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Reflection on relationship of Tethyan palynoflora

R. S. Tiwari & Vijaya

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The Early Carboniferous palynoassemblage from Spiti in Tethyan Himalaya has a restricted comparability with that of Cathaysia, more pronounced relationship with that of Australia and Middle-East while apparent form-similarity with the western Tethyan region. During the Permian, few elements are definitely common between Himalayan Tethys zone and the Angara-Cathaysia assemblages but there are strong indications of an influence of Indian palynoflora on Himalayan Tethys belt. Towards western Tethys wedge, the resemblance decreases gradually and new palynotaxa are observed indicating the European affinity. Similar type of relationship among palynofloras of Tethys realm exists during Triassic. The Jurassic palynoassemblage of Tethyan Himalaya region also exhibits greater affinity with those of Indian Peninsula, although more uniform pattern appears in the assemblages of the globe during Jurassic. It has been concluded that distinct provinciality existed during Carboniferous, Permian and Triassic times. The Himalayan Tethys belt has some relationship with Cathaysia, Middle-East and western Tethyan region; it has a few elements of its own but main thrust of influence is from the Indian Peninsula. The palynological relationship of a greater Indian Plate is thus indicated up to northern Tibet and narrower Tethys sea could have been the cause of such a qualified reflection.

Key-words—Palynology, Tethyan Himalaya, Cathaysia, Indian Plate, Gondwana.

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सारॉंश

टॅथीय परागाणुवनस्पतिजात की बन्धुता की समीक्षा

राम शंकर तिवारी एवं विजया

टॅथीय हिमालय में स्पिती से उपलब्ध प्रारम्भिक कार्बनीफ़ेरी परागाणुसमुच्चय कैथेसिआ से सीमित तुलना प्रदर्शित करती है, ऑस्ट्रेलिया एवं मध्य-पूर्व से अपेक्षाकृत और अधिक बन्धुता इंगित करती है जबकि पश्चिमी टॅथीज़ क्षेत्र से स्पष्ट सजातीयता व्यक्त करती है। परमी कल्प में हिमालयी टॅथीज़ मंडल एवं अंगारा कैथेसिआ समुच्चयों में कुछ अवयव निश्चित रूप से सामान्य हैं परन्तु हिमालयी टॅथीज़ पट्टी पर भारतीय परागाणुवनस्पतिजात के प्रभाव के प्रभावकारी संकेत हैं। पश्चिमी टॅथीज़ सीमा की ओर सजातीयता शनैः-शनैः कम होती जाती है तथा नये परागाणुवर्गक मिलने लगते हैं जिससे यूरोपीय सजातीयता प्रदर्शित होती है इसी प्रकार की बन्धुता त्रिसंघी कल्प में टॅथीज़ के परागाणुवनस्पतिजातों में प्रेक्षित की गई है। टॅथीय हिमालय के क्षेत्र की जूराई कालीन परागाणुसमुच्चय भी भारतीय प्रायद्वीप से अधिक समानता प्रदर्शित करती है यद्यपि जूराई कल्प में ग्लोब की समुच्चयों में एक-सा स्वरूप प्रतीत होता है। यह निष्कर्ष निकाला गया है कि कार्बनीफ़ेरी परमी एवं त्रिसंघी कल्पों में विभिन्न क्षेत्रीयतायें विद्यमान थीं। हिमालय की टॅथीज़ पट्टी का कैथेसिआ, मध्य-पूर्व एवं पश्चिमी टॅथीय क्षेत्र से कुछ सम्बन्ध रहा है; इसमें अपने निजी कुछ अवयव हैं परन्तु इसमें भारतीय प्रायद्वीप का अधिक प्रभाव रहा है। इस प्रकार बृहत् भारतीय प्लेट की परागाणविक बन्धुता उत्तरी तिब्बत तक प्रदर्शित की गई है और इस प्रकार की महत्वपूर्ण घटना के लिए सम्भवतः सकरे टॅथीज़ समुद्र की महत्वपूर्ण भूमिका रही होगी।

THE variation of spore-pollen assemblages is caused by hereditary mechanism as well as the diversified environment. The changing pattern of palynofloras evolves gradually through time by uncoding genetic changes in the back-drop of changing climatic conditions. The degree of speciation is more dependent on the climate and stress-levels induced by palaeogeographical positioning of landmasses.

Concepts, limits and extension of the Indian Gondwana
(Editors : B. S. Venkatachala & Hari K. Maheshwari)
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During Early Devonian, some indications of megafloral provincialism have already started to show (Chaloner & Lacey, 1983; Meyen, 1972, 1979, 1982); however, distinctly marked floral provinces came into being during Late Carboniferous-Early Permian. This was resulted from the environmental stress produced by the widespread glaciation in the Gondwanaland. The Tethys sea which was formed as a shallow new sea, though above the Hercynian basement in mediterranean also contributed in differentiation of provinicial ity. Fragmentation of the Gondwanaland started in Early Mesozoic era (McElhinny, 1973). The northwards movement of Indian Plate and uplifting of Himalaya played a vital role in deciding the evolution, seggregation, admixing and identity of well-known floras.

The biological evidences can be utilized to solve intricate problems concerning nature of Tethyan extent, existence of greater Indian Plate and relationship of floras in circum-Tethys region. The bio-entities are controlled by evolution. They can sort out relationships amongst assemblages of widely separated regions reflecting the degree of their mutual relationship (Visscher, 1967).

In the present communication, the palynological reflections of relationship in Tethys Himalaya have been identified. However, the variable factors, such as differences in environment, taxonomic disparity of palynotaxa, apparent form-similarity, homoplasy and gene-pool relationship of the distant past, have been kept in mind while making comparisons.

PROVINCIALITY OF FLORAS

The Hercynian orogeny as well as the southward polar wandering was responsible for significant climatic changes, which initiated Carboniferous-Permian glaciation in Gondwanaland, but continental climate prevailed in northern hemisphere. Such changes promoted evolution of biota. During Permo-Triassic time also, great changes were initiated and a major part of Palaeozoic flora disappeared and new types of Mesozoic plants appeared in Late Triassic.

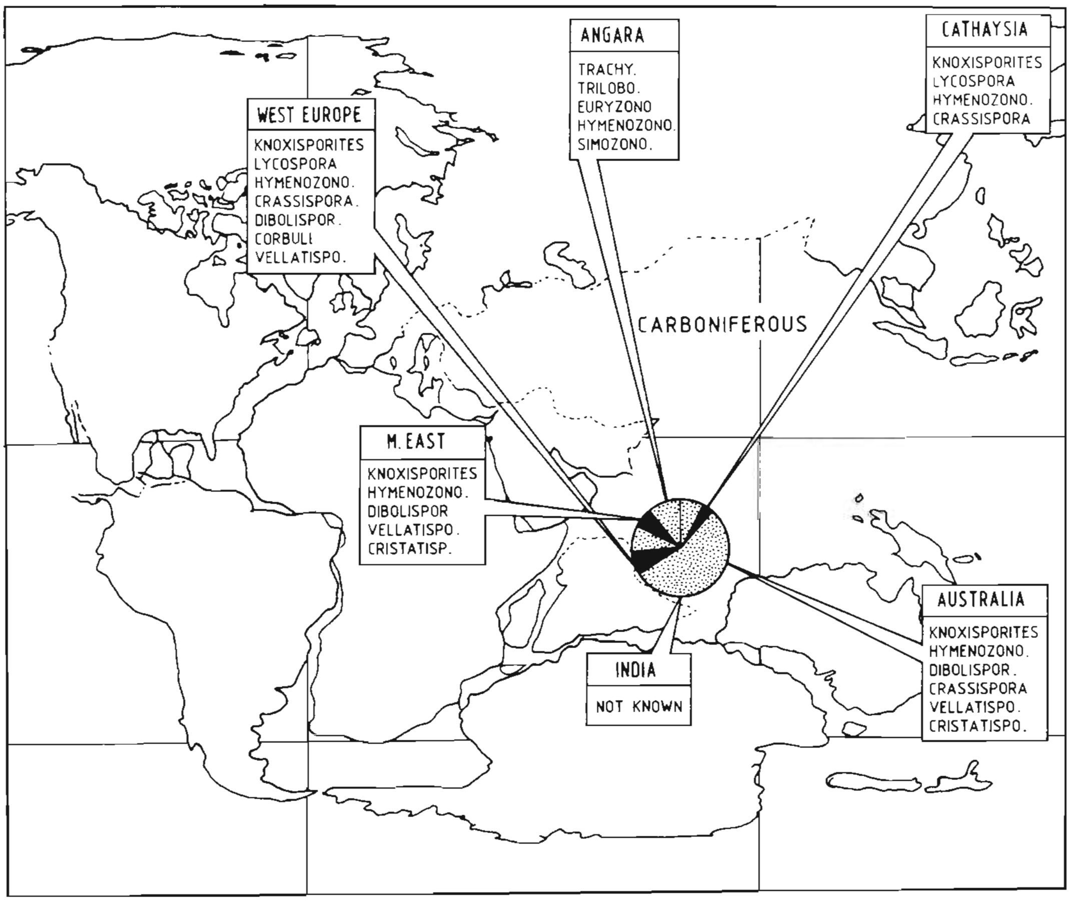
In Late Palaeozoic (Carboniferous to Permian), there were four floras—Angara flora in north, Euramerican flora and Cathaysia flora in middle part, and Gondwana flora in southern region of the globe. These floras were distributed in definite parallel latitudinal belts individually, and least on the longitudinal belts (Asama, 1985). The three northern floras have some common elements amongst themselves; however, the Gondwana flora has its individuality. The earliest view of a cosmopolitan Carboniferous flora held by megafossil workers has been challenged. According to Meyen (1982) the Gondwana megafloral province can be indentified by the Early Carboniferous time. These distinctions become clearer in Permian (Barthel, 1982). The differences are because of palaeogeographical environments and the climate resulting from the marked latitudinal disparity. Therefore, floral interchange between Gondwanaland on one hand and Euramerica and Cathaysia on the other was limited as well as qualified (Asama, 1985).

Search of megaplants beyond the conventional northern margin of the Indian Gondwana Plate may be purposefully utilized in locating its extension. Such attempts have resulted into the discovery of Glossopterids of Gondwana flora in Turkey, southern Tibet and Kashmir Himalayas which indicates that these regions had an influence of Gondwanaland (Wagner, 1962; Hsü, 1976; Singh, Maithy & Bose, 1982; Li, 1986).

Extensive faunal assemblages are on record for Tethys realm. The available data of Himalayan Tethys has revealed a cold water faunal affinity with Gondwana in the Early Permian and Tethyan warm water relationship in Late Permian (Waterhouse, 1976; Dickins & Shah, 1980; Dickins, 1985). The conclusion that a relatively uniform pattern of marine fossils existed in the Mesozoic times needs revision as the latitudinal disparity still existed, and continental positions did not make a drastic change when compared to Permian times. So also, the concept of a globally uniform vegetation in Mesozoic can be questioned, since latitudinally controlled distribution of megafossil provinces has been recognised (Barnard, 1973). Normally, the megafloral and palynofloral range of spatial occurrences do not coincide because of their mode and extend of dispersal from their original habitat. During recent years, much palynological data has been generated from the Tethys realm. In the present communication the comparisons have been done in the broader aspect of Carboniferous, Permian, Triassic and Jurassic palynoassemblages. The relationship has been evaluated on the generic occurrence of some precisely identifiable, characteristic forms with short range of vertical distribution and the assessment has been made after resolution of morphotaxonomy in each case.

INTER-RELATIONSHIP OF PALYNOFLORAS FROM TETHYS HIMALAYA BELTS

The Tethys Himalaya contains a more or less complete succession of rocks ranging in age from Late Precambrian to Upper Cretaceous (Gansser, 1964). From Cambrian, the occurrence of palynofossils and associated microfragments,

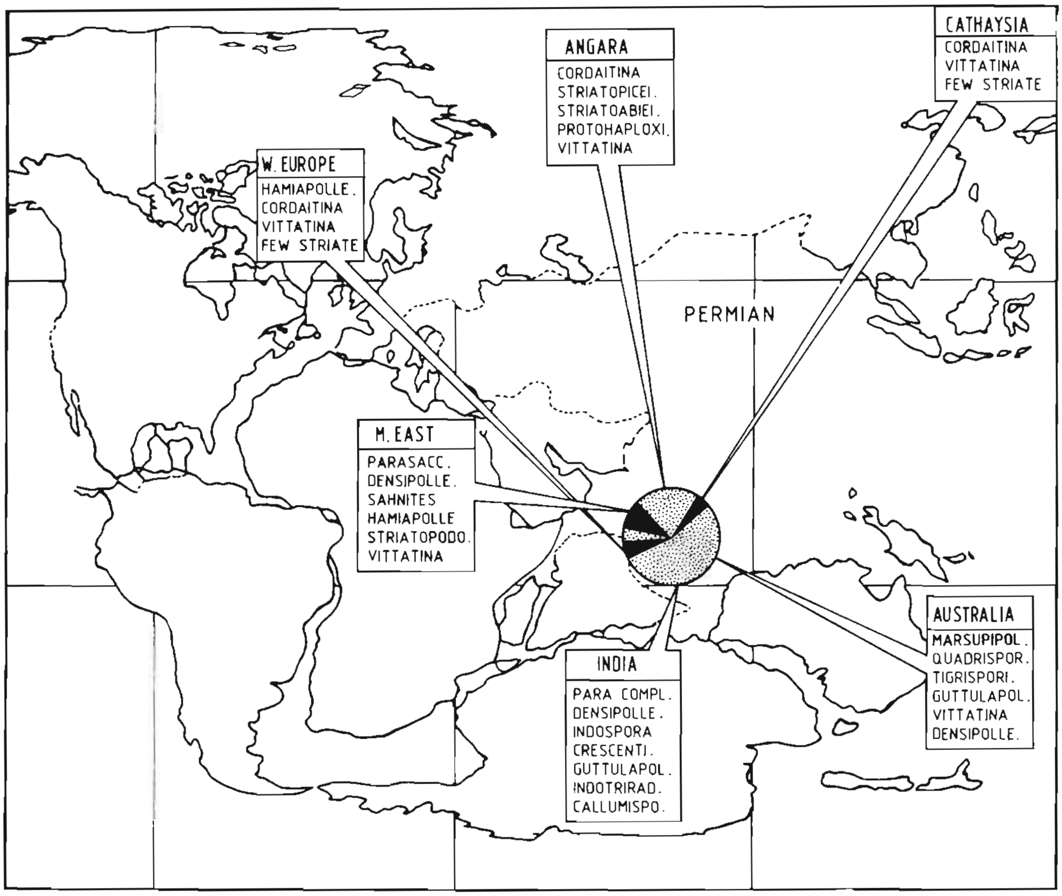


Text-figure 1—Reflection of palynological relationship in circum-Tethys region during Carboniferous time.

apparently comparable to much younger assemblages, has been recorded from Spiti Section and Kashmir region (Ghosh & Bose, 1952; Jacob *et al.*, 1953). However, later search of palynofossils in same horizon proved to be futile. Moreover, the advanced organization of the reported types has made such data a non-acceptable one. From Ordovician and Silurian sediments, groups of microfossils other than spore-pollen are reported from Spiti and Malla Johar areas (Khanna & Sah, 1980; Khanna *et al.*, 1985). Similarly, from Devonian sediments of Tethys Himalaya, the shales associated with Muth Quartzite were analysed by Tiwari *et al.* (1984) but except for chitinozoa, no spores or pollen were recovered. The palynoflora of Lower Carboniferous, Po Formation, Spiti Valley (Khanna & Tiwari, 1983) contains *Retusotriletes, Lycospora, Cristatisporites, Crassispora, Knoxisporites, Hymenozonotriletes, Vallatisporites, Dibolisporites, Retispora, Corbulispora, Phyllothecotriletes, Cingulatisporites, Tripartites, Raistrickia, Apiculiretusispora*, etc. The Teth an Permian palynoflora is on record from the sediments of Amb Formation, Wargal Limestone and Chhidru Formation—Salt Range, Pakistan. The characteristic genera are—*Camptotriletes, Schizosporis, Parasaccites*-complex, *Faunipollenites, Hamiapollenites, Guttulapollenites, Scheuringipollenites*, etc. (Balme, 1970). An younger affinity in the upper part of Chhidru Formation is reflected by *Lundbladispora, Densoisporites, Playfordiaspora, Satsangisaccites*, etc.; thus, a transitional phase from Permian to Triassic is depicted for this assemblage. The prevalence of monolete spore *Polypodiidites, Reticuloidosporites, Lunulasporites* at this level is unique for this region.

Permian sediments of Tethyan origin in Malla Johar area have been studied for their palynological content by Tiwari *et al.* (1980, 1984). The Kuling Shale Formation of Rawalibagar Group, from amongst the whole Permian sequence of this area, has yielded *Callumispora, Lophotriletes, Parasaccites, Densipollenites, Scheuringipollenites, Faunipollenites, Crescentipollenites* and *Striatites* in association with *Lundbladispora*.

The Lower and Middle Triassic sediments at Salt

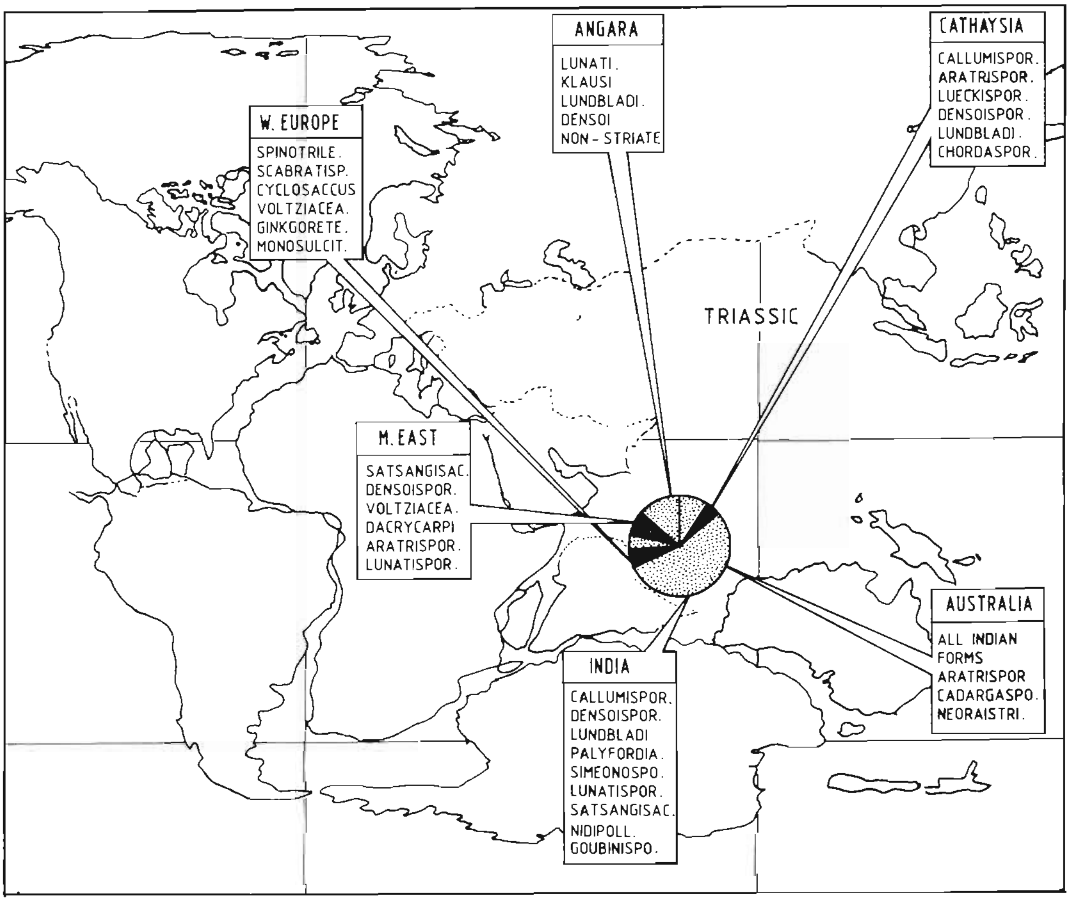


Text-figure 2—Reflection of palynological relationship in circum-Tethys region during Permian time.

Range region represented by Mianwali Formation and Tredian Formation, respectively, have been palynologically investigated by Balme (1970); this study has provided useful data for comparisons. Palynoassemblage of Kathwai Member, thought to be the oldest bed of Triassic, is poor in preservation. In the next two younger horizons, better palynofossils are documented. Significant genera from Mianwali Formation are—*Callumispora = Punctatisporites), Densoisporites, Lundbladispora, Lunatisporites (= Taeniaesporites), Klausipollenites, Osmundacidites, Playfordiaspora, Simeonospora, Aratrisporites, Satsangisaccites (= Falcisporites).* In the sediments of Tredian Formation (Middle Triassic) palynofossils are abundant but less diversified, represented by *Calamospora, Verrucosisporites, Triplexisporites (= Tigrisporites), Densoisporites, Lundbladispora, Playfordiaspora, Aratrisporites, Lunatisporites, Satsangisaccites, Scheuringipollenites*, etc.

From the Triassic sediments of Malla Johar area, Tiwari *et al.* (1980, 1984) reported scanty occurrence of palynofossils from various units of Kalapani Limestone, Kuti Shale, Passage Formation and Kioto Limestone. Recently, a well preserved and diversified palynoflora was found in the top most horizon of the Kalapani Limestone (Late Triassic) Formation by Vijaya *et al.* (1988) containing—*Callumispora, Simeonospora, Neoraistrickia, Scabratisporites, Cadargasporites, Spinotriletes, Tethysispora, Lundbladispora, Playfordiaspora, Voltziaceaesporites, Alisporites, Satsangisaccites, Striatopodocarpites, Lunatisporites, Chordasporites, Cordaitina, Ginkgoretectina*, etc. The Norian palynoflora known from Kuti Shale and Passage Formation comprises *Densoisporites, Lundbladispora, Klausipollenites, Striatopodocarpites, Lunatisporites* and *Pretricolpipollenites.* The Rhaetian palynoflora from Kioto Limestone shows the presenee of *Lundbladispora, Goubinispora, Lunatisporites*, etc. but is poor in contents.

From Kashmir Himalaya, palynological report from Lower Triassic argillaceous sequence of Pahalgaon (Nautiyal & Sahni, 1976), records microplankton and non-striate bisaccate pollen—*Klausipollenites, Platysaccus* and *Scheuringipollenites.* However, this information is too meagre to be considered for comparisons. The Jurassic



Text-figure 3—Reflection of palynological relationship in circum-Tethys region in Triassic time.

palynoflora from variegated shale, Mammal Gorge, Salt Range (Jain & Sah, 1969) contains 22 taxa; the dominant forms are *Classopollis*-complex, *Perinopollenites*, followed by *Matonisporites*, *Eucommidites*, *Podocarpidites* and *Araucariacites*. The saccate pollen are poorly represented.

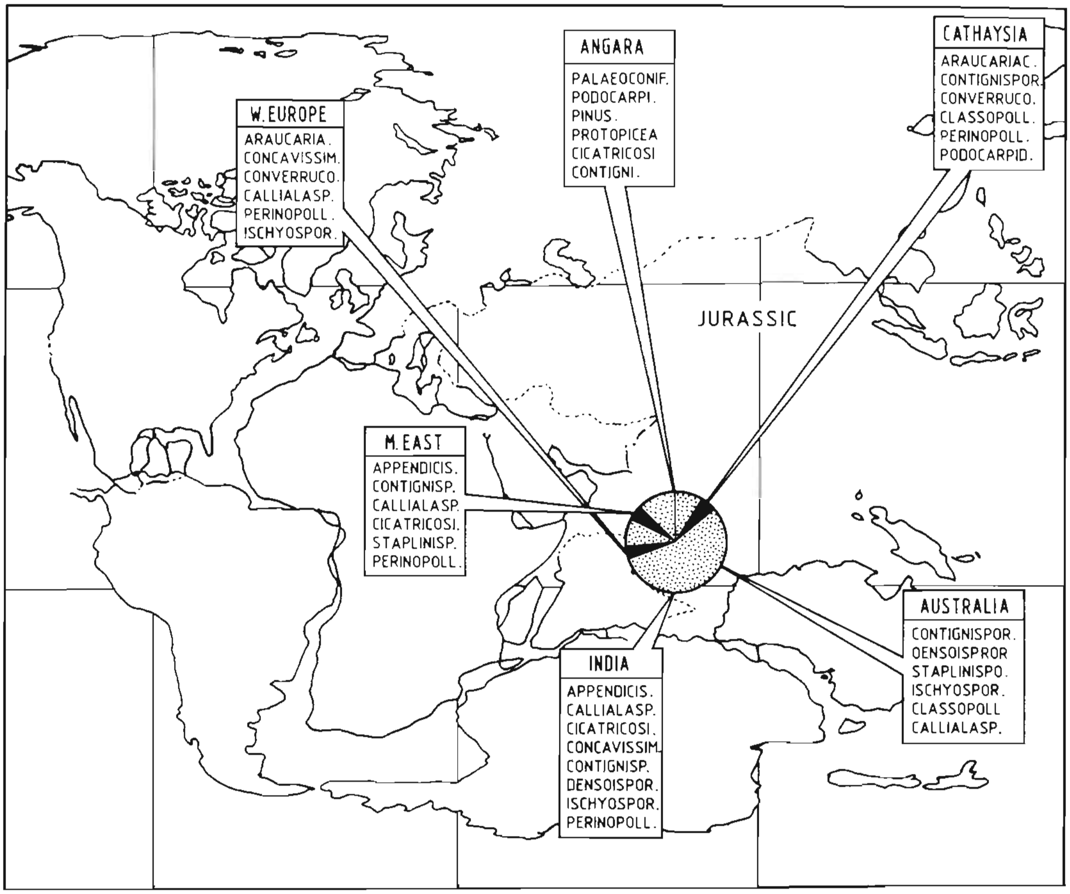
Palynological information is available from Spiti Shale unit of Malla Johar Supergroup, Kumaon Himalaya (Tiwari *et al.*, 1980, 1984; Jain *et al.*, 1984), a Late Jurassic age has been suggested on the basis of hystrichospheres, following pollen spore taxa are identified in this assemblage—*Concavissimisporites*, *Contignisporites*, *Cicatricosisporites*, *Callialasporites*, *Densoisporites*, *Appendicisporites*, *Alisporites*, *Couperisporites*, *Podocarpidites* and *Todisporites*.

Pantic *et al.* (1981) reported the presence of few palynomorphs from Jurassic sediments of Barsong Formation in eastern Bhutan. Beside other micro-organisms, the spore-pollen identified are *Callumispora* (= *Punctatisporites*), *Deltoidospora* and *Alisporites*.

No palynoflora is on record from Cretaceous of Tethys Himalayan belt. From amongst the available data enumerated above, the Salt Range and Malla Johar assemblages of Permian age are relatively better known than the others. These are closely affiliated with each other in most of their palynotaxa constituents, yet some differences can be identified, e.g., the presence of *Camptotriletes*, *Hamiapollenites* and abundance of monolete spores (*Polypodiidites*, *Lunulasporites*, *Reticuloidosporites*) in the Permian of Salt Range, but their absence in Malla Johar.

Palynofloras from the Triassic sediments of Tethys Himalaya in Salt Range, Malla Johar and Kashmir Himalaya are closely related with each other except that a few endemic taxa are present in Kalapani Limestone Formation of Malla Johar area, such as *Tethysispora*, *Lunatisporites tethysensis*, *Striatopodocarpites auriculus*, which are absent from the Salt Range. A significant resemblance is deciphered in the presence of *Cordaitina* in the Triassic of these two areas.

The known palynoassemblages from Jurassic sediments of Salt Range and Malla Johar belong to two different horizons, i.e., Early and Late Jurassic, respectively. Hence, no direct comparison is possible. Only certain taxa of long ranging nature are shared between the two areas, for example—



Text-figure 4—Reflection of palynological relationship in circum-Tethys region in Jurassic time.

Todisporites, Matonisporites, Lycopodiumsporites, Alisporites, Podocarpidites, etc.

REFLECTIONS ON RELATIONSHIP OF TETHYAN PALYNOFOSSILS

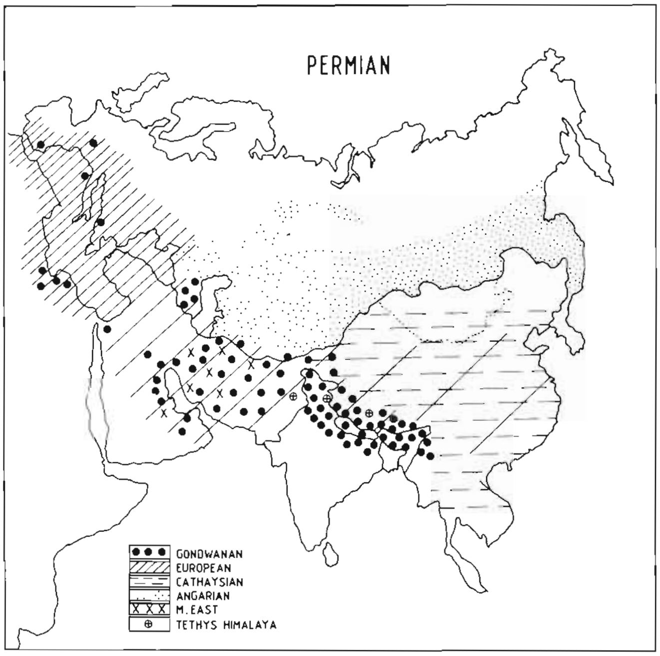
The Himalayan Tethyan palynofloras indicate various degrees of relationships with those of other Tethyan as well as circum-Tethys region. Such comparisons are brought out in the following account. These conclusions are not exclusively based on quantitative data. The qualitative resemblance, relative abundance and comparative prominence have also been determined on the basis of existing information.

Carboniferous

Cathaysian Middle and Upper Carboniferous assemblages, known from Henshanbu, Ningxia (Hui, 1984) and Shaanxi Formation, Gansu Province (Shu & Li, 1980; Du, 1986) do not show close affiliation with the sole record of Lower Carboniferous flora from Spiti Valley, Tethys Himalaya (Khanna & Tiwari, 1983). Leaving aside the long ranging taxa, like *Leiotriletes, Latosporites,* etc. the Cathaysian assemblage is characterised by *Dictyotriletes, Torispora, Pseudolycospora, Reinschospora, Florinites, Stellisporites, Trimontisporites, Waltziaspora, Trachytriletes* and striate and nonstriate disaccate pollen. However, a mild relationship is visible between the assemblages of two areas by the common presence of *Knoxisporites, Microreticulatisporites, Crassispora, Hymenozonotriletes* and *Lycospora.* Such observation opens a possibility of some ground for further comparison which could be purposeful for palaeogeographic determinations.

Assemblages of spore-pollen from Shaanxi and Gansu (Du, 1986), Cathaysian province, have been assigned an Early Permian age but they also contain several characteristic taxa, e.g., *Triquitrites, Torispora, Convolutispora, Lycospora, Florinites* which are characteristic of Late Carboniferous. The Early Carboniferous assemblage of Po Formation does not exhibit remarkable relationship with Shaanxi and Shihhotze palynofloras but, at the same

Text-figure 5



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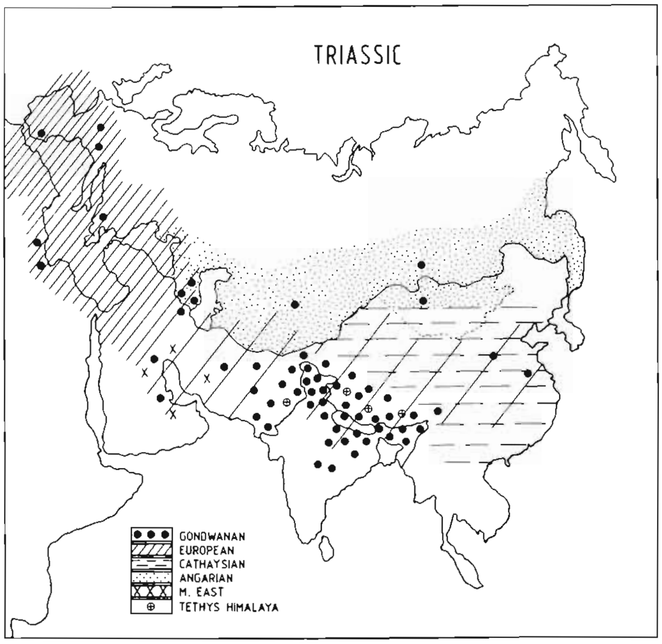

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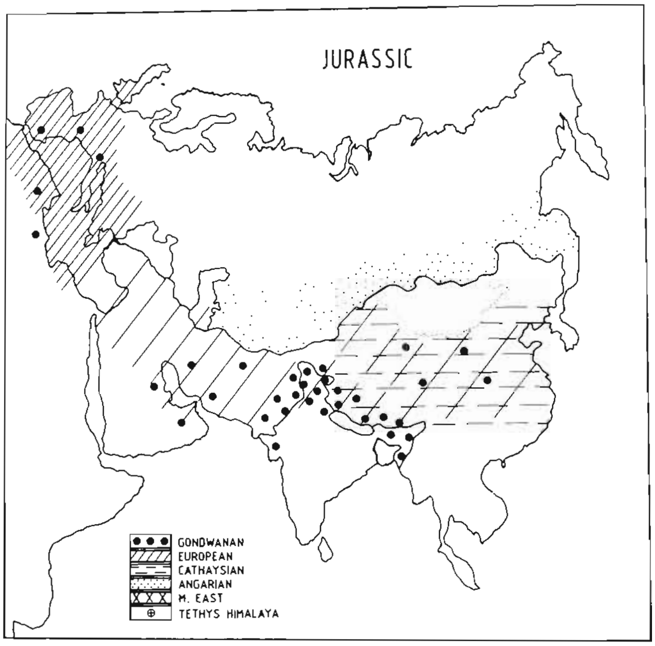

Text-figure 8

Text-figures 5-8—Relative affiliations in palynological composition of circum-Tethys region in various periods : **5**, Carboniferous; **6**, Permian; **7**, Triassic; **8**, Jurassic.

time, a few taxa, e.g., *Lycospora, Knoxisporites* might show some form-similarity.

There is no palynological record of Carboniferous age from Indian Peninsula. With the Australian Carboniferous assemblages (Evans, 1969; Playford, 1976, 1978) the affinity of Himalayah Carboniferous assemblage is reflected in the presence of *Knoxisporites, Hymenozonotriletes, Dibolisporites, Vallatisporites, Crassispora*, etc.

Record of few common elements between the Po Formation and Libyan Carboniferous (Coquel & Morean-Benoit, 1986) is interesting. However, Libyan palynoflora is more akin to the western Tethys realm in the presence of *Dictyotriletes, Geminospora, Cristatisporites, Umbonatisporites, Grandispora* and *Auroraspora*, rather than the eastern Tethys region in overall composition and, as such, only a limited degree of relationship is marked with that of the Himalayan-Australian region in the occurrence of *Dibolisporites, Hymenozonotriletes, Vallatisporites* and *Cristatisporites*.

The Tournasian palynoflora from Saudi Arabia (Hemer, 1965) has a conspicuous set of taxa revealing its individuality, but at the same time, in context to the Po Formation (inspite of age discrepancy of the two within the Carboniferous), a relationship is reflected in the common occurrence of *Densoisporites, Vallatisporites* and *Cristatisporites*; thus a qualified continuity of spore-pollen groups from Himalayan Tethys up to Saudi Arabia is evident.

Carboniferous palynofloras from western Tethyan province are extensively known (*see* Clayton *et al.*, 1977; Wagner *et al.*, 1983). A limited resemblance between the Po Formation assemblage and the west European palynofloras is indicated in the presence of a few common genera, such as : *Vallatisporites, Lycospora, Knoxisporites, Hymenozonotriletes, Corbulispora*, etc. Otherwise, the European palynofloras are distinct in having *Auroraspora, Grandispora, Spelaeosporites*, etc.

The Angara palynoflora of Early and Middle Carboniferous age is distinguishable by the presence of *Trachytriletes, Trilobozonotriletes, Euryzonotriletes* and *Perisaccus*. The apparent resemblance in the presence of *Lophotriletes, Leiotriletes, Hymenozonotriletes, Simozonotriletes*, etc. is diminished when the complex nature of forms and distinctiveness in species of the Angara palynoflora are carefully analysed.

Inspite of insufficient palynological data on the Carboniferous, a closer affinity of Himalayan Tethys with eastern Gondwana continent is evident, which appears to decrease with western Tethyan region. It remains limited with Cathaysian assemblages. Yet, it is clear that some genera are shared by most of the assemblages from Australia, Middle-East, Mediterranian and the Cathaysian region (Text-fig. 1).

Permian

Permian palynoflora from Tethyan Himalaya is comparable in the common occurrence of *Verrucosisporites, Sahnites, Corisaccites, Chordasporites, Platysaccus, Pityosporites, Piceaepollenites*, with the Early Permian assemblages from NW Shansi (Shu, 1964), Shaanxi Formation, Gansu (Du, 1986) and south west Tarim (Hui, 1985). As such, these assemblages are unique in themselves and show closer relationship with Russian Platform. The reflection of Cathaysian palynoflora in Himalayan Tethys are traceable as there exist few distinct forms which are similar in characters.

Most of the palynofossils from Tethys Himalaya reveal closeness with those from India and Australia (Evans, 1969; Balme, 1964, 1970; Kemp *et al.*, 1977; Foster, 1979; Tiwari & Tripathi, 1988, in this Volume; Vijaya & Tiwari, 1988). Some differences, however, can be marked, e.g., absence of *Dulhuntyspora, Rugulatisporites* and *Converrucosisporites*, in Tethys Himalayan, Permian and Indian Permian (Lower Gondwana) and their presence in Australian Upper Permian. Similarly, occurrence of *Cordaitina* in Tethys Himalaya makes it different from other comparable floras of this region. These assemblages are the product of widely extended Glossopteris Flora of the Gondwanaland and variations recorded are attributed to local environmental influence on their composition.

The relationship of Salt Range and Madagascar palynofloras (Goubin, 1969; Balme, 1970) is striking in the overall composition. The common presence of the genus *Guttulapollenites* has been given importance for such a relationship (Bharadwaj, 1976).

From the areas of Middle-East, Permian palynoassemblages are known from Saudi Arabia (Hemer, 1965; Cameron, 1974), north-east Iran (Chateauneuf & Stampfli, 1979), Iraq (Singh, 1964) and southern Israel (Horowitz, 1973, 1974). A limited relationship of these palynofloras with Tethys Himalayan assemblage is evidenced in the presence of *Parasaccites, Indospora, Densipollenites, Hamiapollenites* and *Faunipollenites (= Protohaploxypinus)*; at the same time, however, each assemblage of Middle-East can be distinguished from the Tethys Himalayan palynoflora by occurrence of certain taxa, e.g., *Striatoabietites, Perotriletes, Iraquispora, Fimbriaesporites, Masulipollenites, Wilsonia* and *Labiisporites*, etc. which are absent from the latter. The Middle-East floras are relatively closer to the European palynoflora in the presence of *Endosporites, Gardeniasporites, Perisaccus, Jugasporites* and *Limitisporites*.

A distant resemblance is indicated between the Libyan palynoflora and that of the Tethys Himalaya but the differences are more pronounced (Kar *et al.*, 1972). Well-illustrated palynological information is on record from Southern Alps and Germanic Permian (Klaus, 1963; Visscher, 1966; Visscher *et al.*, 1974). Frequency of identical palynofossils in assemblages of this region and Tethys Himalaya is low, as exemplified by the presence of *Cordaitina*, *Hamiapollenites* and *Vittatina* only. The increase in dissimilarity among the assemblages of two areas is attributed to their palaeolatitudinal positions during Permian time, and it is evidenced by the presence of *Strotersporites, Gigantosporites, Nuskoisporites, Gardenasporites, Perisaccus, Endosporites, Jugasporites, Limitisporites* and *Illinites*.

The Permian palynoflora of Angara region is rich and diversified. The taxonomic treatment is broad-based and morphographic significance attached to organization of spores and pollen varies; hence, comparative determinations cannot be ascertained in each case (Luber, 1970; Zauer *et al.*, 1969). Some pollen of *Parasaccites*-type appear to be present but most varied forms of apparently similar taxon *Cordaitina* are dominating in the Angaraland. This genus is also recorded from Himalayan Tethys. The striate disaccates have form-similarity. *Striatopodocarpites* with different species, is shared but other members of the group, such as *Striatopiceites, Striatoabieites, Protohaploxypinus*, etc. distinguish the Angara flora. The group *Vittatina* and monocolpate-complex although recorded from Tethys, are distinctive elements at specific levels (Sivertseva, 1966; Pokrovskaya, 1966). *Lueckisporites* is shared by both the floras so also some similar non-striate bisaccate pollen.

It is concluded that the Tethys Himalayan Permian palynoflora is rich and qualitatively diversified; it resembles Indian and Australian Lower Gondwana palynoflora. The degree of comparability declines in the Middle-East region and ultimately the spore-pollen complex met within the western most Tethys region shows restricted relationship with Tethys Himalayan assemblage. The pattern observed in Angaran and Cathaysian provinces *vis-a-vis* Tethyan Himalaya are different except for few elements (Text-fig. 2), which are shared by them.

Triassic

Significant palynological data is known from the Triassic sediments in the areas of Gansu (Liu, 1980; Du, 1985) and western Hubei (Li & Shang, 1980) Sichuan. The palynofossils from Cathaysia differ from those of other provinces; consequently, the Chinese workers proposed several new generic names. The remaining forms were placed in Angaran and European taxa which treatment appears to be casual rather than definitive. The Cathaysia palynoflora exhibits its individuality but at the same time it has limited relationship with the Tethys Himalayan assemblage, viz., in the presence of certain non-striate saccate pollen comparable to *Satsangisaccites, Nidipollenites, Klausipollenites* and *Playfordiaspora*, and trilete spores: *Callumispora, Lundbladispora, Densoisporites*. In general, it may be said that certain similarity exists between the two regions.

Resemblance between the assemblages in Triassic of Indian Peninsula and NW Australia with that of Tethys Himalaya has been discussed by Vijaya *et al.* (1988), and an impressive similarity is evident in gross morphography of palynofossils of the two regions. However, in the occurrence of a few endemic forms as well as some elements of other provinces, Tethys Himalaya flora differentiates itself; these taxa are—*Tethysispora, Striatopodocarpites auriculus, Spinotriletes, Voltziaceasporites, Colpectopollis* and *Ginkgoretectina*.

From the areas of Middle-East, rich and diversified palynoassemblages are known from Saudi Arabia (Hemer, 1965), Israel (Horowitz, 1973) and Iran (Kimyai, 1979). A limited qualitative continuity is indicated between the Triassic of Middle-East and Tethys Himalayan palynofloras in the common presence of *Kraeuselisporites, Playfordiaspora, Lunatisporites, Satsangisaccites* and *Voltziaceaesporites*. The Middle-East assemblages are more akin to the European palynofloras rather than those of Himalayan Tethys. The presence of *Jugasporites, Triadispora, Duplexisporites, Ovalipollis* and *Striatoabietites* in the Middle-East having resemblance in species with western Tethyan palynofloras is noteworthy.

The same kind of relationship of Tethys Himalaya is evident with the Triassic palynofloras from Libya (Kar *et al.*, 1972), southern Tunisia (Grignani, 1967) and Sahara (Reyre, 1970).

A comprehensive data on Triassic is known from the widely scattered Triassic sediments of south-west Europe in the areas of south east Spain (Adloff & Doubinger, 1970, 1978; Besems, 1981; Besems & Simon, 1982; Boutet *et al.*, 1982), France (Schuurman, 1977), Germanic and Alps region (Klaus, 1960, 1964; Mädler, 1964; Schulz, 1966; Scheuring, 1970, 1978; Schuurman, 1979; Visscher & Brugman, 1981), extending to western Dolomites, Italy (van der Eem, 1983), Sicily (Visscher & Krystyn, 1978) and Sardinia (Demelia & Del Rao, 1980; Demelia & Flaviani, 1982). The Triassic assemblages of Tethyan Himalaya have only few common elements with western Tethys and surrounding region, e.g., *Spinotriletes, Scabratisporites, Voltziaceaesporites*. Beside these, other taxa having wider distribution are also found to be common between these two areas; they are—*Klausipollenites, Aratrisporites, Lundbladispora* and few bisaccate-striate pollen which are also present in eastern Gondwana and the Tethys of Himalayan region. The latter also exhibits some broader aspects of palynological similarity during Triassic with Angara flora in the taeniate and non-taeniate simple disaccate pollen group (Chalishev & Varukhina, 1966; Romanovskaya, 1966). Recent trend to identify Russian palynotaxa on international pattern has resulted into identification of several species of *Taeniaesporites, Klausipollenites, Lundbladispora, Densoisporites*, etc. Thus, a relationship of Angara flora with the Tethys of Himalayan zone (Yaroshanko, 1978, 1980), could be deciphered. A generalized trend of relationship during Triassic time is depicted in Text-fig. 3.

Jurassic

Jurassic palynoflora from Cathaysian Province is known in the areas of Gansu Province (Liu *et al.*, 1981; Du *et al.*, 1982), Hebei (Zhen-bo, 1986) and SW Shandong (Li & Shu, 1980), where it is characterised by the prominence of *Cyathidites, Monosulcites, Chasmiatosporites, Asterisporites, Duplexisporites* and mainly cytheaceaous spores, and pollen of Cycadopsida, Ginkgopsida and Coniferopsida (*Pinuspollenites, Cerebropollenites, Abietineaepollenites*). On comparison with the Jurassic palynological assemblages of Tethys Himalaya (Jain & Sah, 1969; Tiwari *et al.*, 1984; Jain *et al.*, 1984) a fair degree relations is observed, as indicated by the common presence of *Todisporites, Dictyophyllidites, Perinopollenites, Callialasporites, Concavissimisporites, Contignisporites, Alisporites, Podocarpidites* and *Lycopodiumsporites.*

Indian Jurassic palynofloras are well known. A general account of various assemblages in Jurassic sediments of Peninsular India (Srivastava, 1966; Venkatachala *et al.*, 1969; Venkatachala, 1969; Singh, 1974) reveals that in the older sequence, the *Classopollis*-complex is dominant in association with *Cyathidites, Osmundacidites, Ischyosporites, Cingulatisporites, Monosulcites, Araucariacites* and *Callialasporites.* This closely compares with that of variegated shales of Salt Range (Jain & Sah, 1969). In the next younger horizon, the assemblage is dominanted by *Callialasporites*, or *Araucariacites*-complex. A qualitative change in the spore-pollen spectrum is marked by the appearance of new palynofossils. The Indian Jurassic palynofloras have great resemblance with that of Tethys Himalaya in their quantitative composition. The qualitatively important taxa are—*Perinopollenites, Araucariacites, Cicatricosisporites, Concavissimisporites, Contignisporites, Todisporites, Podocarpidites*, etc.

The same kind of affinity is indicated in Australian Jurassic palynoassemblages (Filatoff, 1975) and that of the Tethys Himalaya. Both eastern and western Australian palynofloras of Early Jurassic are characterised by high proportions of *Classopollis*, but in Middle Jurassic the genus *Callialasporites* becomes more important. The palynofossils from Tethys Himalaya are too few to allow meaningful horizonwise quantitative comparison but qualitatively there is a marked relationship among the taxa—*Ischyosporites, Lycopodiacidites, Alisporites, Perinopollenites*, etc.

Australian Late Jurassic palynofloras are relatively lesser known. Nevertheless, they contrast with the older assemblages by containing morphologically distinctive species, as *Contignisporites cooksoniae* and *Cicatricosisporites australiensis* which range from Late Jurassic to Early Cretaceous assemblages in Australia. However, the mode of relationship with Tethys Himalayan palynoflora is not clear at the present juncture.

In the Middle-East, palynological data is known from Jurassic sediments of Saudi Arabia. The only comparable taxon in known Jurassic palynoflora of Tethys Himalaya is *Appendicisporites.* Recently, more data has been generated from Iraq, Afganistan and Israel (Horowitz, 1974; Achilles *et al.*, 1984; Bharadwaj & Kumar, 1986). Palynofloras of these areas are different in their composition and only a limited comparison of their relationship can be made out in the presence of *Alisporites, Todisporites, Podocarpidites*, etc. which are common with Tethys Himalaya. However, these taxa are universally present, hence their significance is limited.

Early Jurassic palynofloral data from European region is relatively extensive (Mädler, 1964; van Erve, 1977; Del Rio, 1976, 1984; Achilles, 1981; Fisher & Dunay, 1981). The most striking aspect of assemblages from Europe is the high percentage of *Circulina* and smooth trilete spores. The quantitatively dominant taxa of assemblage are different from that of Gondwanaland and also the Tethyan Himalaya. Only qualitative resemblance is depicted with the latter by those forms which are widely distributed and mostly cosmopolitan, such as *Todisporites, Matonisporites, Ischyosporites, Concavissimisporites, Perinopollenites, Callialasporites, Staplinisporites.*

According to Filatoff (1975) more uniform flora was existing during the Jurassic time than other geological period. However, palynological evidences suggest that subtle differences existed and regional distinctions can be brought out by careful comparisons (Text-fig. 4).

DISCUSSION AND CONCLUSION

The reflections of relationship amongst palynofossils in Tethyan realm in Carboniferous through Jurassic periods are variable because the

Tethys cut across the northern and southern subtropical and tropical belts extending up to higher latitude of temperate and subantarctic region of the southern hemisphere. The pattern of land-sea distribution has been changing through this time span. The floral compositions have changed from time to time along the coastal as well as continental domain adjacent to it, which contributed to the pollen-spore population of the Tethyan deposits.

The spores and pollen grains must have been deposited through water and air medium, by travelling from near as well as distant areas in the adjacent landmasses. The vegetation which was growing in nearby areas is expected to be represented dominantly in the palynoflora. To this set up the environmental nitche and floral migration have added further complexity.

The Carboniferous palynoflora—The Himalayan Tethyan palynoflora has closer affinity with Gondwanan palynofloras which progressively decreases towards the Mediterranean wedge (Text-fig. 5). The Angara and Cathaysia palynoassemblages also possess a few comparable forms but their individuality is outstanding. Such situation is the result of distribution of landmasses during Carboniferous time, which were placed at highly differential latitudinal position. At the end of Carboniferous, the continents assembled tightly to form Pangea but Siberia and Cathaysia were still separate landmasses. The distinctions in palynological components can be exemplified by Australian palynoflora which differs from that of the Euramerian, as the latter has been obtained from coal-measures represented by special tropical vegetation (Chaloner & Meyen, 1973). Nonetheless, links are observed with North Africa, Europe and eastern North America (Balme, 1964; Playford, 1976; Galtier *et al.*, 1986). The Carboniferous palynoflora from Cathaysia is mainly dominated by *Triquitrites* in association with *Lunzisporites, Trimontisporites, Crassispora, Codiospora*, etc. but in other respect it is equatable to European assemblages (Shu, 1964; Hui, 1984). Similarly, the interplay of latitudinal belts in shaping the comparability of palynofloras can be demonstrated by greater similarity of Arabian Carboniferous assemblage with Russian assemblage of respective age (Hemer, 1965).

The Permian palynoflora—The Tethys Himalaya palynoflora has much greater similarity with that of the Gondwanan region. The differences increase with the western Tethyan region and the Angara-Cathaysia blocks (Text-fig. 6). Such a marked provinciality in palynofloral distribution during most of the Permian times is attributed to Hercynian orogeny when a complex topographic configuration and sharp climatic gradients were resulted on the northern as well as southern continents. The polar regions remained cold and the equatorial belt was hot. Consequently, distinct floras came into existence; the *Glossopteris* flora remained remarkably unique to south (Plumstead, 1973). In the north, the Siberian and Cathaysian plant communities were styled in their own identity owing to the high latitudinal positions (Chaloner & Meyen, 1973; Li & Yao, 1981). The Tethyan Himalayan palynoflora of Permian age exhibits an impressive similarity with the Gondwanan belt; the minor differences do not warrant a zonal distinction (Balme, 1964; Segroves, 1969, 1970; Vijaya *et al.*, 1988). At the same time, some influence of the western circum-Tethys region has also been recorded by the presence of *Cordaitina* and striate-disaccate pollen genera. An increasing influence of northern palynoflora on the Tethyan Himalayan region occurred because of the decreasing impact of glacial episodes (in Late Permian) in the southern continents; consequently, warming up of climate led to migration of tropical floras into southern region. However, the differences between Eurasian and Gondwanan plant population kept pace even with the southerly migration of floras because the climate of northern hemisphere also became warmer in response to the retreat of southern glacials. The migration must have taken place through the southern shore line and adjacent region of Tethys. This is shown in the progressive dissimilarity of palynofloras of Tethys Himalaya with those of western Tethys, as concluded here.

The Middle-East and Arabian Peninsula have greater influence of Mediterranean region (European belt) than that of India and Australia (Singh, 1964; Hemer, 1965; Horowitz, 1973; Kremp 1974, 1975; Vijaya *et al.*, 1988); this appears to be the result of their being positioned in same broader latitudinal belt which was occupied by northern coniferalean plants.

The Angara and Cathaysia Permian palynofloras have dissimilarity with Tethyan Himalayan belt. Still, certain forms appear to be shared by Cathaysia and the Himalayan Tethys which indicate that some sort of floral admixture has occurred. New data in these areas, particularly from China, may throw light on migratory routes.

The Triassic palynoflora—In Triassic the great Supercontinent Pangaea took its final form encompassing all major segments of continental crust. The floral provinces of Permian time did not change significantly in the Triassic. The Euramerian flora grew under warmer and drier conditions at low latitude while Gondwana flora, though experienced relatively warmer climate than Permian, lay at the southern higher latitude. The infiltration of

European and Mediterranean elements into Himalayan Tethys is more pronounced (*Spinotriletes, Voltziaceaesporites, Colpectopollis, Ginkgoretectina,* etc.) in Triassic because of less intensive climatic variation from equator to the temperate zone, yet the influence of Gondwanic flora remains dominant on the Tethys Himalaya (Text-fig. 7).

The Triassic palynofloras of Gansu and Sichuan Province are distinctive from Tethyan Himalaya yet a few common elements do exist. Some comparability of Cathaysia also exists with European assemblage. This in turn reflects certainly warm and wet climate for this region belonging to subtropical type (Lei, 1986). These trends of relationship implicitly express that the distances between Himalayan region and the Cathaysia were not that great which prevented any intermixing.

The Jurassic palynoflora—In the Jurassic sediments of the Tethys Himalayan belt, the palynofloras are found to be qualitatively comparable in their constituents with almost all other contemporary Tethyan assemblages, but more pronounced resemblance is indicated with India and north-west Australia in the occurrence of podocarpaceous species. Certain forms, e.g., *Matonisporites, Ischyosporites, Concavisporites, Classopollis, Staplinisporites, Callialasporites, Podocarpidites* appear to be present in widely separated areas of circum-Tethys region, but quantitatively they are inconsistent as well as long ranging in distribution. *Classopollis* is an example which reveals a latitudinally controlled abundance in Eurasia and North Africa in the Late Jurassic with the highest frequency occurring nearest to the equator (Hughes, 1973). In other forms also, the qualitative comparisons suggest that Jurassic plants flourished under a wider spectrum of climate. Such a phenomenon of low diversity has been assigned to the temperature gradients which were gentle from equator to pole throughout Jurassic Period. This gave a less diversified character to the climate of the global area, and consequently, the occurrence of relatively more cosmopolitan elements was recorded. However, on reviewing the quantitative composition of assemblages, some differences amongst the Jurassic palynofloras are also clearly brought about. For example, plant microfossils from northern hemisphere are distinguished by paucity of Araucariaceous type pollen and monosulcate pollen, while they are abound in southern hemisphere (Filatoff, 1975; van Erve, 1977; Achilles *et al.*, 1984). Similarly, except for rare forms appearing to be cosmopolitan in distribution during Jurassic time, the palynoflora of Middle-East area has little affinity with the Tethys Himalayan palynoflora, when viewed after moderation of taxonomic discrepancies. It is concluded that although many elements appear to be widely represented in Jurassic palynofloras of the world, the quantitative differences exist and also the qualitative distinctions can be made at specific levels (Text-fig. 8).

The Himalayan Tethys at north-west and western region of India has a great influence of the Gondwanan elements of palynoflora. Positively during Permian and Triassic times, some mild influence of Cathaysia as well as Tarim are evident which indicates that the width of the Tethys sea at this time period was not as great as envisaged so far, but a shallow epicontinental sea must have had existed. India must not have been far away from northern block and the admixing, although of a limited nature, had existed in the circum-Tethys region. With this line of approach, the model proposed by Xuchang and Yanlin (1984) having accretion of four microplates drifted at different period and a narrower Tethys may explain the palynological reflections discussed here. Beside palynology, other palaeontological findings of Gondwanan elements in north Tibet and evidences from tectonics as suggested by Acharyya (1988, in this Volume) further support the contention of a greater Indian Plate extending up to north Tibet and a narrower Tethys. Does the Expanding Earth Theory answer to such indications? (*see* Carrey, 1983; Owens, 1983; King, 1983).

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