Siwalik sediments of Arunachal Himalaya: Palynology, palaeoecology and palaeogeography

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The palynological assemblages comprising angiospermous pollen, pteridophytic spores, fungal remains, gymnospermous pollen, dinoflagellate cysts, acritarchs and reworked Permian spores and pollen, have been reported from Siwalik sediments exposed in Kameng, Subansiri and Siang districts, Arunachal Pradesh. Palynological comparison with extant plants has been attempted to determine the palaeovegetation, palaeoclimate and environment of deposition. Geological history and palaeogeography of Neogene sediments of Arunachal Himalaya have been discussed.

Key-words—Palynology, Palaeoecology, Palaeogeography, Siwalik, Arunachal Himalaya, Miocene (India).

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सारांश

अरुणाचल हिमालय के शिवालिक अवसाद : परागाणविक अध्ययन, पुरापारिस्थितिकी एवं पुराभौगोलिकी

त्रिलोचन सिंह एवं सूर्यकान्तमणि त्रिपाठी

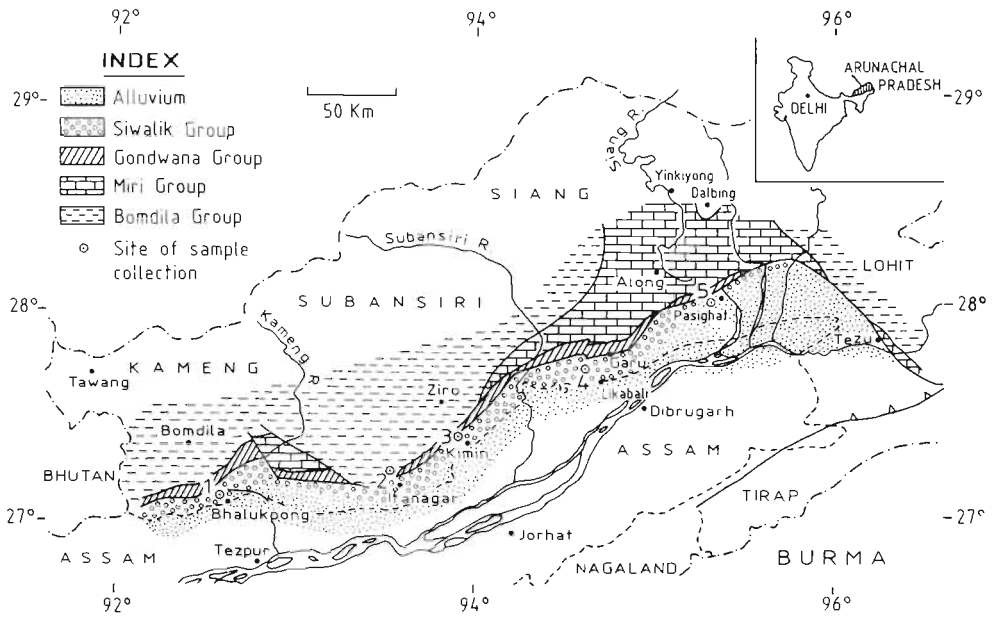
अरुणाचल प्रदेश के कामेंग, सुबनसिरी एवं स्याँग जनपदों में अनावरित शिवालिक अवसादों से उपलब्ध परागाणविक समुच्चय में आवृतबीजी परागकण, टेरीडोफ़ाइटी बीजाणु, कवकीय अवशेष, अनावृतबीजी परागकण, घूर्णिकशाभ पुटीयाँ, ऐक्रीटार्क एवं पुनरीक्षित परमी कालीन परागकण एवं बीजाणु उपलब्ध हुए हैं। पुरावनस्पति, पुराजलवायु एवं निक्षेपण का वातावरण सुनिश्चित करने के लिए वर्तमान पौधों से परागाणविक तुलना करने का प्रयास किया गया है। अरुणाचल हिमालय के पश्चनूतन अवसादों के भूवैज्ञानिक इतिहास एवं पुराभौगोलिकी की विवेचना भी की गई है।

PALYNOLOGICAL study on Siwalik sediments exposed in Kameng, Subansiri and Siang districts, Arunachal Pradesh has been carried out. Taxonomic part of the present palynological work shall be published elsewhere. In the present paper an attempt has been made to apply the obtained data to reconstruct the past vegetation, palaeoecology and environment of deposition.

The Siwalik sediments in Arunachal Himalaya are represented by thick piles of arenaceous and argillaceous sediments which are exposed in a continuous belt all along the Himalayan foot-hills from Kameng District in the west to Siang District in the east (Text-fig. 1). Further eastward in Lohit District, these sediments are covered with alluvium.

The Siwalik sediments mark a change in topography from the plains of Brahmaputra Valley to the Himalayan foot-hills where these rise abruptly and abut against the alluvium. These sediments extend up to 15 to 30 km towards north where they are thrusted against the Gondwana Group of rocks. However, due to overthrusting of the older rocks over the Gondwana rocks, the Siwalik sediments are thrusted directly against the Miri and/or Bomdila groups of rocks.

Palynologically the Tertiary sediments of Arunachal Himalaya are less explored. Dutta and Singh (1980) and Dutta (1980) reported palynological assemblages from these sediments exposed in Kameng District and correlated them with Neogene formations of Upper Assam. The assemblages recovered by them are of mixed type containing elements of Permian, Eocene and Miocene ages.



Text-figure 1—Geological map of the area showing localities of sample collection. **1.** Bhalukpong-Sessa Section, Kameng District; **2.** Itanagar-Doimukh-Kheel Section, Subansiri District. **3.** Kimin-Ziro Section, Subansiri District; **4.** Likabali-Garu Section, Siang District; **5.** Pasighat-Koyu Section, Siang District.

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PLATE 1

(All photomicrographs are magnified, × 500)

1. *Lycopodiumsporites* sp.; Slide no. BSIP 10217, coordinates: 45.5 × 115.9.
2. *Lycopodiacidites* sp.; Slide no. BSIP 10217, coordinates: 48.6 × 112.3.
3. *Lycopodiacidites dextrus* Kar & Kumar; Slide no. BSIP 10198, coordinates: 11.5 × 105.5.
4. *Lygodiumsporites eocenicus* Dutta & Sah; Slide no. BSIP 10200, coordinates: 21.1 × 106.6.
5. *Pteridacidites* sp.; Slide no. BSIP 10206, coordinates: 12.2 × 115.4.
6. *Lycopodiumsporites palaeocenicus* Dutta & Sah; Slide no. BSIP 10199, coordinates: 14.3 × 112.6.
7. *Couperipollis* sp.; Slide no. BSIP 10216, coordinates: 35.9 × 110.1.
8. *Verrualetes assamicus* Singh & Saxena; Slide no. BSIP 10205, coordinates: 20.2 × 108.9.
9. *Verrualetes* sp.; Slide no. BSIP 10203, coordinates: 34.6 × 105.5.
10. *Assamiapollenites ghoshii* Singh & Saxena; Slide no. BSIP 10203, coordinates: 40.3 × 106.1.
11. *Loranthipites* sp.; Slide no. BSIP 10209, coordinates: 41.8 × 105.5.
12. *Palmidites applicatus* Kar & Kumar; Slide no. BSIP 10216, *coordinates: 30.7 × 117.6.
13. *Dictyophyllidites* sp.; Slide no. BSIP 10203, coordinates: 25.6 × 95.1.

14,29. *Tricolporopollis rubra* Dutta & Sah; Slide nos. BSIP 10196 and 10207, coordinates: 38.10 × 110.6 and 25.6 × 104.10 respectively.

15,24. *Meliapollis* sp.; Slide nos. BSIP 10194 and 10195, coordinates: 25.5 × 115.7 and 22.1 × 105.6, respectively.

16,33. *Striatriletes attenuatus* Singh & Tripathi, Slide nos. BSIP 10214 and 10200, coordinates: 25.7 × 103.1 and 45.7 × 106.5 respectively.

17. *Colliumosphaera* sp.; Slide no. BSIP 10192, coordinates: 35.2 × 110.3.

18,31. *Lakiapollis assamicus* Tripathi & Singh; Slide nos. BSIP 10194 and 10193, coordinates: 33.4 × 110.5 and 31.6 × 110.8 respectively.

19. *Liliacidites* sp. 1; Slide no. BSIP 10203, coordinates: 48.3 × 119.7.
20. *Liliacidites* sp. 2; Slide no. BSIP 10203, coordinates: 39.5 × 111.10.
21. *Couperipollis magnus* Kar & Kumar; Slide no. BSIP 10191, coordinates: 46.8 × 117.5.
22. *Intrapunctisporis subtriangularis* Kar & Singh; Slide no. BSIP 10194, coordinates: 60.9 × 111.5.
23. *Palmidites obtusus* Tripathi & Singh; Slide no. BSIP 10189, coordinates: 18.5 × 96.2.
25. *Proxapertites assamicus* (Sah & Dutta) Singh, Slide no. BSIP 10196, coordinates: 32.8 × 111.10.
26. *Palmidites* sp.; Slide no. BSIP 10188, coordinates: 43.10 × 98.2.
27. *Podocarpidites* sp.; Slide no. BSIP 10209, coordinates: 28.2 × 105.7.
28. *Dicolpopollis* sp.; Slide no. BSIP 10213, coordinates: 21.7 × 104.3.
30. *Collospermumpollis laevigatus* Tripathi & Singh; Slide no. BSIP 10191, coordinates: 46.10 × 109.9.
32. *Ctenolophonidites costatus* (Van Hoeken-Klinkenberg) Van Hoeken-Klinkenberg; Slide no. BSIP 10211, coordinates: 32.3 × 106.5.

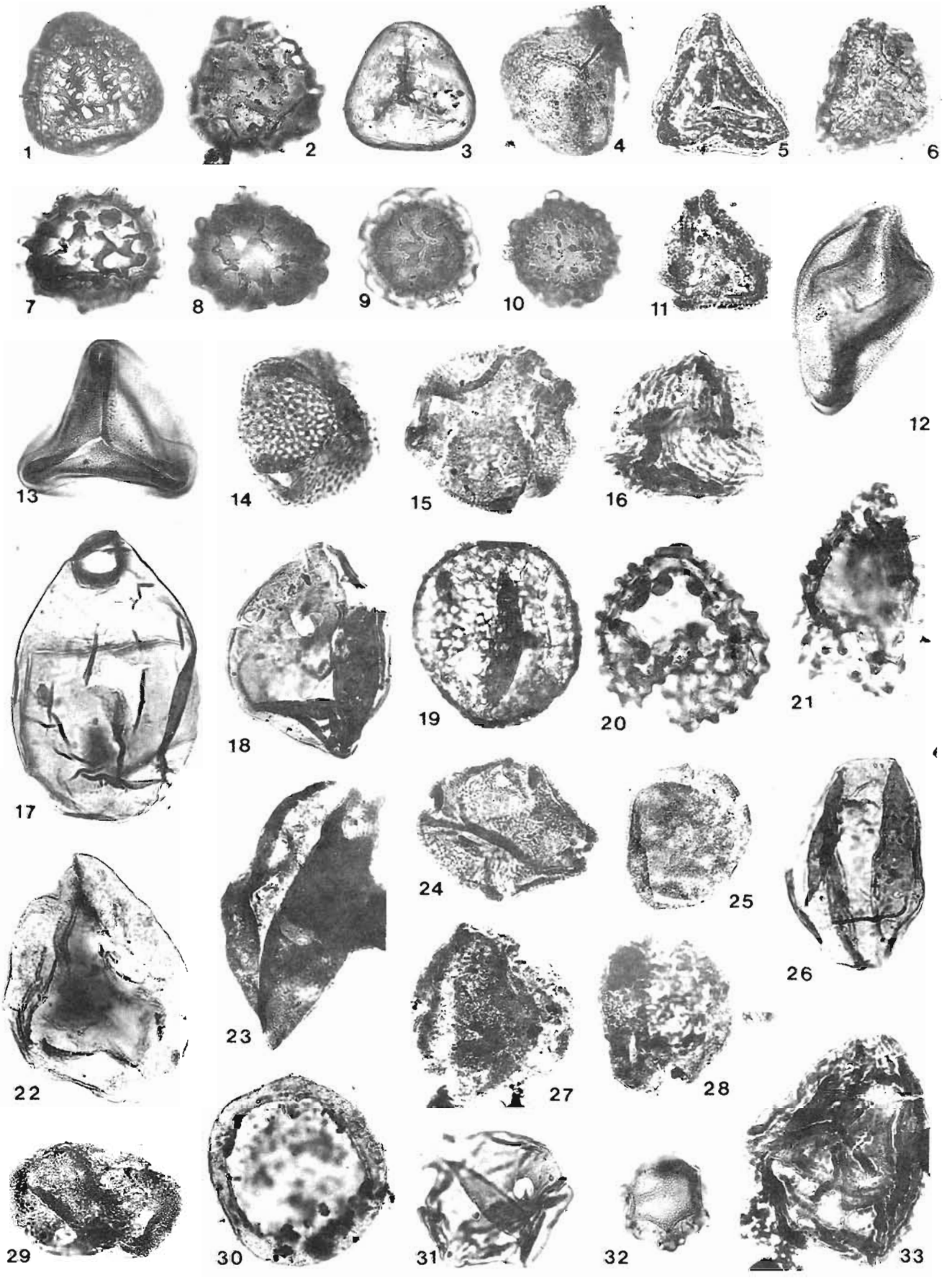
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PLATE 1

Samples for the present palynological study have been collected from the following sections (Text-fig. 1).

1. Bhalukpong—Sessa Section, Kameng District
2. Itanagar-Doimukh-Kheel Section, Subansiri District
3. Kimin-Ziro Section, Subansiri District
4. Likabali-Garu Section, Siang District
5. Pasighat-Koyu Section, Siang District

LITHOLOGICAL CHARACTERS OF SIWALIK SEDIMENTS

The Siwalik sediments are mainly composed of sandstone, siltstone, clay and pebble beds but lot of lithological variation has been noticed in different sections.

The sandstone, in general, is of salt-and-pepper appearance that weather to pale brown colour. It varies from fine to coarse-grained, sometimes gritty, moderately loose to compact, soft to hard. In Bhalukpong-Sessa section, Kameng District, it is often indurated. Generally the sandstone becomes micaceous and the biotite alignment gives colour-banding. Occasionally it is structureless, but mostly it is laminated showing parallel, cross and ripple cross-lamination. The foreset laminae occasionally consists of carbonaceous shale and clay, mica-flakes and detrital coal grains. Pebbles are also noticed within the sandstone occurring as small pockets or thin layers mostly aligned parallel to the lamination. The pebble and clast percentage is variable. The clasts are generally subrounded to rounded, flat or discoidal. Coarser to gritty gradation in the form of conglomerate is also noted in the sandstone.

The calcareous concretions, mostly aligned along the bedding plane, are commonly found in the sandstone. Their diameter varies from 5 to 40 cm and are spherical to subspherical, ellipsoidal to elongate in shape. Thin lenses and streaks of coal, lumps and lenticles of lignite and sporadic carbonised and silicified wood fragments have also been observed in the sandstone. Grey coloured compact sand-balls and thin pseudobeddings that cut across the bedding plane have also been noted in the loose grey to brownish colour sandstone. These sand-balls and veins have been referred to as 'Sandstone dykes' by Kumar and Singh (1982). Associated with the sandstone are greyish-green clay, siltstone and shale, which often show spheroidal and nodular weathering. Siltstone is splintery and at places becomes sandy in nature.

The conglomerate strata, though not common in Arunachal Pradesh, are observed in Pasighat-Koyu section, Siang District, and Bhairabkund-Kalaktang section, Kameng District. In Likabali-Garu section, Siang District, near Siji, there is a thick sequence of conglomerate sandstone alternation with thin silty clay bands. It is doubtful whether this horizon is a part of Upper Siwalik or it belongs to the Quaternary sediments. No palynofossils have been recovered from this part, hence the age of these sediments could not be determined. The conglomerate beds range in thickness from 3 to 34 m with fragments of pebble to boulder size. The pebbles and boulders generally show orientation parallel to the bedding plane but at some places they do not show any preferred orientation. The pebbles and boulders are predominantly of gneisses, quartzites, schists and limestones. In Pasighat-Koyu section, Siang District, some pebbles of volcanic rocks are also observed. The conglomerates are moderately compact to semi-consolidated.

STRUCTURE

The abrupt rise of Siwaliks abutting the older alluvium of Brahmaputra plains is marked by a fault. Towards north, the Siwaliks are thrusted against the Gondwana group of rocks. In Pasighat-Koyu section, Siang District the Siwaliks are thrusted against the older Miri and/or Bomdila group of rocks as a result of overthrusting of these older rocks over the Gondwanas.

The regional Siwalik structure is a monocline, dipping at 15°-50° towards north-west. Locally, the dip changes to north-east. However, towards south near the northern thrust contact in Likabalki-Garu section, Siang District these sediments dip at a very high angle (70°-80°). The Siwalik sandstone shows open symmetrical folds in Subansiri District where sometimes folding becomes very tight and the limbs become nearly vertical. The fold axes, at times, become almost horizontal and plunge 10° towards north-west. A few intraformational low-angle faults are also recorded. One such fault is clearly visible at about 23 km stone in Kimin-Ziro section, Subansiri District, where the rocks show high crushing and fault gauge in a shear zone. There also appears to have taken place the post-Tertiary tectonic activity, which is envisaged by the faults effecting both Siwaliks and Gondwana rocks. Such faults are identified in Likabali-Garu-Basar section, Siang District and Bhalukpong Sessa-Jamiri section, Kameng District. The faults strike roughly N-S direction.

Current bedding, channel fill structures are prominent structural features of sandstones and conglomerates. Small scale synsedimentary faulting is also noticed. All these features indicate shallow

water torrential deposits. In Itanagar section, Subansiri District, boulders of grey sandstone have been found in the brown, loose sandstone indicating penecontemporaneous erosion of the Siwalik sandstones. The scattered longer axes orientation of clasts at places indicate high energy dispersion and parallel orientation of longer axes of the clasts indicates lower energy and traction currents.

PALYNOFLORAL COMPOSITION

Palynoassemblages are impoverished and are constituted by dinoflagellate cysts, acritarchs, fungal spores and fungal fruiting bodies, pteridophytic spores and gymnospermous and angiospermous pollen grains. Quantitative representation of individual taxon is very poor. Thus, it has not been possible to apply the palynological data for stratigraphic zonation. However, an attempt has been made to trace the botanical affinity of palynotaxa with a view to reconstruct the past vegetation, palaeoecology and environment of deposition. A list of recovered palynotaxa and their affinity is given below :

Botanical Group/Family	Present distribution	Palynotaxa	Remarks
PTERIDOPHYTES			
Lycopodiaceae	Tropical to temperate	*Lycopodiacidites dextrus* Kar & Kumar 1986, *Lycopodiacidites* sp., *Lycopodiumsporites* sp.	Inhabits moist and shady places
Polypodiaceae	Cosmopolitan	*Monolites mawkmaensis* Sah & Dutta 1966	
Matoniaceae	Tropical	*Dictyophyllidites* sp.	
Schizaeaceae	Tropical to subtropical	*Lycopodiumsporites eocenicus* Dutta & Sah 1970, *Intrapunctisporis subtriangularis* Kar & Singh 1986	
Osmundaceae	Tropical and temperate	*Todisporites major* Couper 1958	
Parkeriaceae	Tropical to subtropical	*Striatriletes susannae* van der Hammen emend. Kar 1979, *S. attenuatus* Singh & Tripathi 1983, *S. pseudocostatus* Singh & Tripathi 1983	Water fern
Pteridaceae	Cosmopoliton	*Pteridacidites* sp.	
GYMNOSPERMS			
Podocarpaceae	Subtropical to temperate	*Podocarpidites meghalayaensis* Rao 1986, *Podocarpidites* sp.	
Pinaceae	Temperate	*Pinuspollenites* sp., *Abiespollenites* sp., *Laricoidites* sp.	
ANGIOSPERMS			
Arecaceae	Tropical to subtropical	*Palmidites maximus* Couper 1953, *P. applicatus* Kar & Kumar 1986, *Palmidites* sp., *Couperipollis magnus* (Dutta & Sah) Kar & Kumar 1986, *Couperipollis* sp., *Dicolpopollis* sp., *Longapertites klinkenbergii* Rao & Ramanujam 1978	
Araceae	Tropical and temperate	*Proxapertites assamicus* (Sah & Dutta) Singh 1975	

Ctenolophonaceae	Cosmopolitan	*Ctenolophonidites costatus* (Van Hoeken-Klinkenberg) Van Hoeken-Klinkenberg 1966	The plants grow in fresh water swamp forests
Bombacaceae	Tropical	*Tricolporopollis rubra* Dutta & Sah 1970, *Lakiapollis assamicus* Tripathi & Singh 1985	These palynotaxa resemble pollen of *Cullenia* and *Durio* growing in evergreen forests
Meliaceae	Tropical to subtropical	*Meliapollis* sp.	
Liliaceae	Cosmopolitan	*Liliacidites* sp., *Collospermumpollis laevigatus* Tripathi & Singh 1984	
Loranthaceae	Tropical to subtropical	*Loranthipites* sp.	Plants of this family are parasites on trees and shrubs of diverse forests
Malvaceae	Tropical and temperate	*Malvacearumpollis paucibaculatus* Venkatachala & Rawat 1973	

In addition, some palynotaxa have also been recovered whose affinity with living plants could not be traced. These are *Assamiapollenites ghoshii* Singh & Saxena 1984, *Inaperturopollenites* sp. and *Tricolpites* sp.

QUANTITATIVE ANALYSIS

The present palynological assemblage comprises 29 genera and 38 species of pteridophytic spores, gymnospermous and angiospermous pollen. Apart from these, dinoflagellate cysts, acritarchs, fungal remains and reworked Permian spores and pollen have also been recovered. The assemblage is dominated by angiospermous pollen (43%). Pteridophytic spores (20%) are also richly represented. Fungal remains (10%), gymnospermous pollen (9%), dinoflagellate cysts and acritarchs (2%), reworked Permian palynotaxa (12%) and unidentified taxa (6%) constitute the remaining part of the assemblage. Quantitative representation of individual palynotaxa is poor hence no palynozones could be identified.

PALYNOLOGICAL COMPARISON

Dutta and Singh (1980) and Dutta (1980) published Upper Tertiary miofloral assemblages from Kameng District, Arunachal Pradesh. *Proxapertites, Palmidites, Lycopodiumsporites* and *Couperipollis* are common to both the assemblages.

The present palynofloral assemblage is closely comparable to the Miocene palynofloras reported from Bhuban and Bokabil formations of Assam (Saluja *et al.*, 1973; Rao *et al.*, 1985; Rao, 1986; Rao & Singh, 1987; Saxena *et al.*, 1987). Common palynotaxa are: *Lycopodiumsporites, Monolites, Dictyophyllidites, Lygodiumsporites, Striatriletes, Podocarpidites, Pinuspollenites, Abiespollenites, Dicolpopollis, Tricolpites, Couperipollis, Tetracolporites* (*Meliapollis*) and *Proxapertites.*

The present assemblage is also comparable to those recorded from Miocene sediments of Jorajan well-3, Upper Assam (Singh & Saxena, 1984) and Boldamgiri Formation, Garo Hills, Meghalaya (Nandi & Sharma, 1984). *Lygodiumsporites, Striatriletes, Inaperturopollenites, Assamiapollenites, Verrualetes, Tricolopites, Couperipollis* and *Dicolpopollis* are the common elements.

The Miocene palynofloral assemblages recorded from western Himalaya (Banerjee, 1968; Mathur, 1973; Nandi, 1975, 1980; Saxena *et al.*, 1984) and Bengal Basin (Baksi, 1972) are different from the present assemblage.

On the other hand, the Neogene palynoflora of Quilon beds, Kerala (Rao & Ramanujam, 1975, 1978, 1982) compares well with the present assemblage as the following palynotaxa are common to both the assemblages: *Lygodiumsporites, Couperipollis, Longapertites, Dicolpopollis, Retitricolpites* (= *Tricolpites*), *Loranthipites, Ctenolophonidites, Retitricolporites* (= *Tricolporopollis*) and *Meliapollis.*

From the above comparison it is apparent that the present palynoflora resembles those described from the Miocene sediments of Assam Basin (Saluja *et al.*, 1973; Singh & Saxena, 1984; Nandi & Sharma, 1984; Rao *et al.*, 1985; Rao & Singh, 1987; Saxena *et al.*, 1987) and Quilon beds, Kerala (Rao & Ramanujam, 1975, 1978, 1982). Additionally, presence of some Miocene palynotaxa, *Dicolpopollis, Loranthipites, Meliapollis, Assamiapollenites ghoshii, Longapertites klinkenbergii* and *Malvacearumpollis*

paucibaculatus, in the present assemblage in significant. Keeping in view the resemblance of present palynoflora with other known Miocene assemblages, a Miocene age has been assigned.

PALAEOCLIMATE

Palynoflora of Miocene sediments of Arunachal foot-hills indicates that the area was inhabited by tropical-subtropical vegetation. Such conclusion has been drawn by rich representation of pteridophytes and angiosperms belonging to the families Parkeriaceae, Schizaeaceae, Pteridaceae, Lycopodiaceae, Matoniaceae, Arecaceae, Araceae and Bombacaceae. Temperate gymnosperm elements referable to the families Podocarpaceae and Pinaceae represented in the assemblage were, however, transported to the site of deposition. Dominance of pteridophytic spores and prodigality of microthyriaceous fungi indicate the prevailing warm and humid conditions.

ENVIRONMENT OF DEPOSITION

The lithological association of siltstone, sandstone, pebbly sandstone and conglomerate bed indicates that these sediments were largely deposited under fluviatile environment. Based on sedimentological studies Singh *et al.* (1982) indicated that the Siwalik sandstones in Arunachal Himalayas are composed of sands of riverine origin and the material was transported by rolling and suspension to the depocentre. The studies further suggest that these sediments were brought to the river streams by fluvial agencies by rapid erosion from nearby high relief source areas. The current bedding and large thickness of sediments indicate that deposition took place in a rapidly sinking basin. Kumar and Singh (1982), on the basis of sedimentary and microstructural analysis of sandstone dykes in Siwalik sandstone, determined varied conditions of deposition with changing facies from fluvial fan to coastal plain fan-delta.

Dominance of Palm pollen further corroborates the inference that deposition of sediments under study took place in a near-coastal environment. The palynoflora suggests that a stretch of coastal swamp was adjacent to the depositional area and fresh-water elements were also brought to the deposition site by rivarine channels. The high altitude gymnospermic elements, present in the assemblage, indicate an elevated topography in the north of the depositional basin. Thus, the inference of high relief in nearby areas drawn by sedimentological studies (Singh *et al.*, 1982) is supported by palynological studies also.

GEOLOGICAL HISTORY AND PALAEOGEOGRAPHY

Since the Permian time the area remained a landmass and marine transgression took place during late Early Eocene. The marine regression in the Arunachal foot-hill region took place at the end of Middle Eocene and sedimentation recommenced under the brackish water environment during Middle Miocene in front of the mountain range in a basin which acted as a foredeep area where the Siwalik sediments were deposited in the form of alluvial fan or deltaic deposits, or both. The sandstone dykes formed at the sediment-water interface indicate the fluctuating marine conditions.

The Himalayan orogenic movement accentuated the foredeep and large thickness of Siwalik sediments were deposited mainly under fluviatile conditions. Uplift and strong denudation continued giving rise to the contemporaneous deposition and erosion of these sediments. A thick sequence of such deposit is exposed near Itanagar where Siwalik boulders are seen in the same matrix.

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