On the first appearance of some gymnospermous pollen and GSPD assemblages in the sub-Angara, Euramerian and Cathaysia provinces

Ouyang Shu


In this paper the appearance of some gymnospermous pollen and GSPD assemblages in the sub-Angara, Euramerian and Cathaysia provinces has been discussed.

**Key-words**—Palynology, Gymnosperm, Angara, Euramerian, Cathaysia.

Ouyang Shu, Nanjing Institute of Geology and Paleontology, Academia Sinica, Nanjing 210008, China.

THE rise of the Mesophyte is one of the major plant evolutionary events in the global terrestrial floras. However, despite that the "Paleophytic" and "Mesophytic" boundary is a useful concept both in palaeobotany and in palynology, it is by no means indisputable as to how to define it among palaeobotanists (e.g., Dobruskina, 1982, 1987). Just for convenience in the present paper, in some cases, the informal term "Mesophyte" has been used as representing a period of advanced gymnosperms (conifers, higher pteridosperms, cycadophytes and ginkgophytes, etc.) and their pollen dominance following the traditional but somewhat improved definition (Meyen, 1987; Traverse, 1988; Wang, 1989). Considering that various factors (e.g., Neves Effect) may have important influence upon the concentration of pollen/spores and the complex nature of the Mesophyte problem, the purpose of this review is only to trace out the first appearance of some gymnosperm pollen and their dominance with main attention confined to some records known from the sub-Angara area, and the Euramerian/Cathaysia Province. Partly for practical reason, the latter will be treated separately as two provinces.

The mainland of China is one of the ideal areas for studying the vegetational changes and phytoprovincial relationships of Late Paleozoic because the three major phytoprovinces (Angara/sub-Angara, Euramerian/Cathaysia and Gondwana) meet one another at their region. Furthermore, for its formation is resulted from conjugation of several plates, or blocks, at a certain time; then existing seaways
separating them, and subsequent mountain chains formed might have been the main barriers for migration of some Mesophytic plants. Thus, the time discrepancy of the rise of palynofloras with a Mesophytic aspect is remarkable (Text-figure 1; Table 1). Naturally, the palynological data may in turn provide valuable evidence for reconstructing the tectonic history. Unfortunately, palynomorphs of the Gondwana Province in China proper (mainly in Xizang = Tibet) have so far not been reported.

The term "Subangara Area", a unit of the Angara Province ('Kingdom'), is used here in Meyen's sense (1982, 1987). The composition, age and distribution of the Subangara floras are still insufficiently studied, and its southern boundary is unclear in particular, although some attempts have been made (Utting in Lenz et al., 1993). Palynological evidence indicates that N. Xinjiang, the Urals region of Russia, Kazakhstan, Svalbard, NW Canada and possibly northern Greenland may belong to the Subangara as early as in the early Late Carboniferous.

Taking into account of the parent-plant affinity and stratigraphic use as well as the morphological overlap in routine identification for some striate (taeniate included) genera, Ouyang (1991) suggested to establish two Subinfraturmas under the Infraturma Stratoabietis of R. Potońiś tradtural system, namely, the Multistriatiti (including Protobaploxypinus, Stratoabietes, Striatopodocarpites, Hamiapollenites and Vittatina, etc.) and the Raristriatiti (Chor­dasporites, Lueckisporites, Gardenasporites, Scutasporites and Lunatisporites= Taeniasporites, etc.). The latter seems mainly related to conifers based on some in situ pollen findings (e.g., Pseudovolzia and Majonica — Lueckisporites/Gardenasporites; an 'unnamed' conifer — Lunatisporites Clement-Westerhof, 1974, 1988; Lebachiaceseae, Devinostrobus — Scutasporites, Ullmania — Jugasporites/Lueckisporites; Meyen, 1987). Whilst the former is possibly largely derived from pteridosperms, as evidenced by the presence of Protobaploxypinus s.l. in some glossopterids (e.g., Arberiella; Gould, 1981) and Protobaploxypinus and Vittatina in Peltaspermaceseae (Peltaspermmum and Tagarina; Meyen, 1982, 1987). Although overlaps do exist occasionally both in morphology and affinity, for example, a Triassic conifer from the Southern Hemisphere, Rissikia, is said to produce Protobaploxypinus-type pollen (Anderson & Anderson, 1983), and Pteruchus, a pteridosperm, bears Lunatisporites (Townrow, 1962 see Traverse, 1988). Taxa of Multistriatiti, having generally longer vertical ranges than those of Raristriatiti, are mainly characteristic of the Subangara Area, while the Raristriatiti are more common in Europe.

In dealing with the Permian miospores, Meyen (1982) pointed out that "Presently we have enough grounds to state that the similarity between Angara and Gondwana miospore assemblages is essentially related to parallelism". With this view the present author in principle is quite in agreement. Balme (1980) has discussed the drastic rise of gymnosperm pollen in the Gondwana Province and its bearing on the delineation of Carboniferous and Permian. Palynologically, the rise of "Mesophyte" in the Angara Province (e.g., Kuznetsk and Tunguska) seems to start from the base of Kungurian or of the Upper Permian (Andreyeva, 1956; Faddeeva, 1990; Oshurkeva, 1990). The present paper aims at approaching the interesting diachronosity of the base of the "Mesophyte" between these two provinces and its possible backgrounds, hence the Late Paleozoic palynofloras of Angara and Gondwana will not be discussed.

Several abbreviations are used in this paper, namely, GPD = gymnosperm pollen dominance, used in the broad sense and often concerned with pollen or pre-pollen of some Paleophytic plants (e.g., Cordaitales = majority of Florinites and Cordaitina, and ancient pteridosperms, viz., Lyginopteridales, Medullosales and Callistophytales); AGPD advanced gymnosperm pollen dominance, denoting the pollen mostly derived from conifers, cycadophytes and ginkgophytes in additional to some striate forms; and GSPD = gymnospermous, especially striate pollen of advanced pteridosperms playing more important roles in a given assemblage.

1. EARLY RECORD OF SOME SACCATE POLLEN OF ADVANCE GYMNOSPERMS

The palynological data from the North Hemisphere indicate that saccate pollen or pre-pollen (not including radially symmetrical trilete 'pseudosaccate' forms, such as Rhabdosporites) already appeared in
Table 1—Broad correlation of Subangaran, Euramerian and Cathaysian Late Carboniferous and Permian stages (the asterisks indicating the approximate horizon of first appearance of GSPD or AGPD assemblage)

<table>
<thead>
<tr>
<th>System</th>
<th>Chinese Stage</th>
<th>Internatl. Stage</th>
<th>Sub-Angara (N. Xinjiang)</th>
<th>Denetz Basin</th>
<th>Western Europe</th>
<th>Tarim Basin</th>
<th>N. China</th>
<th>S. China</th>
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<td>Heshanggou Fm.</td>
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<td>Upper Gangfanggou Group</td>
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<td>Lower Permian</td>
<td>Changhsingian</td>
<td>Changhsingian</td>
<td>Lower Gangfanggou Group</td>
<td>Zechstein</td>
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<td>Biyouleibaoguzi Group</td>
<td>Schhchiengfeng Formation</td>
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<td>Wujapingian</td>
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<td>Shihhetze Group</td>
<td>Lungtan Formation</td>
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<td>Maokouan Formation</td>
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<td>Bashkirian</td>
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<td>Desmoinesian</td>
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<td>Penchi Formation</td>
<td>Vanghukou Formation</td>
<td>Huanglung Formation</td>
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</table>

Note: The table details the correlation of various stages across different regions, with specific formations and time periods highlighted, indicating the approximate horizon of first appearance of GSPD or AGPD assemblages.
The first appearance of some gymnosperm pollen has not been very clear. Meyen (1987, p. 257) listed the following succession: Mono- and quasi-saccate pollen — near the end of the Early Carboniferous; di- and quasi-saccate — in the first half of the “Middle Carboniferous”; quasi-saccate and striate forms — at the end of the “Middle Carboniferous” and Vittatina at the end of the “Middle Carboniferous”. Meyen uses the term quasi-saccus instead of protosaccus because he thinks this kind of saccus is not necessarily primitive. He is right in this regard because the “eusaccate” forms seem also to have very early origin as known in the Early Bashkirian Striatelebachites junggarensis Wang from N. Xinjiang, NW China. However, the sequence he suggested, or at least for the last three categories, is an equation at issue. According to the data available, the present author considers that three significant events in gymnosperm pollen evolution are worthy of notice.

1. The first appearance of large-sized monosaccate pollen represented by Potoniesporites, e.g., *P. elegans* (Wilson) and *P. grandis* (Luber), derived most likely from conifer and disaccate/mono-fissured pollen Limitisporites in the latest Early Carboniferous (E zone or E+H zones): The former (sometimes indistinguishable from large Florinites when its body is poorly preserved) has been known in northern England (Clayton et al., 1977), in the Yukon-Mackenzie area (Utting in Bamber et al., 1989), in Kazakhstan (Luber, 1955), probably in the Donetz Basin (Inosova et al., 1976; Panova et al., 1990) and in northern Xinjiang (Ouyang et al., 1993). Both genera have been recorded in the coeval strata in Jinyuan, Gansu, N. China (Zhu, 1993). Besides, mono-disaccate transitional forms of unknown affinity, namely, Lamellosaccites and Costatascyslus were reported from the Visean Nanningshui Formation in N. Xinjiang and the Springer Formation (C1/C2 boundary) in the United States (Felix & Burbridge, 1967), respectively.

2. The first appearance of striate and disaccate, non-striate and alete pollen in the Bashkirian.

**Early Bashkirian (R zone)** — The earliest Remysporites varicus—Striatolebachites junggarensis Pro-GSPD assemblage of this age with abundant gymnosperm pollen is known from the Batamayineishan Formation outcropped in the eastern Junggar Basin, N. Xinjiang. The dating of this formation is based on fossil plants in the underlying formation and faunas in the overlying formation. In addition to the presence of large Potoniesporites, one of the most noticeable features is the first appearance of large-sized monosaccate Multistriatitii Striatelebachites and morphological “primitive” Protohaploxypinus, both having similar intrareticulate structure (eusaccate?), and these striate pollen amount to 20 per cent of the total assemblage (Ouyang et al., 1994).

**Middle-Late Bashkirian (possibly R+G zones)** — In the subsurface “Batamayineishan Formation” assemblages similar to that of the same formation in the nearly outcrop section (localities 1-3 in
Text-figure 1) have been found but they contain more abundant and diverse gymnosperm pollen with Potoniiesporites amounting to 11 per cent, and disaccate Striatitii (Protohaploxypinus and Striatopodocarpites) to 12 per cent of the total on average. Pollen of the Vittatina-group (Tiwariasporites) is first seen. There are also disaccate non-Striatitii Pitiosporites and Platysaccus as well as mono fissured Limitisporites (Ouyang et al., 1994). Platysaccus Klausipollenites, Alisporites and Striatopodocarpites are also recorded from the classic Jinyuan section in Gansu of roughly the same age (Zhu, 1993, 1994). But striate pollen in the Carboniferous of N. China are very rare, and reliable occurrence appears first in the latest Carboniferous (Taiyuan Formation).

3. The first appearance of GSPD assemblages in Late Bashkirian-Moscovian or Moscovian in the northern Subangara area.

In the Late Bashkirian-Moscovian Chepaizi Formation from the Junggar Basin, N. Xinjiang an assemblage of gymnospermous, especially striate pollen dominance has been found. It is named as Protohaploxypinus verrucosus-Hamiaipollenites chepaizienensis assemblage. The dating is based on the associated faunas and regional stratigraphic correlation (Ouyang et al., 1994). The following are among those of advanced gymnosperm pollen: Potoniiesporites, Florinites (pars), Vesicaspora (pars), Pitiosporites, Platysaccus Klausipollenites, Voltziaceae sporites, Falcisporites, Piceaepollenites, Abiespollenites and Limitisporites, etc. and monosaccate Striatitii (Striatolebachiites and Striamonosaccites) as well as disaccate Striatitii (Chordasporites, Gardenasporites, Illinites, Protohaploxypinus, Striatolebachiites, Striatopodocarpites, Hamiapollenites, Vittatina and Lunatisporites). Multistratitii genera are especially diverse in species composition. The gymnosperm pollen amount to 77 per cent of the total assemblage in content with disaccate Striatitii to 44 per cent. So this is a real GSPD assemblage.

It deserves of mention that some elements with a Gondwanic aspect occur in this assemblage, they are: Parasaccites obscurus Tiwari, Plicatipollenites indicus Lele, P. cf. P. densus Srivastava, Virkipollenites cf. V. triangularis (Mehta), Crucisaccites indicus Srivastava and cf. C. latusulcatus Lele, etc. (Ouyang et al., 1993). Of these, Crucisaccites is widely reported in the Permian (Talchir to Barakar) in Gondwana, the oldest occurrence of the other three genera have been known from Namurian in Australia and South America (Vijaya & Tiwari, 1992).

Similar GSPD assemblages also have been recorded from the Etttrain Formation of Late Bashkirian-Moscovian age in the Yukon Territory (Barss, 1967, 1972; Bamber et al., 1989), and in the Otto Fiord Formation of Ellesmere Island of Arctic Canada (Utting, 1985); the unnamed strata of Moscovian in the eastern and western slopes of the Urals (Chuvashov et al., 1979, 1984; Chuvashov & Djupina, 1973; Djupina, 1979) and possibly in central Kazakhstan (Chuvashov et al., 1984) and in the Barents Sea (oral communication with Wood, G. D.). Thus, from N. Xinjiang through the Urals-central Kazakhstan-Arctic Canada to Yukon, i.e., the northern Subangara area in the present paper, vegetations composed mainly of conifers and advanced pteridosperms (e.g., Peltaspermaeae and its allies?) based on the palynological evidence would have existed during the Late Bashkirian Moscovian or Moscovian time, constituting a relatively independent ecozone (or ecotone of Meyen), or at least communities living in the xerophilous-mesophilous upland environments. These regions occupy a latitudinal extended belt south to the typical Angara Province and north to the Euramerian/Cathaysia Province (Text-figure 2).

It should be pointed out that although their first appearances are generally somewhat later than in the northern Subangara area, some of those pollen also have long history in the Eurameria. For instance, in the United States, Potoniiesporites already appeared in the Bashkirian (Morrowan), and Pitiosporites, Platysaccus, Alisporites, Sahnisporites, striate Illinites and Rhizomaspora first appear in the Desmoinesian (Moscovian). But they do not dominate the assemblage until in the latest Carboniferous — the Virginian GSPD assemblage found in marine shales in the Midcontinent (Jizba, 1962). Other striate pollen Protohaploxypinus, Striatopodocarpites, Hamiapollenites and Vittatina seem to start from the end of the Late Carboniferous (Frederecksen, 1972).
In western Europe, besides the earlier appearance of *Potonieisporites* as mentioned before, *Ilinites* began to occur in Bashkirian (Neves, 1964) and a few dissaccate *Striatiti* in Moscovian (Westphalian C): But these pollen do not occupy prominent position in the assemblage until the Early Permian (Autunian).

While in eastern Europe which was originally assigned to the Subangara area (Meyer, 1972), as in Poland, gymnosperm pollen had become fairly diverse in Westphalian D in the Mseno Basin, the assemblage contains higher proportion of Paleophytic spores in association with *Potonieisporites, Florinites, Vesicaspora, Alisporites, Limitisporites, Ilinites, Protohaploxypinus, Hamiapollonites, Tumorisporites* and *Vittatina*, etc. (Kalibova, 1989).

### II. DIACHRONOUS CHARACTER OF THE FIRST APPEARANCE OF GSPD OR AGPD ASSEMBLAGES IN DIFFERENT PHYTOPROVINCES

#### 1. Subangara area

The earliest appearance of GSPD/AGPD assemblages in the northern part of this area has been introduced before.

In the southern part of the Pre-Urals, GSPD assemblages containing *Vittatina*, dissaccate *Striatiti* and *Potonieisporites*, etc. (about 60% in content, acritarchs excluded) are generally to start from the Early Asselian (*Schwagerina fusiformis*- *S. vulgaris* zone), and southwards to the Pri-Caspian Basin, GSPD assemblages first occur in the middle-upper parts of the Asselian. Sometimes, the Early Permian assemblages in these regions are characterized by...
abundant acritarchs due to transgression influence (Faddeeva, 1974; Faddeeva in Panova et al., 1990).

In the Donetz Basin of western Russia Platform, the Late Paleozoic palynofloras have more connection with those of Europe. In the Late Moscovian to Kasimovian (Kamenskkyan to Avilovskian) assemblages, monosaccate and disaccate non-Striatiti as well as Striatiti become progressively abundant; however, their content in total is generally less than 20 per cent. It is worth noting that the content of Potonieisporites reaches 10 per cent in the Late Carboniferous (C3), while in the Early Permian it may often reach 20-25 per cent and spores of Paleophytic pteridophytes loss their importance. Without faunal control, here the C/P boundary delineation is slightly different. It is placed between the lithological members P6/P5 within the Araucarilic Formation based on the widespread Callipteris, whilst the palynological boundary of the base of Permian marked by the first appearance of AGPD assemblage is somewhat higher between the member Q7/Q6 within the Kartamyshkian.

In the Tarim Basin, SW China, the macroflora found from the Upper Permian (the Biyouleibaoguizi Group) shows some features of the Angara Province, dominated by plants of Peltaspermaceae. But the palynological record indicates that GSPD or AGPD assemblage already existed in the late Early Permian (Kalundaer Formation). Pollen of advanced gymnosperms (e.g. Potonieisporites and Striatolebachites) in the slightly younger Kaipaizileik Formation may reach up to more than 50 per cent in content of the total assemblage (Zhou & Chen, 1990).

During Late Carboniferous and Permian, Northern Xinjiang and Tarim Basin belong to the Angara Province, as opined by some palaeobotanists (Dou & Sun, 1985; Sun, 1992); however, judging from the palynological evidence, these basins should belong to the Subangara area because of the presence of abundant and diverse striate pollen in the known assemblages although they indeed bear some aspect of the Angara as evidenced by the occurrence of Cordaitina and “Remysporites” (strictly = Nogegerathiopsidodinofoveoites Luber or Psilohymena Hart), etc. Meyen (1987) considered that some multi-striate forms such as Protobaphokeypinuss. 1. Vittatina are characteristics of the Subangara just as fossil plants of Peltaspermaceae are assemblages from the Angara s.s. the striate pollen are usually much more rarer than in the Subangara area.

2. Euramerian Province

1. Western Europe—in Western Europe the lower Autunian assemblages as known in France, Germany (the middle part of the Kusel Group) and Spain (north to Madrid) are generally rich in Potonieisporites, Cheiledonites and Vittatina, named Vittatina costabilis zone, and their main expansion coincides with the base of the Upper Autunian which marks the lower boundary of the Disaccites Striatiti zone (Clayton et al., 1977; Balme, 1980). Meyen (1987) also mentioned that assemblage dominated by conifers, Callipteris, Potonieisporites and Vittatina, typically from the Autunian, occasionally occurs in the ‘barren-facies’ of Stephanian in France. The upper Breitenbacher Schichten in Germany contains abundant or very common Potonieisporites, Illinites and Pitvosporites, sometimes their highest content reaching 51 per cent of the total (Helby, 1966).

The assemblage from the Carboniferous-Permian transition in the Iberian Peninsula, Guadalcanal, SW Spain is still dominated by Paleophytic spores. Onwards there is a break, lacking a part of Permian strata. In the Sakmarian-Kungurian assemblage therein, gnemosperm pollen became dominant (AGPD), including Potonieisporites, disaccate Striatiti and non-Striatiti and monocolpates; altogether reaches 80-88 per cent even some Gondwana forms excluded, they still occupy about 61 per cent on average (Brouin, 1986).

2. North America—in the Maritime Provinces of SE Canada the assemblage of the upper part of the Pictou Group (Stephanian) contains Potonieisporites and Illinites unicus Kosanke, etc. but many Carboniferous elements occur. The top of this group, dated as Wolfcampian in age, is characterized by GSPD assemblage with quite diverse disaccate Striatiti and Vittatina (Barss, 1967). In the Midcontinent of the United States, at the base of Wolfcampian monosaccate pollen and trilete spores predominate with only a few striate forms. The lower part contains a number of Paleophytic spores, and locally trilete spores are very common, but striate forms increased; and the upper part is marked by GSPD assemblage.
According to Gupta (1977), the base of the Wichita Group is marked by the appearance of an association of Hamiapollenites, Vittatina, Striatoabietites, Platsaccus, Potoniesporites, and Nuskoisporites. Gupta regards the lower part of the group as Pennsylvanian, however, Balme (1980) is inclined to correlate the assemblage with that of the Orenburgian-Lower Asselian of Russia (lower and middle Schwagerina zone), i.e., equivalent to the Lower Permian in Balme's correlation scheme. In the Leonardian-Guadalupian strata, saccate pollen, especially L. virkkiae and monocolpates increase progressively (Wood et al., 1991). The Wellington Formation (Artinsk) also bears GSPD assemblage (Wilson, 1987).

To sum up, the drastic rise of GSPD/ASPD assemblages may be within the Lower Autunian and nearly at that base of the Upper Wolfcampian in the hinterland of W. Europe and N. America (Table 1).

3. Mid-East—Holowicz (1972) suggests that the Late Permian assemblage of Israel (Zohar) is of Cathaysian type; this assumption, however, seems more apparent than real because the lack of many typical Cathaysian elements, such as Patellisporites, Nixispora, Proterisporites, Bactrosporites, Yunnanospora and, Macrotisporites and Anticapipollis, in particular as well as numerous species (Ouyang, 1962, 1982, 1986; Chen, 1978). The Israel assemblage contains abundant trilete spores, including some relic forms of Carboniferous, and fairly diverse saccate pollen with low content. In this respect it has similarity to those of Late Permian of the Cathaysian, possibly reflecting a similar ecological background (warm and humid, as in S. China). On the other hand, the subsurface Permian assemblages of Israel (including Zohar) recently studied by Eshet (1990) display different features: In the "Autunian" seems already to be AGPD assemblage, in which Euramerian and Subangarian forms Potoniesporites, Nuskoisporites, Protohaploxypinus and Hamispollenites are in association with Gondwanid Picatippollenites. And the "Thuringian" yields an assemblage of GSPD, showing a stronger Euramerican aspect as represented by L. virkkiae and K. schaubergeri. Eshet concluded that "the Permo-Triassic palynozones of Israel show affinities to key sections in both Gondwana and Laurasia". Combining the data of Holowicz and Eshet, one can at least say that some horizons of the Upper Permian of Israel contain GSPD assemblages, possibly somewhat later than in the hinterland of W. Europe and N. America.

3. Cathaysia Province

1. North China—The early record of a few gymnosperm pollen in Visean and Bashkirian has been mentioned before. In the Yangshukou Formation of Jinyuan, Gansu and Shanxi-Gansu-Ningxia Basin (Westphalian B-D), the Paleophytic spore-dominated assemblages contain Pityosporites, Platsaccus, Klausipollentites, Limitisporites, Vestrigispores and Cycadopites (Wang, 1982; Geng, 1985). The Penchi Formation (Westphalian C-D) from Shouxian, Shanxi (Ouyang & Li, 1980a) yields a similar assemblage with various disaccate non-Striatitii but in very low proportion (5%) Cycadopites of ginkgophytes and cycadophytes also has an early history in China, appearing in the early Late Carboniferous (Namurian R+G zones, e.g., the Hongtuwa Formation in Jinyuan) at the latest, but usually very rare in assemblages through Carboniferous and Lower Permian, partly may be due to its uneasy preservation.

A tendency of increase both in diversity and abundance of gymnosperm pollen may be traced up through the Carboniferous to Permian in China as they do in other parts of the world, however, they did not occupy dominant position until the early Late Permian in N. China. An exception is found in a GSPD or AGPD assemblage from the Shansi Formation (Sakmarian-Chihsian) at Sunar, Gansu Province, where is adjacent to the Subangara area (the author's unpublished data). In the Upper Shihetze Formation (roughly equivalent to the Lower Zechstein), an assemblage found in Ningwu, Shanxi, contains abundant (40-50%) disaccate forms, including the first appearance of L. virkkiae in addition to the Paleophytic Cordaitina and Schopfipollenites, etc. (Gao, 1984). In the same formation from Fanxian and Zhanhua, Shandong, a diagnostic feature of the assemblage is the common presence of the Cathaysia genus Anticapipollis (conifer?). In the upper part of the Upper Shihetze Formation the content of AGP may reach to 37-56 per cent (47% on average) of the total assemblage, and the generic composition is very
diverse, especially for disaccate non-Striatiti (may up to 40%). They are in association with some striate forms, such as *Protohaploxypinus, Striatopodocarpites, Costapollenites, Vittatina* and *Ephedripites* (Zhou, 1987). Therefore, in some places of N. China, AGPD assemblages first appeared in the early Late Permian. Similar tendency has also been observed in the macrofossil plant record (Wang, 1989).

However, the drastic modification of terrestrial floras in N. China only happened in the beginning of the Late Permian (Shihchiengfeng Formation s. s. = Sunjiagou Formation) for GSPD assemblages can be found in vast area of N. China, such as in Shanxi (Lishi) (Qu, 1980), Henan (Pingdingshan) (Ouyang & Wang, 1983) and Anhui (Jieshou) (Wang, 1987). The palynoflora is characterized by the presence of *L. virkiiae*, *Jugaspores, schaubergeroides* and *K. zapfei*. The assemblage of Anhui is more diverse with AGP reaching 60-77 per cent. In addition to individual *Potonieispores*, disaccate non-Striatiti occupy 32 per cent, comprising *Pityosporites*, *Piatysaccus, Alisporites, Vitreisporites, Cedripites, Protopinus, Piceapollenites* and *Pierchhipollenites*; disaccate Stratiti reach 17-30 per cent, including *Illinites, Chordasporites, Gardenasporites, Lueckisporites, Lunatisporites, Protohaploxypinus, Striatopodocarpites* and *Vittatina* as well as *Jugaspores* and *Limitisporites* in association with a few monocolpates. Paleophytic spores (e.g. *Lycospora, Densosporites, Crassispora* and *Thymospora*) are much rarer than preceeding assemblages.

2. South China—During the Late Carboniferous and Early Permian, South China was mostly covered by epicontinental sea, generally devoid of spores and pollen. Only in some places in the Early Permian occur terrestrial-marine alternated sediments known as the Liangshan Formation (or the Basal Chhihsia Coal Series) which have been proved to be palyniferous. For example, a GPD assemblage of the formation known from Kaili, Guizhou has been reported (Gao, 1989). It is still characterized by Paleophytic spores, but contains a plentiful of gymnosperm pollen, amounting to 44-55 per cent in content, except for a majority of *Florinites*(30-50%) of largely Cordaitalean origin, there are *Vitreisporites, Sulcatisporites, Gardenasporites* and *Protohaploxypinus*. Another assemblage of this age from Shiman, Shaoyang, Hunan, is dominated by zonotriletes and monolete spores of Paleophytic pteridophytes, saccate pollen being very rare (Chen, 1978).

The assemblages from the early Late Permian Lungtan Formation (and its underlying Yanqiao Formation) which yields typically the Gigantopteris flora are exclusively dominated by Paleophytic spores, such as known from Changxing in Xheijiang and several localities in Hunan (Ouyang, 1962; Chen, 1978; Jiang, 1982). Gymnosperm pollen are low in frequency (5-10%) but may be quite diverse, including both disaccate non-Striatiti and Stratiti.

The assemblage from the Late Permian Chanshing Formation typically outcropped in Changxing, Zhejiang is often dominated by marine acritarchs. The overlying Lower Triassic, Lower Chinglung Formation contains *Vittatina-Protohaploxypinus* assemblage below and *Lunatisporites-Gnetaceae pollenites* assemblage above, both having *L. virkiiae* and *K. schaubergeri* (Ouyang & Utting, 1991). Recently, GSPD assemblages have been found in several horizons of the upper part of the Chanshing Formation (Ouyang & Hou, 1994, MS). In other words, the first appearance of GSPD assemblage has commenced within the Changhsingian time, i.e., somewhat later than that in N. China.

The assemblages from the Late Permian coal-bearing Xuanwej Formation in Fuyuan, Yunnan, SW China, are still dominated by pteridophytic spores, including quite a number of relic forms of Carboniferous: *Walzispora, Schopfites, Stellisporites, Triquitriletes, Tripartites, Lycospora, Crassispora, Torispora* and *Thymospora*, etc., These elements are thought to be indigenous, i.e., not reworked as discussed in some detail elsewhere (Ouyang, 1982, 1986). Gymnosperm pollen are low in content (5-6%) but fairly diverse, including *Protopinus, Vitreisporites, Abietineae pollenites, Cedripites, Pierchhipollenites, Platsysaccus, Klausspollenites, Limitisporites, Gardenasporites* and Anticapipollisaasociated with individual *Protohaploxypinus, Striatopodocarpites, Vittatina* and *Cycadopites*. The assemblage from the overlying Early Triassic Kayitou Formation at the same locality displays a transitional character of Paleophyte and Mesophyte, especially in its lower part (27-35 m). It contains some relic forms persisted up from older ages on the one hand, and
many Mesophytic forms, including Araritisporites-Lundbladispora and spores of Leptosporangiate plants on the other. A dramatic change is seen from the middle part of the formation in which AGPD (60-80% in content) assemblage is found, mainly composed of disaccate non-Striatitii with similar generic composition as in the preceding Xuanwei Formation, and slightly increased disaccate Striatitii (Ouyang & Li, 1980b).

As manifested by the progressively increase of GSP or AGP both in diversity and abundance and the gradual decrease of spores of arborescent laycopsids, sphenophyllids and articulate as well as pollen of ancient pteridosperm and Euramerian cordaitaleans with time, the rise of the Cathaysia Mesophyte is a long-term process in association with the decline of Paleophytic vegetation which is mostly composed of lowland or coal-swamp communities, while the former reflects mainly of xerophilous-mesophilous vegetation in upland environments (Yao & Ouyang, 1980). Compared with the Cathaysia Province, the Subangarid N. Xinjiang is very peculiar where the Early Carboniferous palynoflora dominated by zonotriletes spores (reflecting the "Lepidophyte Flora", Dou & Sun, 1985) was almost suddenly replaced by the pro-GSPD and GSPD assemblages in the Early Bashkirian and Late Bashkirian-Moscovian, respectively. The early GSPD assemblage is also possibly derived from advanced pteridosperms and conifers. And worth mentioning is that this kind of assemblage runs through the Late Carboniferous and almost the whole Permian in N. Xinjiang, involving both marine (C2-P1) and terrestrial (P2) sediments.

Now, more and more palynological data about the first appearance of GSPD or AGPD assemblages from the Late Carboniferous to the Late Permian have been accumulated, which enables us to improve our knowledge in this regard. Thus the approximate horizons of the beginning of GSPD/AGPD assemblages in the Subangara area, the Euramerian and Cathaysia provinces are marked in the stratigraphic correlation table (Table 1) which is made on the basis of some references (Shen Guanglong, 1994, MS; Balme, 1980; Zhou & Chen, 1990; Sheng et al., 1982; Hou & Wang, 1986; Liao et al., 1990; Zhu, 1983; Ouyang et al., 1994).

### III. DISCUSSION

From the foregoing review and Table 1 one can clearly see that the first appearance of GSPD or AGPD assemblages, or in some cases, the base of Mesophyte, is dischronous in different phytoprovinces or subprovinces. Furthermore, it has a general southward tendency from north to south in the Laurasia (Angara Province s.s. excluded) from the early Late Carboniferous to the end of the Permian Period. It occurs during the Late Bashkirian-Moscovian in the northern Subangara area, nearly at the beginning of the Permian in the hinterland of Europe and N. America, in the late Early Permian in some peripheral places north to the Tethys Sea (e.g., S. Spain and Israel), within the Early Permian in the Tarim Basin, at the beginning of the late Late Permian or somewhat earlier in N. China, in the upper half of the Late Permian in S. China and nearly at the boundary of Permian/Triassic boundary in SW China (Text-figure 2).

This kind of tendency may have been related to several fundamental factors as follows:

1. Some parent plants of GSPD or AGPD assemblages (e.g., Peltaspermaceae and its allies) might have migrated southwards following the general tendency of the Laurasia's constant northward drift during the Carboniferous-Permian times. As Kremp (1977) first pointed out that "the constant northward movement of Pangaea which caused a constant southward shift of the climate zones, which, in turn, forced plant and animal communities into a continuing southward migration in order to stay in the same climate zone".

2. It may be partly explained by the time-differentiation of conjugation of some Eurasia blocks (Scotese & McKerrow, 1990; Zhou & Chen, 1990; Tu, 1993), for instance, the Junggar block (terrain) and the Kazakhstan block as well as the Siberia block (D3-C2), the Tarim block and Junggar block (C2-P1), the North China block and Siberia block (P2), and the South China block and North China block (T3 or earlier) although there is much difference of opinion amongst the scientists as for the conjugation ages are concerned (as shown in the brackets). For example, the age of the main progeny of the Qinling Moun-
There is a tendency that the horizon of the first appearance of GSPD or AGPD assemblages becomes higher and higher from north (the northern Subangara area) to south (north to the Tethys), possibly related to several causal factors, such as the northward drift of the Laurasia which caused southward migration of their parent plants and the drier climate in the Permian caused downward migration of some plants originally living in the upland environments in low latitude, i.e., from upland to lowland aggradational basins. These two major migration events may be used better to explain the drastic changes of the palynofloras of the Late Carboniferous to the end of the Permian Period and the age discrepancy of macro- and microfossil records.

CONCLUSIONS

1. Palynological evidence from the areas reviewed indicates that some monosaccate pollen forms of assumed conifers, as represented by large-sized Potonieisporites and Limitisporites, already evolved in the latest Early Carboniferous (E zone or E+H zones): Lamellosaccites and Costatalcyclus of unknown affinity appeared in the Visean or C1/C2 boundary.

2. Among saccate Multistriatiti, Striatolebachitites and morphologically 'Primitive' Protobaploxyprinus first appeared in the early Late Carboniferous (Early Bashkirian, R zone) of the Subangara area.

3. The first radiation of some disaccate non-Striatiti (Pityosporites, Platsaccus, Klausipollenites and Alisporites, etc.) and disaccate Striatiti (Illinites, Gardeniasporites, Striatopodocarpites) happened during the middle-late Bashkirian (R+G zones) and a representative of the Vittatina group (Tiwariasporis) first appeared in the same age.

4. The first and earliest GSPD assemblages containing abundant and diverse disaccate non-Striatiti and Striatiti (Chordasporites, Striatobabietes, Hamiapollenites, Vittatina and Lunatisporites, etc.) in addition to monosaccate Striatiti and non-Striatiti were originated in the Late Bashkirian—Moscovian and Moscovian in the northern part of the Subangara area.

5. Unlike the sudden rise of angiosperms in the Late Cretaceous in a world-wide scale, the first appearance of GSPD or AGPD assemblages is diachronous in different phytoprovinces and subprovinces, thus in principle it cannot be used as a clue to correlate the strata of inter-provincial areas.

6. There is a tendency that the horizon of the first appearance of GSPD or AGPD assemblages becomes higher and higher from north (the northern Subangara area) to south (north to the Tethys), possibly related to several causal factors, such as the northward drift of the Laurasia which caused southward migration of their parent plants and the drier climate in the Permian caused downward migration of some plants originally living in the upland environments in low latitude, i.e., from upland to lowland aggradational basins. These two major migration events may be used better to explain the drastic changes of the palynofloras of the Late Carboniferous to the end of the Permian Period and the age discrepancy of macro- and microfossil records.
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