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Northern limits of the eastern Gondwana : palaeobotanical evidence

Hari K. Maheshwari & Usha Bajpai

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The northern margin of the Gondwanaland along the Indian block has been debated for sometime now. According to the earlier view the northern margin ran along the Indus-Yarlung-Zangbo Suture. Newly acquired data has been interpreted to show that eastern Gondwana was much bigger than generally believed.

In the present work we analyse the floras that grew around the northern margin of the eastern Gondwana assembly to see if the distribution of plant fossils also provides supporting evidence for a 'greater' India. The floras that have been examined in the present synthesis originate in the Permian of New Guinea, Sumatra (Indonesia), Malaysia, Thailand, Tibet, Northern China, Kashmir (India), Saudi Arabia, Iran, Iraq and Turkey and Mesozoic of Ladakh (India), Bhutan and Nepal.

The analysis shows that though some of the floral assemblages contain certain elements that could be of Gondwana affinity yet the overall composition of almost all the floral assemblages, except the one from Kashmir, is basically Cathaysian. Whether these Cathaysian type floral assemblages occupied the northern margin of the eastern Gondwana or they flourished on the southern margin of Laurasia, or they grew all along the shores of the Tethys, has to be examined.

The latitudinal variation in vegetation, however, does not seem to explain the intermixing of elements of different floral provinces in the coastal vegetation on the two shores of a fairly wide, though shallow, Tethys as in Kashmir and in southern Tibet. Even if both these regions were on the same side of Tethys, intermixing of Gondwana and Cathaysia floras is not explained as no direct migratory routes from Laurasia are available in Gondwana assemblies.

This coupled with the occurrence of northern Mesozoic flora at Fukche, Ladakh, and near Lhasa indicate that the Indian Gondwana did not extend north of the Indus-Yarlung-Zangbo Suture Zone.

Key-words—Gondwana, Indian Plate, Continental Drift.

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सारांश

पूर्वी गोंडवाना की उत्तरी सीमायें : पुरावनस्पतिक प्रमाण

हरिकृष्ण माहेश्वरी एवं ऊषा बाजपेयी

गोंडवाना के भारतीय ब्लॉक की उत्तरी सीमा वाद-विवाद का विषय रही है। पूर्व मतों के अनुसार उत्तरी सीमा सिंधु-यारलुंग-जाँगबो सूचर से परिलक्षणित थी। नये आँकड़ों की व्याख्या से अनुमान लगाया गया है कि पूर्वी गोंडवाना अपेक्षाकृत कहीं अधिक बड़ा था।

क्या पादपाश्मों का वितरण भी 'विशाल' भारत के लिए समर्थक प्रमाण जुटाता है? यह जानने के लिए उन वनस्पतिजातों का विश्लेषण किया गया है जो कि पूर्वी गोंडवाना की उत्तरी सीमा के आस-पास उगते थे। न्यू गिनी, सुमात्रा (इंडोनेशिया), मलेशिया, थाइलैंड, तिब्बत, उत्तरी चीन, काश्मीर (भारत), सउदी अरब, ईरान, ईराक एवं तुर्की के परमी कल्प में तथा लद्दाख (भारत), भूटान एवं नेपाल के मध्यजीवी कल्प के वनस्पतिजातों का विश्लेषण किया गया है।

विश्लेषण से व्यक्त होता है कि यद्यपि कुछ वनस्पतिजातीय समुच्चयों में ऐसे कुछ अवयव हैं जो कि गोंडवानी सजातीयता व्यक्त करते हैं, पर काश्मीर को छोड़कर प्रायः सभी वनस्पतिजातीय समुच्चयों की संरचना वस्तुतः कैथेसीय है। कैथेसीय प्ररूप वनस्पतिजातीय समुच्चय पूर्वी गोंडवाना की उत्तरी सीमा पर

Concepts, limits and extension of the Indian Gondwana
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प्रस्थापित थे या लॉरेशिया की दक्षिणी सीमा पर विकसित थे, अथवा टॅथीय तटों के संग-संग उगे हुए थे, इस विषय का अभी अध्ययन किया जाना है।

वनस्पति की अक्षांसी विभिन्नता से भी विस्तृत परन्तु छिछले टॅथीज़ की तटीय वनस्पति में विभिन्न वनस्पतिजातीय क्षेत्र के अवयवों का अन्तःमिश्रण सुस्पष्ट नहीं होता जैसा कि काश्मीर एवं दक्षिणी तिब्बत में है। यहाँ तक कि यदि ये दोनों क्षेत्र टॅथीज़ के एक ही ओर विद्यमान थे तो भी गोंडवाना एवं कैथेसीय वनस्पतिजातों का अन्तःमिश्रण स्पष्ट नहीं होता।

फ़ुक्से, लद्दाख एवं ल्हासा के समीप उत्तरी मध्यजीवी वनस्पतिजात की उपस्थिति के साथ-साथ इससे इंगित होता है कि भारतीय गोंडवाना सिंधु-यारलुँग-जाँगबो सूचर क्षेत्र के उत्तर में विकसित नहीं था।

THE concept of an Indo-oceanic Supercontinent—the Gondwana—that developed with Suess, has been so well discussed in the past in all its aspects that it needs no introduction. The generally accepted reassembly of the Gondwana Supercontinent comprises two segments: (i) western Gondwana consisting of South America and Africa; possibly Iran-Afghanistan as well, and (ii) eastern Gondwana consisting of Antarctica, Australia and India (Map 1). (We have dropped the suffix 'land' from Gondwanaland as *Gondwana* in vernacular means *land of Gonds*).

The northern margin of the eastern Gondwana has been variously demarcated and has recently become a matter of much discussion or rather speculation. Earlier it was believed that the northern limit of the Indian Gondwana block extended along the Indus Suture Line (Jhingran, Thakur & Tandon, 1982; Shanker, Padhi, Prakash, Thussu & Das, 1982; Nandy, 1982). A few others believe that the Central Crystalline Axis (south of Indus Suture Zone) represents the northern limit of the Indian Plate.

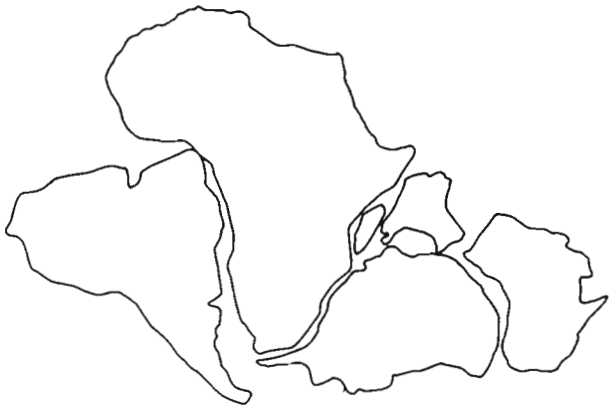
Crawford (1974a, b) opined that the Indus Suture Line is a relic of Permian-Jurassic oceanic opening rather than a relic of oceanic subduction preceding collision. He postulated a Gondwana Supercontinent much bigger than generally believed. The northern boundary of the Indian Plate was pushed beyond Tibet on the north side of the Tarim Basin block and was supposed to probably include parts of northern China, forming one huge crustal unit, the southern half emerged, the northern submerged. Along the former northern oceanic boundary of the Gondwana now lie the Shan mountains. Kaila and Narain (1981) have expressed almost identical views. Rastogi (1981) does not agree with this hypothesis. According to him 'if the northern boundary of the Indian Plate is placed in Central Asia it would pass through some of the stable blocks and cut across or include some portions of very large strike-slip faults'.

However, Crawford (1982, p. 291) changed his opinion and declared that 'There is no evidence whatsoever for assuming that the fragment was more than slightly larger than the present Peninsular continental unit, though it appears always to be assumed by workers that it was very substantially larger'. He also opined that India was never very far from Asia. Carey (1982, p. 401) also believed that 'India has never been further from Asia than she now lies'.

Audley-Charles (1983) proposed substantial additions of large continental blocks to the Gondwana thus drastically changing the northern contour of the eastern Gondwana. These blocks include Turkey, Iran, central Tibet and Indochina besides southern Tibet, Burma, Thailand, Malaysia and Sumatra. Tarling (1972) had earlier gone to the extent of suggesting that southern China and possibly southern Korea were both attached to India and lay west of Australia.

Patriat and Achache (1984) analysed the palaeomagnetic data from southern Tibet and suggested that 'greater' India extended between 500 and 1,000 kilometers further north of than the present northern limit of the Indian subcontinent but that southern Tibet formed southern margin of Eurasia. The northern margin of India collided with Ladakh Island Arc before anamoly 24 (53 Ma). India and Australia became part of the same plate after anamoly 20 (44 Ma). Between these two events about 400 kilometers of Indian continental crust subducted beneath southern Tibet.

Further support to the views detailing the concept of 'greater' Gondwana is derived from several disciplines. For example, the distribution of *Daphniopsis* in Antarctica, Australia, Tibet and Inner Mongolia suggests association of Tibet with Australia (Servenly, 1929). The known distribution of the labyrinthodont *Lystrosaurus* in Tarim, India, South Africa and Antarctica can also be explained under this assumption (Termier & Termier, 1981). It may be noted here that palaeomagnetic evidence shows that the Tarim block was a part of Laurasia in Late Permian (McElhinny *et al.*, 1981). The distribution of conodonts in the Triassic is interpreted to favour placement of Iran adjacent to Arabia and Malaysia adjacent to northwestern Australia and Timor as a part of Gondwana margin (McTavisch, 1975). The distribution of other major groups of marine fauna has also been taken into consideration for grouping southern Tibet, Burma and Southeast Asia at the northern margin of eastern Gondwana. However, Stauffer and Gobbelt (1972) have pointed out that



Map 1—Configuration of Gondwana during Early Permian.

these faunas and lithofacies indicate a tropical or subtropical climate and hence Southeast Asia could not have formed a part of the Gondwana. Palaeomagnetic evidence also does not support the view that Malaysia was a part of the Gondwana (McElhinny *et al.*, 1974).

Tiwari *et al.* (1980) reportedly found Gondwana palynotaxa in the Tibetan Series of the Malla Johar area in Kumaon Himalaya and postulated that this find supports the position of the Indian Plate boundary beyond Tibet in China. It is worth while to record here that almost all the palaeobotanists believe and admit that Tibet had a typical Cathaysian Flora (Li & Yao, 1982).

From the foregoing summary of some of the major works following controversial points arise that need our attention:

(i) The eastern segment of Gondwana was much bigger than previously delineated and that its northern territory included southern Tibet, Northern China and most of Southeast Asia;

(ii) The Indian block extended further north of Indus Suture Line, may be from 2,600 to 4,000 kilometers and that the northern margin of the Indian Plate corresponded with the Tien Shan Ranges, north of Tarim Basin.

In the present work we are concerned mainly with an indepth analysis of the floras that grew around the northern margin of the eastern Gondwana assembly. We examine the palaeofloras to extract supporting evidence, if any, for a 'greater' eastern Gondwana or 'greater' India. A serious attempt in this direction has been lacking probably due to the fact that no accepted diagnosis of a typical Gondwana Flora is available. The genetic affinity of the so-called mixed floras has also been unclear.

We consider a typical Gondwana Flora to be one that is of Early Permian to Late Triassic age and more or less conforms to any one of the peninsular Indian Gondwana floras. The simple occurrence of *Glossopteris*-like leaves outside the main Gondwana provinces does not automatically depict a Gondwanic affinity or connection to a flora unless supported by the presence of typical fertiligers or atleast by the *Vertebraria* axes. *Glossopteris*-like leaves are infact reported from the Rhaeto-Liassic of Vietnam and Yunnan (Zeiller, 1902-1903) and Upper Triassic to Middle Jurassic of Central America (Delevoryas & Person, 1975; Ash, 1981) besides from the Upper Permian of many parts of Soviet Union (Zimina, 1967) and Mongolia (Bobrov & Neuburg, 1957). But we know for sure that these leaves do not represent the *Glossopteris* plant. The glossopteroid venation is reported to occur in a number of unrelated gymnosperms (Chaloner & Meyen, 1973), for example, *Zamiopteris, Pursongia, Mexiglossa, Sagenopteris*, etc. Of course, there is also much difficulty in defining a typical Jurassic—Cretaceous Gondwana Flora because a large number of taxa is cosmopolitan.

The sporadic presence of a sterile northern or southern element, particularly at generic level, does not necessarily make a flora a mixed one, for example, the equisetale *Schizoneura*, originally reported from the Middle Triassic of Europe, has a wide lateral and vertical distribution. It is reported from the Permian of Gondwana, Korea and Japan, Middle Triassic of Australia, Upper Triassic of New Mexico, South Africa, Europe, Siberia and Korea and Lower-Middle Jurassic of Europe (Ash, 1985). But the fructifications of this genus wherever known are different. The same is also true for the genera *Neocalamites* and *Phyllotheca* (Meyen, 1971). Even the distribution of the genera *Sphenophyllum* and *Rhipidopsis* needs a critical reappraisal. All such occurrences need critical reappraisal of (i) their identification, (ii) the reason for their presence, if confirmed—accidental transport, homoplasy in that organ, or actual occurrence. Otherwise one may unwittingly draw fanciful conclusions.

For example, the species *Glossopteris angustifolia, Glossopteris indica, Palaeovittaria kurzii* and *Noeggerathiopsis hislopii* identified in Rhaeto-Liassic of Yunnan and Vietnam were taken as solid evidences of migration of Gondwana elements in the Cathaysia Flora. However, we know that these were wrongly identified (Hsü, 1978). According to Pant (1975) 'there are hardly any structurally or reproductively identified common forms between Late Palaeozoic floras of Laurasia and Gondwanaland'. According to Edwards (1955) 'records of northern glossopterids should now be treated with utmost suspicion unless they are based on very characteristic fructification.'

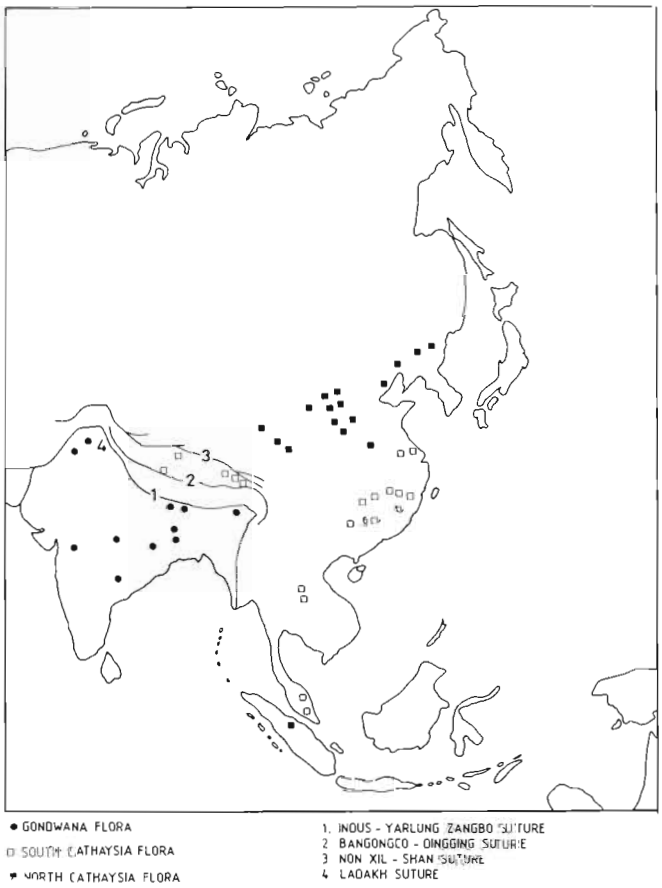
In our definition of the Gondwana floras we have intentionally left out taxa based on spores and

pollen because their taxonomy and nomenclature are still in a developing stage. It would seem that (i) only a limited number of characters is available for permutation and combination, and (ii) spores and pollen being enclosed in sporangia and pollen sacs respectively did not get much exposure to the vagaries of nature and hence there is not much differentiation geographically at any given period of time. The major phytochorias of the Permian Period are: the Euramerica, the Angara, the Cathaysia and the Gondwana. Vakhrameev *et al.* (1970) designate the Gondwana phytochoria as the Gondwana Kingdom and the other three phytochorias as Union of Northern Kingdoms.

The Euramerica Flora extended from Oregon in the west to Urals in the east. The Angara Flora occupied the Siberian region. The Cathaysia Flora covered much of China and extended as south as Sumatra. The Gondwana Flora covered all the southern continents and India.

The Euramerican palaeofloristic province mostly has a lepidodendrid rich assemblage with a fair intermingling of calamites, sphenophylls and pteridosperms. The appearance of *Callipteris conferta* and the presence of *Lebachia* and *Ernestiodendron* mark the Lower Permian. The Angara Flora is generally poorer in lycopods but has many endemic distinctive cordaites and pteridosperms. In the Cathaysia, *Lobatannularia* seems to have been distinctive genus alongwith *Tingia, Emplectopteris* and *Cathaysiopteris*. *Gigantopteris* and allies mostly occur in the upper phase of the Cathaysia Flora. The main constituent elements of the Gondwana Flora are *Raniganjia, Trizygia, Gangamopteris, Glossopteris, Palaeovittaria, Pteronilssonia, Rhabdotaenia, Vertebraria, Noeggerathiopsis, Dicroidium, Glossotheca, Eretmonia, Ottokaria, Dictyopteridium, Lidgettonia*, etc.

The floras that are examined in the present synthesis originate in the Permian of New Guinea, Sumatra, Malaysia, Thailand, southern Tibet, central Tibet, northern Tibet, northern China, Iran, Iraq, Saudi Arabia, Turkey, Kashmir and Mesozoic of Tibet, Nepal and Bhutan.



Map 2—Distribution of Gondwana and Cathaysia floras with relation to each other.

TURKEY (Hazro Flora)

Wagner (1959, 1962) recorded some Gondwana elements in an otherwise typical Cathaysian Flora of Late Permian age from Hazro, Southeast Anatolia. Biogeographically this region was earlier considered to be a part of the Euramerica Province. Most important amongst his finds was a leaf resembling *Glossopteris stricta* Bunbury 1861 (later renamed as *Glossopteris anatolica* Archangelsky & Wagner, 1983). However, according to Plumstead (in discussion on the paper of Wagner, 1962) the Hazro *Glossopteris* may not be related to the Gondwana plant. She rightly remarked that it is 'unwise to extend a name, which is already the subject of much confusion, to a new leaf from a distant area'. In the words of Asama (1966, p. 188) 'in fossil plants the form-genus merely refers to a similarity of form and does not necessarily signify the same genus of the same phylogenetic relation'. In our opinion, too, parataxa based on detached organs may not always be related and could have belonged to different eutaxa. In the absence of a definite glossopterid fertiliger and the root axis *Vertebraria* in the Hazro Flora, and in the lack of knowledge about its fine structure, the affinity of the Hazro *Glossopteris* with the Gondwana plant remains suspect.

Another plant of supposed Gondwana affinity in the Hazro Flora is that figured as *Dicroidium*? vel *Thinnfeldia*? sp. Lacey (in discussion on the paper of Wagner, 1962) compared these specimens with the basal part of a frond of *Neuropteridium validum* Feistmantel and later (Lacey, 1975, p. 129) placed it under the genus *Gondwanidium* Gothan which

many believe is a junior synonym of the genus *Botrychiopsis* Kurtz. Three species of the genus *Botrychiopsis* have been recorded but the Hazro specimen is so fragmentary that it can not be compared with any of these. The Hazro material is inadequate for a proper identification. Two other species from the Hazro Flora, viz., *Pecopteris phegopteroides* (Feistmantel) and *Cladophlebis roylei* Arber, supposed to indicate a Gondwana affinity, have now been transferred to *Pecopteris nitida* Wagner and *Cladophlebis tenuicostata* (Halle), respectively (Archangelsky & Wagner, 1983).

It is thus evident that there is no element in the Hazro Flora that may even remotely suggest a Gondwana connection. The revised list of the taxa identified in the Hazro Flora is as under:

Lobatannularia heianensis (Kodaira) Kawasaki
Sphenophyllum sp. cf. *S. koboense* Kobotake
Botrychiopsis sp. ?
Pseudomariopteris hallei (Stockmans & Mathieu) Wagner
Cladophlebis tenuicostata (Halle) Archangelsky & Wagner
Sphenopteris sp.
Pecopteris calcarata Gu & Zhi
Dizeugotheca sp. ?
Pecopteris nitida Wagner
Pecopteris pirae Wagner
Fascipteris hallei (Kawasaki) Gu & Zhi
Glossopteris anatolica Archangelsky & Wagner
Bicoemplectopteris hallei Asama
Taeniopteris sp.
Cordaites sp.

The overall assemblage has a typical Cathaysian aspect. The Gondwana connection of the flora is not proved inspite of the contention of Archangelsky and Wagner (1983) that the Hazro Flora is of very Late Permian (Dzhulfian) age, the Anatolian species of *Glossopteris* had sufficient time to migrate northwards from northern India. Had it been so, we should find its remnants in the Permian floras of Afghanistan and Iran. The Permian flora of Afghanistan comprises a mixture of Cathaysian and Angaran elements, e.g. *Lobatannularia* sp., *Pecopteris* sp. cf. *P. hemiterioides, Pecopteris* sp. cf. *P. cyathea* and *Taeniopteris* sp. The Upper Permian flora of Afghanistan has characteristic fossils of the Zechstein (Vozenin-Serra, 1984). It is also necessary to take into account the view that *Glossopteris* was a temperate plant whereas Anatolia lay on the southern margin of Permian fusilinid belt indicating a tropical to subtropical climate (Craig, 1961).

SAUDI ARABIA (Unayzah Flora)

Permian strata of Unayzah and Khuff formations in Qasim Province, Saudi Arabia have yielded three successive floral assemblages (El-Khayal, Chaloner & Hill, 1980; Lemoigne, 1981; Hill & El-Khayal, 1983; El-Khayal & Wagner, 1985). The age of the Unayzah Formation is probably early Late Permian while that of the Khuff Formation is later Late Permian. The Unayzah Flora has following taxa:

Lobatannularia lingulata (Halle) Kawasaki
Sphenopteris spp.
Cladophlebis sp.
Fascipteris hallei (Kawasaki) Gu & Zhi
Qasimia schyfsmae (Lemoigne) Hill *et al.*
Dizeugotheca sp. ?
Pecopteris pirae Wagner
Pecopteris sp.
Gigantonoclea sp.
Cordaites sp. cf. *C. principalis* Germar

This flora shows a certain resemblance with the Hazro Flora of Turkey in the common presence of *Fascipteris hallei, Dizeugotheca*? and *Pecopteris pirae*. Surprisingly, however, the Unayzah Flora has no element which may even remotely suggest a Gondwana link. The specimen with reticulate venation identified as *Zamiopteris* sp. by Lemoigne (1981) is not related to the glossopterids.

The Khuff Formation Flora comprises (Hill & El-Khayal, 1983):

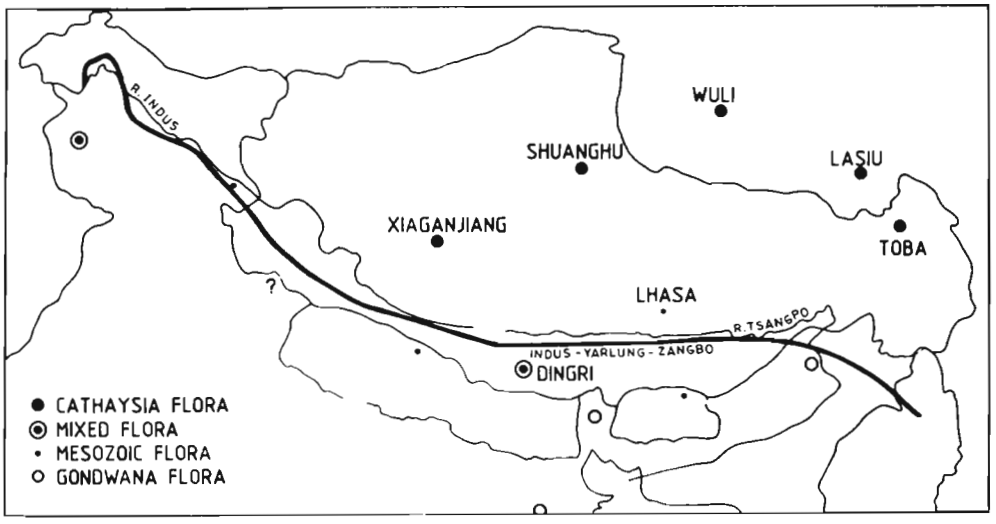
Palaeonitella tarafiyensis Hill & Wagner
Pecopteris sp.
Taeniopteris
Ulmannia
Pseudovoltzia liebeana (Geinitz) Florin
Culmitzschia sp.
Female cone

These are all characteristic elements of Late Permian Euramerican flora.

It is to be noted that the Unayzah and the Khuff floras occur much to the south of Hazro Flora, comparatively near to India and East Africa. If any migration of Gondwana plants into Turkey took place from East Africa, Saudi Arabia should have been *en route*. Even the Permian Ga'ara Flora of Iraq has only typical Cathaysian elements, e.g. *Lobatannularia heianensis* and *Plagiozamites oblongifolius* (Ctyrôky, 1973). The total absence of Gondwana elements in the Permian of Saudi Arabia and Iraq further reduces the possibility of any such occurrence in the Permian of Turkey. Evidently, Afghanistan, Iran, Iraq, Turkey and Saudi Arabia did not form part of the Gondwana floral province.

SOUTHERN TIBET (Qubu Flora)

Hsü (1973) reported a very interesting flora of supposed pure Gondwana affinity from Wolulio, about 30 kilometers north of Mount Jolmo Lungma in Dingri District. He recorded *Glossopteris*



Map 3—Distribution of Gondwana, Cathaysia and mixed floras in relation to the Indus—Yarlung—Zangbo Suture.

communis Feistmantel, *Sphenopteris* sp. cf. *S. hughesii* (Feistmantel) Arber and *Pecopteris* sp. and correlated the beds with the Raniganj Formation of the Indian peninsula.

In 1976, Hsü reported an interesting assemblage of presumed pure Gondwana affinities from the Qubu Formation around Qubu and Kujian, Pazhuo Region, Dingjie District. It is reported to have a predominance of *Glossopteris communis* Feistmantel. Other species recorded are *Glossopteris angustifolia* Brongniart, *Glossopteris indica* Schimper, *Trizygia speciosa* Royle, *Raniganjia qubuensis* Hsü, *Dizeugotheca qubuensis* Hsü and *Dichotomopteris qubuensis* Hsü. This flora, too, is compared with that of the Raniganj Formation.

The fern specimens from Woluluo (Hsü, 1978, p. 132) are too fragmentary to be definitely identified even at generic level. *Raniganjia qubuensis* is believed to belong to the typical Cathaysian genus *Lobatannularia* (Singh *et al.*, 1982). *Dichotomopteris qubuensis* is conspecific with *Pecopteris* sp. cf. *P. arcuata* (Li, 1986) and *Dizeugotheca qubuensis* has been transferred to *Pecopteris qubuensis* (Li, 1983). The venation pattern of *Sphenophyllum (Trizygia) speciosum* illustrated by Hsü (1976, pl. 1, figs 2, 3) does not resemble that of typical *Trizygia speciosa* from the Raniganj Formation. None of the *Glossopteris*-like leaves is complete; no glossopterid fertiliger or *Vertebraria* axes are associated. The fine structure of these leaves is also not known. In the absence of anatomical and reproductive criteria it is hardly justifiable to identify fragmentary specimens with the Indian species (Kon'no, 1968, p. 202).

CENTRAL TIBET (Xiagangjiang Flora)

Li, Wu and Fu (1985) have reported a Permian flora from Xiagangjiang of Gerze District. In all they have identified 17 taxa at species level, of which 6 taxa are assigned a Gondwanan affinity, 3 taxa a Cathaysian affinity; the affinities of the other 8 taxa are not known. However, a look at the photo-illustrations of the so-called Gondwana elements shows that the identifications need confirmation. *Phyllotheca* sp. cf. *P. australis* and cf. *Schizoneura gondwanensis* are recognised only from ribbed stems. However, in the absence of leaf-sheaths these genera can not be identified. Li *et al.* (1985, p. 166) too, believe that 'It is impossible to identify these stem-casts precisely, since species of *Phyllotheca* and *Schizoneura* commonly show little variations in external morphology of their stem-casts'. As mentioned earlier these two genera even otherwise have a wide distribution but the Gondwanan, Cathaysian and Angaran articulates are not genetically related even though the foliage is superficially similar. Their fertile structures differ considerably. The other Gondwana genus identified is *Noeggerathiopsis*. The specimens are badly preserved and in the absence of a cuticle it is difficult to say if they do not belong to *Cordaites*—a northern genus.

NORTHERN TIBET (Shuanghu Flora)

This is supposed to be westernmost extension of the typical Cathaysian flora and is known from Changdu and Shuanghu. The Shuanghu Flora occurs

within 250 kilometers northeast of Arunachal Gondwana in India. The taxa recorded are:

Lepidodendron sp.
Annularia pingoloensis
Lobatannularia multifolia
Sphenophyllum sp.
Pecopteris echinata
Pecopteris shuanghuensis
Gigantonoclea quizhouensis
Compsopteris contracta

This flora is totally different from that of central Tibet or southern Tibet and is similar to that of the Panxians (Hsü, 1978). Even the Late Triassic palynological assemblage from the Togmela Formation in northern Tibet (Shang, 1980) is different from Late Triassic palynological assemblage from India (Maheshwari & Kumaran, 1979; Kumaran & Maheshwari, 1980) or Australia (Dolby & Balme, 1979).

SOUTHERN CHINA (Longtang Flora)

Lee (1974) recorded the occurrence of:
Sphenophyllum speciosum
Glossopteris quizhouensis
Schizoneura manchuriensis
Phyllotheca sp. cf. *P. etheridgei*
Rhipidopsis sp. cf. *R. ginkgoides*
in the Longtang Flora and postulated a close Gondwana connection.

According to Hsü (1978) *Schizoneura manchuriensis* is distinct from the Gondwana schizoneuras. *Phyllotheca* and *Rhipidopsis* are quite common in the Angara Flora as well (Vakhrameev *et al.*, 1970). *Glossopteris quizhouensis* is too poorly preserved to be correctly identified.

INDIA (Mammal Flora)

The Upper Palaeozoic Sequence of the Kashmir Valley shows six plant-bearing horizons; the lower four contain a Devonian—Lower Carboniferous flora and the top two have yielded a Lower Permian flora (Pal, 1978; Singh *et al.*, 1982; Pant *et al.*, 1984). Ahmad *et al.* (1978) date the two upper plant beds as Lower and Upper Permian respectively.

The Upper Palaeozoic succession in the valley is:

Upper Permian	— Zewan Formation	
	— Mammal Formation	— Plant bed 6
Lower Permian	— Panjal Volcanic	
	— Nishatbagh Formation	—Plant bed 5
Upper Carboniferous	— Agglomeratic Slate	
Lower Carboniferous	— Fenestella Shale	—Plant beds 3-4
	— Syringothyris Lst	— Plant bed 2
Upper Devonian	— Aishmuqam Formation	— Plant bed 1
Muth Quartzite		

The Permian megafossil assemblage of the valley is somewhat similar to that of the peninsula but has some characteristic Cathaysian elements. There are many reports on the Permian flora of Kashmir. Hazra and Prasad (1957) and Kapoor (1969) recorded:

Lepidodendron sp.
Alethopteris whitbyense Göppert
Pecopteris phegopteroides Feistmantel
Gangamopteris angustifolia McCoy
Gangamopteris kashmirensis Seward
Glossopteris communis Feistmantel
Glossopteris indica Schimper
Noeggerathiopsis hislopii (Bunbury) Feistmantel
Taeniopteris feddenii (Feistmantel) Arber
Taeniopteris kashmirensis Hazra & Prasad
Psygmophyllum haydenii Seward
Psygmophyllum sahnii Ganju
Vertebraria indica Royle

Apparently this flora has a pure Gondwana affiliation. But recently, Singh *et al.* (1982) and Pant *et al.* (1984) have discovered a number of Cathaysian elements in the Permian of the valley. This flora needs a thorough reinvestigation, but the present list reads:

Sphenophyllum thonii Mahr (varieties)
Trizygia speciosa Royle
Lobatannularia ensifolia Halle
Lobatannularia lingulata Halle
Lobatannularia sinensis var. *curvifolia* Kon'no & Asama
Rajahia mamalensis Singh *et al.*
Gangamopteris kashmirensis Seward
Glossopteris longicaulis Feistmantel
Glossopteris nishatbaghensis Singh *et al.*
Glossopteris intermittens Feistmantel
Glossopteris sp. cf. *G. communis* Feistmantel
Glossopteris sp. cf. *G. feistmantelii* Rigby
Glossopteris sp. cf. *G. taeniopteroides* Feistmantel
Glossopteris angustifolia Brongniart
Psygmophyllum haydenii Seward
Psygmophyllum sahnii Ganju
Vertebraria sp.
? Cordaites sp.
? Nummulospermum sp.

Though no glossopterid fertiliger has so far been reported, the definite record of *Vertebraria* from one of the localities (Hazra & Prasad, 1967, pl. 10, fig. 9) points towards a Gondwana assemblage notwithstanding the presence of several elements having an undoubted Cathaysian affinity. Pant *et al.*

(1984) doubt the presence of the Genus *Rajahia* in the Kashmir flora. *Sphenophyllum thonii* like plants are known from the peninsula, too (Srivastava & Rigby, 1983; Singh, Srivastava & Maheshwari, 1988).

Mention may also be made here of the discovery of Upper Palaeozoic plant fossils from the Blaini-Infrakrol Sequence exposed in a stream cutting near Birbhatii (*vern.* Bir = Beer, bhatii = brewery), Nainital area (Tewari & Singh, 1981). The floral assemblage is reported to comprise: *Lepidodendron* sp., *Calamites* sp., *Annularia* sp. cf. *A. stellata, Phyllotheca* sp. cf. *P. indica, Sphenophyllum* sp., *Gondwanidium* sp., *Gangamopteris* sp. and *Glossopteris leptoneura*. Unfortunately later attempts by many field parties have failed to locate even a single plant fossil in this area and hence this report is not authentic. It is possible that some fossiliferous shale that came mixed with the coal for the brewery was rejected and dumped. With the closure of the brewery, the origin of the dump was forgotten and later strew shale was inadvertently collected as if it was *in situ*.

Tiwari *et al.* (1984) have reported the occurrence of Gondwana spores-pollen in the Malla Johar area of the Kumaon Himalaya. However, the perservation of the microflora is highly unsatisfactory and hence much remains to be done about taxonomy and nomenclature. The preservation is so poor that a specimen originally identified as pteridophytic cf. *Deltoidospora* (Tiwari *et al.*, 1980, pl. 1, fig. 10) was later identified by the same group as gymnospermous *Callialasporites dampieri* (Tiwari *et al.*, 1984, pl. 2, fig. 11). Presence of some modern contaminants also can not be ruled out (Maheshwari, 1982). Malla Johar being located to the north of Main Central Thrust, in alignment with the Dingri locality of Tibet, might have had some Cathaysian elements but the authors have made no comparison with the Cathaysian palynological assemblages (e.g. Onyang, 1964). They have rather tried to decipher an Angara link overlooking the fact that the intervening areas of Tibet had a Cathaysian Flora. Of the thirty odd genera of palynofossils identified by Tiwari *et al.* (1984) from the Malla Johar Succession, atleast 16 genera were first reported in the northern palynological assemblages.

It may be mentioned here that in Arunachal Pradesh, south of the Main Boundary Fault, typical Gondwana mega- and palyno-taxa do occur (Jacob & Banerji, 1954; Srivastava & Dutta, 1977; Acharyya *et al.*, 1979). These include *Phyllotheca griesbachii, Schizoneura gondwanensis, Glossopteris angustifolia, G. conspicua, G. damudica, G. formosa, G. indica, G. longicaulis, G. stenoneura, Gangamopteris cyclopteroides, Vertebraria indica, Dictyopteridium* sp., *Samaropsis* sp. and probably *Trizygia speciosa*.

THAILAND (Phetchabun Flora)

Permian plant fossils were first discovered by Komalarjun at Khlong Wang Ang, Changwat, Phetchabun. Kon'no (1963) identified following taxa:

Bowmanites sp.
Sphenophyllum trapaefolium Stockmans & Mathieu
Alethopteris thailandica Kon'no
Glossopteris sp. cf. *G. angustifolia Brongniart*
Palaeovittaria parvifolia Kon'no
Taeniopteris sp. cf. *T. serrulata* Kon'no
Taeniopteris hallei Kawasaki
Poacordaites phetchabunensis Kon'no

According to Kon'no (1963) 'the Phetchabun flora contains the typical Glossopteroideae, which authenticates the direct migration of the Gondwana floral elements into the Cathaysian floral province through some passageways from the neighbouring Gondwanaland'.

The prospect of cold-temperate Gondwana elements migrating into a warm and humid Cathaysian Province, crossing a wide, though shallow Tethys can not be comprehended. Asama (1966) therefore re-examined the glossopterids in the Kon'no collection and found them to be 'imperfect and few, being one each for the species'. The leaves are so poorly preserved that even the venation is not seen. To confirm the presence of the glossopterid elements in the Phetchabun Flora, Asama made further collection of fossil plants from the same area and identified the following taxa:

Sphenophyllum phetchabunense Asama
Pecopteris sp.
Protoblechnum wongii Halle
Taeniopteris thailandica Asama
Taeniopteris nystroemii Halle
Taeniopteris konnoi Asama (= *T.* cf. *serrulata* of Kon'no)
Taeniopteris hallei Kawasaki
Taeniopteris iwaii Asama
Taeniopteris sp.
Cordaites principalis (Germar) Geinitz
Poacordaites linearis Grand'Eury (= *P. phetchabunensis* of Kon'no)
Psygmophyllum komalarjunii Asama
Samaropsis sp.

Evidently, the Asama collection does not contain even a single glossopterid element and hence any connection of the Phetchabun Flora with the Gondwana Flora, either through migration or otherwise, may be ruled out completely.

THAILAND (Loei Flora)

Permian fossil plants have also been discovered at Loei, north-north-east of Phetchabun. Though the

specimens are fragmentary and poorly preserved, yet following taxa have been identified (Asama, Iwai, Veeraburas & Hongnusonthi, 1968):

Sphenophyllum oblongifolium (Germar & Kaulfass) Unger
Pecopteris lativenosa Halle
Pecopteris hemiterioides Brongniart
Ptychocarpus sp.
Shirakiopteris loeiensis Asama
Alethopteris sp.
Protoblechnum wongii Halle
Bicoemplectopteridium longifolium Asama
?Bicoemplectopteris hallei Asama
?Gigantonoclea lagrelii (Halle) Koidzumi
Taeniopteris nystroemii Halle
Taeniopteris hallei Kawasaki
Poacordaites sp.
Samaropsis sp.

Though, the location of the Loei Flora is geographically close to that of the Phetchabun Flora, yet the former does not possess a single, even doubtful, Gondwana element. It rather has some elements that are typical to the Gigantopteris Flora, e.g. *Bicoemplectopteridium longifolium*, *Bicoemplectopteris hallei* and *Gigantonoclea lagrelii*. Some elements are typically Cathaysian, e.g. *Pecopteris lativenosa, Protoblechnum wongii* and *Shirakiopteris loeiensis*. It is thus evident that during the Permian, Thailand had no Gondwana connection.

MALAYSIA (Jengka Flora)

Kon'no and Asama (1970) have recorded the following taxa from the Permian flora of the Jengka Pass, Pahang, West Malaysia:

Paratrizygia koboensis (Kobatake) Asama
Annularia shirakii Kawasaki
Lobatannularia johorensis Kon'no & Asama
Lobatannularia suntharalingami Kon'no & Asama
Calamitaceae (ramulus)
Neuropteridium yokoyamae Kon'no & Asama
Neuropteris sp.
Pecopteris arcuata Halle
Bicoemplectopteris hallei Asama
Cathaysiopteris sp. cf. *C. whitei* (Halle) Koidzumi
Protoblechnum sp. cf. *P. wongii* Halle
Taeniopteris iwaii Asama
Taeniopteris multinervis Weiss
Taeniopteris latecostata Halle
Taeniopteris shansiensis Halle
Taeniopteris taiyunanensis Halle
Taeniopteris sp. cf. *T. thailandica* Asama
Cordaites schenkii Halle
Cordaites sp. cf. *C. simplicinervis* Jongmans & Gothan
Cordaianthus sp. cf. *C. volkmannii*
Trigonocarpus

The Jengka Flora contains a number of index-fossils of Upper Shihhotse Series which is equivalent to the northern Cathaysia Flora, but not a single Gondwana element.

MALAYSIA (Linggiu Flora)

Kon'no, Asama and Rajah (1970) investigated a Late Permian flora from Linggiu in the Gunong Blumut area in central Johore, very near to the Jengka Pass. They identify the following taxa:

Lepidodendron sp. cf. *L. chosenense* Kawasaki
Tingia subcarbonica Kon'no & Asama
Paratrizygia koboensis (Kobatake) Asama
Paratrizygia glossopteroides cf. *minor* (Kawasaki) Asama
Trizygia sinocoreanum (Yabe) Asama
Trizygia speciosa Royle
Calamites sp. cf. *C. suekowii* Brongniart
Annularia shirakii Kawasaki
Lobatannularia fujiyamae Kon'no & Asama
Lobatannularia johorensis Kon'no & Asama
Lobatannularia johorensis subsp. *minor* Kon'no & Asama
Lobatannularia suntharalingamii Kon'no & Asama
Cladophlebis ozakii Yabe & Oishi
Neuropteridium yokoyamae Kon'no & Asama
Neuropteris sp.
Pecopteris arcuata Halle
Pecopteris yinii Kon'no & Asama
Ptychocarpus malayanus Kon'no
Rajahia bifurcata Kon'no
Rajahia linggiuensis Kon'no
Rajahia pseudohemiterioides Kon'no
Rajahia rajahii Kon'no
Rajahia sengensis Kon'no
Bicoemplectopteridium longifolium (Kodaira) Asama
Bicoemplectopteridium hallei Asama
Gigantonoclea lagrelli (Halle) Koidzumi
Gigantopteris nicotianaefolia Schenk
Tricoemplectopteris taiyuanensis Asama
Validopteris sinensis Stockmans & Mathieu
Aphlebia spp.
Taeniopteris sp. cf. *T. crassicaulis* Jongmans & Gothan
Taeniopteris hallei Kawasaki
Taeniopteris sp. cf. *T. multinervis* Weiss
Taeniopteris nystroemii Halle
Sphenozamites sp.
Rhipidopsis baieroides Kawasaki & Kon'no

Cordaicarpus cordae cf. *elongata* Jongmans & Gothan

Gigantospermum posthumi Jongmans & Gothan

Carpolithus spp.

From the foregoing list it is evident that the flora contains distinctive index-fossils' of north Cathaysian *Gigantopteris-Lobatannularia* Flora.

INDONESIA (Djambi Flora)

The Djambi Flora is of great interest because it represents the southernmost occurrence of the Cathaysian elements, geographically very close to the present day India. The Djambi Flora was very luxuriant and comprised species of the following genera (Jongmans & Gothan, 1935; Jongmans, 1937, 1940):

Lepidodendron (3 spp.)
Lycopodites sp.
Stigmaria (2 spp.)
Maroesia rhomboidea
Calamites (2 spp.)
Annularia (2 spp.)
Asterophyllites (2 spp.)
Palaeostachya incrassata
Sphenophyllum (4 spp.)
Sphenophyllostachys sp.
Sphenopteris (9 spp.)
Monocarpia posthumii
Pecopteris (15 spp.)
Asterotheca (2 spp.)
Aphlebia (8 spp.)
Alethopteris strictinervis
Macroalethopteris hallei
Callipteridium (3 spp.)
Dictyocallipteridium sundaicum
Gigantopteris (3 spp.)
Neuropteris sp.
Neuropteridium sp.
Cyclopteris (3 spp.)
Taeniopteris (9 spp.)
Cordaites (3 spp.)
Poacordaites sp.
Artisia sp.
Cordaitanthus sp.
Cordaicladus sp.
Schuetzia sp.
Tobleria bicuspis
Cordaicarpus (6 spp.)
Rhynchogonicum permocarbonicum
Trigonocarpus sp.

Though this flora is supposed to represent the southernmost extension of the Cathaysia Flora, it rather has 27 Euramerican species as compared to only nine Cathaysian species; not a single Gondwanan element has been recorded. To us it seems that in the lesser known Southeast Asian floras, the identifications and nomenclature of fossils have mostly been subjective. This has depended upon the familiarity of the workers with floras of their own region.

NEW GUINEA

Jongmans (1940) reported Permian plant fossils from two localities in western New Guinea. One of the localities yielded:

Sphenophyllum verticillatum Schlotheim
Pecopteris unita Brongniart
Pecopteris sp. cf. *P. arcuata* Halle
Pecopteris sp. cf. *P. paucinervis* Jongmans
Pecopteris sp. cf. *P. orientalis* Schenk
Taeniopteris sp. cf. *T. multinervis* Weiss
Taeniopteris sp. cf. *T. taiyuanensis* Halle

The other locality, about 10 kilometers from the former, has yielded *Vertebraria* sp. This flora is considered to be of definite Cathaysian affinity and contemporary to the Djambi Flora of Sumatra, but the presence of *Vertebraria* sp. needs explaining.

Visser and Hermes (1962) investigated Permian plant megafossils from another 3 localities in the same general area and recorded following taxa:

Locality 3
Trizygia sp. cf. *T. speciosa* Royle
Cladophlebis sp. cf. *C. australis* Morris
Pecopteris monyi Zeiller
Pecopteris unita Brongniart
Validopteris sp.
Glossopteris sp. cf. *G. browniana* Brongniart
Locality 4
Glossopteris sp. cf. *G. indica* Schimper
Glossopteris sp. cf. *G. retifera* Feistmantel
Vertebraria sp.
Locality 5
Taeniopteris sp. cf. *T. hallei* Kawasaki

The fossils from locality 4 seem to have a Gondwana link in the presence of *Vertebraria* sp.

BHUTAN

Ganesan and Bose (1982) have reported rather poorly preserved plant fossils of Mesozoic age from the upper part of Mo Chu Formation in Lingshi Basin, Bhutan. Tiwari *et al.* (1984), however, locate the Lingshi Basin in Nepal.

The identifiable taxa are:

?Cladophlebis sp.
Pachypteris sp. cf. *P. indica* Bose & Roy
Ptilophyllum acutifolium Morris
Elatocladus jabalpurensis

Pagiophyllum sp.
Coniferocaulon sp. cf. *C. rajmahalense*

The overall composition of the Lingshi plant assemblage is said to be similar to that of the assemblages recovered from Jatamao in Satpura Basin and Kurbei in Kutch Basin. The Jatamao records are, however, not reliable because the fossiliferous rock was not collected *in situ*. The specimens were lifted from loose rabble around pillars erected to mark the boundary of forest divisions (vernacular Kup). Even otherwise the taxa recorded are not such that could be taken as typical Gondwanic. Interestingly, the palynoflora from the Jurassic Barishong Formation, too, has cosmopolitan palynotaxa (Pantic, Hochuli & Gansser, 1981). Palynotaxa from the Permian of Bhutan, on the other hand, seem to have a Gondwana affiliation (Banerjee & Das Gupta, 1983).

NEPAL (Kagbeni Flora)

Bordet, Krummenacher, Mouterde and Remy (1964) discovered a fossiliferous outcrop of Mesozoic age in the Kagbeni Sandstone in Thakkhola River near Kagbeni. Bordet, Colchen, Le Fort, Mouterde and Remy (1971) and Barale, Bassoullet and Bose (1976) identify following taxa in the assemblage:

Nilssonia orientalis
Otozamites abbreviatus
?Taeniopteris spatulata
Ptilophyllum acutifolium Morris
cf. *Ptilophyllum cutchense* Morris
Araucarioxylon nepalensis Barale *et al.*

The palaeobotanical data available is too meagre for postulating on genetic affinities of the flora. It may or may not have a Gondwana connection.

NEPAL (Taltung Flora)

Sakai (1983) collected plant fossils of Mesozoic age from the Taltung Formation outcropping at several localities between middle reaches of Kali Gandaki and Main Boundary Fault in Lesser Himalaya. Kimura, Bose and Sakai (1985) identify the following taxa:

Cladophlebis indica (Oldham & Morris) Sahni & Rao
? Sphenopteris sp.
Pachypteris sp.
Pterophyllum spp.
?Taeniopteris/Pterophyllum
cf. Ptilophyllum cutchense Morris
Weltrichia sp.
Elatocladus tenerrimus (Feistmantel) Sahni

Like the Kagbeni Flora, the Taltung Flora, too, has no marker taxa to indicate its genetic affinities, though Kimura *et al.* (1985) believe that their work 'further supports the view that Upper Gondwana extended right up to the Lesser Himalaya, east of Thakkhola Valley, Nepal.'

INDIA (Ladakh Flora)

Sharma, Gupta and Sah (1980) reported some Mesozoic plants from a newly discovered locality near Fukche, north of Indus Suture Zone, Ladakh. The plant assemblage as reinvestigated by Bose *et al.* (1983) comprises.

Raphaelia diamensis Seward
Piazopteris sp. cf. *P. branneri* (White) Lorch
Acrostichopteris sp.
Taeniopteris sp. cf. *T. uwatokoi* Oishi
Nilssonia sp.
Cycadites wadianus Bose *et al.*
Pterophyllum sp.
Anomozamites sp. cf. *A. minor* (Brongniart) Nathorst
Ptilophyllum sp.
?Zamites sp.
Desmiophyllum spp.
?Elatides sp.

Evidently, the Fukche assemblage does not show any Gondwana element. It is rather more like that of Jurassic of Tethys-Karakorum (Jacob & Shukla, 1955). According to Bose *et al.* (1983) the Fukche assemblage 'suggests that the region just to the north of the Ladakh Range in Demgti-Kayul area represents the southern margin of the Eurasian Landmass'.

Slightly older plant fossils have been reported from the Kayul Group exposed about 5 km south-west of the Fukche locality. These have been referred to *Cladophlebis* (*?Klukia*) sp. and *Cladophlebis* sp. (Sukh-Dev *et al.*, 1983). These taxa are so far not known from the peninsular Gondwana.

DISCUSSION

It is evident that though some of the Permian floral assemblages contain certain elements that apparently seem to have a Gondwanic affinity, yet the overall composition of all these assemblages is basically Cathaysian. Did these Cathaysian type floral assemblages occupy the northern margin of the eastern Gondwana or did they flourish on the southern margin of Laurasia?

The latitude usually controls temperature and precipitation, and hence the vegetation. Gondwana was a huge landmass and hence different communities of vegetation could have occupied

different latitudinal belts. For example, in South America and Africa there are no definite records of the Gondwana type of vegetation, north of the Amazon and north of Niger, respectively. Rather at places these areas have an Euramerican type of vegetation. It is, therefore, possible that the eastern Gondwana had a main Gondwana floral belt, to the north of which existed a Cathaysia floral belt. But the existence of such Gondwana and Cathaysia floral belts would imply a close connection with the main Cathaysian province that colonised China and also Southeast Asia. In case of such a close connection one would expect a rather generous intermingling of Gondwana and Cathaysian floral elements. But it is not so. Except for a couple of records of *Glossopteris* from Turkey and southern Tibet, no definite Gondwana element is known from regions stretching from Iraq to China to Sumatra. Even the genus *Glossopteris* refers to a generalised leaf form which may belong to biologically unrelated plants (Delevoryas, 1973). Similarly the calamite *Lóbatannularia* known from the Kashmir 'Gondwana' may not be related to the northern form. We have already seen that phyllothecas and schizoneuras of the north and south have different types of fructifications.

These vegetative types probably evolved independently, though not necessarily simultaneously, in different floristic provinces from related ancestral forms. During the Early Carboniferous Period, practically the same forms of plants occurred all over the world. Separation of Laurasia and Gondwana could have been a major cause of Late Carboniferous differentiation which became significant in the Early Permian. However, pre-Carboniferous germplasm being common, some of the features may have been repeated in Laurasia and Gondwana.

Foster (1978) and Meyen (1979) do not advise the use of palynotaxa, apparently common to two or more floristic zones, for correlation because these, too, may have resulted due to parallel evolution and may belong to biologically different plants. For example, disaccate-striate pollen have been found in the ovules of the Permian glossopterid *Senotheca* (Banerjee, 1969) and the Triassic conifer *Rissikia* (Townrow, 1969). We must, however, admit that in the Late Triassic and younger periods the quantum of 'shared' taxa is such that it can not be easily explained by parallel evolution. Probably by that time channels of emigration between Gondwana and Eurasia had again materialized. According to Colbert (1979, p. 139) Gondwana was somewhat less isolated from Laurasia in Late Triassic and by Middle Jurassic there was a route of intercontinental movements between the two.

Thus, the data at hand is as yet not convincing enough to support the concept of 'mixed' floras, atleast in Permian of eastern Gondwana. Apparently the Cathaysia and Gondwana floral provinces were widely separated from each other and occupied different climatic zones. Palaeontologic and palaeomagnetic data have been interpreted to show that Tibet, China and Southeast Asia had a tropical to subtropical climate and occupied an equatorial position up to 20° north during the Permian (Stauffer & Gobbelt, 1972; Vine, 1973; McElhinny *et al.*, 1981). The well-diversified fern taxa in the Cathaysia Flora also indicate warm, humid conditions of the tropical/subtropical equatorial belt. On the other hand, the Permian Gondwana vegetation thrived in a temperate climate at higher latitudes.

Palaeobotanical evidences therefore do not support the views that Southeast Asia, China and Tibet north of Indus-Yarlung-Zangbo Suture formed a part of eastern segment of the Gondwana Supercontinent (Map 2). The presence of a typical northern flora in the Jurassic of Fukche, Ladakh and a Cathaysian Flora in Permian of central Tibet firmly rules out the possibility of the Gondwana boundary extending beyond the Indus-Yarlung-Zangbo Suture (Map 3). The palaeomagnetic estimates, too, extend the Indian Plate margin only up to Dingri, the district in which Qubu Flora of southern Tibet is located (Besse *et al.*, 1984). A Wealden flora reported from Linbuzong and Niumagaon near Lhasa in Tibet also does not show any Gondwanic affinity. The flora comprises (Tuan *et al.*, 1977): *Weichselia reticulata* (Stokes & Webb) Ward, *Zamiophyllum buchianum* (Ettingshausen) Nathorst, *Cladophlebis Browniana* (Dunker) Seward, *Ptilophyllum* spp., *Taeniopteris* sp. and *Onychiopsis* sp. The Lower Cretaceous palynomorphs from Tibet also do not exhibit any Gondwana connection (Pons & Vozenin-Serra, 1984).

Though, we are not in a position to support Stauffer's (1974) view that Malaysia was originally attached to the northern coast of Africa, yet we agree with him that Tibet was not adjacent to India until after Oligocene—Miocene Period. The glacial deposits of Arabia or Tibet have to be explained in some other way. In case it is proved that 'mixed' floras did flourish in Kashmir and Tibet, then we shall have to look for alternative explanations. It is then possible that the Indian plate margin extended up to the Bangongco-Dingging Suture Zone and a typical Gondwana Flora occupied the territory A part that included Kashmir and southern Tibet broke away and migrated northwards to join northern Tibet by the Upper Permian. Northern Tibet already had a Cathaysia vegetation and this provided an

opportunity for an intermixing of Cathaysia and Gondwana floras in southern Tibet and Kashmir. This could have also provided *Glossopteris* a migration route to the Soviet Far-East via northern China. A separate Tibetan Plate has already been delineated by Pereira (1977) and McElhinny *et al.* (1981). However, this premise does not satisfactorily explain the Lower Permian occurrence of *Lobatannularia* in Kashmir.

In this case again it is more likely that the Indus-Yarlung-Zangbo Suture marked the northern limit of the Gondwanic India and that the exchange of some elements between subtropical Cathaysia and warm-temperate Gondwana floral provinces took place from northern China through central Tibet, Iran, Saudi Arabia, northern Africa to Kashmir and vice-versa. Such a migration route is supported by the Mesozoic distribution of *Matonidium* and *Phlebopteris*.

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