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Palynology in stratigraphy of Lesser Himalayan sedimentary sequences from Arunachal Pradesh, India

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ABSTRACT

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Arunachal Pradesh has a distinct geological set up and significant data have been generated during the last decade both from Permian as well as Tertiary sediments. The palynoflora investigated from Lesser Himalayan Permian sediments of Arunachal Pradesh has been differentiated into five palynozones . 1. *Plicatipollenites stigmatus*, 2. *Callumispora gretensis*, 3. *Crucisaccites indicus*, 4. *Pseudoreticulatispora barakarensis* and 5. *Primuspollenites* + *Rhizomaspora*; the oldest being Palynozone 1 (Rilu Member, Rangit Formation) representing Late Asselian while Palynozones 2-5 (Garu Formation) represent Early Sakmarian to Early Artinskian age.

The palynoassemblages recorded from Tertiary sediments in Arunachal Pradesh largely show the overwhelming presence of angiosperm pollen, *viz.*, *Lakiapollis*, *Neocouperipollis*, *Arecipites*, *Pellicieroipollis*, and *Ctenolophonidites*. Pteridophytic spores, *viz.*, *Todisporites*, *Cyathidites*, *Striatriletes*, and *Crassoretitriletes* shows similar age connotations. Broadly two distinct palynozones have been differentiated, *viz.*, *Lakiapollis ovatus* and *Striatriletes susannae* assemblage zones. At some sections presence of dinoflagellate and acritarch indicate marine influence during Early Tertiary.

Permian spores also occur in reworked state within Early Tertiary sediments. Palynological investigations carried out along the thrust suggest that some thrust slices of Tertiary rocks are wedged deep within the Permian outcrops. These evidences indicate severe postdepositional tectonic effect in these regions. Palynological evidences along with faunal evidences, wherever possible, have been summarised to decipher the stratigraphic resolutions, palaeogeography and palaeoenvironment of the region.

Key-words—Palynology, Stratigraphy, Arunachal Pradesh, India.

भारत के अरूणाचल प्रदेश से प्राप्त लघु हिमालयी अवसादों का स्तरिकीय परागाणुविज्ञान

सुरेश चन्द्र श्रीवास्तव एवं अनन्त प्रसाद भट्टाचार्य

सारांश

अरूणाचल प्रदेश का भूगर्भीय ढाँचा अत्यन्त विशिष्ट है. यहाँ के परमियन तथा टर्शियरी युगीन दोनों ही प्रकार के अवसादों से विगत दशक में अनेक महत्त्वपूर्ण आंकड़े प्राप्त किए गए हैं. अरूणाचल प्रदेश के लघु हिमालयी परमियन अवसादों से खोजे गए परागाणुवनस्पतिजात को पाँच परागाणु मण्डलों में बाँटा गया है : 1. *प्लिकेटीपोलेनाइटीज़ स्टिग्मेटस*, 2. *काल्यूमीस्पोरा ग्रीटेन्सिस*, 3. *क्रूसीसैक्काइटीज़ इण्डिकस*, 4. *स्यूडोरेटीक्यूलेटीस्पोरा बराकरेन्सिस* तथा 5.

प्राइमसपोलेनाइटीज़+राइज़ोमास्पोरा; इनमें से पहला परागाणु मण्डल (रिलू सदस्य, रैंगिट शैलसमूह) अन्तिम असीलियन महाकल्प का प्रतिनिधित्व करता है, जबकि दूसरे से पाँचवें परागाणु मण्डल (गारू शैलसमूह) प्रारंभिक सैकमेरियन से प्रारंभिक आर्टिन्सकियन आयु का प्रतिनिधित्व करते हैं.

अरूणाचल प्रदेश के टर्शियरी अवसादों से अंकित किए गए परागाणु समुच्चय आवृतबीजी परागकणों, जैसे- *लैकियापॉलिस, निओकूपेरीपॉलिस, एरीसीपिटीज़, पेलिसिएरॉयपॉलिस* एवं *टीनोलोफ़ोनीडाइटीज़* की प्रचुर उपस्थिति प्रदर्शित करते हैं. टेरिडोफ़ाइटी बीजाणु, जैसे-*टोडिस्पोराइटीज़, साइएथीडाइटीज़, स्ट्रायाट्रायलिटीज़* तथा *क्रासोरेटीट्रायलिटीज़* एक समान आयु वाले लक्षण प्रदर्शित करते हैं. इस समुच्चय से दो सुस्पष्ट समुच्चय मण्डल, *लेकियापॉलिस ओवेटस* तथा *स्ट्रायाट्रायलिटीज़ सुज़ानाइ* अवकलित किए गए हैं। कुछ परिच्छेदों में घूर्णीकशाभ तथा एक्रीटार्क की उपस्थिति प्रारंभिक टर्शियरी कल्प के दौरान समुद्री प्रभाव का संकेत करती है. प्रारंभिक टर्शियरी अवसादों के अन्दर परमियन बीजाणु भी पुनः करित अवस्था में उपस्थित हैं। क्षेप के आस-पास किए गए परागाणविक विश्लेषणों से प्रस्तावित होता है कि टर्शियरी शैलों के कुछ क्षेप स्तरी खण्ड परमियन दृश्यांश के भीतर सघनतः वेज हैं. ये प्रमाण इन क्षेत्रों में तेज़ पश्च निक्षेपणीय विवर्त्तनिक प्रभाव के संकेत देते हैं। प्राणिजात प्रमाणों के साथ-साथ यथासम्भव परागाणविक प्रमाणों को इस क्षेत्र के स्तरिकीय विभेदन, पुराभूगोल तथा पुरापर्यावरण के कूट पठन हेतु अनुप्रयुक्त किया गया है.

संकेत-शब्द—परागाणुविज्ञान, स्तरिकी, अरूणाचल प्रदेश, भारत.

INTRODUCTION

THE geology in Arunachal Pradesh from the foot hills is quite different which can be distinguished in almost four units of parallel belts of rocks (Kumar, 1997). These tectono-units vary in age and begin with Upper Tertiary (=U. Siwalik) close to the plains. Next comes narrow belt of Permian sequence followed by a wide belt of metamorphosed rocks belonging to the Miri / Daling - Darjeeling Groups of Precambrian age. In between Daling and Permian there are at places another group of rocks called Buxa Group. Then follows a belt of central Himalayan tourmaline granite. Each of these belt is separated by a thrust plane. The Permian sediments are thrusted over Upper Tertiary rocks and the contact between the Permian and Tertiary rocks in the north-eastern Himalaya is known as the Main Boundary Fault. Acharyya *et al.* (1975) carried out the stratigraphic studies in Kameng, Subansiri and Siang districts and classified the Gondwana sediments into Rangit-Pebble Slate, Khelong and Bhareli formations. The stratigraphy of Arunachal Himalaya has been lately redescribed by Bhushan *et al.* (1990) followed by Kumar (1997, Table 5). However, in the present investigation the classification proposed by Sivastava *et al.* (1988), Srivastava and Bhattacharyya (1996, Table 1; 1998) has been maintained atleast for the Permian sequence of Arunachal Pradesh. In the present study sediments exposed along the contact zone of Permian and Tertiary rocks from : 1. Tippi to Sessa section in West Kameng, 2. Kimin to Zero section in Lower Subansiri , 3. Garu to Rilu near Rilu Village in West Siang, and 4. Passighat to Rengging section from East Siang districts (Fig. 1) have been analysed in order to assess the intermixing of sediments resulted on account of thrust activities in the region.

PERMIAN MIOFLORA

Palynology of the Permian sediments occupying the Lesser Himalayan Zone in Arunachal Pradesh have been studied in detail (Srivastava & Dutta, 1977; Singh. 1979; Dutta *et al.*, 1988; Srivastava *et al.*, 1988; Srivastava & Bhattacharyya, 1996) and correlated with the Permian miofloras of Peninsular Gondwana.

Siang District

Srivastava and Dutta (1977) studied the palynology of the Permian sediments of Garu-Gensi Road section in the West Siang District and found two distinct palynozones, the older being rich in radial monosaccate pollen while the younger palynozone contained the association of *Parasaccites* and *Callumispora*. Singh (1979) also studied the above section and observed that the Bomte Member contained *Callumispora* zone followed by *Parasaccites* zone. These zones are compared with the Karharbari palynoflora of Peninsular Gondwana basins. The Permian palynofloral succession from West Siang District have been investigated in detail by Srivastava and Bhattacharyya (1996). The authors have demarcated five palynozones, the oldest being : (1) *Plicatipollenites stigmatus* followed by (2) *Callumispora gretensis*, (3) *Crucisaccites indicus*, (4) *Pseudoreticulatispora barakarensis* and (5) *Primuspollenites + Rhizomaspora*. Palynozone 1 derived from Rilu Member of Rangit Formation compared with Talchir palynoflora while Palynozones 2-5 in Garu Formation compared with Karharbari and Lower Barakar palynofloras, respectively of the peninsular Lower Gondwana sequence of India.

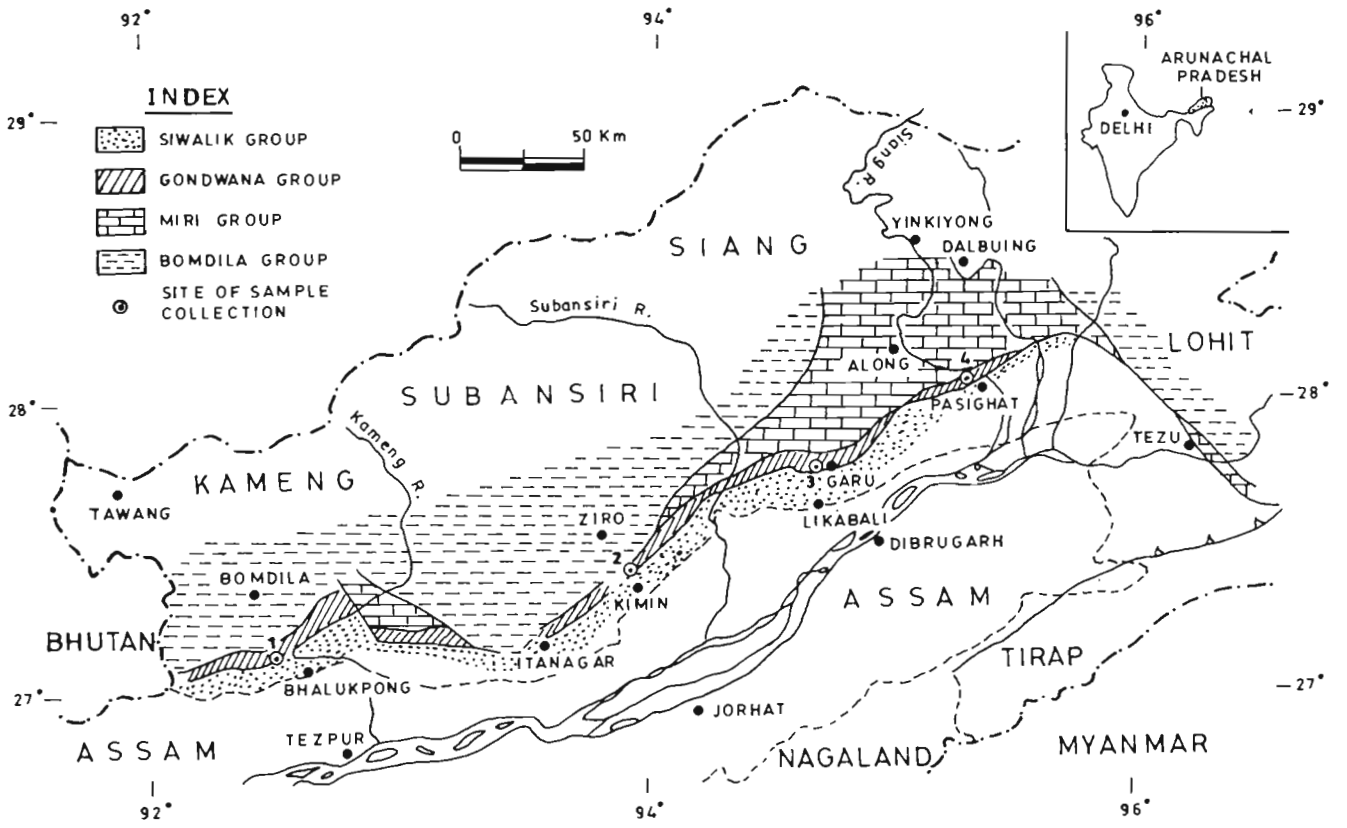


Fig. 1— Map of Arunachal Pradesh showing localities of sediments investigated 1. Bhalukpong - Sessa section, West Kameng District, 2. Kimin - Zero section, Lower Subansiri District, 3. Likabali - Garu section, West Siang District, 4. Passighat - Rengging section, East Siang District (Map after Singh & Tripathi, 1990).

The palynofloras of the Garu Formation in Siang District suggests a stronger relationship with those of Canning Basin, Western Australia (Kemp *et al.*, 1977) in view of the presence of *Diatomozonotriletes townrowi*, *Densosporites solidus* and higher representation of *Pseudoreticulatispora barakarensis*.

Subansiri District

Palynological investigation was also carried out in Lower Subansiri district by Srivastava and Bhattacharyya (1990) from Kheel Section. The palynoflora constitutes *Parasaccites* along with *Callumispora* rich association and was comparable to Karharbari palynoflora (*Callumispora gretensis* palynozone) of Siang District.

Kameng District

Dutta *et al.* (1988) have studied the palynology of the Permian sediments from Bhareli Formation around Elephant Flat in West Kameng District and the palynoflora is closely comparable with Lower Karharbari palynoflora. This palynoflora has closer similarity with that from Siang District (*Callumispora gretensis* palynozone) except slight decrease in the percentage of *Plicatipollenites* and *Potonieisporites* in the former.

TERTIARY MIOFLORA

The presence of Lower Tertiary rocks in Arunachal Pradesh was indicated by Bhandari *et al.* (1974) in the Subansiri District. Later on GSI has also proved the presence of Tertiary rocks in the Kameng, Subansiri and Siang districts on the basis of seismic data and stratigraphy, respectively.

Siang District

Jain and Dutta (1978) have recorded Lower Tertiary dinoflagellate cysts, spores and pollen grains near the contact of Permian and Upper Tertiary rocks from Siang District opposite Garu Rest House on the Likabali-Along Road. They are of opinion that the sediments are of probably Eocene age since the assemblage is characterised by the presence of

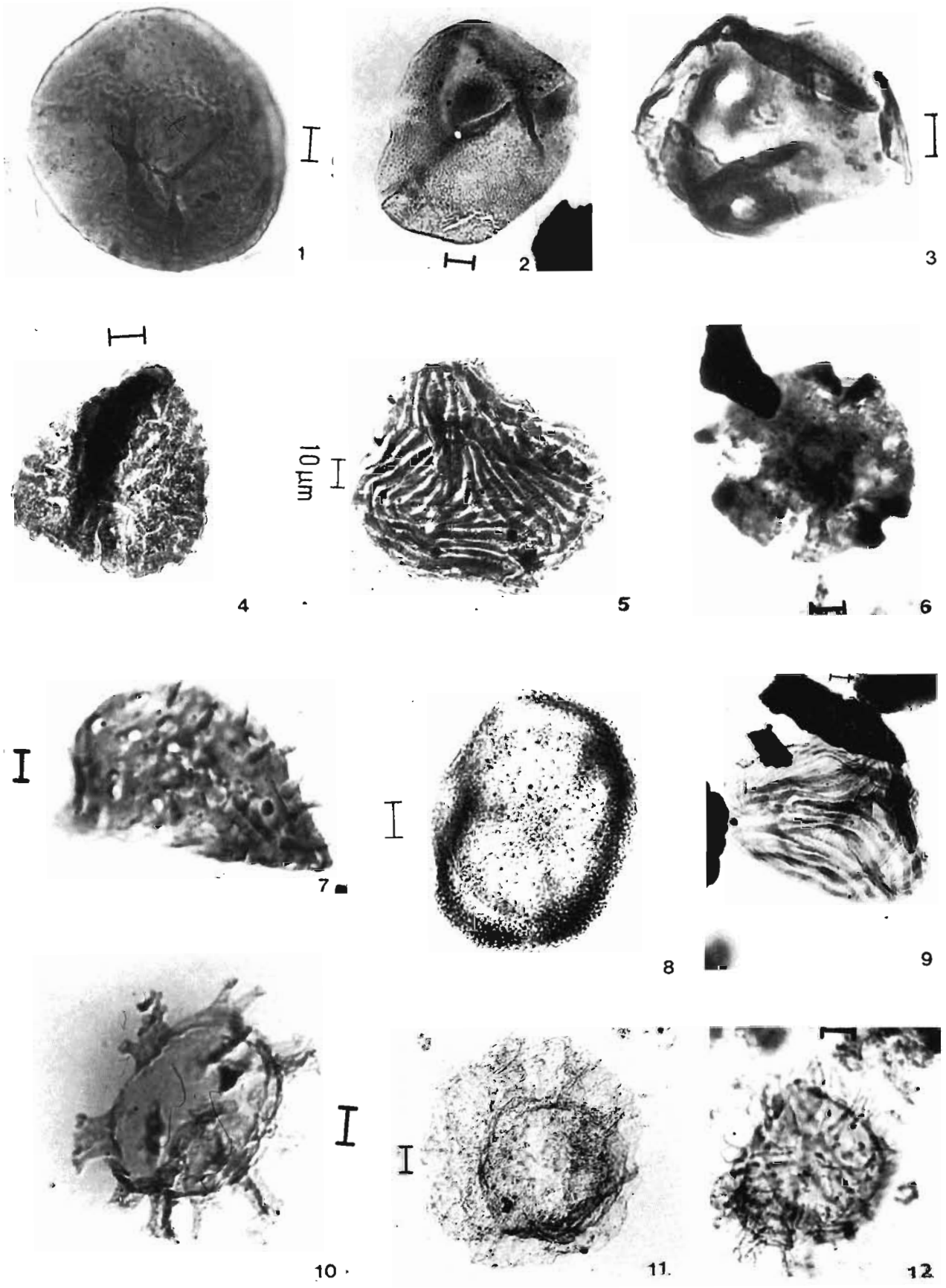


PLATE I

Homotryblium, *Couperipollis*, *Lakiapollis* and *Malvacearumpollis*. Tripathi and Singh (1992) also recorded Early Tertiary palynotaxa from sediments exposed near Rengging along the Siang River, on Yinkiyong-Gobuik Road and Dalbuing section in Yamne Valley of Siang District. The palynotaxa contain *Ctenolophonidites*, *Lakiapollis*, *Tricolporopollis*, *Pellicieroipollis* and *Incrotonipollis*.

Kameng District

Dutta and Singh (1980) studied the Siwalik sediments from Kameng District and showed that palynoassemblages are of mixed nature. The Tertiary assemblage pointed out Miocene age while a huge number of recycled palynomorphs of Permian age are found mixed with Miocene palynoflora. Singh and Tripathi (1990) reported angiosperm pollen, pteridophytic spores, fungal remains, gymnospermous pollen, dinoflagellate cysts, acritarchs and reworked Permian spores and pollen from Siwalik sediments in Kameng, Subansiri and Siang districts and suggested a Miocene age.

During the investigation of the Permian sequence in Arunachal Pradesh the authors have observed that some sediments collected along the Permian-Tertiary contact zone yielded Tertiary palynomorphs (Pl. 1·1-12; Pl. 2·1-13) out of which broadly two distinct palynoassemblages have been distinguished :

Lakiapollis ovatus Assemblage

This assemblage zone has been observed in sediments exposed along : Kimin-Zero Road section in Lower Subansiri (Location 2), near Rilu Village in West Siang (Location 3), and Passighat to Rengging section (Location 4) in East Siang District (Fig. 1). The angiosperm pollen grains recorded are : *Lakiapollis ovatus*, *Neocouperipollis rarispinosus*, *Arecipites* sp. and *Alangium* type pollen. Trilete spores are rare, represented by *Cyathidites australis*, *Todisporites*. *Neocouperipollis* is found in almost all the samples. Reworked Permian and Mesozoic spores are profusely present in Passighat to Rengging and also near Rilu Village sediments. In the samples from Subansiri District a number of dinoflagellate cysts alongwith *Neocouperipollis* and *Lakiapollis* have also been recorded. *Thalassiphora* (Pl. 1·11), *Homotryblium* (Pl. 1·10) and *Operculodinium* sp. are the dominant forms. Bryophytic spore *Operculosculptites* is also present.

Stratigraphical Distribution—This palynozone is confined to Early Eocene.

Striatriletes susannae Assemblage

This zone has been recorded from sediments exposed SW of the thrust in Tippi and Pinjoli nala on Tippi to Sessa Road (Location 1), West Kameng District (Fig. 1) in Arunachal Pradesh. This assemblage is dominated by *Striatriletes susannae* and *S. multicostatus*. Common trilete spores recorded in this assemblage are—*Todisporites*, *Cyathidites australis*, *Crassoretitriletes vanraadshoovenii*, *Verrucatosporites* sp., *Osmundacidites* and *Pteridacidites*. The angiosperm pollen are represented by *Lilliacidites*, *Monosulcites*, *Palmidites maximus*, *Arecipites* sp., *Palaeomalvacearumpollis* sp., *Proxapertites operculatus* and syncolpate pollen (Pl. 2·6,7). Gymnosperm pollen is represented by *Ephedripites*. Fungal spores and fruiting bodies are common, *viz.*, *Heliospermo-sporis*, *Phragmothyrites*, *Staphlosporonites* sp. and *?Lacanella* sp. Some alete spores of uncertain or algal affinity have also been recorded.

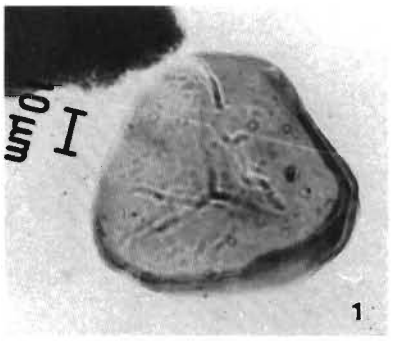
Reworked striate disaccate pollen grains are maximum. Presence of *Densipollenites indicus* (Pl. 3·7), a monosaccate pollen grain, is a common feature of this assemblage. The other notable taxa are : *Leiotriletes*, *Psilalacinites*, *Callumispora greteusis*, *Lophotriletes*, *Gondisporites*, *Parasaccites obscurus*, *Striatites tectus*, *Striatopodocarpites brevis*, *Faunipollenites varius*, *Verticipollenites debilis*, *V. gibbosus*, *Strotersporites decorus*, *Striasulcites*, *Pretricolpipollenites* (Pl. 3·11). In addition to Permian taxa few Mesozoic pollen, although rare, also occur in reworked state , *viz.*, *Falcisporites stabilis* (Pl. 3·4), *Callialasporites trilobatus* (Pl. 3·5).

Stratigraphical Distribution—*Striatriletes* is a common element in Middle Eocene and shows its maximum development in Oligocene and Miocene and dwindles down in Pliocene (Kar, 1992). This Zone is found just above *Cicatricosisporites dorogensis* Zone.

PLATE 1

(Photomicrographs taken on Olympus VANOX microscope. Co-ordinates corresponds to England Finder Number (EF), Scale bar = 10 µm).

1. *Todisporites* sp., Slide no. BSIP 12499, EF No. (Q10).
2. *Liliacidites* sp., Slide no. BSIP 124595, EF No. (T41/3).
3. *Lakiapollis ovatus*, Slide no. BSIP 12504, EF No.(S28).
4. *Crassoretitriletes* sp., Slide no. BSIP 12498, EF No. (N27/3).
5. *Striatriletes multicotatus*, Slide no. BSIP 12501, EF No.(Q45/4).
6. *Alangium* type pollen, Slide no. BSIP 12504 ,EF No.(V32/1).
7. *Palaeomalvacearumpollis* sp., Slide no. BSIP 12494, EF No. (F23) in DIC.
8. *Proxapertites operculatus*, Slide no. BSIP 12502, EF No.(T38/1).
9. *Striatriletes susannae*, Slide no. BSIP 12496, EF No.(Q25/1).
10. *Homotryblium* sp., Slide no. BSIP 12505, EF No.(T44) in DIC.
11. *Thalassiphora* sp., Slide no. BSIP 12505, EF No. (R 25/1) in DIC.
12. *Operculodinium* sp., Slide no. BSIP 12505, EF No. (S22/2)



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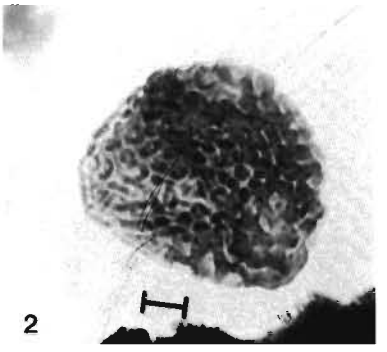
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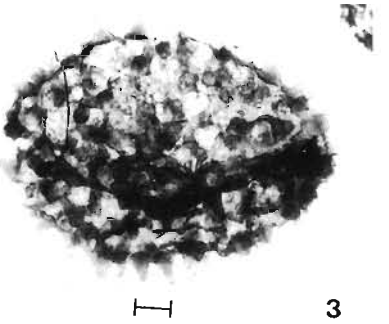
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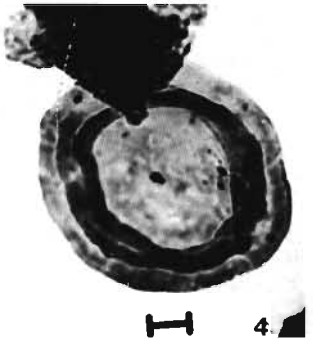
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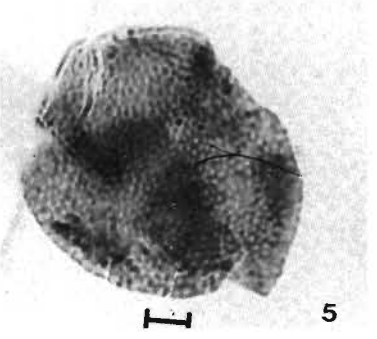
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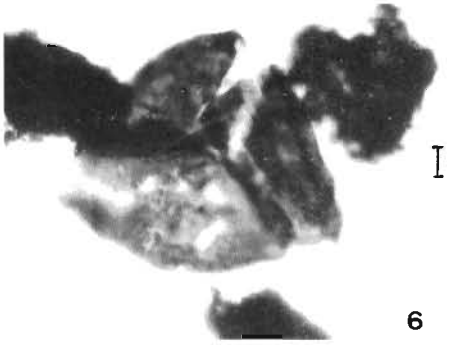
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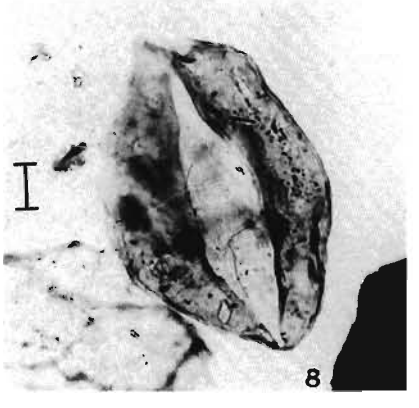
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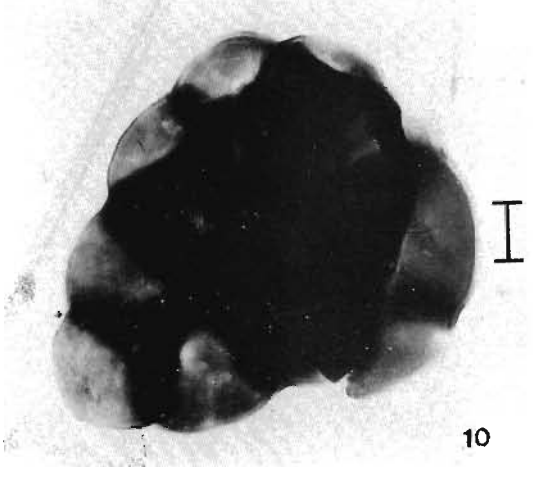
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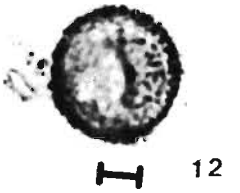
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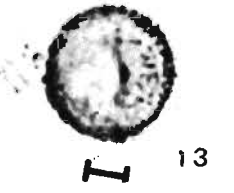
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PLATE 2

COMPARISON OF TERTIARY MIOFLORA

The *Neocouperipollis* and *Lakiapollis* present in sediments from Siang and Subansiri districts are found in the Eocene sediments of India but in South India it occurs in Miocene sediments (Kar & Jain, 1981). *Lakiapollis ovatus* has been reported in Eocene of Kutch (Venkatachala & Kar, 1969; Kar & Saxena, 1981). Therefore, *Lakiapollis ovatus* with *Neucouperipollis* suggest an age not older than Palaeocene.

The sediments from Subansiri District also show the association of *Thalassiphora* along with *Homotryblium*. These taxa occur in Lower Eocene to Upper Eocene Subathu sediments from Himachal Pradesh, India (Khanna, 1978). The palynoflora from Siang District described by Jain and Dutta (1978) has close similarity with the Subansiri Lower Tertiary palynoflora having in common with *Couperipollis, Lakiapollis*, and absence of *Thalassiphora. Homotryblium floripes* and *H. pallidum* is also reported from Lower Eocene of London Clay (Davey & Williams, 1996), Lower Eocene Nanjemoy Formation of Maryland, U.S.A. (Goodman, 1979), Middle Eocene, south-western Kutch, India (Jain & Tandon, 1981). So, the sediments from Subansiri area is not younger than Lower Eocene in age. The absence of *Compositoipollenites, Myripolles* and polyporate forms also suggests that the sediments are older than Oligocene. The presence of *Couperipollis* compares well with the Sylhet Limestone Stage (Lower-Middle Eocene).

The *Striatriletes susannae* occurs in Middle Eocene sediments of Meghalaya and Early Eocene of Rajasthan. Its maximum development has been noted in Middle Oligocene. The present forms are found with *Palmidites, Arecepites, Liliacidites*. So the sediments investigated here from Kameng area are not younger than Oligocene.

Dutta and Singh (1980) studied the palynology from Siwalik beds exposed in Kameng District. The lower unit (Unit D) shows the occurrence of dinoflagellate cyst *Thalassiphora* which is also present in the palynoflora recovered from Subansiri District. Unit B + C shows a mixed assemblage. The youngest Unit A contains *Striatriletes, Todisporites, Palmaepollenites* and *Liliacidites* and Miocene age was suggested. Singh and Tripathi (1990) recovered a Miocene palynoflora from different places in Arunachal Pradesh. Common palynotaxa are *Striatriletes, Proxapertites, Neocouperipollis, Palmidites* and *Todisporites*.

DISCUSSION

The sedimentation during Palaeozoic in Arunachal Pradesh appears to have commenced during Early Permian. The sediments were initially deposited in near shore lake basins which were periodically influenced by marine incursions. The basal most unit, usually referred to Diamictite Member of Rangit Formation (Srivastava & Bhattacharyya, 1996)/Rilu Member of the Bichom Formation (Kumar, 1997)/Rangit Pebble Slate (Acharyya *et al.*, 1975), has not yielded plant microfossil/megafossil but a bryozoa dominated horizon has been traced and on the basis of the presence of *Eurydesma* (Acharyya *et al.* 1975) it has been considered to represent basal Permian (Fig. 1). This horizon is remarkably homogeneous and extends from Sissni in the west to Bichom in east in Kameng District and is correlatable to the Rangit Pebble Slate of Darjeeling and Sikkim. It occurs towards the north at the top of the Permian sequence in these areas but further extension of this unit in Subansiri and Siang is uncertain and difficult to prove convincingly. This member has been earlier described as Bichom Member but Kumar (1997) has given it another name as Sessa Member and raised the Bichom to the status of a Formation. Acharyya *et al.* (1975) also did not mention Bichom while describing Rangit Pebble Slate Member. The overlying Rilu Member of the Rangit Formation (Srivastava & Bhattacharyya, 1996) occurs at the base of the Permian sequence. The outcrop of this member is present in Subansiri and Siang districts close to the MBF and is correlatable with the Rilu Member of the Bichom Formation designated by Kumar (1997). The Rilu Member is best exposed between Balme and Igo and again in Rengging in Siang District. The Sikki Abu Member in West Siang described by Singh (1979) is similar to Rilu Member and repeated at the top of Permian in Sikki Abu as a result of thrusting. The Rilu Member is characterised by khaki green splintery shale, pebbly mudstone and siltstone. It has yielded fairly rich palynomorphs : *Plicatipollenites stigmatus* Zone (Srivastava & Bhattacharyya, 1996) and *Parasaccites* + *Plicatipollenites* assemblage (Srivastava & Dutta, 1977) from Siang District. In peninsular India these two assemblage zones overlie the

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PLATE 2

(Photomicrographs taken on Olympus VANOX microscope, Co-ordinates corresponds to England Finder Number (EF), Scale bar = 10μm).

1 *Cyathidites australis*, Slide no. BSIP 12495, EF No.(N 46).
2. *Crassoretitriletes vanraadshooveni*, Slide no. BSIP 124955, EF No. (F43/1).
3. *Nucouperipollis* sp., Slide no. BSIP 12504, EF No.(X10).
4. *?Lacanella*, Slide no. BSIP 12494, EF No.(F32).
5. Syncolpate pollen, Slide no. BSIP 12495, EF No. (H 44/3).
6. Syncolpate pollen, Slide no. BSIP 12503 ,EF No.(P34).
7 *Inaperturopollenites* sp., Slide no. BSIP 12499, EF No.(Q40).
8. *Palmidites maximus*, Slide no. BSIP 12505, EF No.(M32).
9. *Arecipites* sp., Slide no. BSIP 12503, EF No.(X34).
10. *Staphlosporonites* sp., Slide no. BSIP. 12493, EF No.(T22/2).
11 *Verrucatosporites* sp., Slide no. BSIP 12499, EF No.(S18).
12.&13. *Operculosculptites* sp., Slide no. BSIP 12494, EF No.(G33/2).

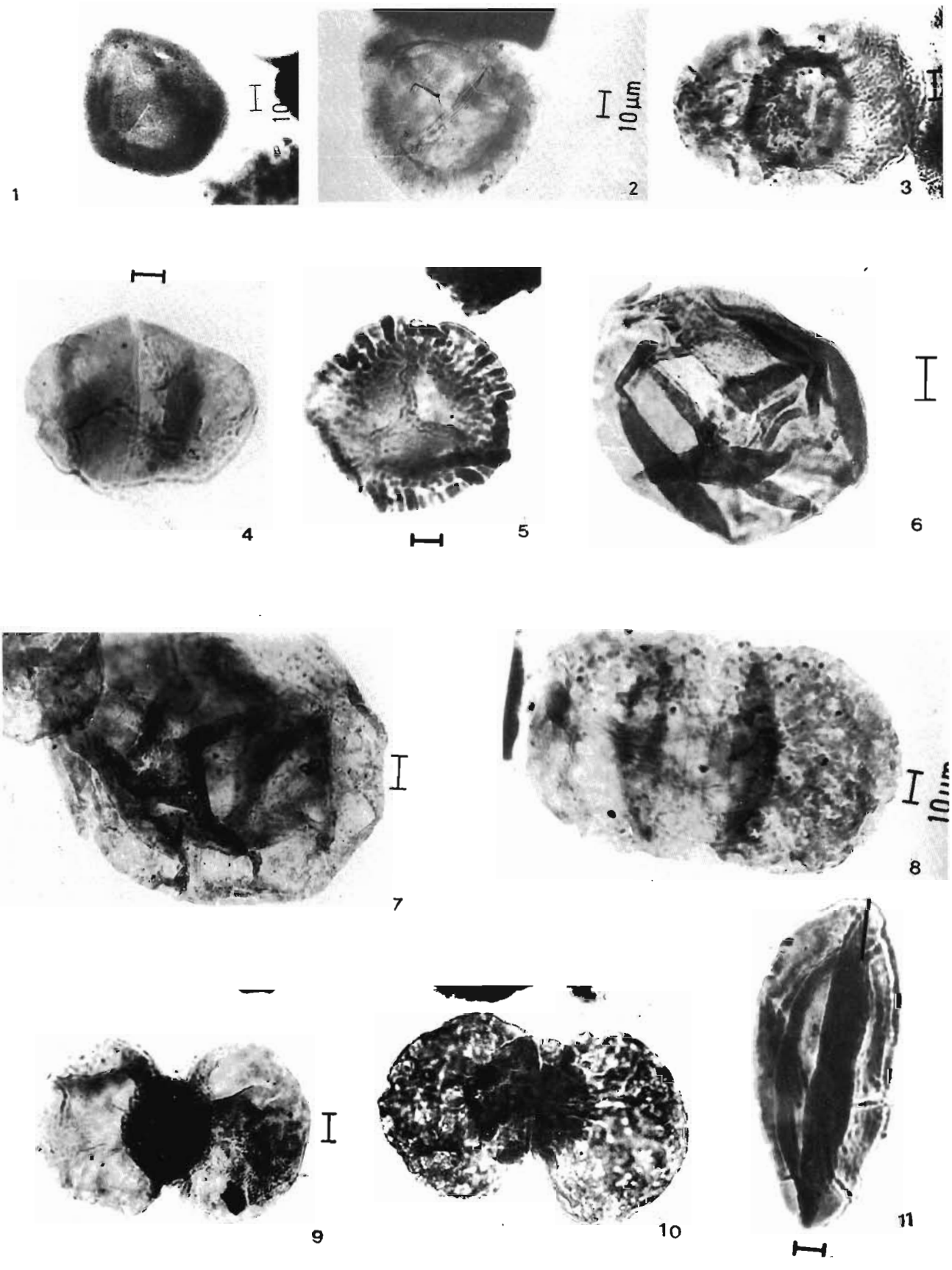

PLATE 3

Eurydesma-Deltopecten beds in Manendragarh (Madhya Pradesh).

The overlying Garu Formaton which fairly corresponds to Bomte Member of the Bichom Formation of Kumar (1997) has been distinguished into three units by Srivastava and Bhattacharyya (1996). The lowermost unit, Unit 1, characterised by bluish grey, medium to coarse-grained sandstone, intercalated with carbonaceous shale containing coal balls, contains *Callumispora gretensis* Zone and *Crucisaccites indicus* Zone and is associated with brachiopod fauna: *Tivertonia, Strophalosia, Costatumulus, Cyrtella, Subansiria, Tomiopsis*, and *Trigonotreta* (Archbold & Singh, 1993). This unit corresponds to Late Tastubian (Sakmarian) age and is comparable to Karharbari Formation of peninsular grabens. The Bomte Member of Singh (1979) corresponds to Unit 1 of Garu Formation designated here. The sediments exposed near Kheel on Doimukh-Sagalee section in Subansiri District (Srivastava & Bhattachayya, 1990) also contains *Callumispora gretensis* Zone. Further west in Kameng District this palynozone is present in sediments exposed along Tippi nala near Elephant Flat (Dutta *et al.*, 1988). The overlying unit (Unit 2), characterised by fine to medium-grained white feldspathic sandstone, intercalated with carbonaceous shale and coal containing coal balls, contains *Pseudoreticulatispora barakarensis* Zone and *Primuspollenites* + *Rhizomaspora* Zone and are equated with Lower Barakar palynoflora of peninsular India and Tastubian to Sterlitamakian assemblages of Western Australia (Kemp *et al.*, 1977). The fauna associated with this unit is characterised by the presence of *Linoproductus, Uraloceras* and *Ambikella* (Singh, 1981). The Unit 3 of the Garu Formation (Srivastava & Bhattacharyya, 1996), characterised by coarse-grained ferruginous sandstone, shale with concretions has not yielded palynomorphs but occasionally contain animal remains (crinoid stems)/plant fossils. This unit is exposed between Takso and Bigi villages of West Siang District.

All the three units of Garu Formation described above are lithologically differentiable and mappable units but have been clubbed together into Bomte Member of the Bichom Formation by Kumar (1997). Acharyya *et al.* (1975) classified the carbonaceous sedimentary sequence of Kameng District into Khelong Formation and Bhareli Formation, the earlier containing the *Gangamopteris, Glossopteris* species while the latter is dominant in *Glossopteris, Schizoneura* and *Vertebraria*. The Khelong Formation has also yielded palynofossils assigned to *Callumispora gretensis* Zone (Dutta *et al.*, 1988) and suggest Lower Karharbari age. These beds are exposed at the base of the sequence in Pinjoli nala on Tippi to Sessa Road. The overlying beds exposed on the road cutting have yielded well preserved plant fossils , *viz.*, *Gangamopteris karharbariensis, Glossopteris communis, G. stenoneura, G. longicaulis, G. indica, G. tenuifolia, G. spatulata, G. taeniensis, G. subtilis, G.* sp. cf. *G. decipiens, Noeggerathiopsis hislopii, Samaropsis ganjraensis, Vertebraria indica* which compares well with the Lower Barakar assemblages of Peninsular India. Singh and Bajpai (1990) described *Glossopteris communis* from shales exposed about 10 km from Khuppi on Khuppi-Kimi Road and *G. stenoneura* from a locality near Kimi Power House in Kameng District but could not assign them a stratigraphic significance due to insufficient fossil evidence. The Bhareli Formation conformably overlies the Khelong Formation and contains plant fossils of Late Permian (=Raniganj Formation) affinity (Acharyya *et al.*, 1975). Bushan *et al.* (1989, 1990) have merged these two units of Acharyya *et al.* (1975) and referred them as Bhareli Formation divisible into two members (*in* Kumar, 1997). The equivalents of these sediments are not present in Subansiri and Siang districts. The Bhareli Formation of Acharyya *et al.* (1975) represents the youngest Permian lithounit in Arunachal Pradesh.

The Rangit Formation (Srivastava & Bhattacharyya, 1996) in Arunachal Pradesh were essentially deposited under wide spread glaciation influenced by marine incursions. This sequence occurs from Rengging in the East Siang District and continues through West Siang and Subansiri. The sedimentation of Garu Formation (Srivastava & Bhattacharyya, 1996) continued under marine influence in Siang and Subansiri districts. However, in Kameng District the sedimentation appear to have witnessed different setting. The Khelong Formation was deposited under euxinic setting while Bhareli Formation was deposited under fluvial facies. These sediments and also the Upper Coal Measures in Darjeeling and Permian sediments in Singrimari in Meghalaya exhibit similar depositional environment. The plant fossils as well as the palynofossils both represent a land flora and there is no evidence of marine influence. The Yamne Formation in Yamne Valley (Kumar, 1997), considered to represent Upper Permian on the basis of invertebrate fossils has no palynological record.

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PLATE 3

(Photomicrographs taken on Olympus VANOX microscope. Co-ordinates corresponds to England Finder Number (EF). Scale bar = 10 μm).

1. *Densoisporites* sp., Slide no. BSIP 12495, EF No.(N27).
2. *Indotriradites korbaensis*, Slide no. BSIP 12499, EF No. (P49/3).
3. *Striatites varius*, Slide no. BSIP 12496, EF No.(Q28).
4. *Falcisporites subtilis*, Slide no. BSIP 12495, EF No. (M51/4).
5. *Callialasporites trilobatus*, Slide no. BSIP 12494, EF No.(F32/3).
6. *Inaperturopollenites* sp., Slide no. BSIP 12493, EF No. (Q23/1).
7. *Densipollenites indicus*, Slide no. BSIP 12502, EF No. (Q39/3).
8. *Arcuatipollenites* sp., Slide no. BSIP 12495, EF No. (X26/3).
9. *Striatites tectus*, Slide no. BSIP 12498, EF No. (H21/4).
10. *Verticipollenites gibbosus*, Slide no. BSIP 12496, EF No.(P34/1).
11. *Pretricolpipollenites* sp., Slide no. BSIP 12495, EF No. (G24/3).

Period	Formation	Member	Siang (Marine) Srivastava & Bhattacharyya ,1996	Subansiri (Marine) Srivastava & Bhattacharyya ,1990	Formation	Kameng	Acharyya *et al.*,1975	Formation	Gopendra Kumar, 1997		Suggested Peninsular equivalents
									Formation	Member	
PERMIAN	GARU	Unit 3			BHARELI		*Glossopteris indica, G. angustifolia, G. longicaulis, G. conspicua, G. formosa, G. communis,* var. *stenoneura, Dictyopteridium* sp., *Vertebraria indica, Phyllotheca* sp, *P. griesbachii, Schizoneura gondwanensis, Samaropsis* sp.	BHARELI	BHARELI		Raniganj
		Unit 2	5. *Primuspollenites + Rhizomaspora* Zone *Ambikella Uraloceras Linoproductus Productus* 4 *Pseudoreticulatispora barakarensis* Zone		KHELONG	*Glossopteris communis G. longicaulis, G. spatulata, G.indica, G. taeniensis, G. subtilis, G.* sp. cf. *decipiens, G. stenoneura, G. tenuifolia, Gangamopteris karharbariensis, Noegerathiopsis hislopii, Samaropsis ganjrensis*	*Glossopteris indica, G. damudica, G. communis* var. *stenoneura, Gangamopteris* cf. *cyclopteroides, Vertebraria indica, Phyllotheca* sp., *Schizoneura* sp.	KHELONG	KHELONG		Barakar
		Unit 1	3 *Crucisaccites indicus* Zone acritarchs, conodont, scolecodont, ?. chitinozoa, foraminifera (Srivastava & Bhattacharyya, 1998) 2. *Callumispora gretensis* Zone *Tivertonia, Strophalosia, Costatumulus, Cyrtella, Subansiria, Tomiopsis, Trigonotreta* (Archbold & Singh, 1993)	*Callumispora gretensis* Zone *Subansiria Syringothyris Eurydesma* Srivastava *et al.* 1988		*Callumispora gretensis* Zone (Dutta *et.al.*, 1988)			BICHOM	Bomte	Karharbari
	RANGIT	Rilu	1 *Plicatipollenites stigmatus* Zone		RANGIT PEBBLE SLATE		Bryozoa dominated Assemblage *Eurydesma, Schizodus*	RANGIT PEBBLE SLATE		Sessa	Talchir
		Diamictite									
	Miri										

Since it is sandwiched between the underlying Geku Formation and overlying Dalbuing Formation (Lower Eocene) it could as well represent a reworked block of Upper Permian. The above evidence suggest that sedimentation during the entire Permian period continued uninterruptedly in North- Eastern Himalaya. After Permian there appears to be a big gap in sedimentation since there are no convincing record of the presence of Triassic, Jurassic and Early Cretaceous sediments. However, the rare presence of *Falcisporites*, *Callialasporites* as reworked pollen in Early Tertiary rocks of Kameng District in the present investigation indicate that Mesozoic sediments could have been present in the near provenance.

The stratigraphic set up in the field in Kameng District is interpreted to represent a reversed succession (Acharyya *et al.*, 1975, p. 72; Kumar, 1997, p. 79). However, the present findings indicate that Lower Permian sediments on Tippi-Sessa Road, occur between MBF and Elephant Flat while Upper Permian strata crops out between Elephant Flat and Sessa. Thus the sequence between MBF and Sessa is in normal order of superposition.

The presence of Bichom/Sessa/Rangit Pebble Slate Member around Sessa can only be explained due to tectonic superposition and not stratigraphic inversion. Similarly in Siang District the Rilu Member is overlain by Garu Formation and the Diamictite Member occur at the top of sequence as a result of the thrust.

Abor Volcanics

The Intertrappean beds associated with Abor Volcanic in Siang Valley have yielded miospores of Lower Permian affinity (Roy Chowdhury, 1984; Prasad *et al.*, 1989). It is considered coeval with the Pir Panjal Volcanic of northwest Himalaya.

The cycle of sedimentation recommenced during Upper Palaeocene - Lower Eocene which led to the deposition of continental facies of Geku Formation (Upper Palaeocene) and marine facies (Lower Eocene) of Dalbuing Formation (Prasad & Dey, 1986; Tripathi & Singh, 1992; Tripathi *et al.*, 1981; Singh & Singh, 1983; Tripathi & Mamgain, 1986), both belonging to Yinkiong Group (Kumar, 1997). The occurrence of *Lakiapollis ovatus* Assemblage in sediments exposed along Passighat - Rengging section in East Siang, Garu-Along road near Rilu Village in West Siang and Kimin-Zero Road in Subansiri District suggests the presence of Lower Eocene sediments all along the MBF. These sediments at several places have wedged deeply into the Permian outcrop forming a melange and are considered to occur in reworked state among the Tertiary and Permian sequence along the Main Boundary Fault. The consistent occurrence of Eocene sediments along the MBF may also indicate that competent beds of Eocene may have come up as result of thrust. The Upper Tertiary sediments were deposited during Miocene - Lower Pleiocene. The Dafla Formation shows abundance of reworked Permian palynomorphs and Tertiary microplankton (Dutta & Singh, 1980). The sediments exposed in Tippi and Pinjoli nalas on Tippi-Sessa Road show that Dafla Formation is also wedged into the Permian at this point north of MBF. The greyish white to greyish green khaki shales of Dafla Formation associated south of MBF are rich in *Striatriletes susannae* and *S. multicostata* exclusively. Further south about 3·6 km from Tippi the carbonaceous shales (Dafla Formation) exposed in Kamala River contain plant fossils : *Ziziphus indicus*, *Dicotylophyllum dioscoreoides* and *Syzygium* sp. These shales on maceration have yielded *Striatriletes susannae* assemblage. The palynoflora of Subansiri and Kimin formations shows the presence of *Striatriletes susannae* Assemblage along with some reworked Permian spores and pollen grains (Dutta, 1980; Dutta & Singh, 1980; Singh & Tripathi, 1990) in fact corroborates to Dafla Formation of Miocene age. These assemblages are comparable to Miocene assemblages of Surma Group of Assam and Warkali beds of West Coast. The presence of *Palmaepollenites* indicates that the basin maintained a constant near shore proximity during the deposition of lower part of Dafla Formation. The Middle Siwalik mioflora from central and western Himalaya have nonstriate pollen of Podocarpaceae and Pinaceae but they have not been recorded in Arunachal Pradesh. Thus the palynofloral affinity of Tertiary sequence of Arunachal Pradesh is more closer to that of Assam rather than that of Siwaliks of central and western Himalayas.

CONCLUSIONS

1. Occurrence of Permian palynospores in reworked state within Tertiary sequence is well known in eastern India. In Arunachal Pradesh also such phenomenon is recorded by Dutta and Singh (1980).
2. However, the presence of Tertiary palynomorphs within the Permian outcrops along the MBF is reported here for the first time.
3. Mostly the Eocene sediments have wedged deep into the Permian country along the thrust contacts at various places in Arunachal Pradesh forming a melange.
4. The stratigraphic set up in Kameng District is inferred to be reversed sequence, but the present investigation suggests a normal sequence between Tippi-Sessa. The presence of Bichom/Sessa Member north of Sessa is a result of tectonic superimposition.

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Fig 2—Reconstructed Permian stratigraphy in Arunachal Pradesh

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