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Extra-peninsular 'Gondwana' basins—stratigraphy and evolution

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The stratigraphy and evolution of the plant-bearing horizons of the extra-peninsular region are reviewed and their similarities and differences with typical peninsular Gondwana are discussed to assess the problem of concepts, limits and extension of Gondwana in this region. It is inferred that the Lesser Himalayan Sequence represents continuation of the peninsular Gondwana Sequence, while that of Tethyan Himalayan region departs from typical mainland Gondwana in sedimentation, flora and geological set up. Thus the use of the informal stratigraphic term Gondwana Sequence for this belt is not justificable. However, the use of the term in palaeogeographic sense, which is widely used appears to be appropriate; for which the term 'Peri-Gondwana' has already been suggested. The evolution of floral beds may be related to the major tectonic events, the imprints of which are well documented in the Tethyan belt.

Key-words—Stratigraphy, Palaeogeography, Peninsular Gondwana (India).

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सारांश

बाह्य-प्रायद्वीपीय गोंडवाना द्रोणियाँ—स्तरविन्यास एवं विकास

हरी मोहन कपूर एवं गोपाल सिंह

बाह्य-प्रायद्वीपीय क्षेत्र के पादप-धारक संस्तरों के स्तरविन्यास एवं विकास की समीक्षा की गई है तथा इस क्षेत्र में गोंडवाना की अवधारणा, सीमायें एवं विस्तार की समस्या के निर्धारण हेतु सामान्य प्रायद्वीपीय गोंडवाना से इनकी सजातीयताओं एवं विभिन्नताओं की विवेचना की गई है। ऐसा अनुमान है कि लघु हिमालय अनुक्रम प्रायद्वीपीय गोंडवाना अनुक्रम की निरन्तरता का निरूपण करता है जबकि टॅथीय हिमालय क्षेत्र भूवैज्ञानिक स्थिति, वनस्पतिजात एवं अवसादन में सामान्य गोंडवाना मुख्यभूमि से पृथकता प्रदर्शित करता है। अतएव इस पट्टी के लिए अनौपचारिक 'गोंडवाना अनुक्रम' शब्द का प्रयोग उचित नहीं है। तथापि, पुराभौगोलिक दृष्टिकोण से इस शब्द का प्रयोग उचित प्रतीत होता है जिसके लिए 'पैरी-गोंडवाना' शब्द पहले से ही प्रस्तावित है। वनस्पतिजातीय संस्तरों का विकास प्रधान विवर्तनिक घटनाओं से सम्बद्ध किया जा सकता है और इसके प्रमाण टॅथीय पट्टी में भी सुपरिरक्षित हैं।

THE plant-bearing horizons of Palaeozoic-Mesozoic times in the extra-peninsular region, particularly in the Tethyan Himalaya, occur in the marine domain, unlike those of Gondwana of the peninsular region, where they are essentially of glacio-fluvial, fluvial and fluvio-lacustrine environment and continental in nature. In fact, Himalayan occurrences have been included under Gondwana due to the presence of Gangamopteris and Glossopteris flora. Inclusion of Tethyan Himalayan sequences under Gondwana also received support in the presence of diamictite and associated *Eurydesma* and Sakmarian marine fauna known from peninsular region and being so characteristic of other Gondwana countries.

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To the contrary, the Tethyan Himalayan sequence could be different from that of peninsular region due to the fact that the flora contains some elements which have affinity with the northern floras and the beds have a different stratigraphic set up with younger marine basement unlike in the Peninsula where it is always Precambrian. The lithology of the Himalayan beds has no genetic relationship with the peninsular Gondwana and have different environmental history. Further, there is no established continuity of Himalayan sequence with any of the peninsular sequences except linkage through marine beds which bear *Eurydesma* fauna.

In this paper, the distribution and stratigraphy of various plant-bearing horizons of extra-Peninsula, their comparison with peninsular occurrences in general and the evolution of plant horizons are discussed with the objective to assess the problem of concepts, limits and extension of Gondwana in this region.

DISTRIBUTION OF FLORAL HORIZONS

The plant beds in extra-Peninsula are known both in the Lesser and the Tethyan Himalayan belts. Rocks of the Gondwana Sequence in the Lesser Himalaya occur tectonically emplaced between Neogene-Quaternary deposits and Precambrian formations. They are developed semicontinuously from central Nepal to Arunachal Pradesh and mainly represent Lower Gondwana Sequence except a solitary record of Upper Gondwana in Tansen area of Nepal. From the Lesser Himalaya of Uttar Pradesh, and Himachal Pradesh no definite sequence of Gondwana is known. Blaini rocks which were earlier equated with the Gondwana, have lately been dated as Precambrian. The reported occurrence of the plants from Nainital area from Infra-Krol has also been questioned. However, the diamictite of Lower Bijni Unit of Garhwal sequence which has Lower Permian marine fauna is significant and worth mentioning though no overlying plant-bearing horizons are developed.

The northern Tethyan Himalayan belt, with an almost complete Proterozoic-Mesozoic, dominantly marine sequence, is stretched from Kashmir-Ladakh to Bhutan and encompasses a number of sedimentary basins (Text-fig. 1), such as, Kashmir, Pira-Mandi, Kumaon, Nepal, Lachi (Sikkim), Lingshi (Bhutan), etc. All these basins lie south of the Indus Suture Zone except Karakoram Basin lying north of the Indus Suture. Several plant-bearing horizons are known from this belt but Kashmir and Spiti show better development of different Palaeozoic floral beds. Jurassic-Lower Cretaceous flora, however, is known from Nepal, Bhutan and Karakoram basins.

There are a few breaks and hiatus in the Tethys Himalaya related to the tectonism which might have played some role in the development of these plant beds. One such important event is referred as Hercynian gap, represented by complete absence of Carboniferous in Kumaon and Salt Range. Transgression and regression of the sea in the basins are demonstrated by different sequence of plant and marine horizons in the Lower and early Middle Carboniferous sequence of Kashmir and Spiti.

STRATIGRAPHY OF LESSER HIMALAYAN GONDWANA

The Gondwana Sequence in the Lesser Himalaya unconformably overlies the Precambrian metasedimentaries and is mainly developed in the Eastern Himalaya in the Daling Basin. They are traceable almost continuously from foot-hills of Darjeeling to Siang District of Arunachal Pradesh. They are mainly Permian in age. West of the Daling Basin, however, they are known from eastern and central Nepal, where Permian and Jurassic/Lower Cretaceous floras corresponding to Lower and Upper Gondwana are developed.

Arunachal Pradesh

Gondwana beds in Arunachal Pradesh are developed in a linear and narrow belt, 300 km long, in the districts of Kameng, Subansiri and Siang and unconformably overlie the Miri Buxa Formation. They are composed of Rangit Pebble Slate, Rilu Formation (=Garu Formation with lower Rilu Member and upper Bomte Member of Singh, 1987), Gensi Formation and Bhareli Formation (Tripathi & Roy Chowdhury, 1983). The last three formations have been grouped under Dumuda Subgroup.

The basal diamictite, Rangit Pebble Slate, about 300 m thick, comprises pebbly to gritty slates and lithic wackes, quartzites, pyritous and carbonaceous argillites, rhythmites, volcanoclastics and marl. A persistent fenestellid bryozoa dominated fauna has been traced for about 50 km in the Kameng District. The assemblage comprises *Fenestella, Polypora ampla, Geinitziella*, brachiopods, bivalves, crinoids, etc. (Acharyya *et al.*, 1975). *Eurydesma, Schizodus*, etc. are also known from Khuppi locality.

The overlying Rilu Formation developed in Siang and Subansiri districts is about 300 m thick and composed of black carbonaceous shale. It contains in the lower part *Eurydesma-Deltopecten* Assemblage and in the upper part *Linoproductus-Uraloceras* Assemblage with *Stepanoviella, Warthia*, etc. (Tripathi & Singh, 1987). From this formation

Parasaccites - Plicatipollenites - Cannanoropollis Assemblage of Talchir and *Callumispora-Parasaccites-Potonieisporites* Assemblage of Karharbari have been recognised (Singh, 1979, 1987).

In Kameng District, the oldest unit, Khelong Formation is composed of shale, marl, calcareous sandstone, feldspathic wacke and contains *Glossopteris* and *Gangamopteris*.

The succeeding 300 m thick Gensi Formation represents oscillatory deltaic facies (Tripathi & Singh, 1987) and is composed of sandstone and slaty shale with occasional marine fossils. The youngest Bhareli Formation represents continental fluvial facies (Acharyya *et al.*, 1979; Tripathi & Singh, 1987) and is composed of sandstone, siltstone, shale containing coal lenses and associated Rotung volcanics. Shales contain *Glossopteris, Vertebraria, Phyllotheca, Schizoneura, Palaeovittaria* and remains of labyrinthodonts. Bhareli group of rocks is considered to be of Late Permian age. A recent record of northern element from Arunachal Pradesh has come to notice (pers. comm. Dr S. K. Acharyya). Abor Volcanics associated with the Gondwana is another significant feature of this part of the Himalaya.

Bhutan

The Bhutan Gondwana is a continuation of the Arunachal sequence. Arenaceous and carbonaceous Damuda Subgroup overlies the Diuri Pebble Slate (= Rangit Pebble Slate) both in eastern and western Bhutan. Damuda Group, however, underlies the diamictite (Jangpangi, 1974). Acharyya *et al.* (1979) consider that reversal of sequence is due to tectonism otherwise stratigraphic polarity is normal. The Gondwana Sequence is composed of coal-bearing quartzite sandstone, carbonaceous slates, calcareous slates and marl containing Lower Gondwana plants. In Dewathung area, east Bhutan fenestellid bryozoans and gastropod-bearing calcareous nodules occur within the carbonaceous shale. Khelong and Bhareli formations of Arunachal Pradesh are believed to continue in Bhutan. The presence of plant fragments and spores of Gondwana is also known from northwestern Bhutan (Gansser, 1984).

Sikkim

The Gondwana represented by the lower Rangit Pebble Slate overlain by the Damuda Sandstone is developed in Rangit Valley, where they are exposed in a tectonic window beneath the overthrusting Daling and Darjeeling metamorphites. The Rangit Pebble Slate is composed of diamictite. Marine fossils reported from Khemgaon and Wak areas of West Sikkim include *Fenestrellina, Protoretepora, Eurydesma, Neospirifer moosakhailensis, Ambikella fructiformis*, etc.

Damuda sandstone is composed of feldspathic sandstone, micaceous siltstone, black laminated siltstone with plant fossils and thin seams of crushed coal. From Khemgaon *Glossopteris, Vertebraria, Schizoneura* and *Phyllotheca* are known. There are also records of older *Glossopteris-Gangamopteris* Assemblage at places (Acharyya *et al.*, 1979).

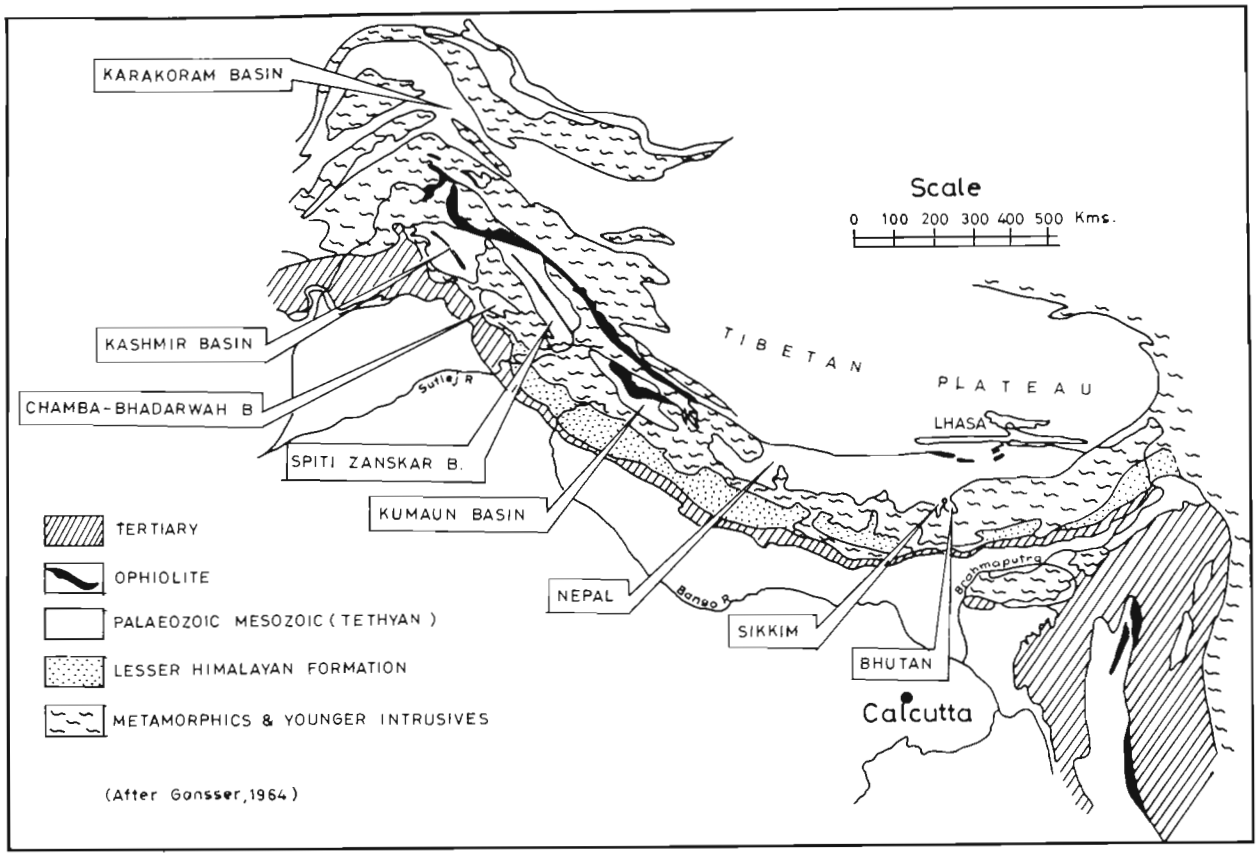
Darjeeling

Darjeeling is the western extension of Arunachal Gondwana. *Eurydesma* in association with *Praeundolomya, Wilkingia, Leptodesma*, etc. was reported from Rangit Pebble Slate of Tindharia in Darjeeling area (Acharyya, 1973). From Damuda Sandstone a rich flora comprising *Phyllotheca, Glossopteris* and *Vertebraria* is known (Acharyya, 1973). The palynological assemblage indicates a Late Permian age.

Nepal Lower Himalaya

Lower Gondwana diamictite with coal-bearing Damuda and Upper Gondwana with volcanics, both are known from Lower Himalaya of Nepal. Crinoid stems have been reported from diamictite associated with slates and conglomerates, black quartzite and streaks of coal from north of Butwal in central Nepal (Singh, 1973). Damuda Sequence, however, is developed in the lower gorge of Sapt Kosi River in eastern Nepal and extends further west in central Nepal. It is composed of coal-bearing sandstone and is underlain by boulder bed. Plants are known from Barahkshetra and miospore *Vittatina* and tracheids from north of Butwal.

Lower and Upper Gondwana have been reported recently by Sakai (1983) in the Tansen area of west central Nepal. Upper Gondwana designated as Taltung Formation of the Tansen Group is composed of basic rock, conglomerate and shale. The formation is divided into two members. The lower member is characterised by cyclic sedimentation of conglomerate, sandstone and shale and the upper member by rhythmic alternations of sandstone and shale. A rich flora composed of *Ptilophyllum, Pterophyllum* and *Elatocladus* is known from siltstone layers of the conglomerate of the lower member. Underlying the Taltung Formation, the Sisne Formation comprises diamictite and black shale of glacial influence. Plant remains are known from this formation and is correlative with the



Text-figure 1—Palaeozoic-Mesozoic basins of Tethys Himalayas.

glacio-fluvial Lower Gondwana. Bryozoans have also been found in the floating blocks (Kapoor & Tokuoka, 1985).

Garhwal Lesser Himalaya

In Bijni nappe, part of the Garhwal nappe, the Boulder Slate sequence called Bijni Tectonic Unit contains a rich marine fauna comparable with that of Agglomeratic Slate of Kashmir. The fauna, worked out by Chaturvedi and Talent (1971), Ganesan (1972), Shanker and Ganesan (1973), Shanker *et al.* (1973), Waterhouse and Gupta (1978) and Bhatt and Singh (1981), contains bryozoa, brachiopods, gastropods, bivalves, etc. Gupta and Visscher (1980) also reported Lower Gondwana palynomorphs.

PRE-GONDWANA AND GONDWANA SEQUENCE IN TETHYAN HIMALAYA

In the Tethyan Himalayan sector, the Palaeozoic-Mesozoic plant-bearing strata can be grouped into three types, (i) with well-developed megaflora and referred as floral beds, (ii) which include fragmentary plant remains, particularly woods and twigs associated with marine fauna, and (iii) marine strata which have yielded palynoflora. Sediments with continental megaflora are mainly important and have been taken into consideration in developing geological history.

The Himalaya including Salt Range and Trans-Indus ranges in Pakistan, according to Nakazawa and Kapoor (1979), represents peri-Gondwana province of Central or Middle Tethys. Here Early Permian sediments have Gondwanic faunal and floral elements, and are succeeded by Late Permian to Jurassic Tethyan sediments.

In this belt, two distinct floras, viz., the pre-Gondwana flora of Devonian-Carboniferous age and "Gondwana" flora of Permian and Mesozoic age are developed.

PRE-GONDWANA FLORA AND ASSOCIATED FORMATIONS

Kashmir Basin

Devonian—The earliest records of plants are from post-Muth sequence, the Aishmuqam Formation (Singh *et al.*, 1982; Tripathi & Singh, 1984). This formation is divisible into two members. Member A is represented by variegated quartz-

arenite with blotchy siltstone and Member B by light yellowish and greenish siltstone with thinly to thickly bedded intercalations of quartz-arenite. The light-coloured siltstone of Member B has yielded *?Protolepidodendron* and *?Taeniocrada* at Kotsu Hill, Diuth Spur and the Spur near Ayun in the Liddar Valley. No associated marine fauna has so far been recovered from this formation.

The overlying Syringothyris Limestone contains Tournaisian conodonts and brachiopods while the underlying Margan Shale contains Devonian brachiopods.

Carboniferous—Three formations, namely, Syringothyris Limestone, Fenestella Shale and part of the Agglomeratic Slate (Diamictite division) are included in the Carboniferous. The last formation will be discussed with the Gondwana.

Syringothyris Limestone has been divided into three members by Singh *et al.* (1982). Member A is yellow-weathering arenaceous limestone with partings of shale and quartzarenite. Member B comprises mainly bedded dark limestone and contains Tournaisan brachiopod fauna. Member C is characterised by limestone, arenite and shale. This member is divisible into four units. Flora has been reported from middle unit of Member C of Syringothyris Limestone throughout the Liddar Valley but important localities are Kotsu Hill, Gokhan gali and Ichhnar Spur. The assemblage includes *Lepidodendropsis fenestrata* and *Palmatopteris* cf. *furcata* and has been dated as Visean on the basis of fauna of the overlying and underlying strata.

Fenestella Shale has also been divided into 4 members (Singh *et al.*, 1982). Member A, referred as Passage Bed by Middlemiss (1910) and Gund Formation by Pal (1978), is dominated by quartz-arenite with shale/siltstone intercalations. Member B, dominated by shale and siltstone with bands of arenite, contains marine fossils. Member C, characterised by arenite with shale intercalations, lithologically resembles Member A and is well-exposed at Wallaroma in Liddar Valley. Member D is similar to Member B and rich in marine fauna. Members A and C contain plant fossils and represent regressive phases. Plant assemblage in both the members is similar and is found at Wallaroma, Kotsu, Gaos, Manigam, etc. in the Liddar Valley and at Gund in Banihal area. They have been dealt in detail by Pal (1978), Pal and Chaloner (1979) and Singh *et al.* (1982). Floral assemblage of Fenestella Shale is more like that of Lower Carboniferous assemblage from Po Series of Spiti (Hϕeg *et al.*, 1955; Dhar *et al.*, 1980) and has been assigned mid-Visean Bashkirian age based on the fauna from Member B and D.

Spiti Basin

Devonian—From the basal and top portions of the Takche Formation some doubtful plant remains are reported. Some doubts have been expressed on their botanical affinity (Tripathi & Singh, 1982) and as such are not dealt in detail. The age of the formation ranges from Ordovician to Early Devonian.

Carboniferous—The Carboniferous Po Formation of Spiti contains Lower Thabo Member characterised by shale and quartz-arenite followed by Upper Fenestella Shale Member with bryozoans and brachiopods of marine affinity. Floral assemblage from Thabo includes *Rhacopteris, Sphenopteridium, Rhodeopteridium* and lycopsids (Hϕeg *et al.*, 1957; Dhar, 1980).

LOWER 'GONDWANA' AND ASSOCIATED BEDS

In the Tethyan belt, mainly Permian plant-bearing horizons comparable to Lower Gondwana of Peninsula are developed in different basins. Permian sequences are widely distributed throughout the Tethyan belt, though development of plant beds is confined to Kashmir, Thanamandi-Pira, Bhallesh-Chamba and Karakoram basins. The advent of Permian is a major biological event and begins with the beds having *Eurydesma-Deltopecten* and *Taeniathaerus-Stepanoviella* assemblages, which are considered to be related to Gondwanic realm and show a regional development in Himalaya. The recent find of these beds from Kumaon (V.D. Mamgain & R. S. Mishra, pers. comm.) has also bridged the gap. These are succeeded by plant-beds with Lower Gondwana flora and both these successions represent up to basal part of Kungurian. In Kashmir, the contact between Lower Permian and Upper Permian is para-unconformable and is true for other parts of Tethyan Himalaya also (Kapoor & Tokuoka, 1985). The hiatus in between represents missing of strata of "Middle Permian".

Kashmir Basin

The Panjal Group (Kapoor & Nakazawa, 1981) includes Agglomeratic Slate, Nishatbagh Formation, Panjal Volcanics and Mamal Formation in ascending order (Kapoor, 1979; Kapoor & Shah, 1979; Singh *et al.*, 1982; Tripathi & Singh, 1987). The formations of this group are formed by the effect of composite diastrophic changes in the basin (Nakazawa *et al.*, 1975). Panjal Group is overlain paraunconformably by Vihi Group of marine rocks ranging in age from Late Permian to Jurassic.

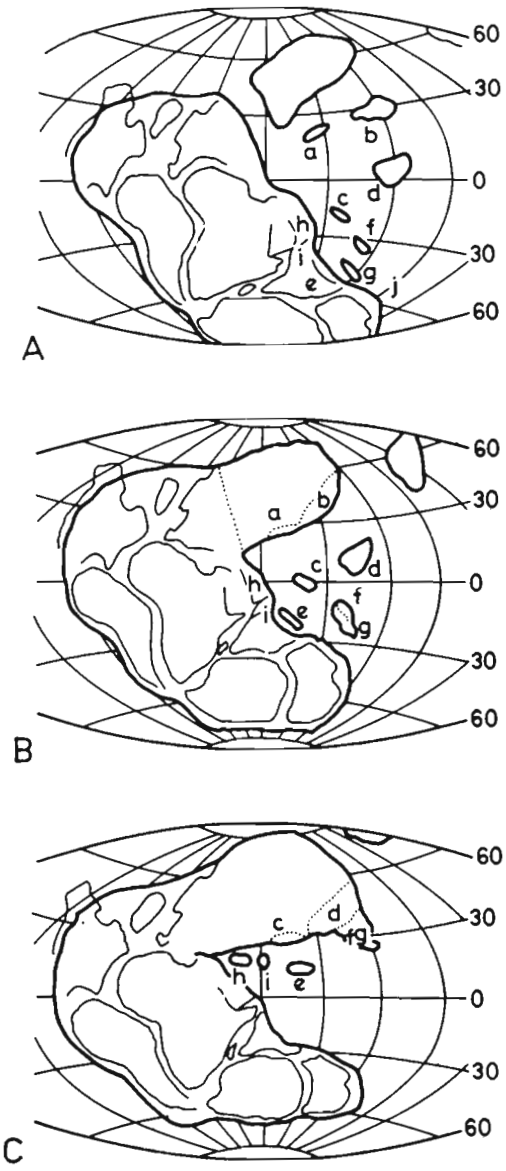
Agglomeratic Slate is a marine succession with several faunal zones occurring at different stratigraphic levels. Nishatbagh and Mamal

formations contain continental flora. Panjal volcanics show a mixed nature of subaerial and subaquous deposition and contain many intertrappean layers of slates and limestones. Limestone intertrappean exposed at Barus Spur contains marine brachiopods (Middlemiss, 1909), which suggest that marine influence existed at times during the volcanic episode.

Agglomeratic Slate is widely distributed and has been divided into lower 'diamictite' and upper 'pyroclastic' division. Diamictite division is composed of varied lithology of immature sediments grouped under diamictite and include grits, grey wacke, slates, boulder slates, etc. The upper division is composed of tuffaceous slates with cinders and volcanic bombs. There are a number of flows within this formation. Late Asselian *Eurydesma-Deltopecten* assemblage is known from various localities, viz., Bren (near Srinagar), near Virseran in Liddar Valley and near Kulgam in Pir Panjal, 30 m below the top of the diamictite division and at times contains fossil wood.

Very little is yet known of the fauna of the Agglomeratic Slate below *Eurydesma-Deltopecten* Zone, except that of *Syringothyris cuspidata* var. *lydekkeri* Zone in the lower horizon in the Marbal Valley, and is considered to be Muscovian (Late Carboniferous) by Bion and Middlemiss (1928). Recently one of us (GS) has encountered another lower horizon in Liddar Valley containing Deltopectenid bivalves of Lower Permian affinity suggesting the possibility of an Upper Carboniferous hiatus. From the upper part of the Agglomeratic Slate of Budil—Pir—Parasing area of Pir Panjal (=Nishatbagh Formation of later workers), Sharma (1976) reported a thick plant bed containing *Rhacopteris* as well as *Gangamopteris* in different layers from Parasing-Gurwatan area. The occurrence of these two elements of different floras together is interesting but need more detailed field studies. Recently Verma *et al.* (1986) brought to light the occurrence of *Rhacopteris, Triphyllopteris* and calamean stems from Fenestella Shale of the same area. This raises the question whether *Rhacopteris* continued in Kashmir in much younger horizons and if so what is its relationship with the marker horizon of Late Asselian faunal zone, as Nishatbagh from available data is not older than Artinskian. Tripathi and Singh (1984) have already pointed out a floral hiatus in Late Carboniferous.

The Nishatbagh Formation overlies the "pyroclastic division" characterised by *Taeniathaerus, Buxtonia, Praeundolomya, Bucaniopsia-Warthia* assemblages representing Sakmarian and Early Artinskian (Nakazawa & Kapoor, 1979). The stratigraphic sequence described as



Text-figure 2—Reconstruction of the palaeogeography (after Nakazawa, 1985). **A.** Early Permian, **B.** Latest Permian, **C.** Late Triassic. **a:** Tarim block, **b:** Sino-Korea block, **c:** Quangtang block, **d:** Yangtze block, **e:** Lhasa block, **f:** Indo-China block, **g:** Malaya block, **h:** Central Iran block, **i:** Central Afghanistan block, **J:** Timor.

Nishatbagh Bed by Kapoor (1977) has been redefined by Singh *et al.* (1982) as Nishatbagh Formation and is the lowest Lower Permian plant-bearing horizon in Kashmir Basin. It was known earlier in north-west Kashmir only (Kapoor, 1979) but lately has been found in Liddar-Naubug valleys, Pir Panjal as well as in Chamba. The formation is composed of shales, quartz arenites and varvites. The floral assemblage includes *Gangamopteris kashmirensis, Glossopteris nishatbaghensis,*

Psygmophyllum, Cordaites, etc. Nishatbagh Bed represents the advent of the land condition in Kashmir.

Four floral beds reported by Kapoor (1979) lying at different levels and showing changes in floral pattern have been grouped under the Mamal Formation by Singh *et al.* (1982) due to common lithological elements like novaculite, limestone, tuffaceous and siliceous shales, arenite, etc. In Pir Panjal area, however, there is absence of novaculite and development of thin bed of conglomerate at the base (Kapoor, 1977). The earlier Vihi Bed, representing lagoonal environment contains several layers with *Gangamopteris kashmirensis, Psygmophyllum* spp., *Cordaites, Vertebraria* and lycopsid remains, as well fishes and labyrinthodonts supposed to be of European affinity. Insect fossils are also known. Most interesting, however, is the presence of a layer of limestone with *Schwagerina* (Azmi, 1976), wherein one of us (HMK) has also observed the presence of bryozoans and algae showing definite marine influence. The succeeding Marahoma Bed exposed at Marahoma Spur, where both Vihi and Marahoma beds are separated by a flow, is characterised by species of *Glossopteris, Gangamopteris, Schizoneura, Sphenopteris, Sphenophyllum, Cordaites, Vertebraria*, etc. No vertebrate has been found in this bed.

The next younger Munda Bed contains a few species of *Gangamopteris, Glossopteris, Psygmophyllum*, etc. with appearance of *Taeniopteris* and *Pecopteris*. The youngest of all is the Mamal Bed from where Kapoor (1977) and Singh *et al.* (1982) reported an assemblage that contains "Cathaysian" as well as Gondwanic elements.

Thanmandi-Pira Basin

From Thanmandi-Pira Basin both Agglomeratic Slate and Permian plant horizons are known after the pioneer work of Wadia (1928) and later observed by geologists of the Geological Survey of India mentioned in unpublished reports. *Gangamopteris* and ill-preserved labyrinthodont from Mandi area suggest correlation with Mamal Formation in Kashmir basin.

Bhallesh-Chamba Basin

This basin has fossiliferous sequence from Early Permian to Lower Triassic, the Bhallesh Group (Kapoor, 1975). It includes Tramawala Formation, Batile Trap and Talai Formation which are similar to Agglomeratic Slate, Panjal Volcanics and Zewan Formation of Kashmir Basin in order of succession. Tramawala Formation includes both diamictite and volcanic divisions and has a lower *Eurydesma-Deltopecten* Assemblage and an upper *Taeniathaerus-Buxtonia-Streptorhynchus* Assemblage of Sakmarian age. Between Batile Trap and faunal zone of Sakmarian, Kapoor (1975) reported faint impressions of leaves in dark slates near Mashan Ghatti Gali. This observation has now been confirmed by G. Kumar who also found a well-preserved leaf of *Gangamopteris kashmirensis* exactly in the same position from Chamba. Thus the formation equivalent to Nishatbagh is developed in this basin also.

Zanskar-Spiti Basin

Fragmentary plants have been recorded in Lower Permian marine beds in Kinnaur (Bassi *et al.*, 1983) and at the contact of calcareous sandstone with Kuling in Kinnaur and Spiti River Section (Bassi *et al.*, 1983; Hayden, 1904).

The marine sequence in the basin is represented by two formations, viz., the Ganmachadam and the Kuling. The Lower Permian Ganmachadam Formation is composed of a 300 m sequence of diamictite, gritstone and quartzite. The Kuling Formation is divided by Srikantia (1981) into Gechang (=Calcareous sandstone of Hayden, 1904) and Gungri members. The Gechang Member, 60 m thick, is composed of calcareous sandstone and gritstone; while Gungri Member has shale with thin limestone.

Eurydesma-Deltopecten Assemblage is known from Lahul (Gupta & Waterhouse, 1978; Srikantia *et al.*, 1978) and Kinnaur (Bassi *et al.*, 1983) from calcareous sandstone of Gechang Member; in the same member, but in younger layers from Spiti, Bhatt and Joshi (1981) reported Artinskian fauna. The fauna of Gechang closely resembles with that of Agglomeratic Slate of Kashmir showing Gondwanic affinity. The fauna of the Gungri Member, however, is close to that of the Late Permian Zewan Formation.

In Zanskar area diamictite and volcanic flows (Ralakung Formation) are known in Lunek Valley which are correlated with the Agglomeratic Slate and Panjal Volcanics (Nanda *et al.*, 1978; Singh *et al.*, 1982).

Kumaon Basin

The Permian Kuling Formation directly overlying the Devonian Muth Quartzite was correlated with Late Permian sequence of other parts of Himalaya and absence of the Lower Permian was considered to be a conspicuous feature. Recently V.

D. Mamgain and R. S. Mishra (pers. comm.) have located a 16 m thick siliceous Limestone at the base of Kuling Formation in Girthi Valley (Malla Johar) continuing in Painkhanda and Byans. This unit contains brachiopods of the family Buxtonidae and Spiriferidae, comparable to the fauna of Gechang Member of Spiti and supports a regional Lower Permian marine transgression throughout the Tethys Himalaya.

Nepal

Bordet *et al.* (1971) and Colchen (1975) recorded a number of faunal zone within Thini Chu Formation from Thakkhola and Nigi-Shang area. The uppermost zone characterised by *Spiriferella rajah* assigning Late Permian age and lower with *Buxtonia Stepanoviella* indicating Early Permian age. Fuchs (1977) has reported prints of tetrapod and plant remains in the Dolpo region, western Nepal. Details of flora are not yet known. Acharyya and Shah (1975) have mentioned the presence of Gondwana spores from this formation.

Mount Everest-Sikkim-Bhutan basins

In the Mount Everest area the Upper Carboniferous to Early Permian Jilong Formation is overlain by Qubu Formation which has yielded *Glossopteris communis, Sphenophyllum speciosum* and *Raniganjia qubuensis.* This formation is conformably overlain by Quberga Formation. The Jilong Formation which is composed of variegated conglomerate, siltstone and sandstone has yielded Early Permian *Stepanoviella, Lissochonetes, Attenuatella, Trigonotreta*, etc.

In north Sikkim, Carboniferous and Permian are represented by Lachi Formation which is composed of 170 m thick shales, sandy shale and quartzite, followed by 200 m thick pebble bed (diamictite), the 100 m arenaceous shale and quartzite and 100 m quartzite and shale. No plant-bearing horizon is known except the mention of plant fragments in the top most 100 m thick quartzite and shale by Acharyya and Sastry (1979). The underlying sequence contains Late Permian forms of *Spiriferella rajah* and *Marginifera himalayaensis* Zone. In north Bhutan, the Permian Shodug Formation comprises diamictite, pink limestone, shale and quartzite but no plant bed. However, in the upper part of the sequence plant fragments and Gondwana type spores are reported from black shales (Acharyya & Sastry, 1979).

Karakoram Basin

A sedimentary sequence of Carboniferous to Cretaceous Tethyan facies is developed over metamorphics of Pangong Tso and Baltic groups. The Chongtah and Aqtash formations represent Permian group of rocks (Gregan & Pant, 1983). The Chongtash Formation is composed of siltstone, sandstone with occasional occurrence of equisetaceous stems and black shale interbedded with volcanic flows. Volcanic lavas have a number of intertrappeans of sandy slate and calcareous shale which contain fusulina showing affinity with the western Tethys. The Aqtash Formation is made of volcanics, conglomerate and grey massive limestone and shale.

Thakur (1984) recorded a thick sequence from the eastern Karakoram above the Fenestella shale represented by Harpatso Formation. This formation consists of diamictite, Gangamopteris Bed and limestone with fusulina.

UPPER GONDWANA FLORA AND ASSOCIATED BEDS

Plant-bearing horizons of Jurassic Lower Cretaceous age are known only from Nepal, Bhutan and Karakoram basins of Tethyan Himalaya. The presence of ill-preserved plants from several horizons between Late Permian and Jurassic are also known. In addition mioflora has also been worked out from some Mesozoic sediments of Kashmir and Kumaon Basins. Nautiyal and Sahni (1976) reported from Kashmir basin the presence of microplankton from basal Khunamuh Formation (Lower Triassic) of Pahalgam. The presence of fragmentary twigs were also noticed by one of us (HMK) at the contact of Zewan and Khunamuh formations at Guryul Ravine Section and plant impressions from a few centimeter thick shaly layer within the Upper Triassic, exposed south of Qazigund. In Wumuh Formation (Jurassic), a carbonaceous shale layer exposed at Sanger and Wumuh, occasionally shows unidentifiable fragmentary plant remains. From Spiti Basin, Hayden (1914) recorded a layer with plant remains in calcareous sandstone at the base of Coral Limestone (Middle Norian). Most interesting, however, is the record of miofloral assemblages from Kuti Shale, Passage Bed (Norian), Kioto Limestone (Rhaetian) and Spiti Shale (Jurassic) by Tiwari *et al.* (1980) from Kumaon Basin. The mioflora of Kuti Shale and Passage Bed, as well of the underlying Kuling Shale is of Gondwanic type.

Karakoram Basin

Norin (1946) listed a few plant fossils from Lingshithang-Depangi Quarutagh and upper Shyok drainage area, which included *Nilssonia* spp. and *Podozamites lanceolatus.*

The plant-bearing horizon at Fukche in the upper Indus Valley, north of the Ladakh range is thrusted over granite (Sharma *et al.*, 1980). The flora is of Middle to Late Jurassic age and compares favourably with the Eurasian flora and not with the Upper Gondwana (Bose *et al.*, 1983). Sukh-Dev *et al.* (1983) also reported *Cladophlebis* from Kayul, eastern Ladakh within the same formation.

Nepal

At the village Thakkhola (upper part of the Kali Gandaki Valley) plant-bed is known from the Kagbeni Sandstone Member of Chukh Formation (Bassoullet & Mouterde, 1977; Bordet *et al.*, 1968, 1971; Barale *et al.*, 1978). Bordet *et al.* (1971) consider the plant-bed to be Wealden in age as it overlies strata containing Tithonian ammonites and underlies beds with Neocomian fauna.

Bhutan (Lingshi Basin)

Mesozoic plant-bearing horizons are known from Mochu and Chebesa formations of Lingshi Group in the Lingshi Basin (Ganesan & Bose, 1982). Mochu Formation consists of laminated quartzite, sandstone and carbonaceous shale; the carbonaceous shale in its upper part shows development of fossil flora. The succeeding Chebesa Formation is mainly marine in nature and is composed of carbonaceous slate and quartzite. The quartzite sometimes contain thin streaks of plant-bearing shale. The age of these plant horizons is assigned Middle to Late Jurassic by Ganesan and Bose (1982).

EVOLUTION OF PLANT BEDS

The evolutionary history of Lesser Himalayan and Tethyan Himalayan belts are different. The Gondwana of Lesser Himalaya developed in the eastern part from Nepal to Arunachal Pradesh, more or less in a continuous linear belt, are continuation of the peninsular Gondwana with the similar stratigraphic set up and represent northern most rift system of the Indian Peninsula (Tripathi & Roychowdhury, 1983). The Gondwana overlie the Precambrian basement with a strong unconformity and have more of a continental facies with a minor marine influence at the base. The presence of Upper Gondwana and associated volcanics in central Nepal further supports this contention. However, being the marginal portion of the Gondwanaland, it has some correlatability to the Tethyan belt, specially with the Lower Permian sequence of Kashmir due to the presence of Abor Volcanics comparable to Panjal Volcanics, which seems to be a feature of the Tethyan belt.

Since the report of Gangamopteris Bed from Kashmir in 1902, evolution and development of floral beds in the Tethyan Himalaya has been of great scientific interest. These floral beds and their distribution, in a marine domain, unlike those of Peninsula, bear the testimony of the palaeogeography, specially the extent of the Gondwanaland to the north. The evolution of these beds can be explained variously, as given below:

1. development of plant beds over an island or a dense archipelago in the Tethys.
2. plant beds developed as coastal vegetation near the southern coast of Tethys.
3. development of land condition due to diastrophic changes and associated transgression and regression of the sea.

The evolution of various plant beds of Palaeozoic-Mesozoic in Tethyan region is complex, as they show local developments and the history of different basins is not identical. The appearance of first land plant on the globe is now considered to have been in Late Silurian. In Himalaya, except some doubtful plants from Ordovician-Silurian in Spiti Basin, the first definite land plant is from Late Devonian of Kashmir. In the Himalayan region, only two basins, namely, Kashmir and Spiti, exhibit continuous Late Devonian to Early Permian stratal sequence. The imprints of major tectonic events are documented in the Tethyan realm, where minor and major changes can be inferred on the palaeontological and stratigraphical evidences.

The shallow water Cambro-Ordovician sequence in the Tethyan Himalaya, ultimately became extremely shallow, where coastal to beach conditions prevailed depositing in the form of Muth Quartzite. This gave rise to the suitable environment, as such the sequence with definite land plants appeared in the Aishmuqam Formation (Muth Quartzite of Middlemiss, 1910) in Kashmir, possibly related to the Caledonian orogeny. This event was followed by a major Lower Carboniferous transgression in northwest and Nepal Himalaya, depositing the Lower Carboniferous Sequence representing the lower carbonate sediments (Syringothyris Limestone, Lipak Formation, Tilicho Lake Formation) and upper argilo-arenaceous sediments (Fenestella Shale, Po Formation, part of Thini-Chu Formation). During this time, the sea level was fluctuating resulting into alternate plant bearing dominately arenaceous sequence representing the regressive phase of the sea and invertebrate bearing marine argillaceous sequence representing the transgressive phase (Tripathi & Singh, 1984).

The instability of the basin became more conspicuous during the deposition of the Agglomeratic Slate and ultimately resulted in the outpouring of extensive lava flows in the Northwest Himalaya during Early Permian. This was followed after some hiatus, by a Late Permian transgression coinciding with the development of rifts in peninsular India.

Nakazawa and Kapoor (1973), Nakazawa *et al.* (1975), Kapoor (1979) and Kapoor and Shah (1979) explained that during Late Carboniferous and Early Permian the Kashmir region faced an unstable condition. The deposition of the Agglomeratic Slate is the effect of composite diastrophic changes in the basin. The lower part of the formation is formed on the depression in a rising crust, while ash and volcanic bombs, confined to the upper part, are of explosive type and were deposited both in depressions and raised portions (Nakazawa *et al.*, 1975). The effects of the Hercynian orogenic movements are reflected in deposition of Agglomeratic Slate and its equivalent in a marine regime. The magma below became mobile and in the initial stages selected weaker portions and forced the crust to rise, and later emitted to the surface through linear fissures; by this time most of the shelf portions were already raised above the sea-surface, as evidenced by the plant-bearing Nishatbagh Formation which underlies the main volcanic flows. In recent years evidences have come that Nishatbagh land conditions had a geographical extent up to Chamba. The emissions of the flows were intermittent, as indicated by a number of intertrappeans. The first plant beds overlying the volcanics and named as Vihi Bed developed in a lagoonal condition. It is interesting, however, to note that beds overlying the trap show a gradual floristic change, though lithological elements in all the beds are the volcanogenic sediments. The presence of the different floral beds above volcanics has been explained by Nakazawa *et al.* (1975) due to overlap and formations of different basins of deposition. Gradual shifting of the trap towards the east was explained by these authors, based on the example of Marahoma Spur, where Vihi Bed is separated by Marahoma Bed by a flow and show different floristic contents. They also presumed for Upper Munda and Mamal beds the same hypothesis of younger level based on floral evidences. Thus according to them during Early Permian there had been development of different basins over the emerged land; where flora of different times got deposited.

The Agglomeratic Slate where Asselian and Sakmarian fauna is found below plant-beds represents a major marine transgression and possibly got linked up with Salt Range on one side and with the eastern Himalaya through Spiti-Kumaon-Sikkim on the other side.

The occurrences of diamictite and plant bed in Karakoram, as well as in southern Tibet from where *Stepanoviella* and Glossopteris Flora are reported are interesting, due to their position further north. For this the palaeogeographic maps produced by Nakazawa (1985) give a good explanation that these portions in the Early Permian were situated further south and were part of the same province (Text-fig. 2).

Nakazawa *et al.* (1975), Kapoor and Shah (1979), Kapoor (1979) and Singh *et al.* (1982) visualised Kashmir region to be an island in Early Permian. It was presumed to be closer to the Gondwanaland and not very far from Cathaysian province. The available information, till date also links the Tethyan region through only marine bed with that of the Peninsula, but the development of the strata in which the flora is found have different sedimentological history. The succeeding Late Permian history, however, is different marine transgressive history of Tethyan realm and took place after Kungurian-Ufimian-Kazanian time gap.

Nothing can be commented about the Kungurian-development of thin floral layers occurring in Triassic in Kashmir and Spiti, and may only be due to near shore conditions. The Jurassic Cretaceous plant beds, however, are possibly attributes of the regression caused at the time of fragmentation and shifting of the Indian Shield from the mainland.

DISCUSSION AND CONCLUSION

There are two models to explain geological history of the extra-Peninsula. First model envisages the presence of two geosynclinal basins, one in the south (Lesser Himalaya) and other in the north (Tethyan or Tibetan) separated by Central Cystallines. The second model considers Lesser Himalaya to be the continuation of peninsular region with the same geological history. It has already been pointed out that the Gondwana of eastern part of the Lesser Himalaya is nothing but a continuation of the peninsular Gondwana as visualised in the second model. It may also be mentioned here that Blaini Formation of Lesser Himalaya, earlier believed to represent Gondwana deposits has now been proved to be older. Therefore the nearest Gondwanic deposits in the western part only is from the Salt Range in Pakistan. However, it has more affinity with that of the Tethyan belt. The question, however, arises whether to include the Tethyan sequence within the limits of

Gondwana? It is normally considered that Indus-Yarlung-Zangbo Suture marks the northern limit of the Gondwanaland but the recent studies have indicated that northern margin of the Gondwanaland had varied and got fragmented at various geological periods, thus its northern limit varied from time to time.

The widespread occurrences of diamictite, similarities in Asselian and Sakmarian marine fauna and Glossopteris Flora (also known from countries of southern hemisphere), in general provide correlation of Gondwana Sequence of Peninsula with those of the Tethyan belt.

All the sedimentation models of the peninsular and Lesser Himalayan regions envisage glaciofluvial, fluvio-glacial and lacustrine environment of the deposition. This has the influence of some marine transgression in the basal part in some of the areas of Peninsula and Lesser Himalaya. The Tethyan Himalaya on the contrary represents paralic to marine sedimentation in the shelf environment. The main difference, between the peninsular and Tethyan belt, however, is in the geological set up. Peninsular Gondwana Sequence deposited over the Archaean basement with a strong unconformity, unlike Tethyan belt where this forms part of the continuous marine Palaeozoic-Mesozoic sedimentaries with both conformable and unconformable contacts at times.

Diamictite, which marks the begining of the Gondwana, though widely distributed both in the Peninsular and Tethyan domains, have also distinct dissimilarities in lithology and the sedimentary history. Diamictite in the Tethyan region are always marine and deposited in an unstable basin. In Peninsula, diamictites are mainly glacial or fluvio-glacial and occasionally marine. They were deposited within the basement depressions in the embryonic basins (Mitra *et al.*, 1979). The Lower Permian Sequence above diamictite in the Tethyan belt is mainly volcanogenic sediments or volcanic flows which are entirely absent in the peninsular region. In Lesser Himalaya, however, there is some evidence of the volcanism (Abor) that possibly indicates that Lower Permian volcanism was confined to the northern margin. Another interesting observation worth mentioning is the occasional marine influence in Lower Permian plant-beds as reported in the Vihi Bed of Kashmir, which has though dominantly *Gangamopteris* bearing lithounits but in some units marine fauna is also present and accordingly the bed has been referred to show a lagoonal environment. No such environment has yet been found in the peninsular region in the Lower Permian. In the peninsular region the Upper Permian and Triassic sequence is represented by argillo-arenaceous continental deposits unlike Tethyan region where the deposits are dominantly argillo-calcareous marine sedimentaries with distinct fauna confined to central Tethyan Province. The Upper Gondwana of the Lesser Himalaya and the peninsular India have close similarity in lithology and associated volcanism of the Jurassic/Lower Cretaceous age. However, in the Tethyan realm, the plant bearing horizons are closely associated with the marine strata and at times contain thin layers of plants, which indicate an overall marine environment. Further no volcanics or volcanogenic sediments have yet been reported from the Tethyan belt.

Another significant aspect of correlating the Tethyan belt sedimentaries with the Gondwana is the floral contents. The Lower Permian flora of Tethyan belt, particularly of Kashmir and Mount Everest area have some definite Gondwana elements like *Gangamopteris cyclopteroides, Glossopteris communis, G. indica, Vertebraria*, etc. but at the same time contain some Cathaysian elements, as known from Mamal Bed, like *Parasphenophyllum thonii, Lobatannularia ensifolia*, with several endemic species like *Gangamopteris kashmirensis, G. nishatbaghensis, Rhabdotaenia kashmirensis*, etc. This mixing of flora has been explained variously; due to migration, due to parallel evolution (or homoplasy), or representing a distinct transitional floral belt within Tethyan realm, lying between Gondwana flora in south and Cathaysia flora in the north. None of these explanations can be regarded as conclusive.

In succeeding Triassic Tethyan sequence no major plant-bearing horizon with identifiable flora is known except for a record from the Salt Range in Pakistan of *Equisetites, Cladophlebis* and *Indotheca sakesarensis*. Its correlatability with the peninsular domain is not clear.

Jurassic/Lower Cretaceous floras are known from Bhutan, Nepal and Karakoram basins. Bhutan and Nepal have flora similar to the Upper Gondwana assemblages, while the Karakoram assemblage is comparable to the Eurasian flora thus considered to be a part of the Asian block. However, the differentiation of the Mesozoic flora which is generally of cosmopolitan nature, present in marine Tethyan sediments in Bhutan and Nepal keeps the question open for future work.

It is not out of place to mention about the pre-Gondwana flora in the Tethyan belt, which has been compared with the northern flora, though same elements are also found in the southern continents but not in peninsular India. The Lower Carboniferous flora in general is considered to be cosmopolitan by some workers; others believe that

differentiation in the flora started earlier and the similarities are apparent and not actual. The Carboniferous floral beds which are confined only to Kashmir and Spiti basins, thus are important to study the evolution of Glossopteris Flora but till date the Carboniferous stratigraphy is not known in detail and there is a lacuna of Upper Carboniferous flor

The faunal aspect and its correlatability gives a peculiar picture. The Asselian and Sakmarian fauna of both Peninsula as well as extra-Peninsula are alike and thus are the result of the common sea. However, vertebrate fauna known from Vihi beds in Kashmir is distinct from that of Peninsula. The fishes and labyrinthodonts, though have been compared with European forms, are endemic specifically. The fusulinid found in the same bed are only known from the similar set up of the Salt Range area and not in Peninsula.

Tectonostratigraphically the Tethyan and peninsular domains fall apart and have distinct dissimilarities, though tectonic event of one domain is reflected in another being the adjacent part to each other. The Lower Permian commences with an important event both in Peninsula as well as extra-Peninsula. Extra-Peninsula witnesses a major sea transgression which invaded even some parts of the Peninsula; while in Peninsula, it gives rise to basin in which thick piles of continental deposits were laid. The Upper Permian transgression in the Tethys Himalaya possibly took place at the time when rifting took place in the peninsular region and different Gondwana basins are formed during post Barakar times. In the raised portion of the marginal shelf of the Tethyan belt, which might have acquired land condition, volcanogenic sediments got deposited in the depressions during Lower Permian There is also a brief hiatus (Kungurian-Ufimian-Kazanian) in the Gondwanic history and Late Permian transgression in Tethyan Belt.

There are diversified views for the use of the term Gondwana in the stratigraphic sense. This aspect was discussed at length in a Colloquium at Geological Survey of India, Calcutta in 1984 and consensus was as follows :

"The Gondwana in stratigraphic sense includes naturally related succession of essentially sedimentary rocks with sandstone, shale, coal, carbonaceous sediments, tillites/tilloids, as well as closely associated rocks which are also characterised by floral and faunal remains having Gondwana affinity; it is thus an observable stratigraphic unit, diagnosed by mainly terrigenous facies (as referred to earlier) which also have Gondwanic floral/faunal bondage, since there is no provisions for formal stratigraphic nomenclature for succession characterised by natural assemblage of both litho- and bio-stratigraphic aspects, this informal term Gondwana sequence appear adequate. Both lithological and bio-aspects are utilised in defining the Lower and Upper contact of the Gondwana sequence. In Indian subcontinent the sequence ranges in time span from basal Permian to Early Cretaceous".

Based on the above discussions, it can be inferred that the Gondwana of the Tethyan belt, shows a distinct departure from the typical Gondwanic sedimentation and floral contents; and the use of the term Gondwana in formal sense of stratigraphy does not appear to be justified. Effort should be to formalise this term in a stratigraphic sense, rather than continuing the informal term Gondwana Sequence. However, the use of the term Gondwana in the palaeogeographic sense as 'Gondwana realm' is widely used and acceptable, for which the term 'Peri-Gondwana' has already been proposed for extra-Peninsula (Tethyan belt) by Nakazawa and Kapoor (1979).

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