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Palynology of the Baratang Formation, Andaman-Nicobar Islands and the significance of reworked palynomorphs

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ABSTRACT

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Spores-pollen and dinoflagellate cysts data from five sections of the Baratang Formation (Baratang Island) are analysed. The record of stratigraphic potential forms indicates an Early to Late Eocene age for the recovered assemblages. The palynoassemblages from this Formation are also associated with the reworked palynofossils belonging to Permian, Triassic and Jurassic-Cretaceous ages. The reworked taxa dominate over the poorly represented Eocene palynomorphs and have Gondwanic affinity. A comparison of Tertiary palynoflora of Baratang with Assam and Myanmar demonstrate the presence of some palynotaxa in all the areas but common occurrence of significant taxa such as *Retitrisyncolpites*, *Baculimonocolpites* and *Lanagiopollis (regularis)* shows more close relationship between Andaman and Myanmar flora than Assam. The recycled palynomorphs of Gondwanic affinity have provided valuable clue to locate the source and direction of sediments. Various views relating to provenance of reworked palynomorphs have been analysed on the basis of present data which suggest that Chindwin Basin of Myanmar mainly supplied reworked palynomorphs containing sediments. The palynological, palaeocurrent and lithological evidences do not support the origin of reworked elements from Wharton Basin, Assam Basin or autochthonous (Triassic) sediments.

Key-words—Palynology, Eocene, Baratang Formation, Reworked fossils.

अण्डमान-निकोबार द्वीप समूह के बारातांग शैलसमूह का परागाणु विज्ञान तथा पुनः करित परागाणु रूपों की प्रासंगिकता

जगन्नाथ प्रसाद मण्डल, अनिल चन्द्रा एवं अनन्त प्रसाद भट्टाचार्य

सारांश

बारातांग द्वीपसमूह के बारातांग शैलसमूह के पाँच अनावरित परिच्छेदों से प्राप्त स्तरिकीय बीजाणु-परागकण एवं घूर्णीकशाभ पुटीय आंकड़े प्रारंभिक से अन्तिम इओसीन आयु इंगित करते हैं। इस शैलसमूह का परागाणु समुच्चय परमियन, ट्रायसिक तथा जुरासिक क्रिटेशस आयु से सम्बन्धित सम्मिश्र वनस्पतिजात निरूपित करता है। पुनः चक्रित वर्गक में गोण्डवाना से निकटता पायी गयी हैं, जो इओसीन परागाणु रूपों में अधिक मात्रा में प्राप्त होते है। असम तथा मयनमार के टर्शियरी परागाणु वनस्पतिजात के साथ अण्डमान की वनस्पतिजातपरक तुलना करने पर प्रदर्शित होता है कि महत्त्वपूर्ण वर्गकों जैसे—*रेटिट्राइसिनकोलपाइटीज़*, *बाक्यूलीमानोकोलपाइटीज़*, *लैनेजियोपोलिस* (*रेगुलेरिस*) की प्रायः उपस्थिति असम की तुलना में अण्डमान तथा मयनमार वनस्पतिजात के मध्य अधिक निकटस्थ सम्बन्धन प्रदर्शित करती है। परागाणविक

आँकड़े इंगित करते हैं कि मयनमार की छिंदविन द्रोणी के आस-पास का क्षेत्र स्थलीय तथा समुद्री परागाणु पादपाश्मों का उद्गम स्थल था। आश्मिक, पुराधारापरक तथा पुराभौगोलिक प्रमाण इस निष्कर्ष की पुष्टि करते हैं।

संकेत शब्द—परागाणुविज्ञान, इओसीन, बारातांग शैलसमूह, पुनः चक्रित पादपाश्म.

INTRODUCTION

THE Andaman-Nicobar groups of islands are a part of Sunda Arc system that extends from Myanmar (Burma) to Sumatra. The sediments in these islands occur in two sets of exposures. The chain of north, middle and south Andamans including Baratang forms the primary island part and the other set is the small islands lying on east and west of the main chain. The primary chain of islands ranges in age from Late Cretaceous to Oligocene while the peripheral chain of islands is Neogene in age. The sediments of main Andaman islands are deep-sea flysch sediments, which were deposited through turbidity currents (Karunakaran *et al.*, 1964; Pandey, 1972; Pandey *et al.*, 1992). These flysch sediments are classified into two formations, namely the Baratang and the Port Blair formations (Chatterjee, 1967) with an unconformable junction. The Baratang sediments are mainly argillaceous and can be easily differentiated from the overlying arenaceous Port Blair Formation.

The marine fossils are meagre to absent in the flysch sequences of the main islands. Occasionally, the flysch sediments yield palynofossils as these sediments predominantly consist of land-derived clastics containing a variety of palynodebris. The palynological study is therefore, important for dating and correlation of these islands. The present work reports the result of palynological investigation of Baratang Island for deciphering the age of sediments, relationship of flora with neighbouring areas and to deduce the provenance of reworked palynomorphs.

PREVIOUS PALYNOLOGICAL WORK

The palynological data from the flysch–turbidites of Andaman-Nicobar Basin are few and are confined to the Middle Andaman and Baratang islands. Banerjee (1966) first recorded palynoflora of Port Blair Formation from Baratang Island. However, Jafar and Tripathi (2001) pointed out that this section actually belongs to Baratang Formation. A variety of angiosperm palynofossils were documented by Banerjee (1966) and he deduced a Palaeogene age by comparing this palynoassemblage with that of Assam. In subsequent publication, Banerjee, 1967 described an Upper Cretaceous palynoflora from the Middle Andaman and he compared this assemblage with the assemblages from Assam, Bengal and Krishna-Godavari basins. The palynoflora from the upper part of Baratang Formation, Middle Andaman (Mathur & Mathur, 1980) closely resembles with palynoassemblages of Laisong and Burdwan formations of Assam and Bengal basins respectively. Late Triassic terrestrial palynomorphs and dinoflagellate cysts were also documented from Middle Andaman (Sharma & Mehrotra, 1984; Sharma & Sarjeant, 1987). Mandal *et al.* (1994) recovered Early Eocene palynofossils from Middle Andaman and concluded that the assemblage compares grossly with those from Indian mainland and is closely similar to the Early Eocene flora of Myanmar. The mud of Mud volcano ooze from Baratang Island has yielded spores, pollen and dinoflagellate cysts and the rich assemblage consisted of palynomorphs belonging to Late Cretaceous to Oligocene (Mandal *et al.*, 1996). Recently Jafar and Tripathi (2001) reported Late Triassic mixed Late Cretaceous palynoassemblage from the Middle Andaman.

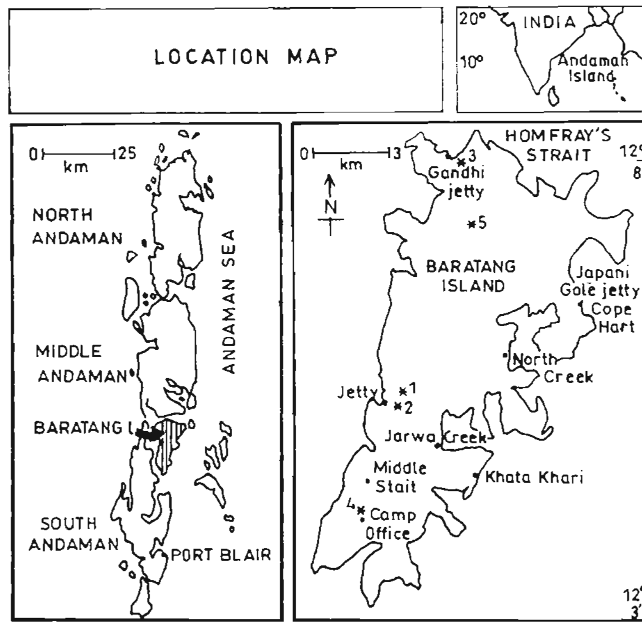

Fig. 1—Map of Baratang Island showing the locations of sections marked as * (Map adopted from Rajsekhar *et al.*, 1990).

It is therefore clear that palynofossils have been recorded only from the Baratang Formation of the main Andaman islands and the recorded assemblages do not resemble closely to each other. This dissimilarity may be due to difference of facie or interval time of deposition. However, the assemblages have one common feature in containing recycled palynomorphs of different ages.

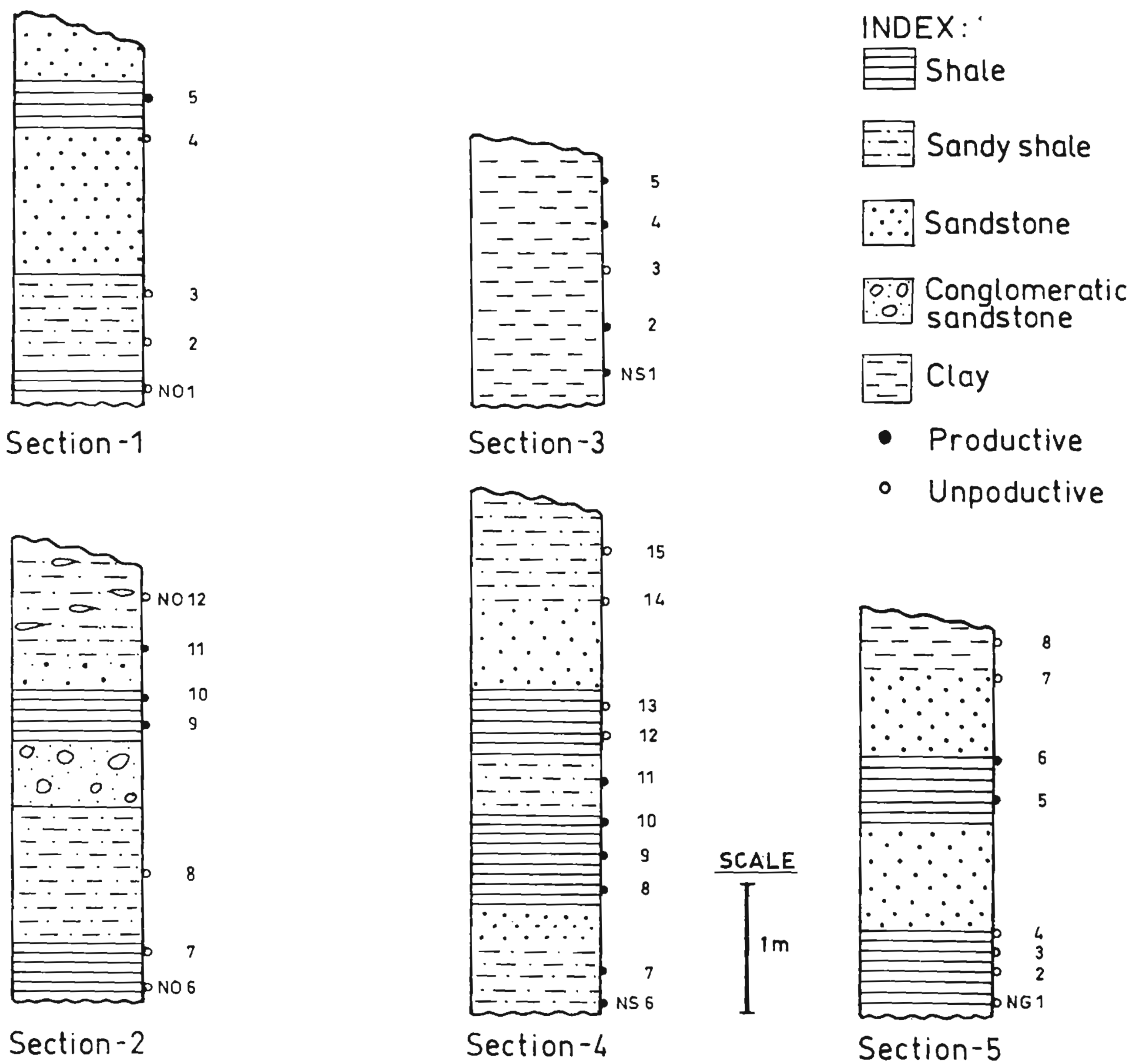

Fig. 2—Lithocolumns showing the position of samples.

MATERIAL AND METHODS

During the field session of 1984 two of us (AC & JM) collected samples from different locations of the Baratang Island. Thirty-five samples belonging to Baratang Formation collected from five sections have been studied. The locations of sections and lithocolumns indicating the position of samples have been shown in Figs. 1 & 2 respectively.

Samples

Section 1 (Nilambur–Oralkachcha Traverse)

The section is exposed in a nala behind the Oralkachcha School. The rocks are black and green splintery shale, sandy shale alternating with white, medium grained sandstone.

Section 2 (Nilambur Church premises)

The section contains black shale, grey sandy shale, black clay, nodular clay and conglomeratic sandstone. The samples were collected from a well pit within the church premises.

Section 3 (Nilambur–Shastri Nala Traverse)

This pit section lies 4 km before Gandhi Jetty on right side of Nilambur–Gandhi Jetty Road. The whole section consists of black clay.

Section 4 (Forest Camp Office Section)

The section consists of black splintery shale, grey sandy shale and white medium grained sandstone. The outcrop section lies in a nala on west side of the Forest Camp Office.

Section 5 (Nilambur–Gandhi Jetty Traverse)

The outcrop section is exposed on left side of Nilambur–Gandhi Jetty Road near 13 km post which consists of grey splintery shale, black clay and white sandstone.

Methods

The samples were chemically processed following the usual maceration procedure using HCl, HF, HNO_3 and 5% KOH solution. The polleniferous residue was mixed with polyvinyl alcohol and spread over the cover slip. After drying the cover slip, it was mounted in Canada Balsam. The slides and photonegatives have been deposited in the Museum of Birbal Sahni Institute of Palaeobotany, Lucknow.

RESULTS

Out of thirty-five studied samples, only sixteen samples have yielded spore-pollen including dinoflagellate cysts in one section (Section 4). The yield of palynomorph is poor to moderate and majority of the specimens are badly preserved. Consequently, a number of specimens could not be identified. The location of productive samples is indicated in Fig. 2. Sections 3 and 4 are rich in palynomorph contents than other sections. Minimum number of palynofossils has been recovered from Section 5. However, all the sections produced reworked palynomorphs of older ages. These recycled palynotaxa belong to Permian, Triassic and Jurassic-Cretaceous ages and they out number the Tertiary palynomorphs. Simultaneously, Lower Cretaceous taxa are more common than Permian and Triassic forms. In contrast, Tertiary palynomorphs are meagre and require careful search to find them. Thus, no qualitative analysis is possible of these assemblages. In this context it is important to mention that sections 1 and 5 did not yield any palynofossil of Tertiary age.

The following is the list of palynomorphs recovered from each section. The taxa (reworked) with asterisk mark indicate restricted vertical range. Other taxa occasionally cross the time boundaries. Some of the important palynomorphs have been documented in plates 1–3.

Section 1

Permian—**Faunipollenites varius* Bharadwaj emend. Tiwari *et al.*, 1989; **Scheuringipollenites maximus* (Hart) Tiwari, 1973; **Aurangapollenites brevizonatus* (Tiwari) Bharadwaj & Dwivedi, 1981.

Triassic—**Klausipollenites schaubergeri* (Potonié & Klaus) Jansonius, 1962.

Jurassic–Cretaceous—*Araucariacites australis* Cookson, 1947; *Alisporites grandis* (Cookson) Dettmann, 1963.

Comment—Tertiary palynomorphs have not been found.

Section 2

Permian—**Faunipollenites varius* Bharadwaj emend. Tiwari *et al.*, 1989; **Corisaccites alutas* Venkatachala & Kar,

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PLATE 1 →

(Bars on the photographs represent 10 μm. England Finder numbers are given within bracket after slide number)

1. *Alangiopollis* sp., Slide No. BSIP 12651 (S30).
2. *Lakiapollis ovatus* Venkatachala & Kar, 1969, Slide No. BSIP 12649 (W48).
3. *Baculimonocolpites andamanensis* Mandal *et al.*, 1994, Slide No. BSIP 12658 (K33/1).
4. *Retitrisyncolpites thaungii* Mandal *et al.*, 1994, Slide No. BSIP 12653 (Q23).
5. *Striatriletes susannae* v.d. Hammen emend. Kar, 1979, Slide No. BSIP 12661 (Y36).
6. *Lanagiopollis regularis* Morley, 1982, Slide No. BSIP 12644 (S18).
7. *Palaeocystodinium australinum (*Cookson emend. Malley, 1972) Lentin & Williams, 1976, Slide No. BSIP 12653 (J15/1).
8. *Striatopollis* sp., Slide No. BSIP 12648 (N34).
9. *Spinizonocolpites baculatus* Muller, 1968, Slide No. BSIP 12650 (J21/4).
10. *Polypodiaceaesporites* sp., BSIP Slide No. 12666 (N10/4).
11. *Minutitricolporites minutus* Kar, 1985, Slide No. BSIP 12645 (Y39/2).
12. *Polypodiisporites impariter* (Potonié & Sah) Dutta & Sah, 1970, Slide No. BSIP 12659 (U17/3).
13. *Dandotiaspora telonata* Sah *et al.*, 1971, Slide No. BSIP 12642 (R40).
14. *Bacutriporites* sp., Slide No. BSIP 12659 (T 35/1).
15. *Dactylopollis magnificus* Muller, 1968, Slide No. BSIP 12659 (X 46).
16. *Proxapertites operculatus* v.d. Hammen, 1956, Slide No. BSIP 12662 (J30/4).
17. Palynomorph type 1, Slide No. BSIP 12654 (G 44).

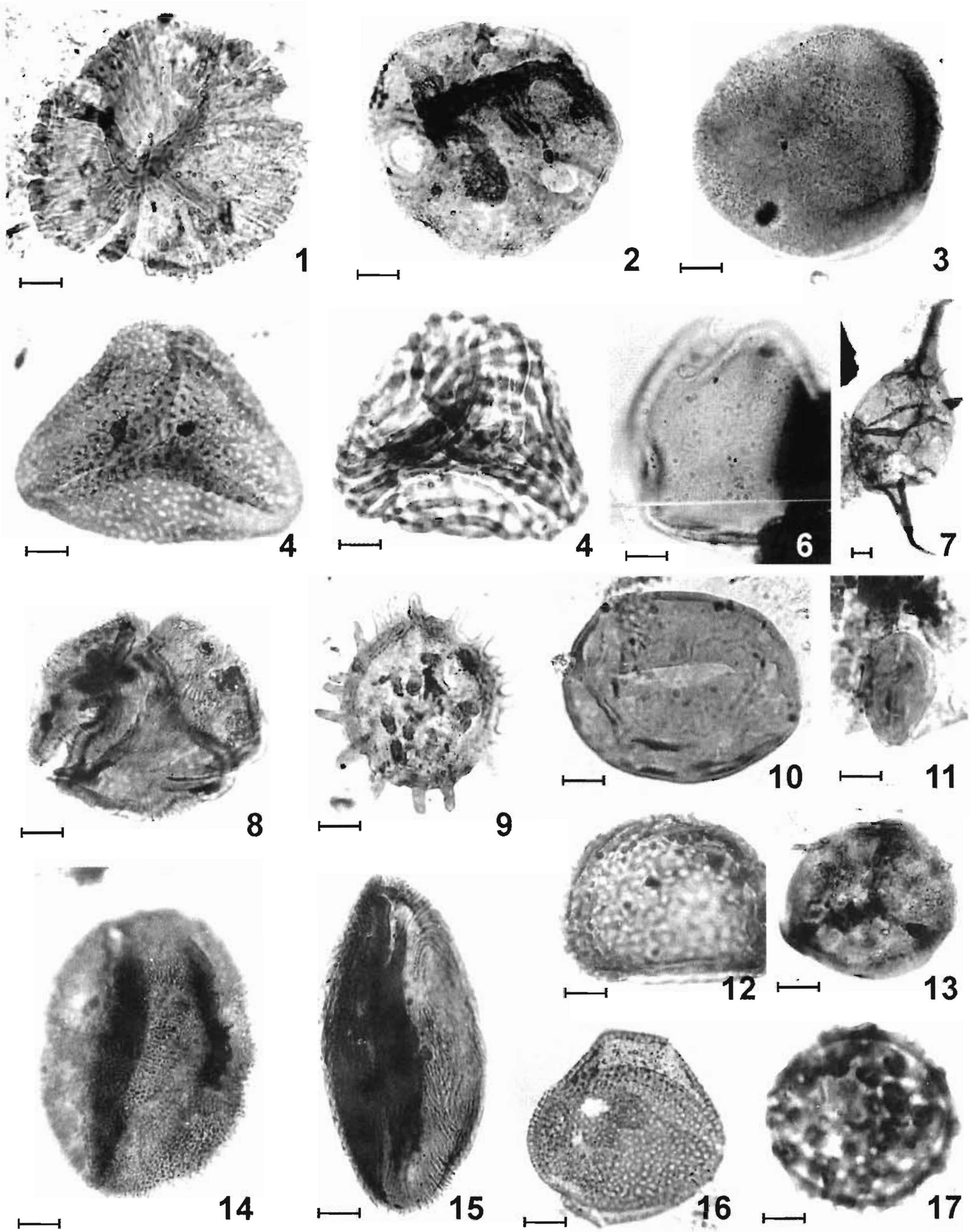

PLATE 1

1966; **Caheniasaccites indicus* Srivastava, 1970; **Chordasporites* sp.; **Scheuringipollenites maximus* (Hart) Tiwari, 1973; **Striatites varius* Kar, 1968; **Crescentipollenites fuscus* (Bharadwaj) Bharadwaj *et al.*, 1974; **Densipollenites invisus* Bharadwaj & Salujha, 1964; **Microbaculispora* sp.

Triassic—*Verrucosisporites* sp.; **Klausipollenites schaubergeri* (Potonié & Klaus) Jansonius, 1962; **Falcisporites stabilis* Balme, 1970; **Staurosaccites quadrifidus* Dolby in Dolby & Balme, 1976; **Ovalipollis* sp.; *Tikisporites complicatus* Kumaran, 1980.

Jurassic–Cretaceous—*Araucariapollenites* sp.; *Cicatricosisporites* sp.; **Aequitriradites dubius* Delcourt & Sprumont emend. Delcourt *et al.*, 1963; **Callialasporites dampieri* (Balme) Sukh-Dev, 1961; **C. lucidus* (Pocock) Maheshwari, 1974; *Alisporites grandis* (Cookson) Dettmann, 1963; *Cerebropollenites* sp.; *Osmundacidites* sp.; **Triporoletes reticulatus* (Pocock) Playford, 1971; *Dactylopollis magnificus* Muller, 1968; *Bacutriporites* sp.

Tertiary—*Cyathidites australis* Couper, 1953; *Dictyophyllidites* sp.; *Polypodiisporites impariter* (Potonié & Sah) Dutta & Sah, 1970; *Polypodiaceaesporites* sp.; *Striatriletes susannae* v.d. Hammen emend. Kar, 1979; *S. paucicostatus* Kar, 1985; *Retitrisyncolpites thaungii* Mandal *et al.*, 1994; *Striacolporites cephalus* Sah & Kar, 1970; *Minutitricolporites minutus* Kar, 1985; *Polyadopollenites miocenicus* Ramanujam, 1966; *Proxapertites operculatus* v.d. Hammen, 1956; *Baculimonocolpites andamanensis* Mandal *et al.*, 1994; *Striatopollis* sp.; *Neocouperipollis brevispinosus* (Biswas) Singh & Sarkar, 1988; *Phragmothyrites eocenicus* Edwards emend. Kar & Saxena, 1976.

Comment—Only 10% palynofossils belong to Eocene.

Section 3

Permian—**Crescentipollenites fuscus* (Bharadwaj) Bharadwaj *et al.*, 1974; **Indotriradites korbaensis* Tiwari, 1964; * *Striatites varius* Kar, 1968; *Lundbladispora* sp.; *Densoisporites* sp.; **Scheuringipollenites maximus* (Hart) Tiwari, 1973; *Vesicaspora* sp.; * *Trochosporites tripus* Venkatachala & Kar, 1968; *Aurangapollenites brevizonatus* (Tiwari) Bharadwaj & Dwivedi, 1981.

Triassic—**Klausipollenites schaubergeri* (Potonié & Klaus) Jansonius, 1962; **Falcisporites stabilis* Balme, 1970; *Chordasporites* sp., *Brachysaccus* sp.; **Staurosaccites quadrifidus* Dolby in Dolby & Balme, 1976; **Playfordiaspora cancellosa* (Playford & Dettmann) Maheshwari & Banerjee emend. Vijaya, 1995; **Goubinispora indica* Tiwari & Rana, 1981.

Jurassic-Cretaceous—**Aequitriradites spinulosus* (Cookson & Dettmann) Cookson & Dettmann, 1961; *Alisporites grandis* (Cookson) Dettmann, 1963; *Podosporites* cf. *P. tripakshi* Rao emend. Kumar, 1981; *Cerebropollenites* sp.; *Podocarpidites khasiensis* Dutta & Sah, 1970; *Ginkgocycadophytus* sp.; *Araucariapollenites* sp.; *Cicatricosisporites* sp.; * *Callialasporites dampieri* (Balme) Sukh-Dev, 1961; **C. lucidus* (Pocock) Maheshwari, 1974; *Polycingulatisporites reduncus* (Bolkhovitina) Playford & Dettmann, 1964; **Contignisporites* sp.

Tertiary—*Dandotiaspora telonata* Sah *et al.*, 1971; *Lygodiumsporites eocenicus* Dutta & Sah, 1970; *Polypodiaceaesporites* sp.; *Minutitricolporites minutus* Kar, 1985; *Lanagiopollis regularis* Morley, 1982; *Tricolporopilites pseudoreticulatus* Kar, 1985.

Comment—Only 3% specimens belong to Eocene age.

Section 4

Permian—**Crescentipollenites fuscus* (Bharadwaj) Bharadwaj *et al.*, 1974; *Lunbladispora* sp.; *Densoisporites* sp.; **Scheuringipollenites maximus* (Hart) Tiwari, 1973.

Triassic—**Falcisporites stabilis* Balme, 1970; **Staurosaccites quadrifidus* Dolby in Dolby & Balme, 1976; **Klausipollenites schaubergeri* (Potonié & Klaus) Jansonius, 1962.

Jurassic–Cretaceous—**Aequitriradites spinulosus* (Cookson & Dettmann) Cookson & Dettmann, 1961; *Alisporites* sp.; * *Callialasporites dampieri* (Balme) Sukh-Dev, 1961; *Cerebropollenites* sp.; *Podocarpidites khasiensis* Dutta & Sah, 1970; *Araucariapollenites* sp., *Bacutriporites* sp.

Tertiary—*Cyathidites australis* Couper, 1953; *Polypodiisporites impariter* (Potonié & Sah) Dutta & Sah, 1970; *Retitrisyncolpites thaungii* Mandal *et al.*, 1994; *R.*

PLATE 2 ⟶

(Bars on the photographs represent 10 μm. England Finder numbers are given within bracket after slide number)

1. *Caheniasaccites indicus* Srivastava, 1970, Slide No. BSIP 12654 (G44).
2. *Faunipollenites varius* Bharadwaj emend. Tiwari *et al.*, 1989, Slidě No. BSIP 12655 (G30).
3. *Tikisporites complicatus* Kumaran, 1980, Slide No. BSIP 12660 (Q25).
4. *Callialasporites lucidus* (Pocock) Maheshwari, 1974. Slide No. BSIP 12664 (K46).
5. *Trochosporites tripus* Venkatachala & Kar, 1968. Slide No. BSIP 12646 (V23/4).
6. *Cuneatisporites exiguus* Salujha, 1965, Slide No. BSIP 12666 (P22/4).
7. *Callialasporites dampieri* (Balme) Sukh-Dev, 1961, Slide No. BSIP 12659 (T36/3).
8. *Polycingulatisporites reduncus* (Bolkhovitina) Playford & Dettmann, 1964, Slide No. BSIP 12642 (L14).
9. *Striatites varius* Kar, 1968, Slide No. BSIP 12661 (L46/1).
10. *Contignisporites* sp., Slide No. BSIP 12647 (O37/2).
11. *Staurosaccites quadrifidus* Dolby in Dolby & Balme, 1976, Slide No. BSIP 12659 (W31).
12. *Araucariapollenites* sp., Slide No. BSIP 12642 (L40).

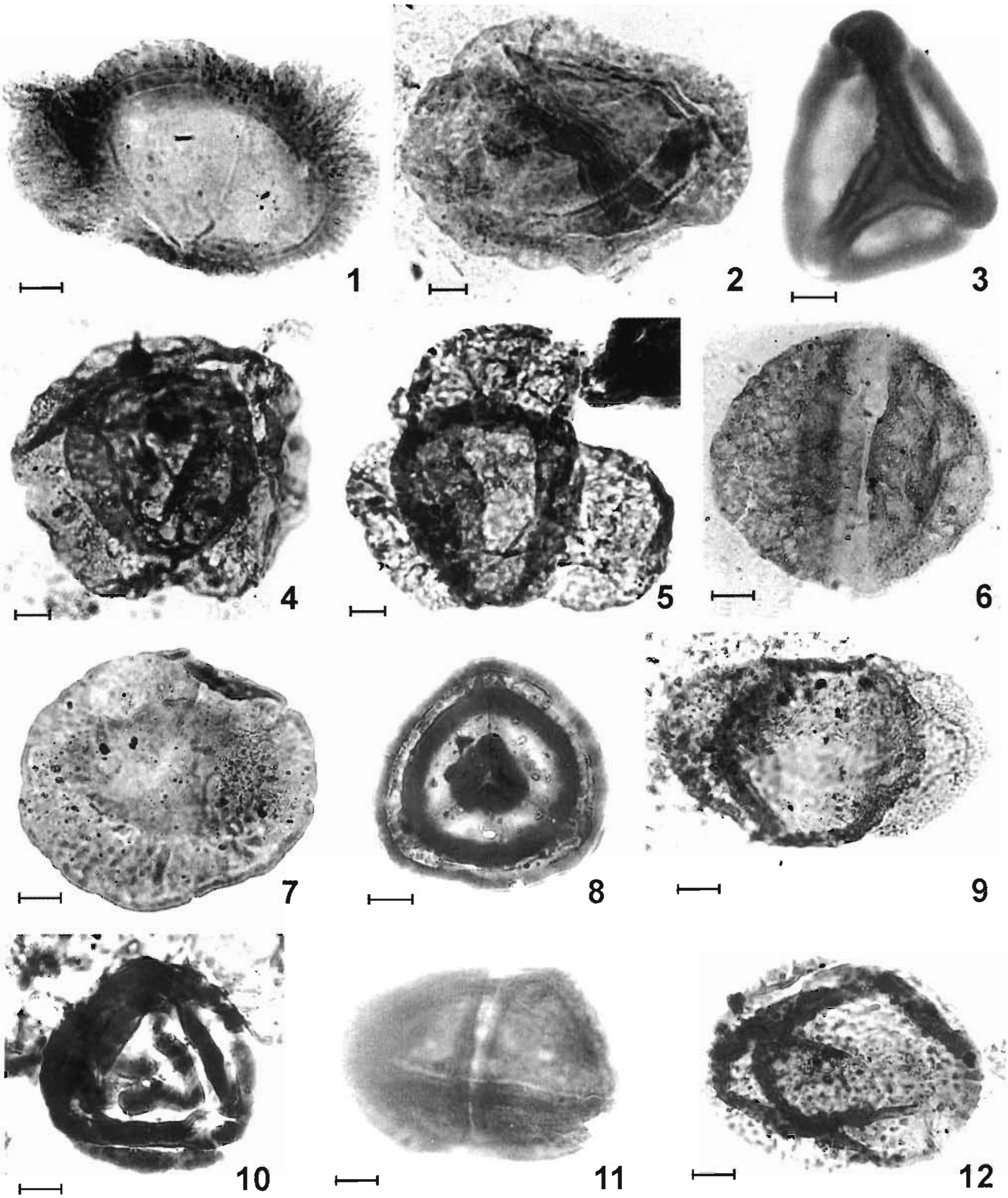

PLATE 2

reimannii Mandal *et al.*, 1994; *Monocolpites spinosus* Baksi, 1962; *Spinizonocolpites baculatus* Muller, 1968; *Lakiapollis ovatus* Venkatachala & Kar, 1969; *Proxapertites operculatus* v.d. Hammen, 1956; *Baculimonocolpites andamanensis* Mandal *et al.*, 1994; *Alangiopollis* sp.; *Acanthotricolpites kutchensis* (Kar & Kumar) Singh & Misra, 1991; *Neocouperipollis brevispinosus* (Biswas) Singh & Sarkar, 1988; *Pellicieroipollis* sp.; *Phragmothyrites eocenicus* Edwards emend. Kar & Saxena, 1976; *Notothyrites* sp.; *Operculodinium centrocarpum* (Deflandre & Cookson) Wall, 1967; *Achomosphaera* sp.; *Cleistosphaeridium brevispinosum* Jain & Millepeed, 1975; *Polysphaeridium subtile* (Davey & Williams) Bujak *et al.*, 1980; *Palaeocystodinium australinum* (Cookson emend. Malley, 1972) Lentin & Williams, 1976.

Comment—The reworked palynomorphs are about 50% at the base of the section which gradually decrease and become scare at the upper level.

Section 5

Permian—**Cuneatisporites exiguus* Salujha, 1965; **Striatites varius* Kar, 1968.

Triassic—**Falcisporites stabilis* Balme, 1970; **Playfordiaspora cancellosa* (Playford & Dettmann) Maheshwari & Banerjee emend. Vijaya, 1995.

Jurassic-Cretaceous—**Aequitriradites dubius* Delcourt & Sprumont emend. Delcourt *et al.*, 1963; *Callialasporites* sp.; *Araucariacites* sp.; *Alisporites grandis* (Cookson) Dettmann, 1963.

Comment—Tertiary palynofossils are absent in this section.

SYSTEMATICS

Descriptions of a few uncommon taxa and new to this area are given below.

Genus—DACTYLOPOLLIS Muller, 1968

DACTYLOPOLLIS MAGNIFICUS Muller, 1968

(Pl. 1·15)

Horizon—Baratang Formation, Late Cretaceous–Eocene.

Description—Pollen grain prolate, longitudinally folded, 93·5 µm in equatorial view. Tricolpate, colpi long and slit-like. Exine 2·5 µm, nexine thinner than sexine, 1 µm at equator, indistinct at poles. Surface striate at poles and colpus margins; striae fine, 1 µm wide, parallel to colpi, anastomose forming long narrow lumina, curve at margin and pass on to opposite surface. Surface foveo-reticulate in equatorial area, muri 1 µm, lumina circular to oval, irregular in arrangement which gradually change to striate pattern.

Comments—Single specimen has been found from Section 2. This specimen is very distinct and closely similar to *Dactylopollis magnificus* Muller, 1968. However, second ornamentation type below the reticulate-foveolate zone could not be recognised. Muller (1968) described this taxon from Senonian to Palaeocene sediments of Malaysia but is unknown from India and Myanmar.

Genus—LANAGIOPOLLIS Morley, 1982

LANAGIOPOLLIS REGULARIS Morley, 1982

(Pl. 1·6)

Horizon—Baratang Formation, Late Cretaceous–Eocene.

Description—Pollen grain subtriangular, oblate, amb convex, 60·5 µm in polar view. Tricolporate, colpus and pore characters indistinct due to oblique preservation, pores appear costate. Exine 3·5 µm at mesocolpia; sexine 1·5 µm, thinner than nexine (2 µm); both sexine and nexine gradually thin out towards aperture. Exine tectate, tectum ca. 1 µm, columellae distinct, closely placed, ca. 0·5 x 1 µm. Surface microreticulate on low focus; muri very low, simplicolumellate, lumina generally circular.

Comments—Single specimen has been recovered from Section 3. The thicker nexine and reticulate surface feature compare with *Lanagiopollis regularis* Morley, 1982. However, the present specimen has thinner exine and muri than the holotype. The character of aperture is masked due to oblique preservation.

PLATE 3 →

(Bars on the photographs represent 10 µm. England Finder numbers are given within bracket after slide number)

1. *Vesicaspora* sp., Slide No. BSIP 12644 (E27).
2. *Aequitriradites dubius* Delcourt & Sprumont emend. Delcourt *et al.*, 1963, Slide No. BSIP 12663 (L49).
3. *Klausipollenites schaubergeri* (Potonié & Klaus) Jansonius, 1962, Slide No. BSIP 12657 (G10/1).
4. *Goubinispora indica* Tiwari & Rana, 1981, Slide No. BSIP 12645 (P42).
5. *Falcisporites stabilis* Balme, 1970, Slide No. BSIP 12658 (H22/3).
6. *Klukisporites* sp., Slide No. BSIP 12651(K17).
7. *Aurangapollenites brevizonatus* (Tiwari) Bharadwaj & Dwivedi, 1981, Slide No. BSIP 12647 (P37).
8. *Cerebropollenites* sp., Slide No. BSIP 12652 (U25/2).
9. *Crescentipollenites fuscus* (Bharadwaj) Bharadwaj *et al.*, 1974, Slide No. BSIP 12656 (F11/1).
10. *Scheuringipollenites maximus* (Hart) Tiwari, 1973, Slide No. BSIP 12655 (O25/2).
11. *Corisaccites alutas* Venkatachala & Kar, 1966, Slide No. BSIP 12655 (S15/4).
12. *Brachysaccus* sp., Slide No. BSIP 12642 (Q23).
13. *Ovalipollis* sp., Slide No. BSIP 12643 (P27/2).
14. *Playfordiaspora cancellosa* (Playford & Dettmann) Maheshwari & Banerjee emend. Vijaya, 1995, Slide No. BSIP 12665 (H26/2).

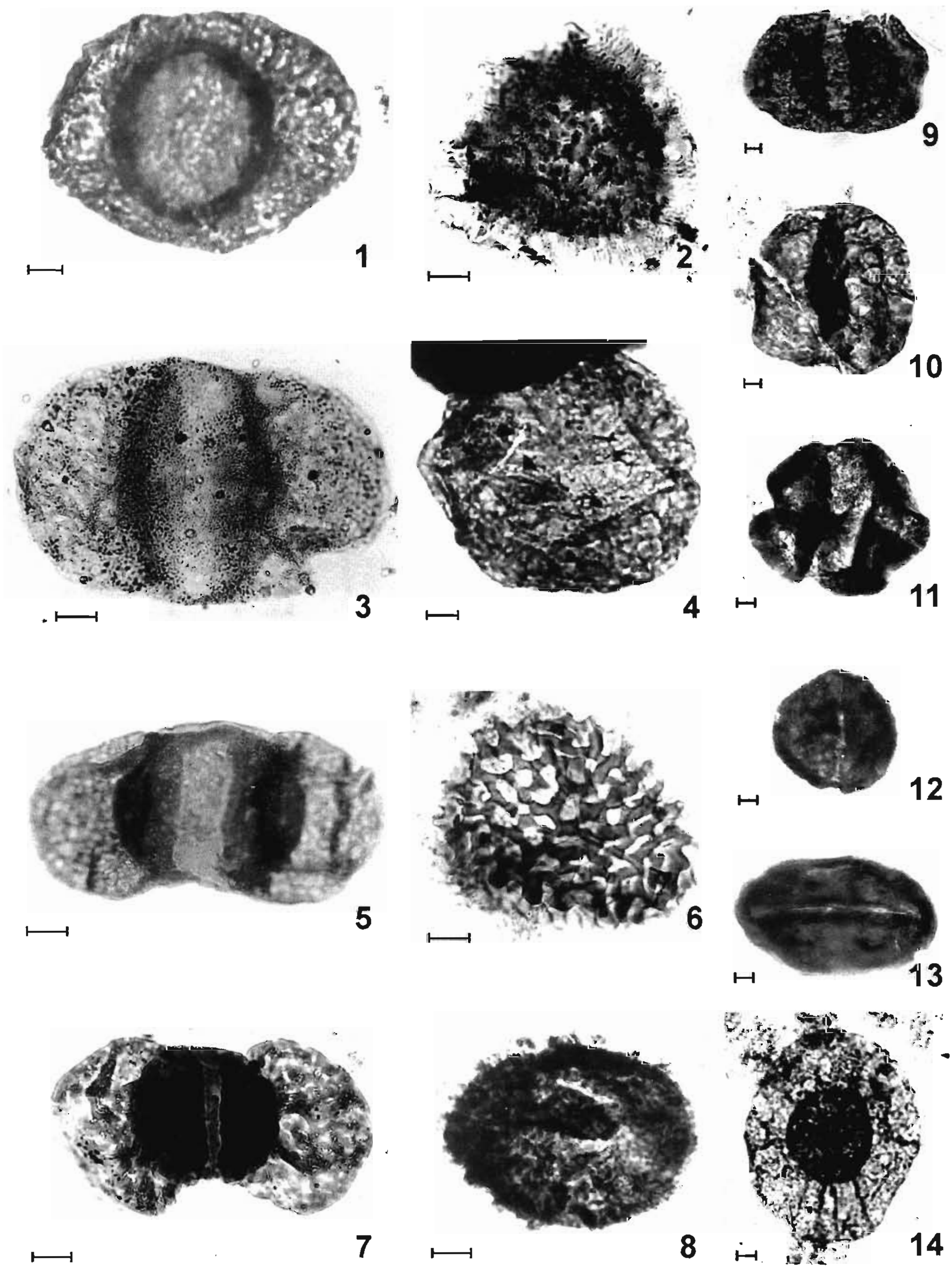

PLATE 3

Genus—ALANGIOPOLLIS Krutzsch, 1962

ALANGIOPOLLIS sp.

(Pl. 1·1)

Horizon—Baratang Formation, Late Cretaceous–Eocene.

Description—Pollen grains rounded triangular in polar view, 70 x 79 µm. Tricolporate, colpi long, 22 µm, tapering towards pole, margin granular; pore lalongate, 9 µm in diameter, thickening absent on colpus and pore margins. Exine 3·5-4 µm; sexine-nexine not separable and thickness near aperture not clear. Surface striate, striae parallel to colpi, varies in thickness of width, 1-2 µm, thicker at equator, anastomoses occasionally forming long narrow lumen, more common on polar area, lumen width always lesser than the striae. Only a single structural pattern (striate) present.

Comments—Two specimens have been recovered from Section 4. The character of exine is similar with the generic description of *Alangiopollis* by Morley (1982). The specimens are distinct having only one structural pattern and no comparable forms could be found.

Genus—STRIATOPOLLIS Krutzsch, 1959

STRIATOPOLLIS sp.

(Pl. 1·8)

Horizon—Baratang Formation, Late Cretaceous–Eocene.

Description—Pollen grain folded, oblate, 82 µm in equatorial view. Tricolpate, colpi long, slit-like, characters not distinct due to fold. Exine 4 µm at mesocolpium, 2 µm at apocolpium, nexine indistinct, 1 µm at mesocolpium. Surface intectate, columellae free, long, form pseudo-striate pattern on polar areas in low focus; 2 µm long, 1 µm wide, closely placed, closer and shorter at apocolpia and absent near colpi.

Comments—Section 2 has yielded single specimen. The specimen is grossly comparable to *Perfotricolpites neyvelii* (Navale & Misra) Mandal & Kumar, 2000 but differs in being smaller in size. Moreover in the present specimen, columellae are not digitate and surface is pseudo-striate but not perforate-reticulate.

Palynomorph Type—1

(Pl. 1·17)

Horizon—Baratang Formation, Late Cretaceous–Eocene.

Description–Single specimen, nearly circular, 37 x 39 µm, aperture not discernible. Surface beset with some raised structures, about 18 structure on one surface, intrastructural areas smooth; structures 2 µm high with little swollen base and flat tips. Each structure has 1 µm deep cavity at tips. Wall 2 µm thick, ca. 4 µm including the structure.

Comments—Single specimen has been recovered from Section 2. The specimen grossly compares to algal taxon *Intubidinium* Shanfu, 1999 in surface characters but the Chinese specimens have comparatively larger size, thinner wall and more surface structures (canals) than the present form.

COMPARISON OF ANDAMAN PALYNOFLORA

It is necessary to compare the Palaeogene palynoflora recorded till date from Andaman with Assam and Myanmar to examine their relationship. Few palynological data generated from Myanmar (Potonié, 1960; Reimann & Thaung, 1981) allow limited but significant comparison. Several taxa namely *Palmidites, Palmaepollenites, Dandotiaspora, Striatriletes, Disulcites, Neocouperipollis, Triporopollenites, Striacolporites, Triorites, Proxapertites, Meliapollis, Lakiapollis* and *Margocolporites* are present in all the three areas and a number of them are common at species level. In addition to the similarity, a few genera like *Retitrisyncolpites, Baculimonocolpites* and *Lanagiopollis (regularis)* are common between Andaman and Myanmar. On the other hand, few taxa, such as *Tricolpites phillipsii* and *Distaverrusporites margaritatus* of Malaysian affinity are present in Myanmar but are unknown from Andaman. Similarly, *Dactylopollis, Striatopollis* and *Meyeripollis* are present in Andaman while they are absent in Myanmar. A few genera known from Andaman like *Matanomadhiasulcites, Dermatobrevitricolporites, Sastripollenites, Minutitricolporites, Tricolporopilites, Meyeripollis* and *Striatopollis* are common in Assam and Andaman flora but many of them do not compare at species level.

The comparison thus indicates that though the Palaeogene palynoflora is grossly similar in Andaman, Assam and Myanmar but the common presence of few dominant and significant taxa like *Retitrisyncolpites, Lanagiopollis* and *Baculimonocolpites* point closeness of Andaman microflora with Myanmar rather than with Assam.

AGE OF THE SEDIMENTS

In the absence of marine nannoplankton and scarcity of marine fauna, palynology plays an important role in determination of age of the Andaman flysch sequences. The present assemblages contain palynomorphs of various ages and thus the palynofossils indicating youngest age is considered as the age of the sediments. Geologically the age of Baratang Formation ranges from Late Cretaceous to Eocene (Chatterjee, 1967). Though the palynomorphs (Tertiary) are poor in number, some of them are important marker and the range of vertical distribution is well defined. Thus age has been postulated from their known distribution range. The distribution of selected stratigraphically significant palynomorphs in the Baratang Formation has been presented in Fig. 3.

Taxa	Early Eocene	Middle Eocene	Late Eocene
Dandotiaspora telonata	———		
Baculimonocolpites andamanensis	———		
Lakiapollis ovatus	———		
Pellicieroipollis sp.	———		
Spinizonocolpites baculatus	———		
Retitrisyncolpites spp.	———	———	
Striatriletes susannae		———	———
Polyadopollenites miocenicus			———
Minutitricolporites minutus	———	———	———
Lanagiopollis regularis	———	———	———
Acanthotricolpites kutchensis	———	———	———

Fig. 3—Distribution of some stratigraphically important palynomorphs from Baratang Formation.

Section 2

The section yielded a variety of taxa that provide evidence on the age of assemblage. The first appearance of *Retitrisyncolpites* has been recorded in the Early Eocene of Myanmar (Reimann & Thaung, 1981) and Middle Andaman (Mandal *et al.*, 1994). The taxon abundantly occurs till Middle Eocene and is rare in Late Eocene in Myanmar (Reimann & Thaung, 1981). Similarly *Minutitricolporites* and *Striacolporites* also appear at the same time (Kar, 1985) and continued through Palaeogene. However, *Striatriletes* first appeared in the Middle Eocene in Indian main land (Kar, 1983) and is abundant in the overlying sequences. In Myanmar, the taxon appeared in Early-Middle Eocene as *Cicatricosisporites macrocostatus* (Reimann & Thaung, 1981). However, in other tropical areas the taxon was recorded later in the earliest Neogene (Germeraad *et al.*, 1968). The genus *Polyadopollenites* is commonly known from Oligocene in Assam but has also been recorded from the Late Eocene of Nagaland (Mandal, 1996). The above analysis indicates that the assemblage ranges from Middle to Late Eocene in age. In the absence of Oligocene marker taxa like *Crassoretitriletes, Trisyncolpites* and *Meyeripollis* the assemblage cannot be taken as younger than Late Eocene.

Section 3

The meagre Tertiary palynofossils recovered from this section do not help much in age assignment. The taxa *Minutitricolporites* and *Lanagiopollis regularis* appear in Early Eocene (Morley, 1982; Kar, 1985) and are restricted within the Eocene. *Dandotiaspora*, except *D. dilata* also rarely extends beyond the Early Eocene. Other taxa or their association in the assemblage do not reflect Middle Eocene or younger ages. Thus, at least an Early Eocene age may be postulated from the palynoassemblage.

Section 4

The dinoflagellate cysts, *Operculodinium centrocarpum, Cleistosphaeridium brevispinosum* and *Polysphaeridium subtile* recorded in this section are long ranging taxa (Eocene-Miocene) but dominantly occur within the Eocene (Williams *et al.*, 1993). However, *Palaeocystodinium australinum* is restricted within Early to Late Palaeocene. Considering the absence of other Palaeocene marker dinocysts and terrestrial palynofossils, the taxon *Palaeocystodinium* seems to be reworked.

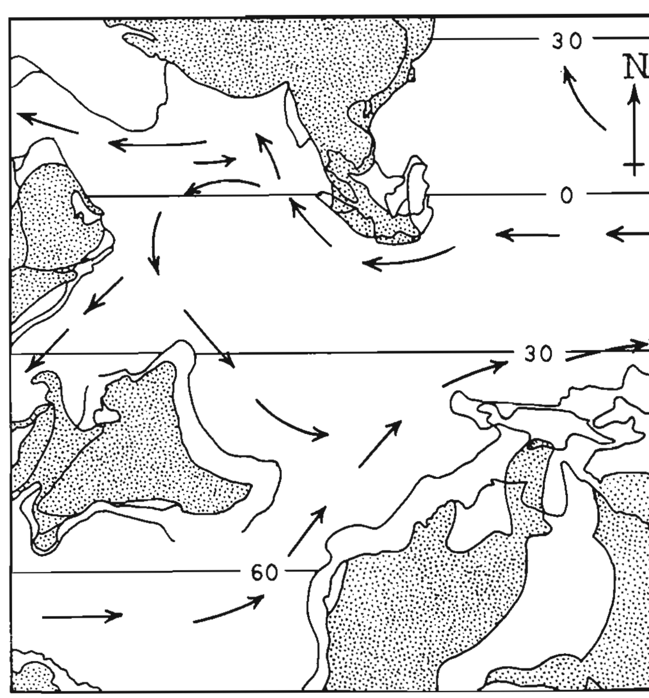

Fig. 4—Palaeogeography and ocean circulation during the middle Cretaceous (after Haq, 1985 in Kunihiro & Kunio, 1991).

The terrestrial taxa *Retitrisyncolpites, Baculimonocolpites, Lakiapollis ovatus, Pellicieroipollis, Proxapertites, Acanthotricolpites* and *Neocouperipollis* have limited vertical distribution. They present abundantly in the Late Palaeocene-Early Eocene sediments. *Lakiapollis ovatus* and *Pellicieroipollis* range within Late Palaeocene to Eocene (Thanikaimoni *et al.*, 1984; Venkatachala *et al.*, 1989) though *Lakiapollis* is known to extend rarely to the Early Miocene (Rao, 1996; Singh *et al.*, 1992). *Retitrisyncolpites* dominantly occurs in Early to Middle Eocene sediment of Myanmar. The last appearance of *Spinizonocolpites baculatus* is recorded in the Early Eocene (Muller, 1968). Moreover, *Proxapertites, Acanthotricolpites* and *Neocouperipollis* are rare to absent in overlying sequences of the Early Eocene. Thus, Early Eocene age can be assumed from the abundance of *Retitrisyncolpites* and *Baculimonocolpites* and in absence of any other marker taxa of Palaeocene or younger ages. Dinoflagellate cysts are long ranging and do not help in precise age determination.

Sections 1 & 5

Both the assemblages from sections 1 and 5 consist of Permian, Triassic and Jurassic-Cretaceous palynofossils without any Tertiary taxa. Obviously, Early Cretaceous age may be fixed for these two assemblages. However, it can be mentioned that reworked palynomorphs are similar to other sections containing Tertiary taxa. This indicates same source of the sediments containing these recycled palynofossils. Only one sample in Section 1 and two samples from Section 5 (Fig. 2) have poorly yielded palynomorphs. Had more samples been productive, it seems that palynomorphs of younger age would have yield. The assemblages do not contain *Aquilapollenites, Ariadnaesporites* and *Scordilla* to support Late Cretaceous age. However, Late Cretaceous taxa like *Dactylopollis* and *Bacutriporites* have been recorded here in the Eocene assemblage.

In Baratang Island, two horizons of fauna are known. The lower horizon has the indigenous *Globotruncana* assemblage of Late Cretaceous age and the upper horizon contains recycled Cretaceous fauna ranging in age from Palaeocene to Late Eocene (Pandey *et al.*, 1992). The Cretaceous–Palaeocene microfauna are known from Baratang Formation (Guha & Mohan, 1965; Pandey, 1972; Pandey & Rao, 1976; Kumar & Soodan, 1976). Cretaceous planktonic foraminifera and marine algae are also recorded from this Formation (Rajshekhar *et al.*, 1990; Badve & Kundal, 1986).

Though Cretaceous faunal assemblages have been recorded, palynoflora of Cretaceous or Palaeocene age is not known from Andaman Islands. The only Cretaceous palynoassemblage (Banerjee, 1967) reported from Middle Andaman, in fact contains Tertiary palynomorphs but abundance of Cretaceous forms led him to fix age as Cretaceous (Banerjee, 1967; p. 213). Similarly the Oligocene assemblage includes the reworked taxa (e.g., *Alisporites:* Mathur & Mathur, 1980; pl. 1, figs 8, 9). Recently Jafar and Tripathi (2001) claimed the recovery of Late Cretaceous palynoassemblage from Middle Andaman but did not mention the names of taxa or photo documented the specimens.

The above synthesis demonstrates that the Late Cretaceous palynoassemblage is still unknown from Andaman. Thus, from the palynoassemblages of sections 1 and 5, Cretaceous age connotation would be doubtful and age assignment remains unresolved.

SIGNIFICANCE OF REWORKED PALYNOFOSSILS

In the studied five sections from Baratang Island, recycled Permian, Triassic and Jurassic-Cretaceous pollen taxa of Gondwanic affinity are present. The previously recorded assemblages from Andaman Islands, except one, reveal similar admixture of pollen-spores of different ages. However, Permian palynotaxa have been recorded for the first time in the present assemblage. It is surprising that the Early Eocene assemblage recovered from lignitic sediments of Kadamtala, Middle Andaman (Mandal *et al.*, 1994) is completely free of reworked taxa. The sediments of Baratang Formation are flysch in nature and were deposited through turbidity currents. How this assemblage remained free from recycled palynomorphs within such terrain remains an unsolved issue.

The presence of Triassic palynomorphs and dinoflagellate cysts (Sharma & Mehrotra, 1984; Sharma & Sarjeant, 1987) has lead to conclusion that Triassic sediment present in Andaman Islands (Sharma & Mehrotra, 1984). This has aroused much debate. Several researchers (Pandey, 1986; Kumar, 1990; Jafar & Tripathi, 2001) ruled out the presence of Late Triassic sediment as inliner or exotic blocks in Middle Andaman. According to them Late Triassic palynomorphs are reworked. On the other hand Mehrotra and Sarjeant (1990) conformed the presence of Triassic sediments in the Andamans and strongly argued for the authocthonous nature of the Triassic elements. However, Jafar and Tripathi (2001) reported Late Triassic palynomorphs at several levels in the Late Cretaceous succession of Chainpur Section- the locality from where Sharma and Mehrotra (1984) reported Late Triassic sediments. Furthermore, microforaminifera of Cretaceous–Palaeogene age have been recovered from the same samples which Sharma & Mehrotra, 1984 had studied (Pandey, 1986). Mehrotra, however, in a written communication disagreed with the observation of Pandey (1986) and states "the samples containing Triassic spores-pollen and dinocysts do not contain any younger palynomorphs. Pandey (1986) while preparing the Cretaceous- Palaeogene microforaminifera from these has not given details of sample nos. and recorded species."

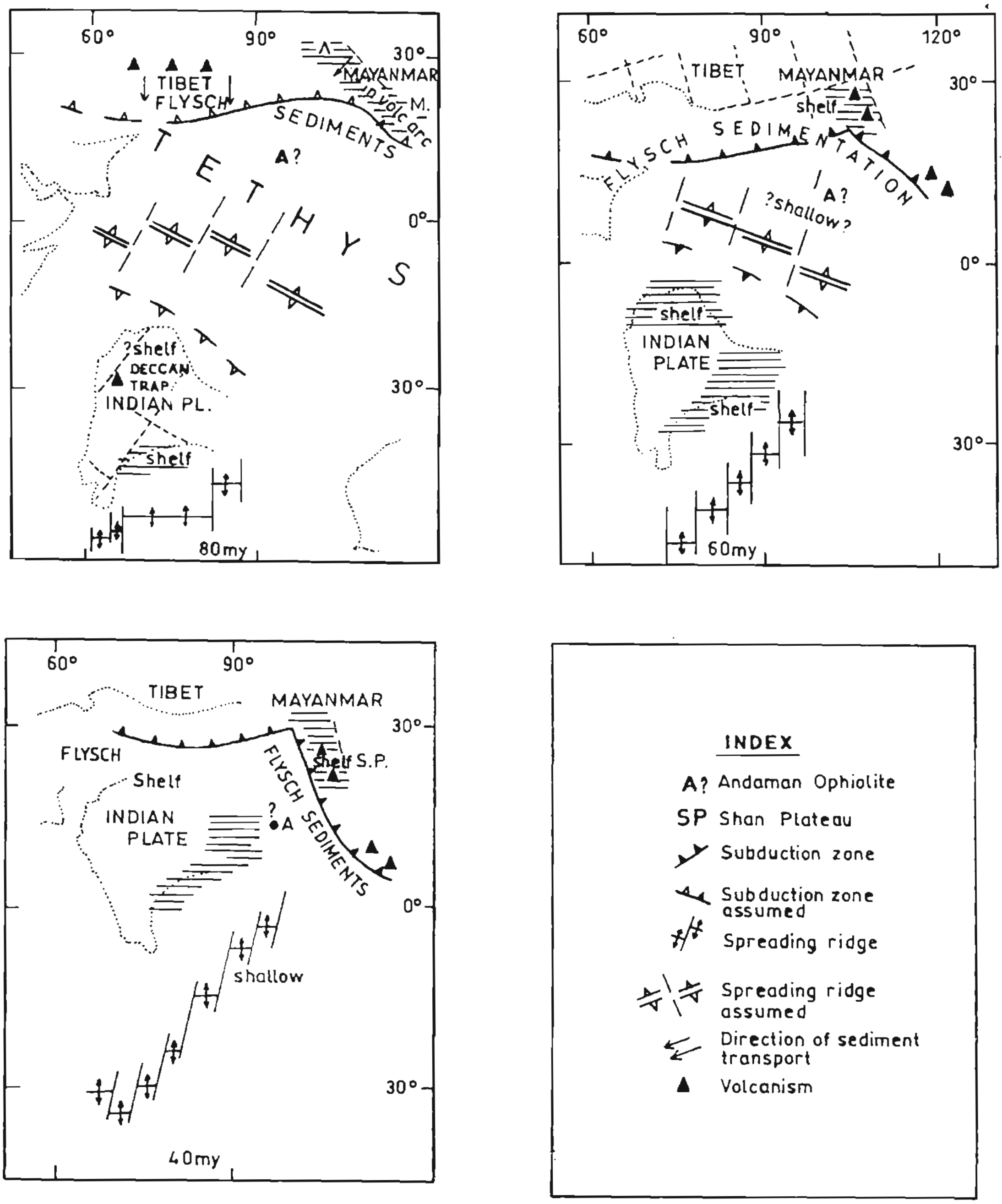

Fig. 5—Plate tectonic maps during 80 my, 60 my, 40 my of Myanmar-Andaman area (after Bender, 1983).

In the present work Triassic taxa recovered together with palynofossils of different ages from all the sections. Such recycling is expected in flysch turbidites of Middle Andaman. These Triassic specimens are reworked which were carried by the sediments with other Gondwanic elements and redeposited in Andaman. Though there is no significance of these recycled palynomorphs in age determination, they are very useful in palaeogeographical reconstructions.

Jafar and Tripathi (2001) remarked that Late Cretaceous sections of Andaman contain reworked Late Triassic palynomorphs while Late Cretaceous fossils occur in the Eocene assemblage. Although the present study shows that

Maastrichtian taxa like *Dactylopollis* and *Bacutriporites* present in Eocene assemblage and therefore, such conclusion needs verification. The taxa of Permian e.g., *Caheniasaccites, Faunipollenites, Corisaccites* and *Scheuringipollenites*: Triassic e.g., *Staurosaccites, Klausipollenites, Playfordiaspora, Brachysaccus* and *Goubinispora* in addition to Jurassic-Lower Cretaceous e.g., *Callialasporites, Cerebropollenites, Aequitriradites* and *Triporoletes* occur together in the Eocene assemblage of Baratang. Additionally, nearly same association of reworked taxa is also part of the assemblages of sections 1 & 5 which did not yield any Tertiary palynofossils. Moreover, as mentioned earlier, no Late Cretaceous and Palaeocene palynofloral assemblages have been documented from Andaman Islands. Hence the source of palynofossils must be the area around Andaman where both the terrestrial and marine sediments of these ages existed.

SOURCE OF THE REWORKED PALYNOMORPHS

Since the Cretaceous-Palaeogene sequences of Andaman Islands are turbiditic deposits, recycled fossils have Gondwanic affinity and Gondwana provinces were present around Andaman Basin, three schools of thoughts have emerged as to the provenance of the reworked taxa. Although three groups agree on the Gondwana land origin of the reworked fossils, they differ markedly on the provenance of sediments carrying these spores-pollen. According to Pandey (1986) long distance transportation of sediments including Permo-Triassic palynomorphs in Andaman was from "somewhere coalfield belt of Bihar". He postulated that long rivers draining through Bihar carried huge quantities of sediments and the mouth of the rivers opened in the Assam areas. As a result, Laisong (Barail Group) spore–pollen mixed with Gondwana palynomorphs were deposited in Upper Baratang through turbidity actions (Pandey, 1986; fig. 11). Similar composition of palynoassemblages with Gondwana palynofossils in Assam and Andaman during the Upper part of Palaeogene supports this hypothesis. Moreover, the genus *Meyeripollis,* an Oligocene marker taxon in Assam is also present in Andaman (Mathur & Mathur, 1980; Mandal *et al.*, 1996), which further strengthens the view. But the taxon *Meyeripollis* occurs in several parts of southeast Asia (Morley, 1991). Additionally, the above view cannot answer the occurrence of Late Triassic dinoflagellate cysts and Eocene terrestrial palynomorphs like *Retitrisyncolpites, Baculimonocolpites, Lanagiopollis regularis, Alangiopollis* sp., and *Dactylopollis* in Andaman. Marine Triassic sediment is not known from peninsular India, particularly from Bihar area. Moreover, the above-mentioned pollen taxa have not been recovered from any Indian section including Assam.

Jafar and Tripathi (2001) advocated that Triassic taxa including marine forms originated from Wharton Basin/ Exmouth Plateau which lies in the "Northeastern" sector of Andaman-Nicobar Basin. Late Triassic to Cretaceous marine strata is present in Wharton Basin (Rad *et al.*, 1992) but transportation of these sediments to Andaman Basin through the turbidity current during the Late Cretaceous remains unanswered. The palaeogeographical maps of this region during Cretaceous (Bender, 1983, fig. 66b; Acharyya, 1994, fig. 4; Rich & Vickers-Rich, 1999, fig. 5) show position of Andaman Islands at about 15°N latitude while Wharton Basin lies near to 30°S (Jafar & Tripathi, 2001). The palaeocurrent map of Cretaceous (Fig. 4) shows the flow of current from Andaman side towards northern margin of Australia. The authors also opined that the sedimentation provenance changed after Late Cretaceous from Australian direction to the north. In fact, change in directional pattern of sediments started in Andaman area with the uplift of Andaman geanticlines at the Early Miocene (Karunakaran *et al.*, 1964; Pandey, 1972), which stopped the pre-existing northerly turbidity channel. Palynological evidences also demonstrate identical recycled pollen-spore association in all the recorded assemblages. This indicates that source of sediment was same during deposition of Baratang Formation. Still, the validity of the hypothesis can be tested only after the recovery of Late Cretaceous palynoassemblage from Andaman.

The third view advocates that sediments in Andaman came from Myanmar (Kumar, 1990; Pandey *et al.*, 1992; Mandal *et al.*, 1994). The present palynological study substantiates the above contention. Most of the Eocene taxa like *Dandotiaspora, Striatriletes, Lakiapollis, Striatopollis, Neocouperipollis, Acanthotricolpites, Retitrisyncolpites, Spinizonocolpites, Proxapertites* and *Lanagiopollis* recorded from Andaman also occur in Myanmar. However, the genera *Retitrisyncolpites, Dactylopollis* and *Lanagiopollis regularis* recorded in Andaman are not known from mainland of India. The genus *Retitrisyncolpites* is a dominant element of Chindwin flora of Myanmar like Andaman.

In fact, Myanmar (western and southern part) was a part of Gondwanaland and was connected on the northern margin of Australia before fragmentation (Metcalfe, 1988; Acharyya, 1994; Hutchison, 1989). A nearly continuous Palaeozoic and Mesozoic sequences including marine strata are present in Myanmar (Krishnan, 1982; Bender, 1983; Kumar, 1990). Lithologically the turbiditic sediments of Andaman Islands (Baratang Formation) show gradual coarsening towards north (Pandey *et al.*, 1992). According to Ray (1982), Andaman flysch sequence comprises material from distant extrabasinal distributive source situated far beyond the limits of this mobile crustal belt and were brought within through turbiditic currents. Moreover, the evidences of palaeocurrents (Fig. 4) suggest that the current flow to Andaman Basin was from NNE or NE direction before the Oligocene. These currents carried the flysch sediments to fill the fast subsiding geosyncline and the provenance is the northern and northeastern frontiers of Myanmar or beyond it. The occurrence of palynomorph type 1 that has gross resemblance with Chinese algal taxon *Intubidinium* favours flow of sediments from northern province also. However, there is no evidence to establish flow from the continents situated on eastern and western sides of Andaman (Karunakaran *et al.*, 1964, 1968). The plate tectonic maps (Fig. 5) indicate that consolidation and uplift of the Sino-Myanmar Ranges which was caused by Kimmeridgean orogeny resulted continental erosion. The sediments were deposited subsequently in intermontane basins of Myanmar and in the Indo- Myanmar geosynclines. The flysch sediments also from Asian Plate including Myanmar stretched to the west and covered parts of oceanic Tethys sea floor reaching to Andaman Islands through turbidity during Cretaceous to Oligocene (Bender, 1983).

Thus the above evidences clearly demonstrate that the area around Chindwin Basin was the source of sediment of Andaman Islands (Baratang Formation) containing the recycled palynofossils.

CONCLUSION

The palynology of Baratang Island shows that the constituents of palynoassemblages are dissimilar in different sections and the sediments span Early to Late Eocene age. The assemblages contain mixed palynoflora belonging to Permian, Triassic, Jurassic-Cretaceous together with Eocene palynomorphs. The reworked taxa have Gondwanic affinity and are the major constituents of the assemblages. Moreover, dinoflagellate cysts of Tertiary Period and Permian recycled pollen have been recorded for the first time from Andaman islands. A number of Tertiary palynomorphs of Andaman are common with Assam and Myanmar but the assemblages compare closely with that of Myanmar due to common occurrence of some stratigraphically important taxa like *Retitrisyncolpites* and *Baculimonocolpites*. The evidences from palynology together with lithology, palaeocurrent and palaeogeography favour that the source of terrestrial as well as marine palynofossils in Andaman was Myanmar.

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