.3 Microfloral phytogeography in western Yunnan

Now it is becoming evident that the late Paleozoic microflora in western Yunnan does show some provincialism difference with the accumulation of the Gondwanan type palynomorphs in the past several years. The microflora might prove to be the major contribution to the phytogeography in western Yunnan due to the bad preservation of plant fossils and the scarcity of plant data in this area. The following will be a main introduction of microfloral phytogeography in western Yunnan based upon the palynological data as many as we obtained so far. In fact, there is quite little paper dealing with microfloral provincialism before. Since Playford claimed that the early Carboniferous *Granulatisporites frustulentus* assemblage only distributed in Southern Hemisphere, people became more concerned about the probable provincialism of microflora. It might be the same for microflora as megaplant flora that the phytogeography gradually grew distinct since early Carboniferous.

The matter of microfloral provincialism in western Yunnan become to search for the typical Gondwanan microflora due to the finding of some Gondwanan species first from Tengchong, then subsequently from Baoshan, and even a few found from the Changning-Menglian Belt. The fol-

Table 18. Lower Permian palynological assemblages with Gondwanan affinity in western Yunnan.

	Tengchong		Baoshan
	Kongshuhe	Dashuigou-Qiaotou	
Artinskian		*Primuspollenites levis* *Scheuringipollenites maximus*	
Sakmarian Asselian	*Microbaculispora tentula* *Jayantisporites pseudozonatus*		*Pseudoreticulatispora confluens* Zone

Table 19. Geographic distribution of key taxa of the *P.conluens* Opple-Zone (modified from Foster, 1988).1 **Australia:** Canning Bonaparte, Ttoubridge Basins; **2 South America:** Argentina, Chaco-Parana, Paganzo, Parana, Colorado, Central Patagonian Basins: Brazil; **3 India:** Talchir Formation, Bap Formation; **4 Africa:** Dwyka Tillite; South Africa, Tanzania, Zimbabwe; **5 Antarctica:** various Late Palaeozoic tillitic sequences in Transantarctic Mountains; **6 S.W.China:** Kongshuhe Formation, Tengchong; **7 S.W. China:** Dingjiazhai Formation, Baoshan. + taxa present; C closely comparable.

Taxa	Localities						
	1	2	3	4	5	6	7
Spores							
Apiculatisporis cornutus	+	+	C	+			
Brevitriletes levis	+		+	+			
Densosporites rotunaidentatus	+						
Pseudoreticulatispora confluens	+	+	+	+			+
Horriditriletes ramosus	+	+	C	+		C?	C
Jayantisporites pseudozonatus	+	C	+	+		+	
Microbaculispora grandegranulata	+			+			
Microbaculispora tentula	+		+	+	+	+	+
Pachytriletes densus	+	+		+			
Punctatisporites gretensis	+	+	+	+	+	+	
Pollen							
Cannanoropollis spp.	+	+	+	+	+		
Caheniasaccites ovatus	+	+	+		+		
Cycadopites cymbatus	+		+	+	+		
Limitisporites rectus	+	C	+		+		+
Marsupipollenites striatus	+	+					
Plicatipollenites spp.	+	+	+	+	+		C
Protohaploxypinus limpidus	+	C	+		+	C?	+
Protohaploxypinus acutus	+			+			
Striatoabieites multistriatus	+	+					+
Stellapollenites spp.	+		+	+			

lowing is introducing massif by massif from west to east the late Paleozoic palynomorphs already found in western Yunnan.

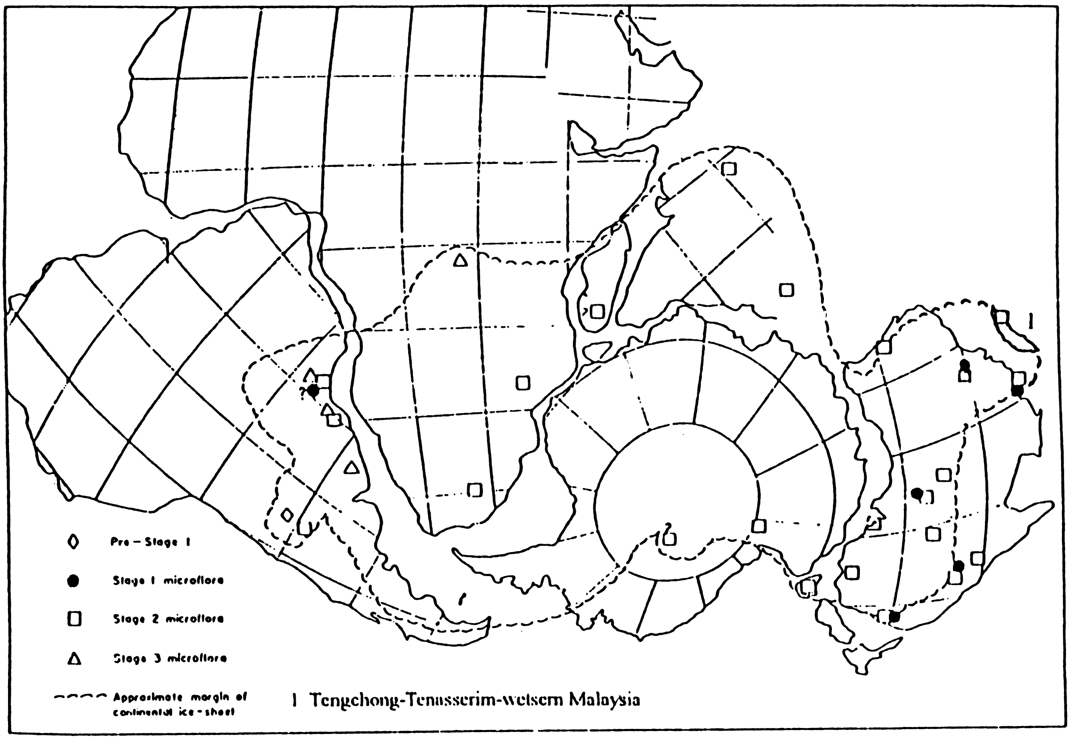

Fig.8. The distribution of late Carboniferous and Permian four stages microflora within the glaciated Gondwana area (modified from Kemp, 1973).

3.3.1 Gondwanan type palynomorphs in the Tengchong and Baoshan Massifs

There are so far three localities in which lower Permian Gondwanan type spores and pollen have been achieved for the first time in western Yunnan, the two in Tengchong, the third one in Baoshan. Table 18 is showing the main Gondwanan type assemblages from both Tengchong and Baoshan. The author insists on that any paleobiogeographical study will lose its value if the biostratigraphy in that region is quite uncertain or rough. So before discussing the microfloral provincialism, the palynostratigraphy and precise correlation is still needed. As documented earlier, the TP zone in Kongshuhe, Tengchong and *Pseudoreticulatispora confluens* in Baoshan have been correlated closely with the upper part of Stage 2 or *P. confluens* Opple Zone in Australia. That makes easy to deal with the microfloral provincialism. In 1988, Foster once made a geographic distribution of key taxa of the *P. confluens* Opple zone. With the finding of *P. confluens* comparable assemblages in western Yunnan, the author added more data in it and then modified this distributive chart in Table 19.

Now it is becoming apparent that Stage 1 in eastern Australia or Unit I in western Australia might be useless in biostratigraphy since Powis (1984) already stated that Stage 1 was probably a facies controlled palynoflora. In 1988 Foster also claimed that there was no other time-significant spore-pollen indices on Stage 1. These impoverished palynological assemblages might well represent a specialised, environmentally restricted communal plant-subset. From the above claims to-

Table 20. The microflora zonation within the Lower Gondwana Series of India (after Yin, 1997).

Age	Litho-Units	Megaplants	Microflora	Climate	Moisture
		Sastry, et.al.1979	Tiwari & Tripathi, 1987		
$P_{2}c$		*Glossopteris retifera* *Gl.conspicus*	*Striatopodocarpites-Crescentipollenites* *Striatopodocarpites-Densipollenites* *Striatopodocarpites-Gendisporites* *Striatopodocarpites-Faunipollenites*	Warm	very wet
$P_{2}w$		*Cyclodendron*	*Densipollenites- Striatopodocarpites*	Warm	semi-arid
$P_{1}m$	Barakar Fm.	*Baradkaria dichotoma-* *Walkomeilla indica*	*Faunipollenites-Scheuringipollenites* *Scheuringipollenites- Faunipollenites*	mild warm cool	wet
$P_{1}q$	Karharbari Fm.	*Botrychiopsis*	*Parasaccites-Callumispora*	very cold	semi-arid
$P_{1}s$		*Buriadia*	*Callumispora- Parasaccites*	cold	wet
$P_{1}a$	Talchir Fm.	*Gangamopteris* *Paranocladus*	*Parasaccites - Plicatipollenites* *Plicatipollenites- Parasaccites*	very cold extremely cold	semi-arid arid

gether with the actual localities of palynoflora in the Gondwanan continents, we would like to accept Stage 2, Unit II, *P. confluens* and the current TP zone in Tengchong, *P. confluens* comparable assemblage in Baoshan as the most remarkable earliest Permian palynoflora throughout the whole Gondwanan continents. But the following two things are still uncertain. One is whether or not the lower boundary of this palynoflora event coincides with the lower boundary of Asselian stage. The two is there was once some problems of "old" and "new" Stage 2 usage.

With respect to the palynology of the Permian glaciation in southern hemisphere, Kemp (1973) once established four stages describing the distribution of microflora within the glaciated Gondwana area. Among these, microflora of Stage 2 were the most widespread in their geographic distribution, occurring on all the continents (Fig. 8). The palynological evidences found in both Tengchong and Baoshan are just two more cases to support the above claims.

However, one more important phenomena should be noticed here that both the Tengchong assemblage and the Baoshan assemblage lack of monosaccate pollen. Tiwari and Tripathi (1987) once claimed that monosaccate pollen could link with very cold climate condition based upon Indian lower Gondwanan data. According to the correlation chart (Table 12,20), the TP zone from Tengchong and *P. confluens* comparable assemblage from Baoshan have been correlated with Zone II or part of Zone III in India, e.g. *P. gondwanensis* Zone or *Parasaccites-Plicatipollenites* Zone, which were supposed to be a very cold climate. But why the palynological assemblages from the glacigene sequences in western Yunnan have no monosaccate at al. The probable answer to this question could be a matter of tectonic, which will be discussed later.

3.3.2 Mixed palynomorphs in the Changning-Menglian Belt

The Changning-Menglian Belt (or Ocean) is treated as the most conspicuous boundary separating the two different tectonic domains of Gondwana and Cathaysia and represents the main oceanic basin of the Paleotethyan Archipelagos Ocean (Liu *et al.*, 1989, 1991a, b, 1993; Wang *et al.*, 1990). Due to the complexity of geology, the Changning-Menglian Belt has attemptly been di-

Table 21. Late Paleozoic palynological assemblages in the Changning-Menglian Belt.

Changning – Menglian Belt			
	West Area	Middle Area	East Area
P_1			**Laba Fm. in Haibang** *Striatopodocarpites cancellatus* *Striatoabietites multistriatus* ?
C_1	**Longba Fm. in Sipaishan** *Lycospora pusilla* *Grandispora spiculifera*		**Nanduan Fm. in Menglian** *Cristatisporites menendezii* *Granulatisporites frustulentus* *Anapiculatisporites redactus* *Tricidarisporites phippsae* *Racemospora cumulata*
D_3	*Retispora lepidophyta*		

vided into three areas as already stated before. Palynological data have been extracted from both the West Area and the East Area (see Table 21). In West Area, some very significant miospores assemblages yielded from the Longba Formation, very latest Devonian to early Carboniferous miospores assemblages had been dated. The early Carboniferous miospores assemblage from this formation also bears some elements which only found in Australia by Playford, such as *Granulatisporites frustulentus*, *Grandispora spiculifera* and so on (see Table 11).

In East Area, both early Carboniferous and early Permian palynomorphs have been obtained successively. The early Carboniferous palynological assemblage from the Nanduan Formation in Menglian also bears some Australia-distributed species like *Cristatisporites menendezii*, *Granulatisporites frustulentus*, *Tricidarisporites phippsae*, etc. And the most interesting assemblage in this area is the lower Permian one, which yielded from the supposed Laba Formation in Haibang of Ali. Some Gondwana-distributed members like *Striatopodocarpites cancellatus, Striatoabietites multistriatus* also occurred in this area within the Changning-Menglian Belt. Therefore, in terms of microflora, some part of the Changning-Menglian Belt could relate to the Gondwana Realm. However, the most critical issue concerned about this mixture of palynomorphs will be a question of whether this kind of mixture is a part of tectonic setting or just the phenomena of sedimentary reworking. Obviously, there is not any kind of evidences to show the sedimentary reworking in this area.

3.3.3 Cathaysian type palynomorphs in the Lanping-Puer Massif

In the Lanping-Puer Massif or the Simao Massif called sometimes by some people, Gondwanan type spores and pollen had never been found so far. Although the palynological data available in this region are not as many as we expect, all of these palynomorphs seem to be Cathaysian, Eurasian type or world-wide elements. In spite of the palynostratigraphic dating is not strong enough, the palynological data in this massif mainly came from the Permian sequences since these palynomorphs-yielding strata had also been bounded by some other fossils like megaplant fossils, e.g., *Gigantopteris nicotianaefolia, Lepidodendron acutangulum*, etc. So far,

Table 22. The Cathaysian type palynomorphs in the Lanping-Puer Massif.

	Lanping-Puer Block
P2	Dengkong, Mojiang *Jansoniuspollenites ovatus, Alisporites taeniolis, A. ovatus* *Limitisporites* sp., *Piceopollenites* sp., *Protohaploxypinus* spp. Namutian, Mengla *Florinites mediapudens, Laevigatosporites perminutus* *Lycospora rotunda*
C	? ?

the spores and pollen obtained from this Lanping-Puer Massif are Permian and mainly Cathaysian or Eurasian type palynomorphs (see Table 22).

Since the Carboniferous spores and pollen are not available in this massif, the comparison between the Lanping-Puer Massif and the Changning-Menglian Belt could not be made. However, with the aid of megaplant fossils of lower Carboniferous *Neuropteris gigantea* from Mamushu and Xuemochang of Mengla; late Carboniferous *Pecopteris* spp. from Baliu of Mojiang; lower Permian *Cladophlebis* sp. *Tingia* sp. from the Lazhuhe Formation of Lanping, we can still predict that the phytogeographic provincialism of the Lanping-Puer Massif should be included in the Cathaysian or the Eurasian Realm.

3.4 Evolutionary paleobiogeography of late Paleozoic in western Yunnan

In the following, the author is trying to outline the evolutionary process of the paleobiogeography in Paleozoic time period in western Yunnan, in other words, to demonstrate the paleobiogeography of western Yunnan period by period in the whole late Paleozoic time period.

In Cambrian, especially middle and upper Cambrian, western Yunnan (Baoshan) was put in the western fringe of platform margin of (Yangtze) biome by Yang Jialu (1988). Based upon the late Cambrian trilobite studies in western Yunnan by Sun and Xiang in 1979 and Luo in 1982, 1984. This biome consists of abundant trilobites, including large benthic and many plankton agnostids and other nektonic trilobites. Many of them are local members such as *Chatiania, Fenghungella, Dingxiangaspis, Neoanomocarella, Paracidaspis, Wanshania, Yuepingia, Pseudoyuepingia, Stigmatoa, Paradamesella, Pseudophelaspis, Rhyssometopus,* and *Olenus austriacus*. However, Yang Jialu (1988) has put Mangsi of Luxi County in western Yunnan into the basal biome belonging to extra-platform (of Yangtze) biome. Among the relatively fewer trilobite genera, the nekton takes up half of the total number. Most of the trilobites are widespread, but a few are restricted, such as *Erixanium fuyangia, Zhajia, Wujiajiania, Metalizania, Charchaqia subquadrata, Westergaardites tachenensis, Olenus sinensis, Xystridura yaxianensis, X. hainanensis* and *X. orientalis*.

In Ordovician, the biota in western Yunnan also exhibits some similarity to the ones in the Yangtze region (Li Zhiming, 1988). Middle Ordovician trilobites have been found in the lower part of Lower Pupiao Formation of the Baoshan Massif including *Ampyxinella, Baisiliella, Birmanites, Calymenesun, Iiaenus* and *Lonchodomas*. *Calymenesun* was a typical member of the

Yangtze region; the other fossils were also common in the Yangtze region; thus it belongs to the Yangtze Province. In late Ordovician typical South China fauna such as *Nankinolithus* and *Hirnantia-Dalmanitina* developed in Jinping in western Yunnan.

In general, the biota in Sibumasu which western Yunnan belong to, were quite close with those in North China and Australia during Cambrian and Ordovician based upon some works by Burrett (1987), Burrett and Stait (1985, 1987), Lu Yanhao (1974), Yu Wen *et al.*(1984), Chen Yiyuan *et al.* (1985) and Kobayashi (1986).

In Silurian, western Yunnan was first put into the Tibet-Western Yunnan Province by Lin Baoyu (1979) and more or less began to be circled into the Gondwanan Realm by He Xinyi in 1988. Western Yunnan yields nautiloids from the strata of middle and upper Silurian, the species and genus are monotonous, with *Michelinoceras* and its subgenus *Kopanioceras* in full flourish. The fauna differ from those of Yangtze, but have a similarity with West Europe and directly comparable to the nautiloids of the same stage in middle-upper Silurian of Bohemia (Chen, 1975). And the Himalayan region also provides *Michelinoceras* and its subgenus *Kopanioceras* and *Columenoceras* from the middle and upper Silurian strata. Then He Xinyi (1988) called these areas to be the Southern Tibet-Western Yunnan Province. The Renheqiao Formation of lower and middle Silurian in the Shidian area in Baoshan has been found to yield trilobite *Leonaspis* and *Primaspis*. They are also different from the Yangtze trilobite fauna. In late Silurian, the upper Silurian in western Yunnan is mainly composed of shell facies containing cephalopods and conodonts, which are also similar to those in the Bohemian area.

In Devonian, some fish (Macropetalichthyridae) and brachiopods (*Retzia* sp., *Howella* sp.) have been respectively reported from the Shizishan Formation of early Devonian. In the Baoshan-Changning district yielded graptolites, *Monograptus fragensis* and *Neomonograptus himalayensis*, and plant, *Zosterophyllum* sp. which is one of the representative flora of early Devonian in South China. These graptolites are similar to those in the northeastern Thailand, South Tibet and Malaysia. Middle Devonian fossil corals are abundant in western Yunnan. Song Xueliang (1982) provided that some species like *Cylindrophyllum, Amplexiphyllum, Barrandeophyllum,* and *Pexiphyllum* rarely appear in South China and some are the same as those in South China. It is considered by Yu Changmin that western Yunnan belong to the 'West China faun' , which is similar to the faunas of Australia and Europe and has no elements in common with the ' East China fauna' in South China. The brachiopods in western Yunnan shows similarity to those in Burma, which both these areas might belong to the southern belt of Pro-Tethys. The latest Devonian fish study by Long and Burrett (1989) did show some strong links in between South China, Sibumasu and Australia.

In Carboniferous, the paleobiogeography of western Yunnan was once treated differently by Yang Fengqing in 1988 in early Carboniferous and late Carboniferous. In early Carboniferous she put western Yunnan in the Northern Tibet-Western Yunnan province belonging to Tethyan realm while in Late Carboniferous in the Himalaya-Gongdise-Nianqingtanggula province belonging to the Gondwanan Realm due to the report of the discovery of glacigene sequences and related fauna and flora which now have been attributed to earliest Permian. In early Carboniferous, the bipolarity distribution of faunas seems to be evident in Baoshan and Shidian (western Yunnan) as well as

Table 23. The possible zonation of various fossils in Early Permian in both Tengchong and Baoshan.*P1q and P1m stand for Lower Permian Chihsian and Maokouan respectively in South China.

		fusulinids	corals	brachiopods
*P1m	Capitanian Wordian	*Chusenella-* *Yangchienia iniqua*	*Iranophyllum* *Ipciphyllum*	*Orthotichia* *Compressoproductus* *Crytospirifer*
*P1q	Roadian Kungurian	*Nankinella orbicularia* *Schwagerina tschernyschewi*	*Wentzelellites simplex* *Szechuanophyllum szechuanensis*	*Costiferina-* *Waagenites* *Calliomarginatia* *Taeniothaerus*

Jianshui and Yanshan (southeastern Yunnan), yielded not only *Cystophrentis* and *Pseudouralinia* typical of the South China Province, but also *Humboldtia, Keyserlingophyllum,* and *Siphonophyllia* of 'northern type' (Song Xueliang 1982). The 'northern typ' genera are dominant in Baoshan and Shidian, which reflects the close relationship of corals in this province with West Europe and Russia. The distribution of early Carboniferous *Kueichouphyllum* in South China, Sibumasu and Australia also could infer the close relationship in between these regions (Hill, 1973; Duan, 1985). Similarly, brachiopods also display both the common elements *Eochoristites* and *Martiniella* of South China and the common species of the Junggar-Xingan Province, such as *Marginatia, Syringothyris, Tolmatchoffia,* and *Grandispirifer* (Yang Shipu, 1983). Yang Fengqing also pointed out in her paper that the term 'northern type', traditionally used in Chinese literature, actually means Gondwanan type, because the above-mentioned corals and brachiopods also occur in the Himalaya-Gongdise-Nianqingtanggula Province belonging to the Gondwanan Realm. The late Carboniferous in Tengchong and Baoshan are missing. In Gengma, late Carboniferous fusulinids developed very well from the Shidongsi Formation from *Pseudostaffella* zone to *Profusulinella* zone and *Fusulina -Fusulinella* zone. Conodonts *Streptognathodus* sp., *Gondolella* sp. and brachiopods *Choristites* sp. as well as coral, crinoids stem are also yielded from this region, which are quite comparable to those in South China.

In Permian, Xu Guirong and Yang Weiping in 1988 proposed that western Yunnan could be included in the Gondwana-Tethyan region belonging to the Gondwanan Realm in early Permian times. They used the Central Tibet-Western Yunnan Province, which is sometimes called by someone the South China transition or mixed region. The deposits in this region are mainly composed of the supposed glacigene sequences, marine carbonates, argillites, and other clastics interbedded with median-basic and medium-acidic volcanics. Besides the doubtful bivalve *Eurydesma* and plant *Glossopteris* ? sp and the Gondwanan type palynomorphs, which have been stated in the early part of this paper, the major fossils in this region, are fusulinids, brachiopods and corals. Table 23 is displaying the possible zonation of different fossil taxa in the early Permian in

Table 24. A comparison table showing the difference of three notions related to Gondwana.

	Gondwanaland	Gondwana facies		Gondwana realms
Temopral	late Proterozoic- late Paleozoic (Mid-Carboniferous)	started when Gondwanaland merged in Pangea (Mid Carboniferous-Triassic Jurassic)		Cretaceous Triassic – Jurassic Carboniferous-Permian mainly started from Silurian
Spatial	originally, Peninsular India southern & middle Africa Madagascar lately, rest of Africa, Arabia South America, Antarctica Australia parts of S.E.Asia	Austral facies of the Pangea super-sequences distinctive climatic environment of Gondwana province separate from the rest of Pangea tropical continental zone in west	oceanic gulf of Tethys in east	*Ptilophyllum* (J) *Lepidopteris-Dicroidium* (T) *Glossopteris, Eurydesma* (P) *Lysosaurus* (C) *Granulatisporites frustulentus* (C1) *Malvinokaffric* (D) *Malvinokaffric* (S)

both Tengchong and Baoshan. No upper Permian is recorded in both Tangchong and Baoshan. But in the Lanping-Puer Massif typical late Permian fossils were documented before. They included fusulinids *Codonofusiella, Galloweyinella, Palaeofusulina sinensis, Reichelina pulchra*; brachiopods *Dictyoclostus margaritatus, Leptodus nobilis, Oldhamina; corals Waagenophyllum* and plants which are obviously Cathaysian type.

3.5 Tectonic implication

The tectonic implication of western Yunnan based upon the Gondwanan biota found so far in Tengchong and Baoshan will directly relate to or relay on the knowledge or notion about Gondwanaland, Gondwanan sequence, Gondwanan facies and Gondwanan realm(Table 24).

In Veevers ′ s opinion, The independent Gondwanaland lasted between the break-up of a late Proterozoic supercontinent and the late Palaeozoic coalescence of the Pangean supercontinent.

The typical Gondwanan sequence of Peninsular India comprises Permian, mainly nonmarine, glacial facies overlain by coal-measure facies containing the *Glossopteris* flora and by Triassic-Jurassic nonmarine facies containing the *Dicroidium* and *Ptillophyllum* floras (Sastry *et al.*, 1977). However, the Gondwanan sequence of India-equivalent in Australia (Innamincka), Southern Africa (Laroo), Brazil (Delta and Delta-A), and Antarctica (Victoria Group; Elliot, 1975) constitute the austral facies of the Pangea super-sequence, distinguished by mainly nonmarine glacial strata at the base, reflecting mid to high southern latitudes (Veevers and Powell, 1987) and succeeded by strata, again mainly nonmarine, that contain a provincial biota.

The Gondwanan facies started to be deposited after Gondwanaland lost its identity by merging in Pangea. During the late Paleozoic and early Mesozoic span of Pangea, the Gondwanan facies was deposited in the distinctive climatic environment of the Gondwanan province under a tectonic regime that applied across Pangea (Veevers, 1988). Gondwanan province glacials and endemic biota were isolated from the rest of Pangea not by wide continental separation but by the tropical continental zone on the west and by the oceanic gulf of Tethys on the east (Anderson, 1981).

The Gondwanan biotic realm was formed after the late Early Paleozoic and was best defined during late Paleozoic and Triassic. Mainly referring non-tropical biota, it has been called the *Malvinokaffric* realm for Silurian and Devonian times, representing southern temperate marine biota. Later, it included the Permo-Carboniferous *Glossopteris* flora and glacio-marine fauna, signifying cool temperature to cold subantarctic and Antarctic realm, and also the Triassic *Dicroidium* flora and Gondwana Tethyan fauna, denoting austral biotas grading from temperature to subtropical (Yin, 1994). Yin also pointed out that the Gondwanan realm does not completely coincide with Gondwanaland. Microplates such as South China may once have belonged to the Gondwanan realm but were not necessarily merged with Gondwanaland. Table 24 displays their difference of these Gondwana related notions.

Although the glacio-marine nature of the pebbly mudstones and the evidences of the presence of cold water faunas in western Yunnan, especially in Baoshan had once been doubted or rejected by Zhou and Fang (1990), Duan (1991) and Fang (1991), the substantial progress in both sedimentological study and paleontological study in both Tengchong and Baoshan in western Yunnan have been made since then. Wopfner and Jin (1993), and Jin (1994) did a systematically sedimentologic and petrographic study of the above sequences from the Dingjiazhai Formation of the Baoshan Massif and the Menghong Group of the Tengchong Massif. They confirmed the above mentioned sequences from these two massifs to be glacigene sequence, and furthermore subdivided this remarkable sequences into three folds in ascending order of (1) diamictites and coarse clastics, (2) pebbly mudstones and laminites, and (3) black pyritic, organic rich mudstones. They also claimed that these above three-fold clastic sequences are corresponding respectively to the glacier highstand, glacier retreat and deglaciation.

Besides this sedimentological study, the following paleontological studies also played an important role to determine the Gondwanan sequence nature of western Yunnan. In 1994 and 1996, the typical Gondwanan lower Permian spores and pollen had been reported by Yang Weiping from the above glacigene sequence (3) the black mudstone of the Kongshuhe Formation in Tengchong. In 1996, Shi *et al.* reported an Early Permian brachiopod fauna of Gondwanan affinity from the limestone at the top of the Dingjiazhai Formation. And furthermore, Australian-comparable *P.confluens* Oppel Zone has also been found by Yang Weiping from the grey or black mudstones below the above brachiopod-yielding limestone of the same Dingjiazhai Formation in Baoshan.

Therefore, both paleontology and sedimentology in western Yunnan strongly support that the Dingjiazhai Formation of the Baoshan Massif and the Menghong Group (the Kongshuhe Formation) of the Tengchong Massif were more likely to be the lower part of Gondwanan sequence or the base part of the lower Gondwanan series.

Then, the next will be how to understand this remarkable Gondwanan sequence of western Yunnan in tectonic. Metcalfe (1984, 1988), Hutchison (1989), Wopfner (1993) and Jin (1994) once discussed about these supposed Gondwana-derived terranes in SE Asia. The following is a brief tectonic implication based upon the evolutionary paleobiogeography through Cambrian to Permian of these massifs. Fig.9 is showing the shifting of paleobiogeographical provincialism of the world through Cambrian to Permian based upon various authors in the book of "The

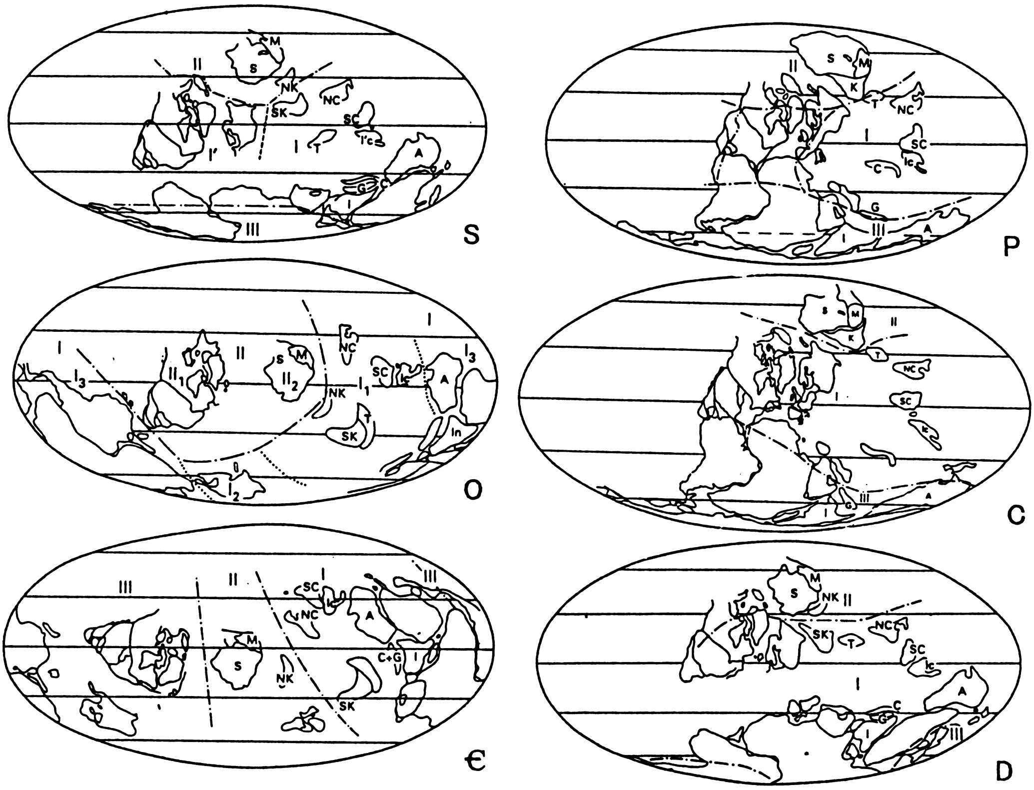

Fig.9. The shifting of paleobiogeographical provincialism of the world through Cambrian to Permian.A: Australia; C: Central Tibet and western Yunnan or Qiangtang; G: Gangdise; I: India; Ic: Indochina; K: Kazakhstan; M: Mongolia; NC: North China; NK: North Kazakhstan; S: Siberia; Sc: South China; SK: South Kazakhstan; T: Tarim. Cambrian: I Asia-Australian realm; II Siberian realm; III America-Atlantic realm; Ordovician: I Austral realm; II North American-Siberian realm; Silurian to Permian: I Tethyan realm; II Boreal realm; III Gondwana realm.

paleobiogeography of China" .

Tables 25, 26 are displaying the paleobiogeographical comparison among the following tectonic units, Australia, South China, North China, and western Yunnan and its vicinity. Then the implication of the paleobiogeographical provincialism of these blocks for plate tectonics could be roughly inferred.

Globally, Cambrian plates were sited at similar latitudes, so the global climate of latitudinal zonation had little paleobiogeographic significance during this period. The global realms were only separated by oceans and deep seas. In Cambrian, three realms were recognised by Yang Jialu (1988). They are Asian-Australian realm, the North America-Atlantic realm, Siberian realm. Both South China and western Yunnan displayed strong links with Australia rather than North China (see Table 25).

However, the latitude-controlled global scale climate zonation played a role in Ordovician paleobiogeographical provincialization, because the southward shift of Gondwana placed a large part of the continent in medium and high latitudes. The rest were still scattered plates and situated

Table 25. The paleobiogeographical comparison between western Yunnan, Australia and South China (modified from Yin, 1994).

	Australia	Western Yunnan	South China	North China	Mongolia-Xingan
T	*Dicroidium*	*Dictyophyllum* *Claraia griesbachi*	*Dictyophyllum* *Clathropteris* ass.	*Bernoullia* *Danaeopsis* ass.	Uralian type
P	*Glossopteris* flora Gondwana fauna Gondwanan microflora	*Glossopteris* ? sp. Gondwanan affinity brachiopods Gondwanan microflora	Cathaysian fauna Cathaysian flora South type	North type	Boreal fauna Angara flora
C	*Granulatisporites frustulentus*	some *Australian* type microflora	Tethyan fauna Euramerican flora		Boreal fauna Angaran flora
D	Wuttagoonaspid etc	Macropetalichthyridae *Siphonophrentis* *Neoacrinophyllum* *Macgeea*	South China type brachiopods & corals polybranchiaspid etc. endemism (20-30%)	Land	
S	Tasman fauna	*Kopaninoceras* *Primaspis* *Leonaspis*	*endemism* 42.9% *Sichuanoceras* → *Coronocephalus* → *Pentamerus* →	(land)	*Trocholites* *Encrinurus* *Tuvaella*
O	← *Hirnantia - Dalmanitina* ass. → ← *Agetolites* ass. → *Taihungshania* ← *Ninkianolithus* *Yangtzella* → ← Othoceratids →			← *Favistella* *Amsassia* → ← armenoceratids →	*Calapocia* etc.
Cm	similar agnostids abundant brachiopods & earliest skeletal fossils endemic archaeocyathids — endemic archaeocyathids ← Redlichina trilobites →			rare agnostids few brachiopods & earliest skeletal fossils unknown	transitional endemic

mostly in low latitudes, but a few of them were also distributed in both medium and high latitudes. For the early Ordovician, the world can be divided into a North America-Siberian realm and a Meridional realm. The later one included the Baltic-Scandinavian region, the Sino-European region, and the South America-Australian region (Li Zhiming, 1988). Based upon Table 25, South China, western Yunnan and Australia yielded quite similar brachiopods, corals, nautiloids etc, therefore, they were still in the same realm as well.

The distribution pattern of plate tectonic and the paleobiogeography of the world changed greatly from Silurian times. This might be due to the further clockwise rotation caused Gondwana and Siberia to enter southern high and northern middle latitudes, respectively. Subsequently, four paleobiogeographic realms in Silurian were climatically differentiated, namely the Boreal realm,

Table 26. The paleobiogeographical comparison of plates and terranes of South - West China.

	Himalaya	Gangdise	Western Yunnan	Qiangtang	South China
Tr	North China type Hipparion fauna				
K	Gondwana fauna	*	*Trigonioides* assemblage *Peregrinoconcha* assemblage		
J		*	* *Eolamprotula* assemblage		
T		Tethys fauna		* Tethys fauna	* Tethys fauna
P_2 P_1^2	Gondwana fauna	mixed fauna		* Tethys fauna	
P_1^1 C	Gondwana fauna		Gondwanan affinity fauna & microflora	* mixed fauna	Tethys fauna
D	Pseudosyrinx small solitary corals (*Metriophyllum*)		*Siphonophrentis* *Neoacrinophyllum* *Macgeea*	*	Disphyllidae *Yunnanella*
S	*Triplophyllum* *Kopaninoceras* *Primaspis* *Leonaspis*	*Sichuanoceras* *Kopaninoceras* *Primaspis* *Leonaspis*			*Pentamerus* *Coronocephalus*
O	blastoids		*Dalmanitina* *Hirnantia*		*Yangtzella* *Boreolasma*
	Note: *** stands for radiolaria belt				

East and West Pro-Tethyan realms, and the *Malvinokaffric* realm. Although South China and western Yunnan as well as Australia had been put into the same realm (He Xinyi, 1988), the biota in western Yunnan seemed to be a little different from those in Australia and even South China (Table 25), but more likely similar to those in the Himalaya region (Table 26).

In Devonian, the paleobiogeographic pattern of the whole world inherited Silurian' s three realms, the Boreal realm, the Proto-Tethyan realm, the *Malvinokaffric* realm. Western Yunnan and Australia were put into the southern region of Proto-Tethyan realm (Zhao Xiwen, 1988). However, the coral fauna of the upper part of the Heyuanzhai Formation shows more resemblance with those from Rutog, Tibet and Chitral, northwestern India as well as Dolpo of Nepal (Wang Xunlian, 1996). And the Devonian fish found from Tengchong was quite similar to the one in Australia (Long and Burrett, 1989).

The supposed Siberia-Australia axis had rotated through 90° since the Cambrian, and both were then in their maximal high latitudinal positions during Carboniferous and Permian times (Yin, 1994). Consequently, the demarcation of three biotic realms (Boreal, Paleo-Tethys, and Gondwana) became much clear and distinctive except some areas like western Yunnan and Tibet, possible in the middle latitudinal position. South China, owing to its tropic nature, showed high endemism, hence an eastern Cathaysian region was definitely established. While Australia, owing to far away from South China developed a unique microfloral in early Carboniferous. This microflora was called by Playford (1991) *Granulatisporites frustulentus*, Fortunately, some Australia lower Carboniferous miospores like *Granulatisporites frustulentus*, *Grandispora spiculifera*, *Anapiculatisporites largus*, had been found from Sipaishan in Gengma, western Yunnan. This could mean that Gengma Massif or part of western Yunnan could locate in the southernmost side of Tethys, close to Australia, where some Australia miospores could arrive. Furthermore, the dominant fossils of early Carboniferous in Baoshan and Shidian were also quite similar to the ones in Himalaya-Gongdise-Nianqingtanggula province and other Gondwana localities (Yang Fengqing, 1994). Therefore, In Carboniferous, both the fauna and the microflora in western Yunnan could strongly infer its transitional location in between middle and high latitudinal in southern hemisphere, closely to Himalayan vicinity (Table 26).

The Permian paleobiogeographic provincialism of the world is Paleo-Tethyan realm, Boreal realm, and Gondwanan realm. To most people understanding, Gondwana was the region characterised by the wide distribution of the *Glossopteris* flora and glacial deposits. Due to glaciation, the early Early Permian glacial deposits covered a large part of Gondwana area including Africa, Australia, India, South America and even South Tibet and western Yunnan. Subsequently the cold-water fauna like *Eurydesma* and *Glossopteris* flora appeared in the sequences just above these remarkable glacial deposits. *Eurydesma* and *Glossopteris* have been positively found in Tibet while these fossils had been reported with question marks in western Yunnan. However, the typical late Asselian to lower Sakmarian Australian palynomorphs found in both Tengchong and Baoshan together with Gondwanan affinity brachiopods in Baoshan will remedy the uncertainty or the lack of these remarkable fauna (*Eurydesma*) and flora (*Glossopteris*) mentioned above in western Yunnan, which directly contributed to the positive understanding of the property of these Gondwanan sequences in western Yunnan. Some *Glossopteris* specimens with question mark were found from the succeeding sequence in both Baoshan and Gengma. And some interesting spores and pollen assemblages yielding a few Gondwanan elements also had been found even in the Changning-Menglian belt. In the late Early Permian, with the deglaciation and gradually warming in Southern Hemisphere, tropical or subtropical fauna invaded western Yunnan suddenly due to its location nearby the southern margin of Tethys. However, some endemic members only distributed in Himalayan, Iran etc- southern Tethys or bipolarity distributive members were also present in western Yunnan, such as *Monodiexodina*, *Costiferina*, and *Calliomarginatia*. The late Permian in Baoshan and Tengchong was missing. But the east to Tengchong-Baoshan Massifs in western Yunnan developed a very diversity Cathaysian Tethys biota (Bureau, 1990).

In Triassic, some Tethys fauna and South China type flora were yielded from Baoshan and to the east of it (see Table 27). After the late Jurassic red beds deposits of post-Indosinian, the western Yunnan became a complete unit.

In summary, in the latest Precambrian, Cambrian and Ordovician, the supercontinent Rodinia, centred about the southern hemisphere, broke apart as blocks drifted northward. Western Yunnan shared similar biota with South China and Australia (Table 25). Therefore, geographically, western Yunnan could be closer to South China and Australia in the South Hemisphere than the others.

Since Silurian about a third of the Rodinian mass was torn apart and moved to equatorial regions, such as South China block. But western Yunnan and Himalaya could be slower than South China and Australia even less due to the clockwise rotation. Presumably, western Yunnan and Himalaya might geographically be in between South China and Australia based upon the biota

Table 27. A tentatively paleobiogeographic comparison of terranes in western Yunnan.

	Tengchong	Baoshan	Gengma	Changning-Menglian	Lanping-Puer
J	Red beds				
T		*Dictyophyllum* ——— *Claraia gresbachi* ———			*Dictyophyllum* *Clathropteris* *Costatoria goldfussi*
P_2	no deposits		Tethys fauna	Tethys fauna	*Gigantopteris* sp.
P_1^2	*Scheuringipollenites maximus* *Primuspollenites levius*	*Glossopteris* ? sp	*Glossopteris* ?.sp	*Striatopodocarpites cancellatus* *Striatoabietites multistriatus*	*Cladophlebis* sp.
P_1^1 C_2	*Microbaculispora tentula* *Jayantisporites pseudozonatus*	*Stenoscisma* sp. *Elivina yunnanensis* *P. confluens*			*Tingia* sp. *Pecopteris* sp.
C_1		mixed fauna	*Lycospora pusilla* *Grandispora spiculifera*	*Calamites* sp.	*Neuropteris* sp.
D	Macropetalichthyidea *Retzia* sp. *Howella* sp.	*Siphonophrentis* *Neoacinophyllum* *Macgeea*	*Retispora lepidophyta* *Zosterophyllum*		*Leptophloeum rhombicum* *Sublepidodendron* *Knorria* *Taeniocrada* *Zosterophyllum*
S		*Kopaninoceras* *Primaspis* *Leonaspis*			
O		*Dalmanitina-Hirnantia*			

comparison (Tables 25, 26). However, during the late Devonian and early Carboniferous western Yunnan and Himalaya still shared to some degree similar biota like fish and miospores (Table 25) with Australia. When the Siberia-Australia axis had rotated enough to be in their high latitudinal positions respectively during Carboniferous and Permian times, especially in the latest Carboniferous and earliest Permian. Even western Yunnan and Himalaya could also suffer this maximum rotation at this period to be down southword than before since the great glaciation influenced upon a majority of southern hemisphere, mainly the Gondwanaland and even Himalaya and western Yunnan (glacigene sequences). Gondwanan affinity biota had been found in both Himalaya and western Yunnan (Table 26). However, the lack of monosaccate pollen in Western Yunnan could infer that it was slightly warm and lower latitude location than the others in Gondwana at that time.

During the latest Paleozoic into the early Mesozoic, Pangea lay extant, across the equator. Several slices like Tibet and western Yunnan were removed from the northeastern margin of Gondwana and drifted across the Tethys Ocean to collide with Asia. Western Yunnan joined eventually with Asia at middle Jurassic (Table 27).

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Plate captions

All the specimens are housed in Nanjing Institute of Geology and Palaeontology, Academia Sinica. The figures are transmitted - light microscope micrographs of late Palaeozoic palynomorphs from western Yunnan, S.W.China. Micron is abbreviated to *um* throughout. The palynomorphs taxa are illustrated in plates 1-8 at a magnification of 800 unless otherwise stated.

Plate 1 (showing specimens of early Permian Gondwanan type assemblage from the Kongshuhe Fm. in Tengchong, western Yunnan)

1-4. *Microbaculispora tentula* Tiwari 1965, TKIII-5-2.
  1. distal view, median focus, 2. proximal view, high focus, 3. proximal view, high focus, 4. proximal view, median focus.

5. *Microbaculispora* cf. *trisina*, TKIII-5-2.
  5. proximal view, median focus.

6,9. *Horriditriletes tereteangulatus* (Balme and Hennelly) comb. Backhouse 1991, TKIII-5-2.
  6. distal view, median focus, 9. proximal view, median focus.

7. *Retusotriletes* sp., TKIII-5-2.
  7. proximal view, high focus

8. *Altitriletes densus* Venkatachala and Kar 1968, TKIII-5-2.
  8. proximal view, median focus.

10, 11. *Jayantisporites pseudozonatus* Lele and Makada 1972, TKIII-5-2.
  10. distal view, high focus; 11. distal view, median focus.

12. *Propinguispora praetholus* Price, 1983, TKIII-5-2.
  12. lateral view, high focus.

Plate 1

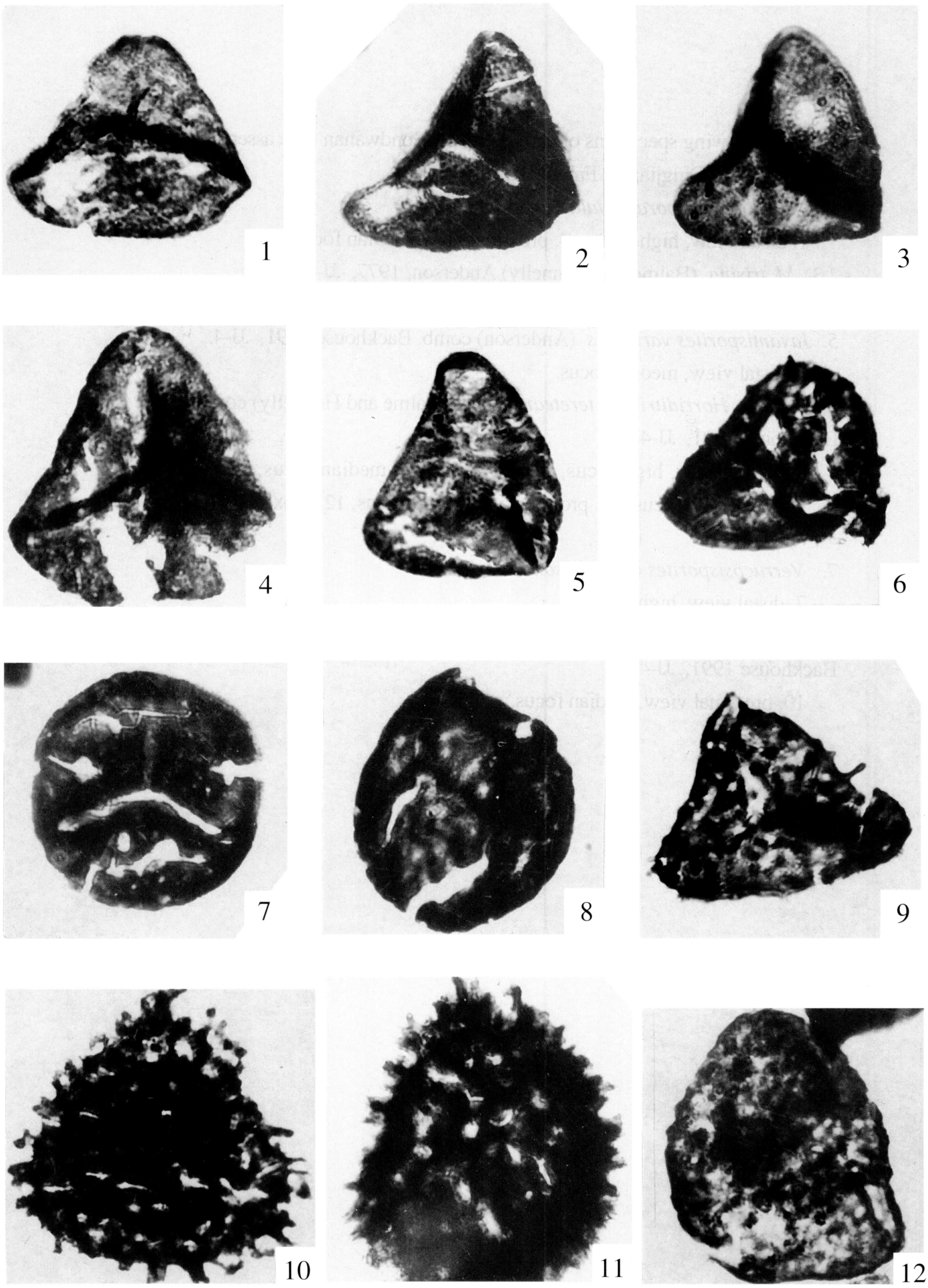

Plate 2 (showing specimens of early Permian Gondwanan type assemblage from the Dingjiazhai Fm. in Baoshan)

1,4. *Microbaculispora tentula* Tiwari 1965, JJ-4.

1. distal view, high focus, 4. proximal view, median focus.

2,3. *M. trisina* (Balme and Hennelly) Anderson, 1977, JJ-4.

2. distal view, low focus, 3. proximal view, high focus.

5. *Jayantisporites variabilis* (Anderson) comb. Backhouse 1991, JJ-4.

5. distal view, median focus.

6,8,9,11,12. *Horriditriletes tereteangulatus* (Balme and Hennelly) comb. Backhouse 1991, JJ-4.

6. distal view, high focus, 8. proximal view, median focus, 9. distal view, median focus, 11. proximal view, high focus, 12. proximal view, low focus.

7. *Verrucosisporites* cf. *andersonii*, JJ-4.

7. distal view, high focus.

10. *Pseudoreticulatispora confluens* (Archangelsky and Gamerro) comb. Backhouse 1991, JJ-4.

10. proximal view, median focus.

Plate 2

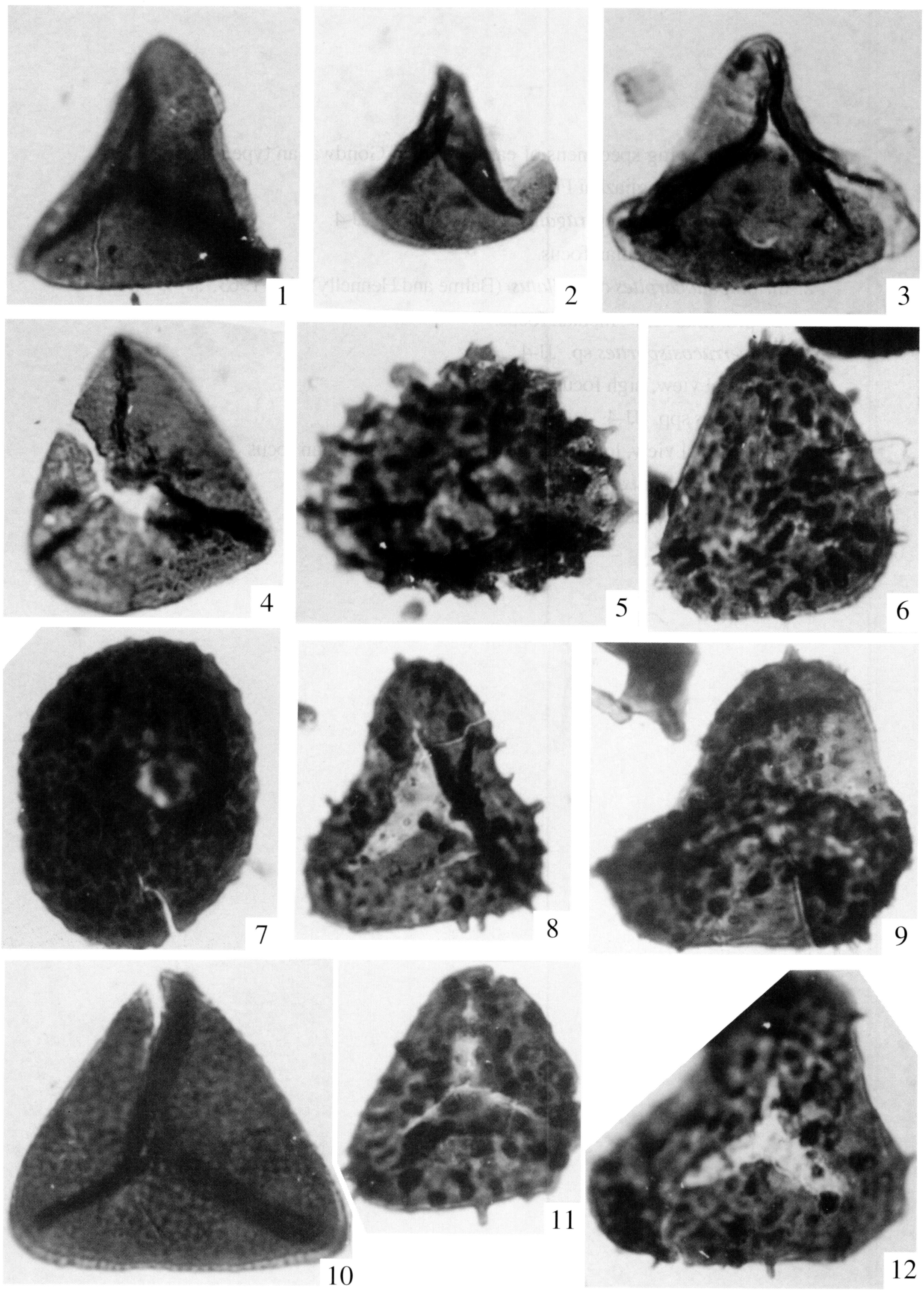

Plate 3 (showing specimens of early Permian Gondwanan type assemblage from the Dingjiazhai Fm. in Baoshan)

1. *Protohaploxypinus* cf. *rugatus* Segroves 1969, JJ-4.
   1.distal view, median focus.
2. *Striatopodocarpites cancellatus* (Balme and Hennelly) Hart 1963, JJ-4.
   2. proximal view, median focus.
3. *Converrucosisporites* sp. JJ-4.
   3. lateral view, high focus

4,5. *Sahnites* spp. JJ-4.
   4. proximal view, low focus, 5. proximal view, median focus.

6. *Protohaploxypinus* sp. JJ-4.
   6. distal view, median focus.

Plate 3

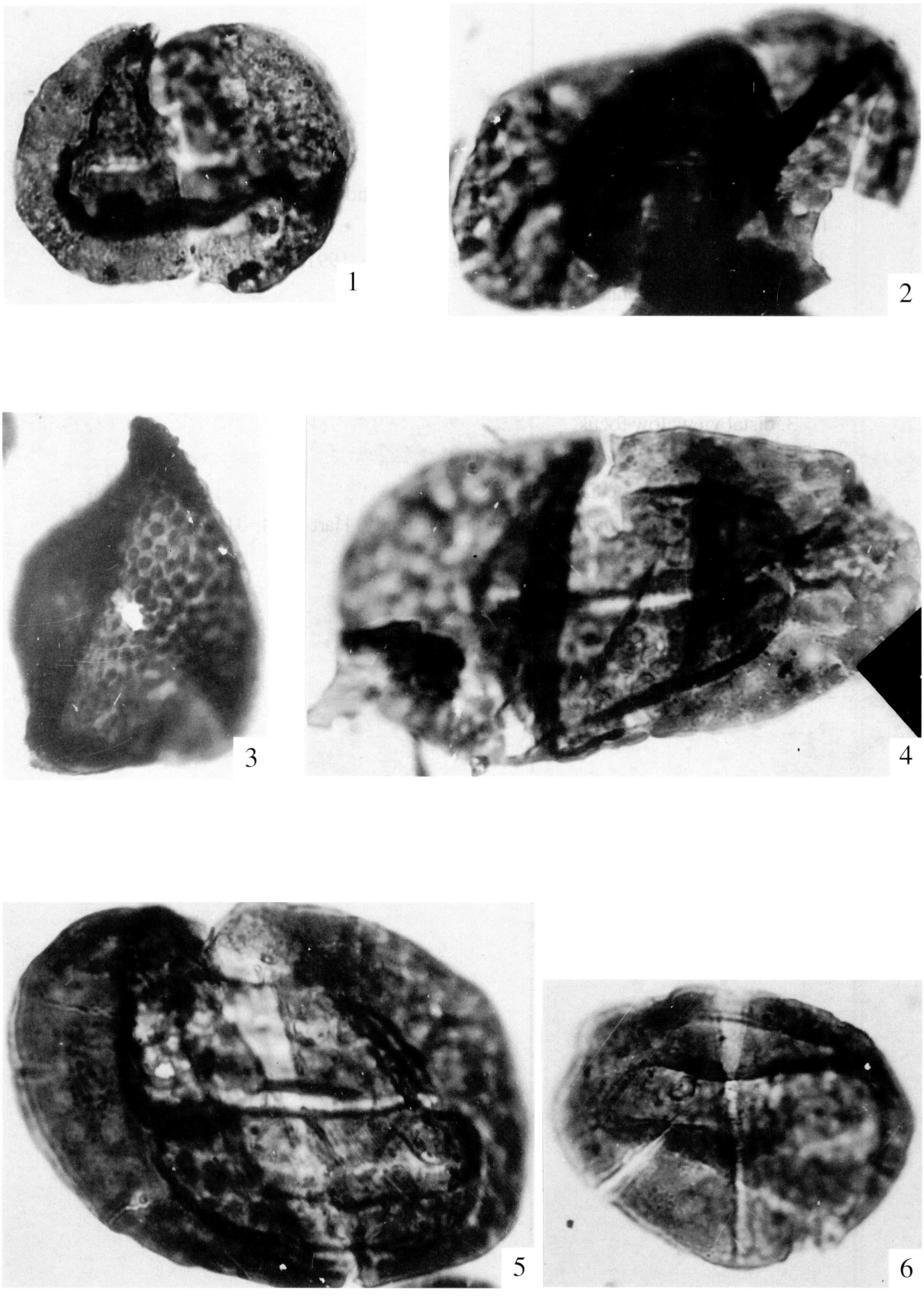

Plate 4 (showing specimens of early Permian Gondwanan type assemblage from the Dingjiazhai Fm. in Baoshan)

1. *Indotriradites niger* (Segroves) comb. Backhouse, 1991, JJ-4.
   1. distal view, median focus

2,4. *Vittatina fasciolata* (Balme and Hennelly) Bharadwaj 1962, JJ-4.
   2. proximal view, median focus 4. distal view, median focus.

3. *Striatopodocarpites fusus* (Balme and Hennelly) Potonie 1956, JJ-4.
   3. distal view, low focus.

5. *Horriditriletes* cf. *tereteangulatus*. JJ-4.
   5. proximal view, median focus.

6. *Protohaploxypinus amplus* (Balme and Hennelly) Hart 1964, JJ-4.
   6. proximal view, median focus.

Plate 4

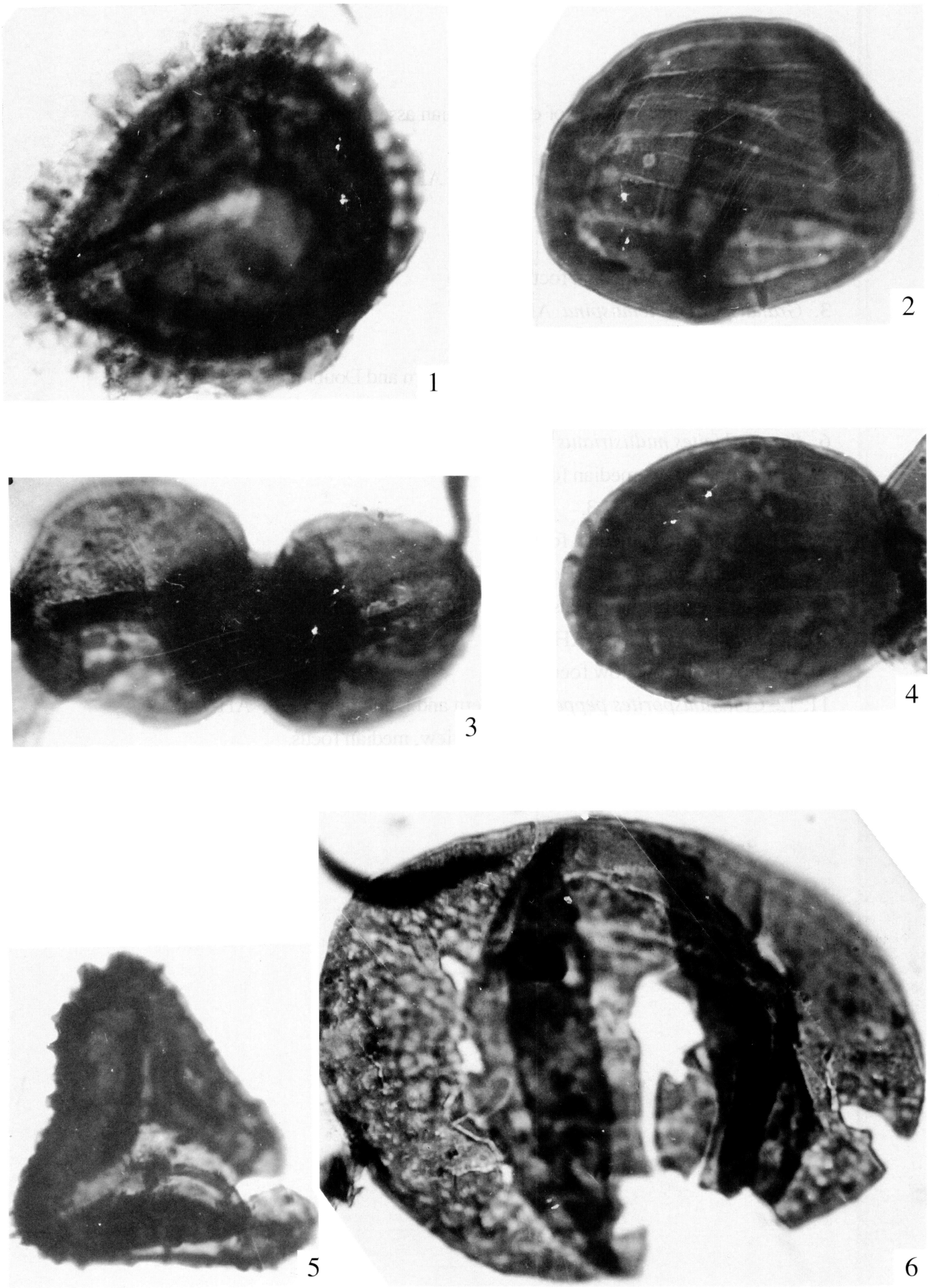

Plate 5 (showing specimens of early Permian assemblage from Ali Haibang in the Changning-Menglian belt)

1. *Retusotriletes planus* Dolby and Neves, AH-7-3.
   1. proximal view, median focus.
2. *Leiotriletes* sp. , AH-7-4.
   2. proximal view, median focus.
3. *Grandispora* cf. *tenuispina* AH-7-3.
   3. proximal view, median focus.

4,5. *Laevigatosporites vulgaris* (Ibrahim) Alpern and Doubinger 1973, AH-7-4.
   4. lateral view, high focus; 5, proximal view, low focus.

6. *Striatoabieites multistriatus* (Balme and Hennelly) Hart 1964, AH-7-3.
   6. proximal view, median focus.
7. *Alisporites* spp. AH-7-3.
   7. proximal view, median focus.

8,9. *Weylandites magmus* (Bose and Kar) comb. Backhouse 1991, AH-7-3.
   8. distal view, median focus, 9. proximal view, median focus.

10. *Florinites* cf. *occultus* AH-7-4.
   10. proximal view, low focus.

11, 12. *Columinisporites peppersii* Alpern and Doubinger 1973, AH-7-4.
   11. distal view, high focus, 12. lateral view, median focus.

Plate 5

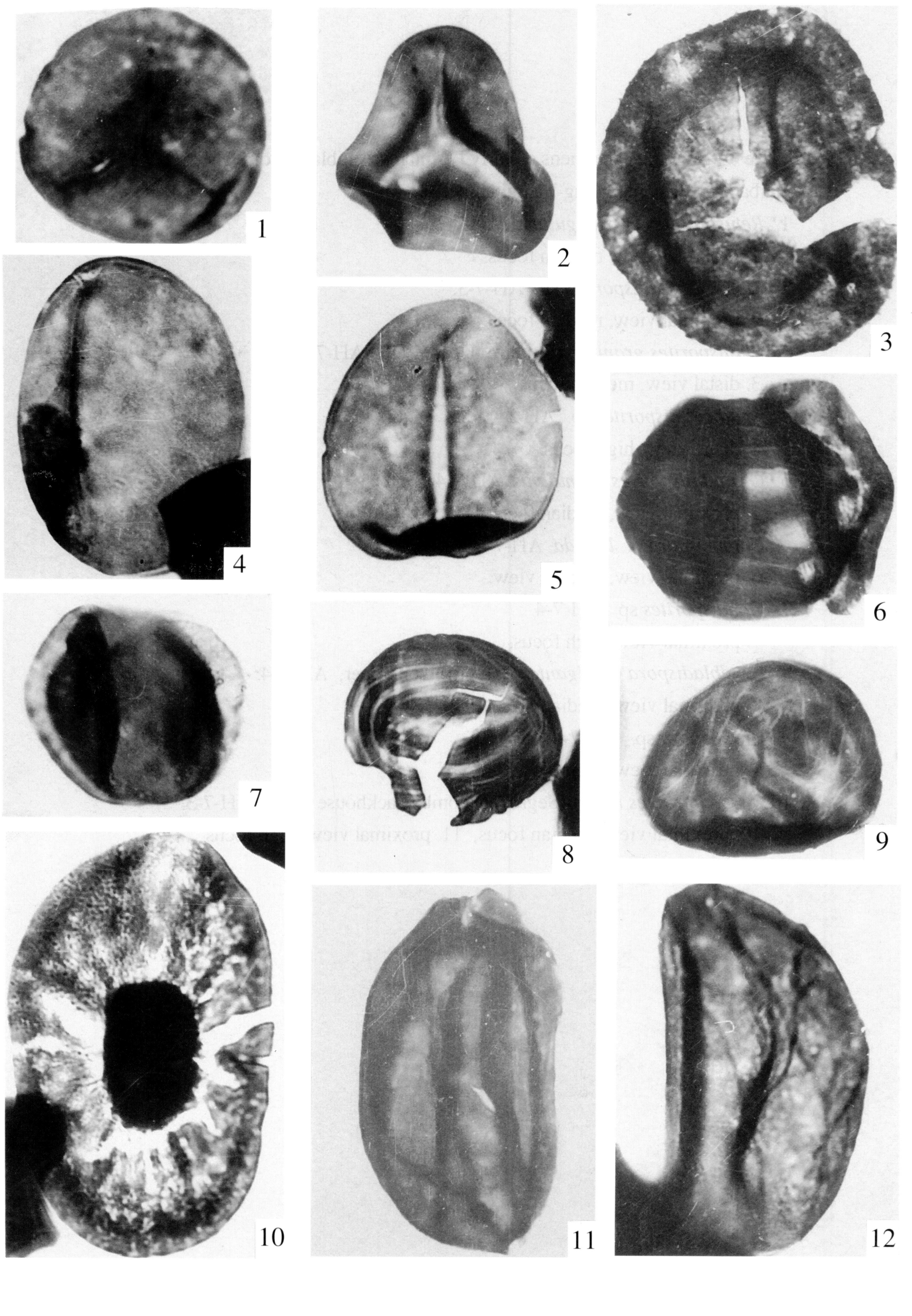

Plate 6 (showing specimens of early Permian assemblage from Ali Haibang in the Changning-Menglian belt)

1. *Retusotriletes* cf.*triangulatus* AH-7-3.
   1. proximal view, median focus.
2. *Microreticulatisporites* sp. AH-7-3.
   2. proximal view, median focus.
3. *Planisporites granifer* (Ibrahim) Knox 1950, AH-7-3.
   3. distal view, median focus.
4. *Anapiculatisporites* sp. AH-7-4.
   4. distal view, high focus.
5. *Granulatisporites granulatus* AH-7-4.
   5. proximal view, median focus.
6. *Calamospora* cf. *liquida* AH-7-4.
   6. proximal view, median view.
7. *Gondisporites* sp. AH-7-4.
   7. proximal view, high focus.
8. *Lundbladispora* cf. *gigantea* (Alpern) Doubinger, AH-7-4.
   8. proximal view, median focus.
9. *Crassispora* sp. AH-7-4.
   9. proximal view, high focus.

10, 11. *Indotriletes niger* (Segroves) comb. Backhouse 1991, AH-7-3.
   10. proximal view, median focus, 11. proximal view, high focus

Plate 6

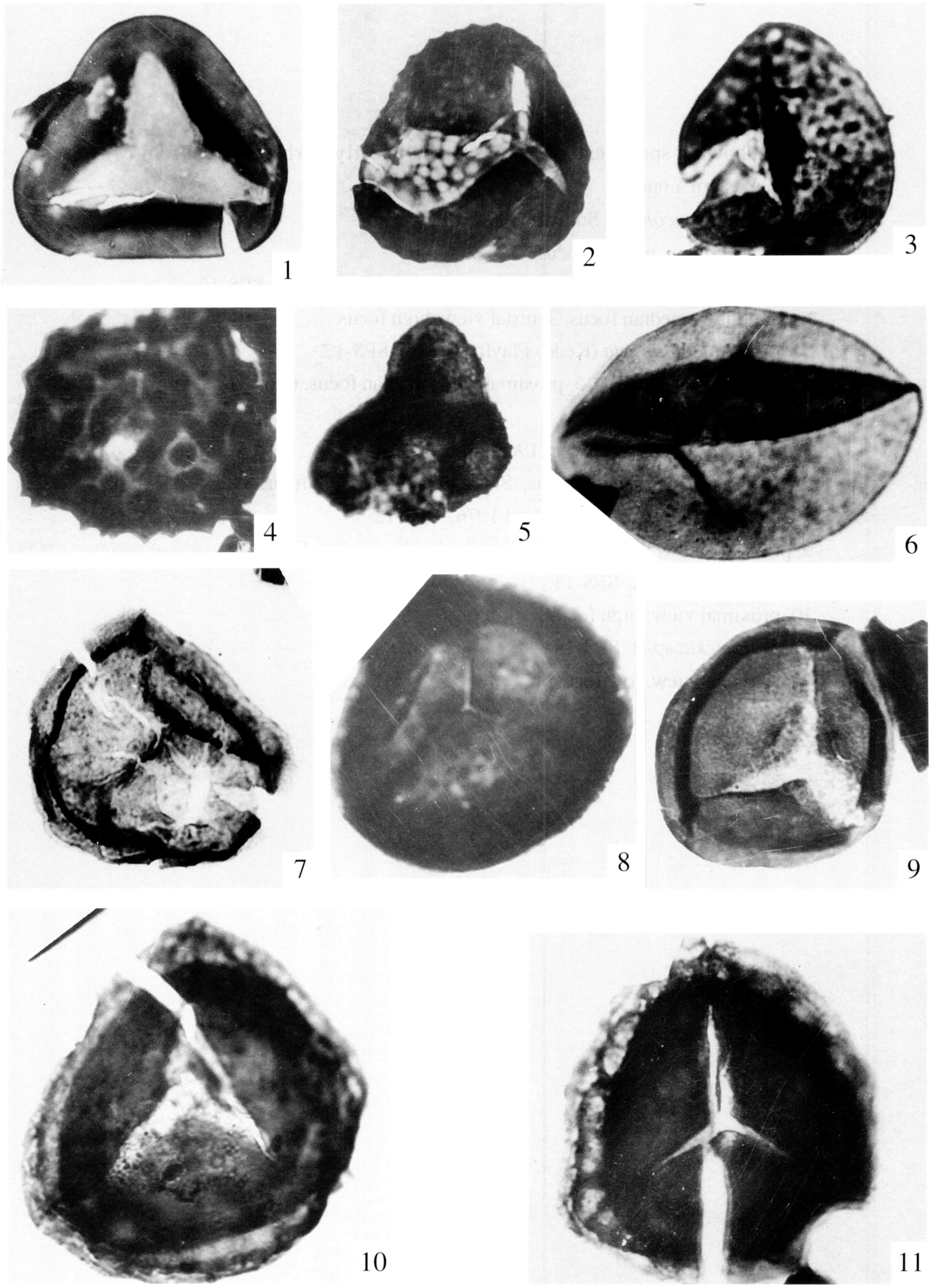

Plate 7 (showing specimens of late Devonian to early Carboniferous from Gengma, western Yunnan)

1. *Retusotriletes incohatus* Sullivan 1964, SPS-12.
   1. proximal view, median focus.

2,3. *Bascaudaspora collicula* (Playford) com.Higgs et.al., 1988, SPS-12.
   2. distal view, median focus, 3. distal view, high focus.

4-6. *Retispora lepidophyta* (Kedo) Playford 1976, SPS-12.
   4. distal view, high focus, 5. proximal view, median focus, 6. proximal view, median focus.

7,8. *Auroraspora macra* Sullivan 1968, SPS-13.
   7. proximal view, median focus, 8. proximal view, high focus.

9,12. *Grandispora praecipua* Playford 1976, SPS-12.
   9. proximal view, high focus, 12. proximal view, median focus.

10. *Neoraistrickia* sp-A SPS-13.
   10. proximal view, high focus.

11. *Neoraistrickia* sp-B SPS-13.
   11. proximal view, low focus.

Plate 7

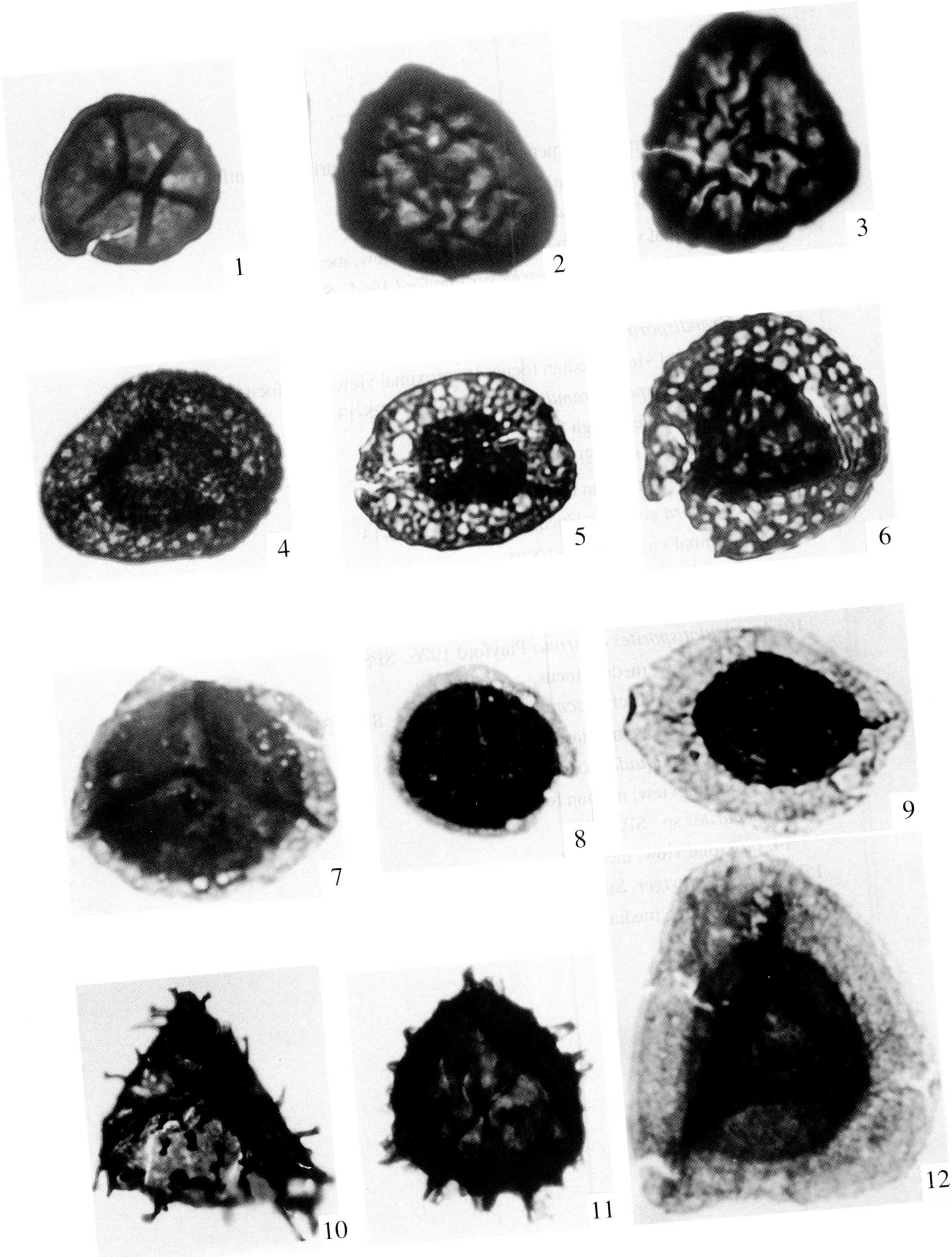

Plate 8 (showing specimens of late Devonian to early Carboniferous from Gengma, western Yunnan)

1,2. *Grandispora cornuta* Higgs 1975a, SPS-13.
1. proximal view, high focus, 2. proximal view, median focus.

3,5. *Anapiculatisporites hystricosus* Playford 1964, SPS-13.
3. distal view, high focus, 5. distal view, median focus.

4,16. *Grandispora notensis* Playford 1971, SPS-13.
4. proximal view, median focus, 16. proximal view, high focus.

6. *Apiculiretusispora granulata* Owens 1971, SPS-13.
6. proximal view, high focus.

7. *Neoraistrickia* spp. SPS-13.
7. distal view, median focus.

8. *Grandispora echinata* Hacquebard 1957, SPS-13.
8. proximal view, median focus.

9,13. *Grandispora spiculifera* Playford 1976, SPS-13.
9. proximal view, median focus, 13. proximal view, low focus.

10. *Anapiculatisporites austrinus* Playford 1976, SPS-13.
10. distal view, median focus.

11. *Verrucosisporites* cf. *V.scoticus* Sullivan 1968, SPS-13.
11. proximal view, median focus.

12. *Calamospora liquida* Kosanke 1950, SPS-13.
12. proximal view, median focus.

14. *Latosporites* sp. SPS-13.
14. proximal view, median focus.

15. *Schopfites claviger* Sullivan emend Higgs *et.al.*,1988, SPS-13.
15. lateral view, median focus.

Plate 8