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Permian palynofossils from the eastern Himalaya and their genetic relationship

Suresh C. Srivastava, Anand-Prakash & Trilochan Singh*

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Palynofossils from the Permian sediments of the eastern Himalaya have been critically revised with reference to the marine invertebrate fossils contained at various levels. The Pebble Slate Member of the Rangit Formation having sporadic presence of *Eurydesma* (Biozone 1) has not yielded palynofossils but the younger Rilu Member has yielded a radial monosaccate rich assemblage (Biozone 2). The association of *Leiosphaeridia* in this assemblage in Barpathar area characteristically indicates marine influence. Biozone 3 characterised by *Callumispora* + *Parasaccites* association is present in marine Garu Formation in Siang and Subansiri, non-marine Bhareli Formation in Kameng and Lower Coal Measures in Darjeeling District. *Scheuringipollenites* rich Biozone 4 is characteristically associated with the marine invertebrates in Siang District (Garu Formation) only; elsewhere it occurs independently. Biozones 5 and 6 are characterised by the abundance of striate-disaccate pollen grains, the latter having *Indospora, Thymospora* and *Crescentipollenites* and represent Upper Barakar and Raniganj palynofloras, respectively.

The Permian sediments in eastern Himalaya are in lithological contrast with the intracratonic continental sediments of the Peninsula but their floristic resemblances are close. Biozones 1 and 2 are comparable to Talchir palynoflora which is related to glacio-marine model of sedimentation. During the deposition of sediments containing Biozone 3, comparable to Karharbari palynoflora, the marine environment seems to have existed continuously from Siang to eastern Kameng but westwards certain areas were under fresh water environment. Similarly the Biozone 4 is associated with marine fossils in Siang only but elsewhere it is typically associated with fluvial sediments. Thus an eastward regression of sea is plausible during Karharbari and Lower Barakar times. During the younger palynofloras having Upper Barakar (Biozone 5) and Raniganj (Biozone 6) affinities the conditions of deposition appear to be exclusively fluvial in nature. It is clearly indicated that a larger segment of sedimentation in these marginal basins of eastern Himalaya has continued under marine environment while in peninsular India the intracratonic depositional basins were under fluvial environment during the same time span.

Key-words—Palynology, Stratigraphy, Biozonation, Genetic relationship, Permian sediments (India).

Suresh C. Srivastava, Anand-Prakash, Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India.

**Trilochan Singh, Wadia Institute of Himalayan Geology, General Mahadeo Singh Road, Debradun 248 001, India.*

सारांश

पूर्वी हिमालय से परमी युगीन अश्मित परागाणु एवं इनकी आनुवंशिक बन्धुता

सुरेश चन्द्र श्रीवास्तव, आनन्द प्रकाश एवं त्रिलोचन सिंह

पूर्वी हिमालय के परमी अवसादों से उपलब्ध परागाणविकरूपकों का विशेष पुनरीक्षण किया गया है तथा विभिन्न स्तरों में विद्यमान समुद्री अरीढ़धारी अश्मित जन्तुओं पर भी विशेष ध्यान दिया गया है। **यूरीडेस्मा** (जैवमंडल I) की कदाचनिक उपस्थिति से युक्त रेंगीट शैल-समूह के गोलाश्म स्लेट सदस्य में

Concepts, limits and extension of the Indian Gondwana
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परागाणविकरूपक उपलब्ध नहीं हुए हैं परन्तु अल्पायु रिलु सदस्य से अरीय एक-कोष्ठीयों से युक्त समुच्चय (जैवमंडल 2) उपलब्ध हुआ है। बारपथर क्षेत्र में इस समुच्चय में **लिओस्फेयरीडिआ** का साहचर्य लाक्षणिक रूप से समुद्री प्रभाव प्रदर्शित करता है। **केल्यूमिस्पोरा + पेरासेक्काइटिस** साहचर्य से अभिलक्षणित जैवमंडल 3 स्याँग और सुबनसिरी में समुद्री गारू शैल-समूह, कामेंग में असमुद्री भरेली शैल-समूह तथा दार्जिलिंग जनपद में अधरि कोयला-मेज़र्स में विद्यमान है। **श्यौरिंगीपोलिनाइटिस** से भरपूर जैवमंडल 4 लाक्षणिक रूप से केवल स्याँग जनपद में समुद्री अरीढ़धारीयों का साहचर्य प्रदर्शित करता है, अन्य स्थानों पर यह स्वछंद रूप से मिलता है। जैवमंडल 5 एवं 6 रेखीय-द्विकोष्ठीय परागकणों की बाहुल्यता से अभिलक्षणित हैं। ये जैवमंडल **इंडोस्पोरा, थाइमोस्पोरा** एवं **क्रीसेंटीपोलिनाइटिस** से युक्त हैं तथा क्रमशः उपरि बराकार एवं रानीगंज परागाणुवनस्पतिजातों का निरूपण करते हैं।

पूर्वी हिमालय में परमी अवसाद प्रायद्वीप के अन्तराक्रेटानी अलवणीय अवसादों से शैलविन्यास में भिन्न हैं परन्तु इनमें घनिष्ठ वनस्पतिजातीय समानता है। जैवमंडल 1 एवं 2 तालचिर परागाणुवनस्पतिजात से तुलनीय हैं जिसे अवसादन के हिमानी-समुद्री मॉडल से सम्बद्ध किया गया है। जैवमंडल 3 से युक्त अवसादों के निक्षेपण के समय करहरबारी परगाणुवनस्पतिजात से तुलनीय समुद्री वातावरण स्याँग से पूर्वी कामेंग तक अविच्छिन्न रूप से विद्यमान प्रतीत होता है परन्तु पश्चिम की ओर कुछ क्षेत्र अलवणीय जल-वातावरण से प्रभावित थे। इसी प्रकार जैवमंडल 4 केवल स्याँग में समुद्री जीवाश्मों से सहयुक्त है और अन्यत्र यह नदीय अवसादों से सम्बद्ध है। अतएव करहरबारी एवं बराकार काल में समुद्र का पूर्व की ओर अवनमन तर्कसंगत लगता है। उपरि बराकार (जैवमंडल 5) एवं रानीगंज (जैवमंडल 6) से सजातीय अल्पायु परागाणुवनस्पतिजातों के समय निक्षेपणीय परिस्थितियाँ अधिकतर नदीय प्रतीत होती हैं। यह स्पष्ट रूप से इंगित किया गया है कि पूर्वी हिमालय की इन तटीय द्रोणीयों में अवसादन का अधिकतर भाग समुद्री वातावरण में रहा है जबकि प्रायद्वीपीय भारत में अन्तराक्रेटानी निक्षेपणीय द्रोणीयाँ इसी कल्प में नदीय वातावरण से प्रभावित थीं।

THE sedimentary sequence of the eastern Lesser Himalaya occurs continuously from the foot-hills of Darjeeling to Siang District. The Permian sediments are tectonically emplaced between Tertiary rocks of the sub-Himalaya and the metamorphics of the Lesser and Central Himalaya. The Tethyan sedimentary sequence in the north forms almost a parallel belt and is rich in marine fauna whereas the Permian of the Lesser Himalaya is largely unfossiliferous. The Permian sediments are customarily compared to the Gondwana sediments of peninsula and on the basis of fossil contents are equated to the Damuda Group. However, the tectonics and environment of deposition of the Lesser Himalayan Permian sediments is in typical contrast with the intracratonic continental sediments of the Peninsula. The continuity of the Permian sediments in the direction of strike is truncated east of Siang by the Siang Fracture Zone (Nandi, 1976) or the Dibang Section (Jain & Thakur, 1975). The apparent discontinuity at some places along the alignment is largely due to the intermittent cover caused by the thrust slices of other formations.

The Permian sediments are wedged in between two thrusts. The southern boundary is against the Siwalik Group, usually referred to as Main Boundary Fault (MBF), while the northern boundary is marked by a plane of discordance against the metamorphic rocks. The sediments are highly deformed and show a wide range of lithological variation. The general dip of the rocks is northwards, thus bringing the younger rocks apparently under the older ones near the thrust. The basal sediments are characterised by the diamictite in Arunachal Pradesh and pebble slate in Bhutan, Sikkim and Darjeeling areas. These lithounits are comparable to the Talchir sediments of the Peninsula. Therefore, it is suggested that in Eastern Himalaya also a similar pattern can be followed for describing these sediments under one common name. With this idea, the diamictite and pebble slate units exposed in various parts of eastern Himalaya have been described here under Rangit Formation. The lithofacies variations and nature of fossil contents in different areas are as follows :

DARJEELING

Acharyya (1972) divided the Permian sediments into three formations, viz., Dalingkote Formation (Upper Coal Measures), Chunabati Formation, and Rongtong Formation (Lower Coal Measures). However, Pawde and Saha (1982) have preferred to keep the Permian Sequence unclassified. As the Permian sediments occur in thrust slices at various places it appears difficult to correlate them on lithological characteristics alone.

The lowermost unit, Rangit Pebble Slate, comprises pebbly to gritty slates and pebbly quartzitic sandstones. This unit is normally correlated to the Talchir Boulder Bed of the Peninsula. Acharyya (1972) has reported a marine fauna which includes *Eurydesma* sp. and has assigned a Lower Permian age.

The sediments of the Damuda Group have been divided into two units. The Lower Coal Measures have a very limited aerial extent and include sandstone, shale and coal. The sandstones are largely fine-grained and have been compared with the Barakar Formation. The Upper Coal Measures have a comparatively wider extent and comprise predominantly sandstones which are medium-to coarse-grained. The coal seams in this unit are highly crushed and semi-anthracitic. This unit has been correlated with the Raniganj Formation on the basis of the dominance of *Glossopteris* over *Gangamopteris*.

The Chunabati Formation equated to the Barren Measures Formation is, however, debatable as the rocks exposed around the type area Chunabati are

exclusively Tertiaries. The lithological similarity of the above sequence with the equivalent sediments in the Peninsula is, however, only apparent as there are distinct differences in details. The comparison is furthermore difficult due to the effect of tectonism as the sediments are often influenced by the metamorphism. The sandstones have become quartzitic, shales have turned into slates and coals are highly crushed and semi-anthracitic in nature.

SIKKIM

Permian sediments of north Sikkim form a part of the Tethyan Sequence. In south Sikkim the sediments occur in the Lesser Himalayan Zone and are exposed in the Rangit Tectonic Window, in Rangit River Valley. Here the sediments are overridden by the rocks of Daling and Buxa groups on all sides. The stratigraphic sequence of Permian sediments is as follows:

Namchi Formation	Sikkip Member	Dark grey to bluish grey sandstone, carbonaceous shale, coal
	Namchi Member	Coarse gritty grey sandstone, conglomerate, shale
Rangit Formation	Rangit Pebble Slate	Poorly sorted clasts embedded in argillaceous matrix, siltstone and thin limestone
.....		Thrust .....
Buxa Group		

The Rangit Pebble Slate comprises poorly sorted clasts that range in size from granules to pebbles to boulders embedded in argillaceous matrix. The matrix is also calcareous at places. Generally, the rocks do not show stratification except near Tatapani where they have attained a slaty character.

Sinha Roy (1980) has grouped the overlying unclassified Permian sediments in Namchi Formation. In the present synthesis the Namchi Formation has been further differentiated into two members, the Namchi Member and Sikkip Member.

The Namchi Member has been restricted to older unit comprising sandstone and conglomerate. The sandstones are grey in colour, coarse to gritty and hard in nature. The conglomerate includes well polished, rounded to oval-shaped pebbles cemented in arenaceous matrix. Dark grey slaty shales are also associated with this sandstone. This member has yielded well-preserved brachiopods, gastropods and bryozoans.

The Sikkip Member is characterised by interbedded sandstone, slaty shale and coal. The sandstones are dark grey, hard, quartzitic, fine- to coarse-grained and often gritty in nature. Well-preserved ripple marks, current bedding and graded bedding are seen in the sandstones.

The slaty shales often contain plant fossils, viz., *Glossopteris, Gangamopteris, Vertebraria, Schizoneura*, etc. Coal occurs as thin bands between the shales and sandstones and is highly crushed, semi-anthracitic to graphitic in nature. Bands of calcarenite and thin limestone are also found associated with gritty sandstones.

BHUTAN

The Permian sediments in Bhutan occur as thin, discontinuous thrust slices. In eastern part they form a continuous patch and attain their maximum thickness. The stratigraphic sequence is divided into Diuri Boulder Slate Formation and Thungsing Quartzite Formation.

The Diuri Boulder Slate Formation is marked by the presence of dark grey, boulder and pebble slate, carbonaceous and silty slate and quartzitic sandstone. This formation attains maximum thickness of 2,500 m and its contact with the overlying Permian Sequence is sheared and faulted. It is interbedded with Thungsing Quartzite at one place while in other sections it overlies the same.

The Gondwana sediments include quartzitic sandstone, carbonaceous slates, coal, calcareous slate and marl, etc. The interbedded slate often contains fragmentary plant remains (*Glossopteris, Vertebraria, Gangamopteris*, etc).

ARUNACHAL PRADESH

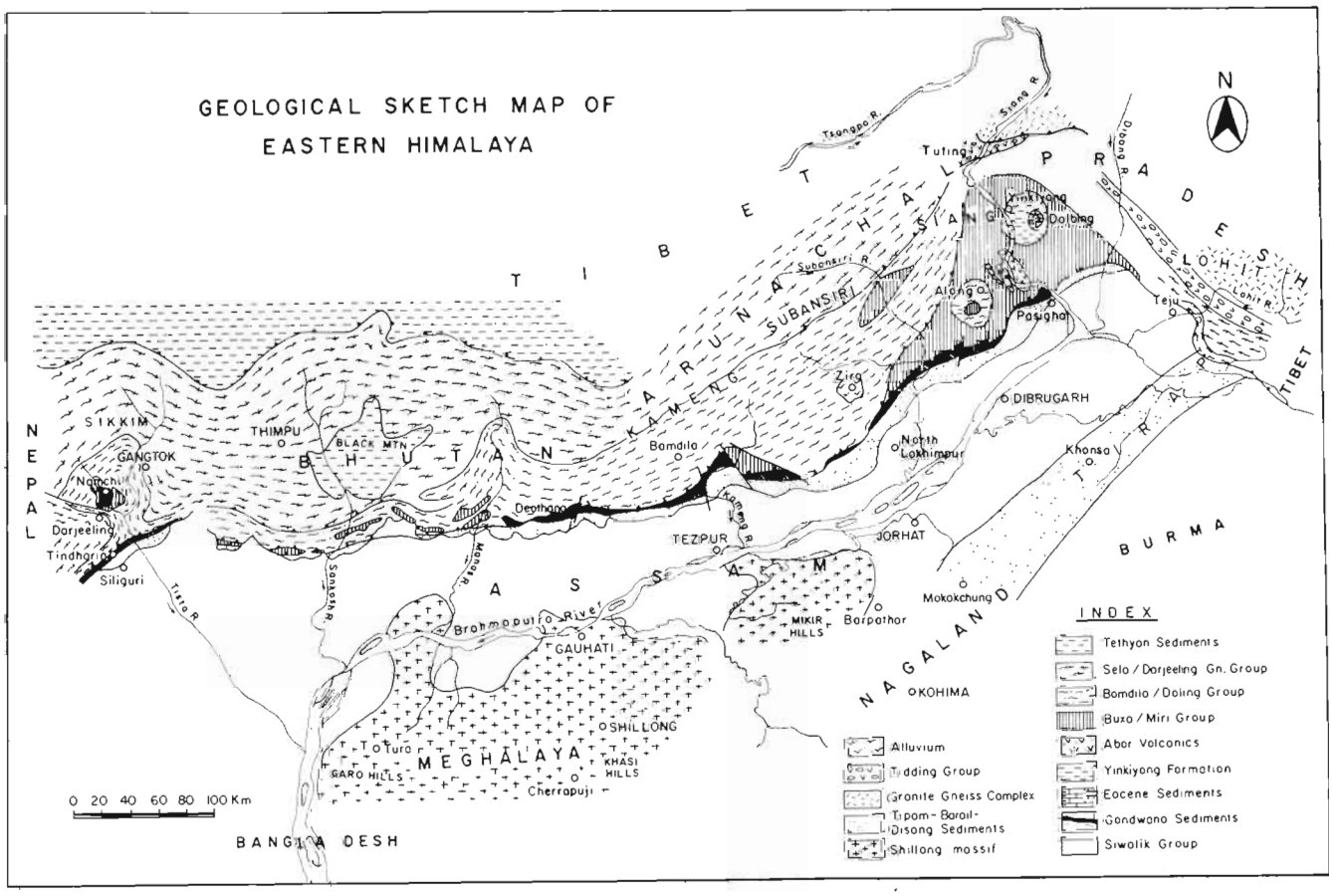
The Permian sediments extend from Kameng District in the west to Siang District in the east. The geological setting in each district is being described here separately.

Kameng District

The stratigraphic succession of Permian sediments is as under :

Bhareli Formation	Light grey, white or yellowish, pepper and salt type felspathic sandstone, impersistent carbonaceous shale and coal seams
Rangit Formation	Greenish or khaki, pebbly or gritty, frequently pyritous lithic wackes (i.e. diamictite), splintery shales, siltstone, quartzite-wacke, impure limestone

The Rangit Formation is a bryozoa dominated horizon. This assemblage includes well-preserved



Map 1—Geological sketch map of eastern Himalaya.

shells of *Eurydesma*. A Lower Permian age has been assigned to this formation.

The Bhareli Formation shows coarse, gritty felspathic sandstone showing parallel and cross lamination. The sequence represents finning upward cycle and is rich in plant fossils, viz., *Glossopteris, Dictyopteridium, Vertebraria, Phyllotheca, Schizoneura, Samaropsis,* etc.

Khelong Formation (Acharyya *et al.*, 1975) is not lithologically distinguishable in the type area and has been included in the Bhareli Formation. The bryozoa-dominated horizon (Acharyya *et al.*, 1975) near Khuppi represents a part of the Bhareli Formation and has no resemblance with the sediments of Rangit Formation.

Subansiri

The Permian sediments are exposed in a very narrow belt that pinches out at many places due to the overthrusting of Miri and Bomdilla group of rocks. The diamictite unit is not exposed in Subansiri District. The Permian sediments are exposed near Petepara on Kimin-Zero Section, and ahead of Bini in Tamen-Bini-Gogamukh Section. However, at Kheel in Doimukh-Sagalee Section, these sediments are very much reduced and almost sandwiched between the Siwalik sandstones in the south and gneisses in the north.

The Permian sediments are characterised by green-coloured shale, siltstone and mudstone having poorly sorted small clasts, dark grey to black carbonaceous shale with coal balls. There is no record of plant fossils from these sediments as yet. The fauna associated with coal balls includes a variety of invertebrate fossils. The interbedded sandstones are fine-grained and soft. Characteristic coal lenses are also found associated with shale and siltstone.

Godwin-Austen (1875) reported some clayey shale, often carbonaceous in nature, interstratified with coarse-grained sandstone exposed in Dikrang River Section. These carbonaceous shales often grade into splintery coal. The sequencee is considered to be continental in nature.

Siang District

The Permian sediments occur in a linear belt forming low hills in between the high hills of

Siwalik sediments in the south and Miri rocks in the north. The sediments attain maximum thickness towards west near Tatamari and thins out eastwards being cut off by two thrusts near Daring. Further east they reappear again near Renging on Passighat—Along Road and are again cut off further east by the Siang River. The sequence in the southern part of the district is as follows:

Garu Formation		Predominantly carbonaceous shale, coal and sandstone. Coal balls containing marine animal fossils
Rangit Formation	Rilu Member	Olivegreen splintery shale, greenish siltstone and mudstone with scattered clasts
	Diamictite Member	Massive conglomeratic rock with poorly sorted, angular clasts set in dark-grey or greenish argillaceous matrix. Interstratified siltstone and shale
	Thrust	
Miri Formation		Dominantly quartzites and limestones

Rangit Formation

The Rangit Formation constitutes the lowermost unit of the Permian Sequence and includes pebble slate, shale, siltstone, mudstone, etc. The formation is stratigraphically emplaced above the Miri Formation and the contact between the two is by and large tectonised.

Diamictite Member—The diamictite Member is massive and conglomeratic in nature and contains poorly sorted polymictic clasts which possess characteristic faceted and striated appearance. It often contains stratified layers of siltstone and shale. The diamictites are predominantly dark grey or greenish in colour and argillaceous in nature. The clasts are mostly derived from the adjacently exposed metamorphic rocks which vary in size from granules to boulders.

Isolated outcrops of this unit are present on Garu-Basar Section, Renging-Rotung Section and Bodak-Maryang Section. The lower and upper contacts of the Diamictite Member are usually tectonised. However, an unconformable relationship has been assumed on the basis of local nature of phenoclasts derived from the subadjacent and adjacently exposed pre-Permian rocks. The authors have observed that the Permian sediments were deposited over the uneven basement of Miri rocks like most of the Gondwana sediments of the Peninsula deposited over metamorphics. The erosional contact with the Miri rocks has been observed at many places, particularly in the sections exposed along the Garu-Basar Road and along the Passighat-Renging Road. However, due to the severe tectonic affect the true nature of the contact is visible only at few places.

Rilu Member—The Rilu Member consists of olive-green splintery shale with intercalated thin bands of fine-grained greenish siltstone. The splintery shales grade upwards into buff-grey to greenish-grey earthy mudstone containing scattered clasts of pink quartzite. Calcareous concretions of varying size are commonly found in the mudstone. This member attains maximum thickness near Rilu, east of Garu Village.

The Rilu Member was earlier included in the Garu Formation by Kumar and Singh (1974). The Siki-Abu Member or the Upper Diamictite Unit described by Kumar and Singh (1974) is considered here as a part of the Diamictite Member.

Garu Formation

The Garu Formation includes a succession of carbonaceous shale, coal layers and sandstone. Sedimentary structures are generally lacking. It extends from Tatamari to Renging and its maximum thickness has been observed near Gensi. Its contact with the Rilu Member is conformable. The Garu Formation now refers only to Bomte Member of Kumar and Singh (1974).

The sediments are highly crumpled and contorted. The maximum thickness has been observed near Bomte but the thickness reduces on either sides. The sandstones are generally bluish grey, coarse to medium-grained and often contain carbonaceous matter and well-preserved bryozoa. Coal balls, containing invertebrate fossils, occur irregularly dispersed in coal and carbonaceous shales and are largely calcareous in nature. Near Tatamari a 23 cm thick bed, so rich in fossils that it may be termed as 'Coquina' or named as 'Productus Bed', has been observed. In addition to these, dolomitic and cherty coal balls are also present in these sediments. The sandstones in the upper part of the sequence are largely ferruginous and often contain ferruginous or pyritous concretions which rarely contain animal fossils. The marine invertebrate fossils occur in all the units of Garu Formation including the sandstone but mostly are frequent in the carbonaceous units, particularly in coal balls.

The black shales and felspathic sandstones of the Gondwana sediments described by Jain *et al.* (1974) and the 'Garu Shale' and 'Gensi Formation' described by Roy Chowdhury and Boral (1978) from the same area also represent Garu Formation.

Coal Balls—The term 'Coal Ball' has been recently assigned to the concretions occurring among the coal and associated sediments of the Garu Formation (Anand-Prakash *et al.*, 1988). These concretions can be marked on the outcrop surface by their rounded to subrounded, oval-elongated shape and hard nature which protects them from weathering. The coal balls are mostly composed of calcium carbonate while those having magnesium carbonate, iron carbonate and iron-oxide are comparatively less common. Most of the coal balls, especially those rich in calcium and magnesium carbonates, have yielded well-preserved invertebrate marine fossils as well as palynofossils. Ferruginous concretions showing concentric rings often do not contain fossils.

Abor Volcanics

The Abor Volcanics mark the abrupt culmination of the general ENE to NE oriented structural trend of Kameng-Subansiri-Siang Himalaya. Abor Volcanics are developed in Igo-Along Section intersliced with Miri Formation as well as younger Permian Sequence. The volcanic sequence consists of basaltic to andesitic flows, silicic tuffs, lapillis, and agglomerates. It also includes basaltic dykes and sills. A few intertrappean beds within the Abor Volcanics have been reported in the type area, the Siang District. The rocks of Abor Volcanics are associated with the rocks of Miri Formation and the basal Diamictite Member of the Rangit Formation.

Yinkiong Formation

The Yinkiong Formation occupies a large tract in Siang and Yamne valleys in Siang District and is best exposed between the Dihang Bridge and Yinkiong on Geku-Yinkiong Road. Jain *et al.* (1974) considered it to be of Precambrian to Middle Palaeozoic in age. Singh (1984) has assigned a Permian age to these beds on the basis of brachiopods *Chonetes, Chonnetina, Marginifera* and cephalopods—*Nucula* and *Nuculina* discovered by Chatterjee *et al.* (1981). These fossils were recovered out of rolled boulders near Geku and their *in situ* presence still remains unknown. Hence, the age of Yinkiong Formation remains an open question.

Meghalaya

The Permian sediments are exposed around Singrimari (Hallidaygunj). The general stratigraphic sequence (Geological Survey of India, 1981) is as follows:

	Karharbari Formation	Very coarse to coarse grained sandstone with conglomeratic lenses/bands at the base, siltstone, shale, carbonaceous shale and coal—110 m thick
Lower Gondwana Group	Talchir Formation	Basal tillite, sandstone with conglomerate bands, siltstone and shale—75 m thick
	Unconformity	
Precambrian		

The Talchir Formation consists of basal tillite, yellow siltstone, sandstone, khaki-green to green shales with a few outsized clasts. The uppermost bed is marked by a thick conglomeratic band.

The Karharbari Formation includes coarse-grained sandstone, grey shale, carbonaceous shale and coal. The general contact with the underlying Talchir Formation is conformable and shows a general dip towards west. The full thickness of this formation is not exposed due to alluvial cover and the Barakar Formation may overlie in the west in the subsurface.

Palynology

The palynological studies of the Permian sediments of north-east Himalaya are limited to few reports only. There is no record of palynofossils from the Rangit Pebble-Slate/Diamictite units while the overlying carbonaceous sequences have yielded varied assemblages. A check list of palynomorphs recorded so far is given below :

Leiotriletes tenuis, L. plicatus, Hennellysporites sp., *Callumispora gretensis, C. barakarensis, Pseudoreticulatispora barakarensis, Brevitriletes unicus, Didecitriletes* sp., *Psilalacinites* sp., *Indotriradites korbaensis, I. sparsus, Jayantisporites pseudozonatus, Caheniasaccites indicus, C. ellipticus, C. elongatus, Divarisaccus ovatus, D. lelei, D. strengeri, Parasaccites obscurus, P. diffusus, P. bilateralis, P. distinctus, Plicatipollenites densus, P. indicus, P. gondwanensis, P. stigmatus, Virkkipollenites densus, Crucisaccites indicus, C. medius, Stellapollenites* sp., *Potonieisporites crassus, Limitisporites* sp., *Sahnites jayantiensis, Vesicaspora* sp., *Scheuringipollenites tentulus, Faunipollenites varius, Circumstriatites talchirensis, Striatopodocarpites multistriatus, Ginkgocycadophytus vetus, Quadrisporites horridus, Leiosphaeridia* sp., *Botryococcus* sp., *Maculatasporites* sp.

The detailed palynological compositions of Permian sediments from various areas are described here.

Darjeeling District

The palynostratigraphic succession of Permian sediments, specially the coal and associated sediments, has been described by Ghosh (1973, 1983). We have investigated palynofossils from the Lower Unit south of Tindharia. The palynological assemblages demarcated in the Coal Measures are described here.

Lower Coal Measures

Parasaccites Assemblage—Parasaccites (36%), *Scheuringipollenites* (12%), *Crucisaccites* (9%), *Cahleniasaccites* (8%), *Ibisporites* (8%) and *Vesicaspora* (6%) are important elements. The assemblage is characterised by the abundance of monosaccate pollen (56%). Nonstriate disaccate pollen are 29 per cent. The trilete spores are rare. Striate disaccate pollen grains are also low (8%).

Lophotriletes Assemblage—The assemblage is rich in trilete spores. *Lophotriletes* (28%), *Horriditriletes* (12%), *Brevitriletes* (9%) and *Cyclogranisporites* (6%) are characteristic elements. Striate disaccate pollen grains represented by *Striatopodocarpites* and *Faunipollenites* average up to 20 per cent.

Faunipollenites + Striatopodocarpites Assemblage—Striate disaccate pollen rise to overall dominance (60%). *Faunipollenites* (16%), *Striatopodocarpites* (14%) and *Labirites* (13%) are the chief constituents. Trilete spores are only 16 per cent.

Upper Coal Measures

Striate-disaccate Assemblage—The palynoflora recovered from the coal of Upper Unit is rich in striate disaccate pollen grains (60-70%) represented chiefly by *Striatites, Verticipollenites, Crescentipollenites, Striatopodocarpites*, etc. A sizeable percentage of trilete and monolete spores 924-38%) is recorded. The presence of *Indospora, Thymospora, Verticipollenites, Crescentipollenites, Distriatites* and *Gnetaceaepollenites* in this assemblage is significant.

The palynological assemblage of the Lower Unit (Ghosh, 1983) is also rich in striate disaccate pollen grains and almost all the genera mentioned above occur in the Lower Unit. The percentage of *Striatopodocarpites, Labirites* and *Indospora* increase in the Lower Unit. Thus the two units show a continuation of same Palynological assemblage which compares with the Raniganj palynofloras of the Peninsula. The Upper Barakar affinity as suggested by Ghosh (1983) is apparent only in view of the presence of striate disaccate pollen grains but the consistent presence of *Indospora, Thymospora, Verticipollenites, Crescentipollenites, Distriatites, Gnetaceaepollenites* alienates it more closer to the flora of Raniganj. The *Faunipollenites + Striatopodocarpites* Assemblage of the Lower Coal Measures shows similarity with the palynoflora of Lower Unit of Ghosh (1983) in having the dominance of striate disaccates but the above mentioned Upper Permian (Raniganj) taxa have not been observed in the Lower Coal Measures.

SIKKIM

Sikkip Member—Important elements in the coal and associated sediments of Sikkip Member are *Striatites* (18%), *Brevitriletes* (17%), *Scheuringipollenites* (13%) and *Lophotriletes* (10%). The trilete spores together total up to 35 per cent, striate disaccate pollen 34 per cent and nonstriate-disaccate 21 per cent. Monolete spores, colpate pollen and alete spores are also present.

The dominance of *Brevitriletes* along with nonstriate and striate-disaccate pollen alienates it with the Lower Barakar palynoflora of the Peninsula. However, in this assemblage nonstriate disaccate genera appear to be on the decline, while striate disaccates show a rising trend. Such a change is usually present near the transition from Lower to Upper Barakar palynofloras.

BHUTAN

The Permian sediments exposed along Darranga River near Dewthung in East Bhutan (Banerjee & Das Gupta, 1983) show dominance of *Scheuringipollenites* (18%), *Primuspollenites* (10.9%), *Cyclogranisporites* (9%) and *Marsupipollenites* (8%).

The above assemblage has been compared with the Middle Barakar palynoflora by Banerjee and Das Gupta (1983). However, the high frequency of *Marsupipollenites* in high percentage is significant as this genus is present in similar frequency in Upper Permian *Vittatina* Assemblage of Australia (Balme, 1964). The presence of *Microfoveolatispora, Densipollenites, Crescentipollenites, Gnetaceaepollenites* and *Vittatina* also indicates a younger aspect to this palynoflora.

ARUNACHAL PRADESH

Kameng District

The sediments exposed along Bhareli River near Elephant Flat have yielded a palynoflora which is characterised by the presence of trilete spores (43%), chiefly *Callumispora* (34%). This is associated with *Parasaccites* (25%), *Plicatipollenites,*

Table 1—Biostratigraphic zonation of Permian sediments in eastern Himalaya

Biozone	*Siang* *Palynoassemblage/ Invertebrate fossils*	*Subansiri* *Palynoassemblage/ Invertebrate fossils*	*Kameng* *Palyno-/ Plant assemblage*	*Bhutan* *Palynoassemblage/ Invertebrate fossils*	*Sikkim* *Palynoassemblage/ Invertebrate fossils*	*Darjeeling* *Palynoassemblage/ Invertebrate fossils*	*Meghalaya* *Palynoassemblage*	*Barpathar* *Palynoassemblage*	*Peninsular equivalent*
6			*Glossopteris*-dominant *Gangamopteris*-absent (Acharyya *et al.*, 1975)			*Striatopodocarpites, Indospora, Verticipollenites* (Ghosh, 1983)			Raniganj
5					*Striatites, Brevitriletes*	*Faunipollenites, Striatopodocarpites*			Barakar
4	*Scheuringipollenites/ Uraloceras, Ambikella, Linoproductus, Productus*			*Scheuringipollenites* (Banerjee *et al.*, 1983)	*Ambikella, Productus*	*Lophotriletes, Brevitriletes*	*Scheuringipollenites* (Banerjee *et al.*, 1977)		
3	*Callumispora/ Subansiria, Fenestella, Deltopecten, Eurydesma*	*Callumispora/ Subanisria, Syringothyris, Eurydesma*	*Callumispora, Parasaccites*	*Fenestellids, Bryozoa, Gastropods* (Dewathung Area)	*Eurydesma, Fenestella* (Singh, 1981)	*Parasaccites*			Karharbari
2	*Parasaccites, Plicatipollenites*							*Parasaccites, Leiosphaeridia*	Talchir
1						*Eurydesma, Sanguinolites* (Acharyya *et al.*, 1975)			

Caheniasaccites and *Indotriradites* are in low percentages. Monosaccate pollen are up to 36 per cent. These sediments comprising the Bhareli Formation, were equated with the Raniganj Formation by Acharyya *et al.* (1975). The palynological investigation, however, reveals that atleast a part of Bhareli Formation contains Lower Karharbari palynoflora (Dutta *et al.*, ms).

Subansiri District

The carbonaceous shales exposed near Kheel contain a palynoflora similar to that observed in Kameng District suggesting a Lower Karharbari aspect to these sediments.

Siang District

The Permian sediments exposed between Tatamari and Passighat contain three distinct palynological assemblages :

Parasaccites + Plicatipollenites Assemblage—The argillaceous olive green splintery shales of Rilu Member contain a palynoflora rich in radial monosaccate pollen (up to 60%) (Miofloral Zone 1 of Srivastava & Dutta, 1977; Rilu Member Assemblage of Singh, 1979). *Parasaccites* is the dominant component and is associated with subdominant *Plicatipollenites. Virkkipollenites, Potonieisporites, Caheniasaccites, Rugasaccites* and *Stellapollenites* also occur persistently though in low percentages. Trilete spores are represented by *Callumispora, Microbaculispora, Lacinitriletes* and *Leiotriletes.* Disaccate pollen grains are very rare and so also the alete spores which are represented by *Leiosphaeridia, Pilasporites, Quadrisporites* and *Maculatasporites.*

Callumispora Assemblage—The black carbonaceous shales of Garu Formation show rise of the genus *Callumispora* to overall dominance (40-

60%), *Parasaccites* decreases to subdominance (20-30%). *Indotriradites* also increases to 10-15 per cent. In some samples near Passighat the percentage of *Indotriradites* has been observed to attain even higher values only next to the genus *Callumispora*. *Crucisaccites* is confined to this assemblage alone. *Caheniasaccites* is also associated with this assemblage and its percentage increases towards Passighat but in all the cases it remains next to the genus *Callumispora* or *Indotriradites*.

Scheuringipollenites Assemblage—In the carbonaceous sediments of the Garu Formation exposed near Takso Village *Scheuringipollenites* attains overall dominance while radial monosaccate pollen and trilete spores decrease considerably. Striate and nonstriate disaccates record increase in their percentage.

Coal Balls

The coal balls, particularly the calcareous coal balls, have yielded well preserved microflora which is similar to the palynoflora of the Garu Formation. In addition to the spores and pollen grains conodonts and microforaminifers have also been recovered, though their percentage is less.

Abor Volcanics

Roy Chowdhury (1977) has reported the occurrence of *Cyclogranisporites, Striatopodocarpites, Vittatina, Scheuringipollenites* (= *Sulcatisporites*) in the inter-trappean carbonaceous shales in Dihang Valley. Laskar and Roy Chowdhury (1979) consider these forms to represent Lower Gondwana.

Barpathar Area, Assam

The subsurface Permian sediments of Barpathar Area, Jorhat District (Assam) have yielded the following palynoflora (Sharma *et al.*, 1986):

Parasaccites + *Plicatipollenites Assemblage*—This assemblage shows dominance of radial monosaccate pollen (60-70%), e.g., *Parasaccites* (up to 40%) and *Plicatipollenites* (25-30%). *Callumispora* remains subdominant (10-15%). The total percentage of monosaccate pollen grains range between 60-70 per cent. Other trilete spores represented by *Jayantisporites, Microbaculispora, Indotriradites* range between 10-15 per cent. The presence of *Leiosphaeridia* is significant. Its frequency is up to 26 per cent in the older sediments but progressively reduces in younger sediments yet remains significant. Sporadic presence of *Botryococcus, Maculatasporites* and *Pilasporites* has aso been observed.

Meghalaya

The Permian sediments exposed on the western margin of Garo Hills near Hallidaygunj in Meghalaya has been studied by Banerjee *et al.* (1977). The assemblage is rich in *Scheuringipollenites* while other group of spores are present in low amounts.

The quantitative representation is not known and hence a correct assessment remains to be done. It appears that Lower Barakar palynoflora has already developed in the younger part of the sequence which are at present classified as Karharbari Formation. Lithologically the Barakar sediments are suspected to be present under the alluvial cover westwards in Hallidaygunj area.

BIOSTRATIGRAPHY

The frequent lithological variations, vertical and lateral both, limit the certainty of correlating the various rock units from different areas. The lithologic development, both marine and continental, is better pronounced in Arunachal Pradesh as compared to other areas of Eastern Himalaya. Similarly the fossil contents are also better preserved in Arunachal Pradesh. Therefore, a tentative stratigraphic sequence has been attempted on the basis of their biotic contents.

Biozone 1

Acharyya (1973) has reported Eurydesma Fauna from the Rangit Pebble Slate/Diamictite from Darjeeling Area. Fenestellids, bryozoa and gastropods have also been reported from Diuri Boulder Slates from Dewathung area in Bhutan. On the basis of the invertebrate fossils the Rangit Pebble Slate/Diamictite Member is dated as Asselian (Lower Permian) and is correlated with the Talchir Boulder Bed of the Peninsula.

Biozone 2

Biozone 2 has a radial monosaccate dominant assemblage which is comparable to the Talchir palynoflora of the peninsula. It is recorded from the Rilu Member. A similar assemblage is also known from the subsurface sediments in Barpathar area (Sharma *et al.*, 1986). This *Parasaccites* + *Plicatipollenites* Assemblage is rich in leiosphaerids in the lower part of the sequence but the same decreases in the younger part. The assemblage of the Rilu Member which contains smaller percentage of leiosphaerids is comparable to the upper part of the sequence in Barpathar area.

Biozone 3

The *Callumispora* Assemblage of the Garu Formation represents Biozone 3. The invertebrate fossils present in these sediments include *Deltopecten, Megadesmus, Phestia, Subansiria* and *Fenestella* in the lower part of Bomte Member; *Subansiria, Ambikella, Spirifer, Chonetes,*

Syringothyris, Connularia and *Eurydesma* in Subansiri District; and *Eurydesma* and *Fenestella* in Namchi Member (Namchi Formation) from Sikkim (Singh, 1981). These faunal assemblages are closely similar to the *Eurydesma-Deltopecten* Assemblage of the Agglomerate Slate, Kashmir corresponding to Sakmarian age. Thus, the palynoflora as well as the fauna both complement each other in Siang, Subansiri and eastern Kameng. The *Callumispora* Assemblage is also present in the coal and carbonaceous sequence exposed in Bhareli River near Elephant Flat in Kameng District. However, the coal balls and animal fossils are totally absent in this section. Thus, the Karharbari palynoflora is associated with animal fossils in Siang and Subansiri while in Kameng it occurs independently. The faunal assemblage similar to that of the Garu Formation (rich in fenestellids, bryozoa and gastropods) is also reported from Dewathung area, east Bhutan. In south Sikkim the fauna described from the sediments of Namchi Member also correlates with that of the Garu Formation being rich in *Eurydesma, Fenestella, Spirifer*, etc. In Darjeeling the animal fossils are not known from the coal and carbonaceous shales which contain radial monosaccate dominant assemblage (Upper Karharbari). The above evidences tend to indicate that the Eurydesma Fauna and Karharbari palynoflora have occurred contemporaneously and hence are coeval.

Biozone 4

It is represented by the *Scheuringipollenites* Assemblage from the carbonaceous sediments of Garu Formation exposed near Takso village in Siang District and is comparable to the Lower Barakar palynoflora of the peninsula. In Darjeeling the Lower Barakar palynoflora (*Lophotriletes* Assemblage) is rich in trilete spores alongwith striate-disaccate pollen grains. The palynoflora described from Dewathung area, Bhutan (Banerjee *et al.*, 1983) shows dominance of *Scheuringipollenites*. However, the presence of *Marsupipollenites* in this assemblage indicates a younger aspect. The *Scheuringipollenites* dominant assemblage from Hallidaygunj area, Meghalaya (Banerjee *et al.*, 1977) also represents a Lower Barakar palynoflora. The *Scheuringipollenites* dominant assemblage recorded from the upper part of the Garu Formation in Siang is associated with *Linoproductus, Uraloceras, Ambikella* and crinoids. The comparable flora is not known from Sikkim. However, a fauna comprising *Ambikella, Spirifer* and *Syringothyris* described from Namchi Member (Singh, 1981) may be considered equivalent to this biozone. All the above faunal elements suggest Artinskian age.

Biozone 5

Faunipollenites + *Striatopodocarpites* Assemblage recorded from the Lower Coal Measures of Tindharia, Darjeeling District represents Biozone 5 and is comparable to the Upper Barakar palynoflora of the Peninsula. The striate-disaccate dominant assemblage described from Sikkip Member (Namchi Formation, Sikkim) has also been included in this biozone, though it contains trilete spores and nonstriate-disaccate pollen in subdominance.

Biozone 6

The youngest biozone is also characterised by the dominance of striate disaccate pollen grains which is present in Upper Coal Measures from Darjeeling District (Ghosh, 1983). This assemblage shows its similarity with that of Biozone 5 in view of higher percentage of striate disaccate pollen grains but the same is differentiable by the presence of *Indospora, Thymospora, Distriatites, Crescentipollenites* which indicates a younger aspect and as a whole is comparable with the Raniganj palynoflora. There is no other record of such assemblage from any other area in eastern Himalaya at present. The megafossils showing dominance of *Glossopteris* and absence of *Gangamopteris* in the Bhareli Formation from Kameng District is considered to be equivalent to the Raniganj flora (Acharyya *et al.*, 1975).

PALAEOENVIRONMENT

The Rangit Pebble Slate/Diamictite Member of the eastern Himalaya is usually correlated to the Talchir Boulder Bed of the Peninsula (Oldham, 1887; Fox, 1931; Auden, 1934, 1935). This major key horizon in eastern Himalaya exhibits distinct lithologic dissimilarity with those of the peninsular Talchir Boulder Bed. The genesis of this member is debatable. Some consider them to be glacial in origin (Ghosh, 1952, 1956; Nautiyal *et al.*, 1964) while the others view them to have been formed due to slide/slump or turbidity currents (Rupke, 1968; Acharyya, 1973).

The presence of *Eurydesma* fauna (Acharyya, 1973) in Rangit Pebble Slate suggests a cold marine environment during the deposition of these sediments. The Diamictite of Arunachal Pradesh is characterised by poorly sorted angular to subangular clasts which are mostly faceted; some of them show striations and polishing. These evidences document a glacial origin of these diamictites. The palynoflora of the Rilu Member in Siang and also subsurface sediments in Barpathar area further substantiates a wide spread glaciation associated with marine influence for at least a part of the Rangit Formation.

The black carbonaceous shales and coal succeeding the Rilu Member are characterised by the Lower Karharbari palynoflora. The fauna in the coal balls and also the sediments containing them is rich in *Eurydesma, Chonetes, Spirifer* and *Productus.* The species of *Eurydesma* are more varied in Siang, Subansiri (Garu Formation) and South Sikkim (Namchi Member) than in the Rangit Pebble Slate Member. Perhaps the Garu Formation and the equivalent sediments represent the acme of *Eurydesma* with its first appearance in Rangit Pebble Slate Member. *Productus* marks its appearance but remains low in occurrence and the number of species recorded is also low. The presence of *Eurydesma* fauna in these sediments suggests continuance of a cold marine environment. The development of black shales and coal which are devoid of any sedimentary structures except fine laminations and also the formation of coal balls suggests deposition in stagnant and tranquil waters. It is possible that reducing environment, developed under anaerobic conditions in coastal lagoons formed as a result of regressive epicontinental sea, has generated formation of black shales and coal of Bomte Member and other equivalent sediments. These conditions of deposition have prevailed all along in the Siang and Subansiri districts but in Kameng were restricted to eastern part only as west of Khuppi the sediments are exclusively continental. Further west the existence of similar fauna in Bhutan and Sikkim suggests the presence of similar depositional environment but in Darjeeling the sediments are again continental. Thus, the above evidences clearly suggest that these sediments were deposited during the regressive phase of sea and fluvial conditions were already under development, though restricted in aerial extent.

The depositional environment during the sedimentation of the upper part of the Garu Formation containing Lower Barakar palynoflora in Siang District appears to have been marine as the *Ambikella-Uraloceras* rich fauna is also present in the same sediment. This is the youngest record of marine influence in Arunachal Pradesh and also Sikkim (Namchi Member) as elsewhere in Bhutan (Banerjee *et al.*, 1983), Sikkim (Sikkip Member), Darjeeling (upper part of the Lower Coal Measures) and Hallidaygunj (Meghalaya) the sediments are characteristic of deltaic environment as the sandstones show horizontal ripples and laminations. The coal and carbonaceous shales are also thinner and streaky as compared to that of the Garu Formation.

The sediments of the Bhareli Formation in Kameng and Upper coal Measures in Darjeeling District show full development of sandstone and coal seams. These sediments represent a typical fluvial facies. Megafossils as well as the microfossils both represent a land flora and there are no evidences of marine elements.

GENETIC RELATIONSHIP

The term 'Gondwana' was applied to essentially fluviatile sediments which were widely distributed in peninsular India and are believed to have been deposited in tectonically controlled linear-sublinear basins/grabens. The eastern Himalayan Permian sediments, however, occur as allochthonous sheets all along the foothills of Himalaya, or as windows or discontinuous thrust sheets within the older metamorphics (Acharyya, 1975). The lithological similarity of the Rangit Pebble Slate/Diamictite is in typical contrast with those of the Talchir Boulder beds. However, the faunal and floral relationships are closely similar with their peninsular counterparts. The presence of *Eurydesma* at the base of Talchir Formation in Manendragarh is comparable with the Eurydesma Fauna of Rangit Pebble Slate. Similarly the *Parasaccites* + *Plicatipollenites* dominant assemblage of Rilu Member is also comparable with the *Parasaccites* Assemblage of Manendragarh (Bharadwaj *et al.*, 1979).

The black carbonaceous shale and coal of the Garu Formation contain *Callumispora* Assemblage in association with marine invertebrate fossils. The Lower Karharbari sediments of the Peninsula though resemble palynologically yet are devoid of animal fossils. The sediments of the Garu Formation are also characteristically associated with the faunal coal balls which are totally absent in Karharbari Formation. The overlying assemblage near Takso Village in Siang District (*Scheuringipollenites* Assemblage) is also associated with animal fossils in which *Linoproductus-Ambikella* predominates. Thus, there is a distinct contrast in sedimentational history of Peninsula and eastern Himalayan Permian sediments. The sediments of the Lower Permian sequence were largely under marine influence which continued as late as Lower Barakar times while in the Peninsula it is restricted to the Talchir times only. Venkatachala and Tiwari (1988—this Volume) have also suggested the presence of marine incursions throughout the Gondwana Sequence. However, the marine conditions never prevailed during the formation of coal in the peninsular Gondwana basins and whatever marine intercalations are known are associated with the shales and sandstones of the Talchir Formation. Besides, the occurrence of true faunal coal balls having marine fossils suggests that atleast the Arunachal Permian coals are autochthonous in

origin. Contrary to this the peninsular Gondwana coals are believed to be of allochthonous origin. Therefore, it is difficult to compare the coals and associated sediments of eastern Himalaya with the Gondwana sediments of the Peninsula as they are different in nature as well as in their mode of formation. So far, these sediments have been grouped together mainly on the basis of their general appearance and regional lithologic characters. But a critical assessment of their genesis and mode of formation indicates that both these sediments are of entirely different nature, particularly having no similarity in their depositional history, as one is largely marine and the other is exclusively continental. Thus, to group these sediments together in Gondwana Sequence seems to be illogical, atleast without modifying the present concept of the Gondwana litho-unit which can only accommodate continental sediments. However, some minor marine intercalations may be placed in this unit. But how a dominantly marine sequence with such a large aerial extent can be placed in a unit designated and defined for essentially fresh water deposits? Under the circumstances it is suggested that if the Permian sediments of lesser Himalayan Zone of eastern Himalaya are to be grouped in the Gondwana Sequence a suitable modification is required in the prevailing concept else these sediments may be given a separate identity of their own. The similarity grows closer only during late Permian as the sediments in both the places are exclusively fluvial and show lithological similarity alongwith the fossil evidences.

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