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Further palynological investigation of coaliferous sequences of Tura Formation of Nangwalbibra, East Garo Hills, Meghalaya: inferences on palaeovegetation and palaeoclimate

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ABSTRACT

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The coal and carbonaceous shales collected from the Tura Formation (late Palaeocene) of Nangwalbibra, East Garo Hills, Meghalaya, have been analysed for palynological study to deduce palaeovegetation and palaeoclimate. The palynoflora represented by pteridophytic spores and angiospermic pollen grains shows similarity with other contemporaneous deposits of the Garo, Khasi and Jaintia Hills of Meghalaya. The palynoassemblage dominated by angiosperms depicts subtropical to tropical vegetation during the late Palaeocene in the region. The fossil pollen grains show their similarity with modern plants of various tropical angiosperm families, like Alangiaceae, Anacardiaceae, Annonaceae, Arecaceae, Bombacaceae, Clusiaceae and Gunneraceae, etc. which indicate the existence of tropical evergreen to moist deciduous forest. Some of the taxa resemble the floral elements growing near swamps in the tropical zone. The fossil palynoflora indicates warm and humid climate during the depositional period. The study is supported by plant megafossil data known from the same horizon.

Key-words—Spore, Pollen, Tura Formation, Late Palaeocene, Garo Hills, Meghalaya.

मेघालय में पूर्वी गारो पहाड़ियों के नॉगवलबिब्रा में तुरा शैलसमूह के कार्बनयुक्त अनुक्रम के और परागाणविक अन्वेषणः पुरावनस्पति एवं पुराजलवायु के निष्कर्ष

प्रियंका मोंगा, गौरव श्रीवास्तव, माधव कुमार एवं आर.सी. मेहरोत्रा

सारांश

मेघालय में पूर्वी गारो पहाड़ियों के नॉगवलबिब्रा में तुरा शैलसमूह से संगृहीत कोयला और कार्बनमय शेलों के परागाणविक विश्लेषण द्वारा पुरावनस्पति एवं पुराजलवायु का निर्धारण किया गया है। टेरिडोफाइटी बीजाणुओं एवं आवृतबीजी पराग कणों से निरूपित परागाणुवनस्पतिजात मेघालय की गारो, खासी व जैंतिया पहाड़ियों के अन्य समकालीन निक्षेपों के संग सदृश्ता दर्शाती है। आवृतबीजियों से प्रभावी परागाणुसमुच्चय समूह विलम्बित पुरानूतन काल के समय उपउष्णकटिबंधीय से उष्णकटिबंधीय वनस्पति चित्रित करती है। ये जीवाश्म पराग कण एलेनजीएसी, एनाकार्डिएसी, एन्नोनेसी, एरेकेसी, बाम्बेकेसी, क्लुसिएसी एवं गुन्नेरेसी इत्यादि जैसे उष्णकटिबंधीय आवृतबीजी परिवारों के आधुनिक पेड़–पौधों के साथ उनकी सदृश्ता दर्शाते हैं जो उष्णकटिबंधीय सदाहरित से कोष्ण पतझड़ी वन की मौजूदगी इंगित करते हैं। कुछ टैक्सा उष्णकटिबंधीय मंडल में दलदलों के निकट उग रहे पुष्पी तत्वों से समानता प्रदर्शित करते हैं। इन्हीं कोयला स्तरों से प्राप्त जीवाश्म परागाणुवनस्पतिजात निक्षेपणीय अवधि के दौरान कोष्ण एवं आर्द्र जलवायु इंगित करती है। अध्ययन इसी क्षितिज से ज्ञात पादप स्थूलजीवाश्म आंकड़े से समर्थित है।

सूचक शब्द—बीजाणु, पराग, तुरा शैलसमूह, विलम्बित पुरानूतन, गारो पहाड़ियां, मेघालय।

INTRODUCTION

COALIFEROUS sequences of the Tura Formation occur at various places in the Garo Hills, Meghalaya (Raja Rao, 1981). Palynological studies of this formation dealt mostly with taxonomy, stratigraphic ranges of the palynotaxa and age determination (Banerjee, 1964; Biswas, 1962; Chatterjee & Ghosh, 1962; Ghosh AMN, 1954; Ghosh TK, 1969; Kar *et al*., 1972; Sah & Singh, 1974; Singh, 1977a, b, 1982). These palynoassemblages are characterised by dominance of angiosperm pollen showing botanical affinities with the plants pertaining to the megathermal evergreen forests existed in the region during the late Palaeocene. Saxena *et al*. (1996) and Tripathi *et al*. (2000) provided brief sketches on the palaeoclimate and environment of deposition. Strata of coal and shale, predominantly sandwiched by sandstones (Fig. 1) are exposed at Nangwalbibra (Fig. 2) and comprise spores and pollen grains derived mainly from the lowland tropical vegetation. The macrofloral record is primarily of leaves (Mehrotra, 2000, 2003) indicating the occurrence of tropical rainforest thriving under the warm and humid climate in the region.

The present study is based on spores and pollen grains collected from Nangwalbibra near Williamnagar, Meghalaya with the objectives to build the palaeofloristics, unravel the palaeoclimate and palaeoecology of various taxa occurring there during the depositional period.

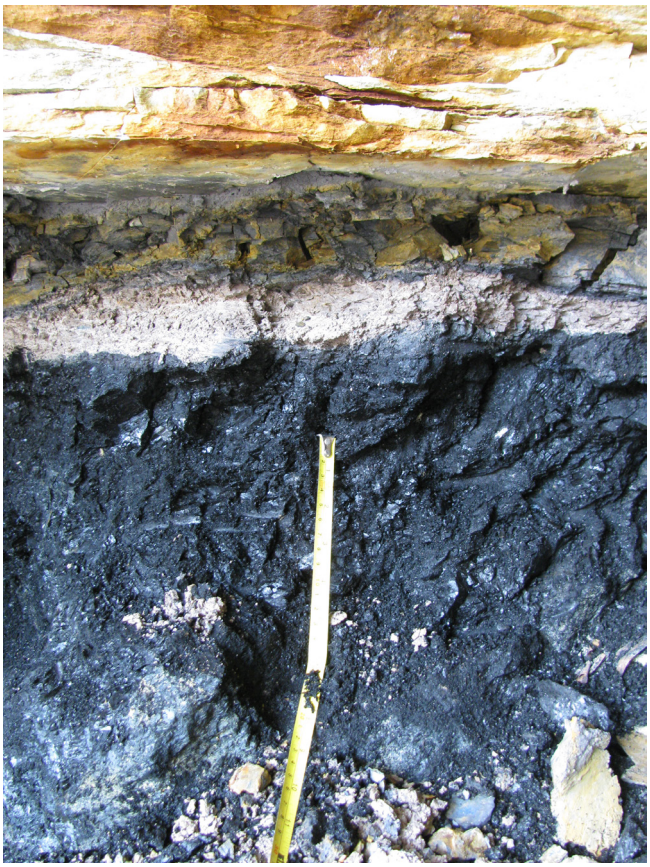

Fig. 1—Photograph of the coal bearing sequences.

STRATIGRAPHIC SETTINGS

Coalfields of Garo Hills are located in the southwestern part of the Shillong Plateau. Coal bearing sequences of the Jaintia Group occur in a large area in isolated patches and are considered to be formed over Precambrian platform under stable shelf conditions. The Jaintia Group comprises coal bearing Tura Formation, non–coaliferous sediments of Siju Limestone (early Eocene) and the late Eocene Kopli Formation (Anonymous, 1989; Baksi, 1974; Biswas, 1962; Raja Rao, 1981). The Tura Formation is further divided into lower, middle and upper members (Raja Rao, 1981). The lower member consists of massive sandstones with pebbly interbands. The middle member is argillaceous in character

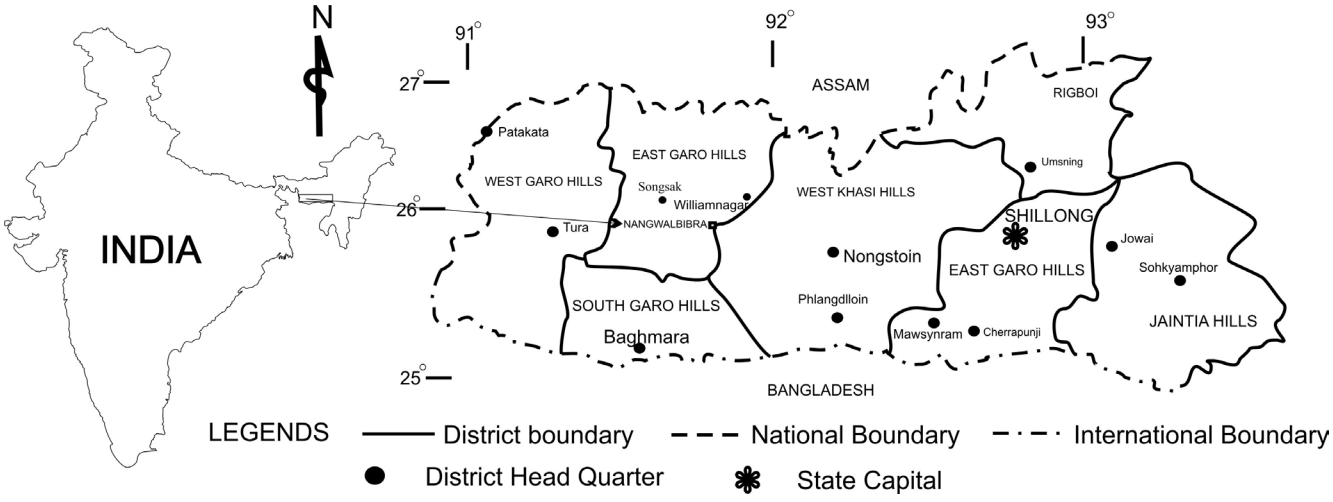

Fig. 2—Location map of the study area.

comprising lithomargic clays, argillaceous sandstones along with shales and coal seams of variable thickness, while the upper member is arenaceous with a pebble bearing layer. The sandstones are ferruginous in nature and profusely cross bedded at places. The generalised lithostratigraphic sequence (after Raja Rao, 1981) is given in Fig. 4.

MATERIAL AND METHODS

The samples for the present study were collected from the Tura Formation of Nangwalbibra (25º26'47.4" N; 90º42'28.9" E), East Garo Hills District, Meghalaya (Fig. 3). The exact locality lies at a distance of about 2 km SSE of the town. Thirty grams each of the coal and shale samples collected from the exposed section were crushed and kept in plastic jars. The crushed shale samples were treated with 20% HCL and 40% HF followed by concentrated HNO_3 while coal samples were treated directly with concentrated HNO_3. After treatment with acids, all the samples were thoroughly washed with water. Finally, the acid free material was treated with 3% KOH solution for 3–5 minutes to remove humic matter. The residues of the productive samples were sieved using 400 µm mesh sieve and collected in plastic jars. The slides were prepared in polyvinyl alcohol and mounted in canada balsam. These samples contain moderate quantity of spores and pollen grains and thus, their frequency representation in the stratigraphic sequence is not possible. Slides of the taxa shown in Pl. 1 are housed in the Museum of Birbal Sahni Institute of Palaeobotany, Lucknow with repository numbers (BSIP 14901–14905).

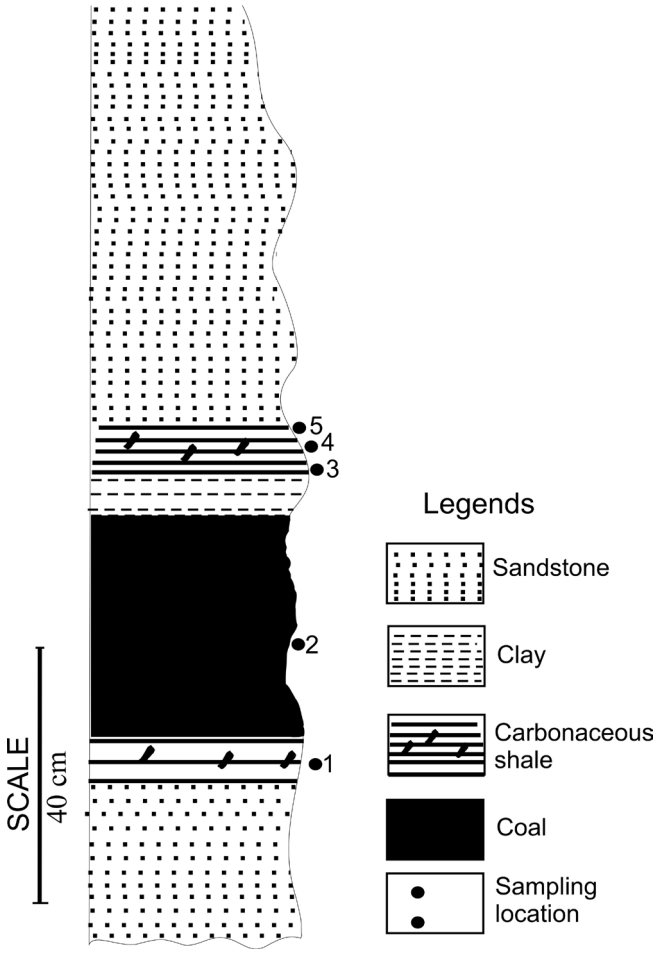

Fig. 3—Litholog of the section.

Age	Group	Formation	Lithology
Oligocene		Simsang (100 m thick)	Fine–to medium–grained sandstone with minor siltstones and shale intercalations.
Palaeocene – Eocene	Jaintia	Kopli (450 to 500 m thick)	Splintary shales with phosphatic nodules, siltstones and fine–grained sandstones.
		Siju Limestone (100 to 160 m thick)	Fossiliferous foraminiferal limestone
		Tura Formation (180 to 250 m thick)	Upper–cross bedded sandstone with pebble layers. Middle–clays and argillaceous sandstone with coal and shales. Lower–Massive sandstone with pebbly inter–bands
Upper Cretaceous			Coarse–grained sandstone and conglomerate (~ 60 m thick)
	Unconformity		
Precambrian			Coarse–grained granite, granodionite, banded gneiss and quartzite.

Fig. 4—The generalised lithostratigraphic sequence of Garo Hills, Meghalaya (after Raja Rao, 1981).

	Taxa	Affinity	Habitat	Climate	Geographical range
1.	*Lycopodiumsporites* sp.	Lycopodiaceae	Moist places	Tropical to subtropical	Cosmopolitan
2.	*Dandotiaspora dilata* Sah *et al*., 1971	Matoniaceae	Moist, swampy	Tropical to subtropical	Southern Hemisphere
3.	*Polypodiaceaesporites* sp.	Polypodiaceae	Rain forest	Tropical to boreal	Cosmopolitan
4.	*Rhoipites kutchensis* Venkatachala & Kar, 1969	Anacardiaceae	Variable	Tropical to subtropical	North America, Asia
5.	*Proxapertites assamicus* (Sah & Dutta) Singh, 1975	Araceae	Evergreen, climbing plant	Tropical to temperate	Southeast Asia
6.	*Polycolpites* sp.	Pedaliaceae	Mostly inhabiting along shores	Tropical to subtropical	Africa, Madagascar, India, Southeast Asia, Malaysia, Australia
7.	*Tricolpites* sp.	Gunneraceae	Lowland	Tropical and excessive humid environment	Southeast Asia, Madagascar, New Zealand, Africa
8.	*Tricolporopollis decoris* Dutta & Sah, 1970	Alangiaceae	Lowland	Temperate, subtropical to tropical	Western Africa, Madagascar, Southern and Eastern China
9.	*Retimonosulcites ovatus* (Sah & Kar) Kar, 1985	Arecaceae	Lowland near shore or variable	Tropical to subtropical	Cosmopolitan
10.	*Matanomadhiasulcites kutchensis* (Saxena) Kar, 1985	Annonaceae	Lowland evergreen forest	Tropical with few species in temperate regions	Southern Hemisphere
11.	*Kielmeyerapollenites syncolpites* Kar & Kumar, 1986	Clusiaceae	Uncertain	Temperate to mostly tropical	Southern Hemisphere

Fig. 5—Ecological requirements and geographical ranges of some modern comparable taxa of the fossils in the Garo Hills, Meghalaya.

RESULTS

The spores and pollen grains recovered from coal and shale samples are shown in Pl. 1. The botanical relationship of these palynotaxa with the modern plants alongwith their ecological requirements and distribution is given in Fig. 5. The angiospermic pollen grains are dominant in the flora, followed by pteridophytic spores. Amongst the spores, *Lycopodiumsporites speciosus* and *Dandotiaspora dilata* are dominant. The pollen grains are dominated by *Matanomadhiasulcites kutchensis* (Annonaceae), followed by *Lakiapollis ovatus* (Bombacaceae), *Polycolpites indicus*, *Palmidites plicatus* and *Retimonosulcites ovatus*. The pollen grains of *Kielmeyerapollenites syncolporatus*

PLATE 1
(scale bar = 20 μm)

1, 2. *Lycopodiumsporites* sp. BSIP 14901, E 23/3, BSIP14903 H, 43/4.
3. *Lycopodiumsporites palaeocenicus* Dutta & Sah, 1970, BSIP 14903, U 46/2.
4. *Dandotiaspora dilata* Sah, Kar & Singh, 1971, BSIP 14902, Q 39/2.
5. *Polypodiaceaesporites* sp., BSIP 14902 Q 31/3.
6. *Rhoipites kutchensis* Venkatachala & Kar, 1969, BSIP 14903, T 46/2.
7. *Proxapertites assamicus* (Sah & Dutta), Singh, 1975, BSIP 14904, S 36/4.
8. *Polycolpites* sp. BSIP 14901, N 22.
9. *Tricolpites* sp. BSIP 15904, D 33/4.
10. *Tricolporopollis decoris* Dutta & Sah, 1970, BSIP 14904, G 56/3.
11. *Polycolpites multirimatus* Dutta & Sah, 1970, BSIP 14903, R 38.
12. *Tricolpites crassireticulatus* Dutta & Sah, 1970, BSIP 14905, M 25.
13. *Retimonosulcites ovatus* (Sah & Kar) Kar, 1985, BSIP 14902,Q 42/1.
14. *Matanomadhiasulcites kutchensis* (Saxena) Kar, 1985, BSIP 14904, Q 41/1.
15. *Kielmeyerapollenites syncolporatus* Kar & Kumar, 1986, BSIP 14901, O 22/3.

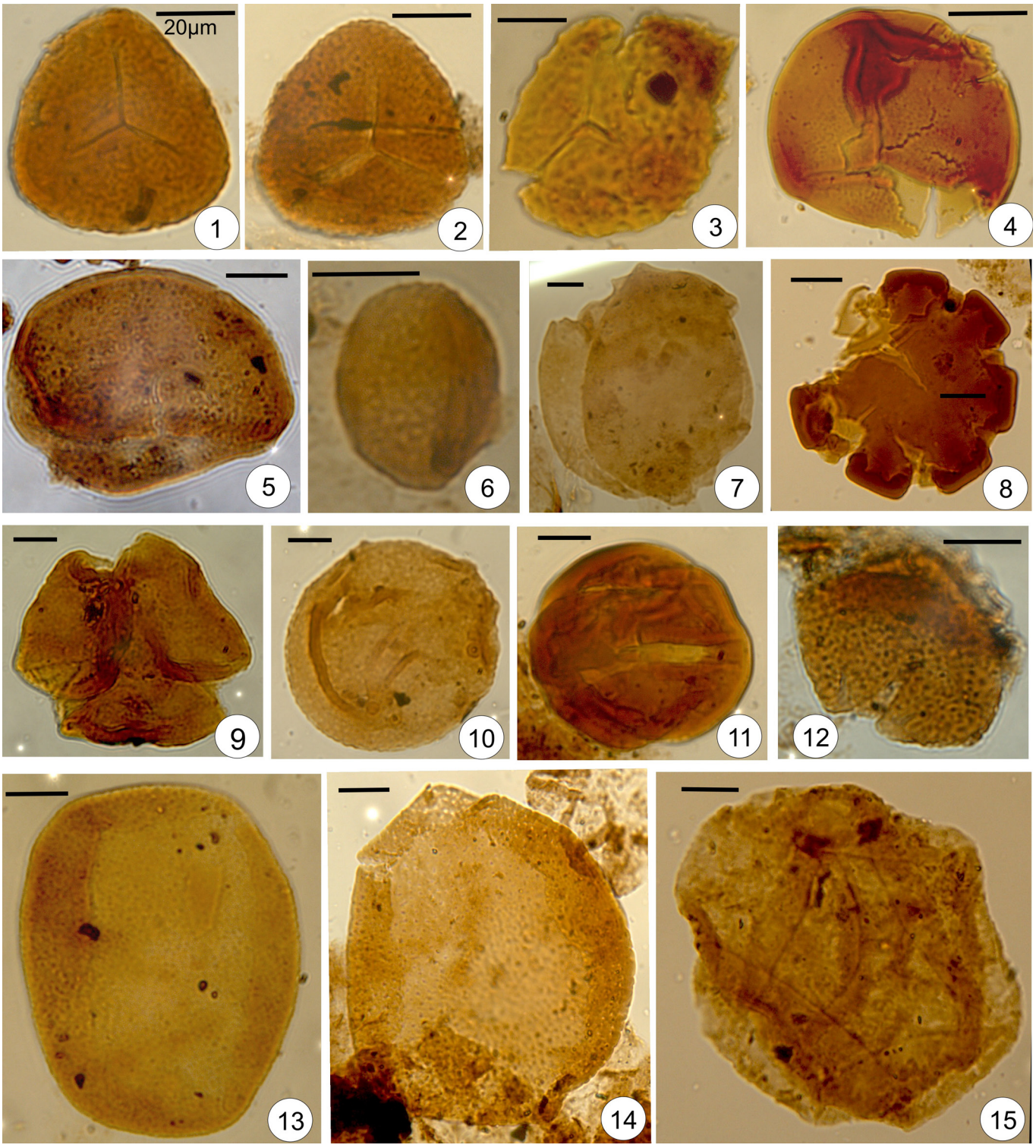

PLATE 1

(Clusiaceae), *Tricolpites reticulatus* (Gunneraceae), *Tricolpites crassireticulatus*, *Polycolpites* sp., though few in number are also recorded in the palynoassemblage. Some palm pollen grains mostly distributed in lowland tropical forest along the coast are represented by *Palmidites plicatus* and *Retimonosulcites ovatus.* Such pollen grains commonly occur in the late Palaeocene sediments of Meghalaya (Kar & Kumar, 1986; Kumar, 1994).

The palynoassemblage shows coevality with other contemporaneous deposits of the Lakadong Sandstone Formation (late Palaeocene) of Khasi Hills (Dutta & Sah, 1970, Kar & Kumar, 1986) and Jaintia Hills (Kumar, 1994). A comparison of the present palynoassemblage with other contemporaneous deposits of northeastern India is mentioned below:

Garo Hills—The common palynotaxa of the Tura Formation of Garo Hills (Sah & Singh, 1974; Saxena *et al*., 1996) are: *Dandotiaspora dilata, Lycopodiumsporites palaeocenicus, Lycopodiumsporites speciosus, Matanomadhiasulcites kutchensis, Polycolpites multirhimatus, Proxapertites assamicus* and *Tricolporopollis decoris*.

Khasi Hills—The palynotaxa *Dandotiaspora dilata, Lycopodiumsporites speciosus, Lycopodiumsporites palaeocenicus, Proxapertites assamicus, Retimonosulcites ovatus* and *Kielmeyerapollenites syncolporatus* have also been recorded from the late Palaeocene coaliferous sequence of Lakadong Sandstone Formation (Kar & Kumar, 1986).

Jaintia Hills—Dandotiaspora dilata, Lycopodiumsporites speciosus, Kielmeyerapollenites syncolporatus and *Tricolpites* sp. of the present study are some of the common taxa recorded from the Jarain and Laitrymbai coalfields of the Lakadong Formation (Kumar, 1994).

DISCUSSION

The recovered palynoflora, namely *Kielmeyerapollenites syncolporatus* (Clusiaceae), *Matanomadhiasulcites kutchensis* (Annonaceae), *Proxapertites assamicus* (Araceae), *Retimonosulcites ovatus* (Arecaceae), *Rhoipites kutchensis* (Anacardiaceae) and *Tricolporopollis decoris* (Alangiaceae) show similarity with the modern plants of tropical megathermal angiosperm families. Their ecological requirements and geographical ranges are shown in Fig. 5 (Croizat, 1958; Frederiksen, 1985; Good, 1953; Thanikaimoni *et al*., 1984; Tryon & Tryon, 1982; Willis, 1973). The pteridophytic spores, viz. *Dandotiaspora dilata* (Matoniaceae), *Lycopodiumsporites* spp. (Lycopodiaceae) and *Polypodiaceaesporites* spp. (Polypodiaceae) and monosulcate pollen of *Proxapertites assamicus* (Arecaceae) generally occur near moist and swampy habitat. The presence of families, like Alangiaceae, Araceae, Arecaceae, Clusiaceae, etc. indicates that wet evergreen forest flourished and deposited in fluvio–lacustrine setup in the region. The occurrence of fungal hyphae exhibits warm and humid climate during the late Palaeocene.

A number of megafossils described from the same horizon by Mehrotra (2000) are: *Nelumbo nucifera* of the Nymphaeaceae, *Grewia*, *Triumfetta rhomboidea* of the Tiliaceae, *Atalantia monophylla* of the Rutaceae, *Schleichera trijuga* of the Sapindaceae, *Mangifera indica* of the Anacardiaceae, *Terminalia catappa*, *Calycopteris floribunda* of the Combretaceae, *Syzygium* of the Myrtaceae, *Heteropanax fragrans* of the Araliaceae, *Chrysophyllum* of the Sapotaceae, *Ligustrum*, *Osmanthus suavis* of the Oleaceae, *Phoebe lanceolata* of the Lauraceae, *Artocarpus chaplasa* of the Moraceae and *Nypa fruticans* of the Arecaceae. They indicate the existence of tropical evergreen to moist deciduous forest. *Terminalia catappa* and *Nypa fruticans*, typical beach forest elements, indicate the existence of estuarine condition indicating warm and humid climate with higher rainfall during the depositional period than occurring at present (Mehrotra, 2000).

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REFERENCES

Anonymous 1989. Recent advances in the study of Tertiary stratigraphy of North Eastern India–a critical resume. North Eastern Region Geological Survey of India Special Publication No. 23: 1–22.

Baksi SK 1974. Significant pollen taxa in the stratigraphical analysis of the Tertiary sediments of Assam. *In*: Surange *et al*. (Editors)—Aspects & Appraisal of Indian Palaeobotany: 502–515. Birbal Sahni Institute of Palaeobotany, Lucknow.

Banerjee D 1964. A note on polospores from Tura Formation, Simsang River Section, Assam. Bulletin of the Geological Mining & Metallurgical Society of India 32: 1–6.

Biswas B 1962. Stratigraphy of the Mahadeo, Langpar, Cherra and Tura formations, Assam, India. Bulletin of the Geological Mining & Metallurgical Society of India 25: 1–48.

Chatterjee NN & Ghosh TK 1962. Fungal spores in Tertiary coal from Garo Hills, Assam. Quarterly Journal of the Geological Mining & Metallurgical Society of India 34: 147–148.

Croizat L 1958. Panbiogeography. Published by author, Caracas (Venezuela).

Dutta SK & Sah SCD 1970. Palynostratigraphy of the Tertiary sedimentary formations of Assam: 5. Stratigraphy and palynology of South Shillong Plateau. Palaeontographica B 131: 1–72.

Frederiksen NO 1985. Review of Early Tertiary sporomorph palaeoecology. American Association of Stratigraphic Palynologists Contribution Series No. 15: 1–92.

Ghosh AMN 1954. The Tura Sandstone Stages of the Garo Hills–its possible stratigraphical position. Records Geological Survey of India 83: 423–444.

Ghosh TK 1969. Early Tertiary plant microfossils from the Garo Hills, Assam, India. *In*: Santapau H *et al*. (Editors)—J Sen Memorial Volume: 123–138. Botanical Society of Bengal, Calcutta.

Good R 1953. The geography of the flowering plants. Longmans Green & Company, London.

Kar RK 1985. The fossil floras of Kachchh–IV. Tertiary palynostratigraphy. Palaeobotanist 34: 1–280.

Kar RK & Kumar M 1986. Palaeocene palynostratigraphy of Meghalaya, India. Pollen et Spores 28: 177–218.

Kar RK, Singh RY & Sah SCD 1972. On some algal and fungal remains from Tura Formation of Garo Hills, Assam. Palaeobotanist 19: 146–154.

Kumar M 1994. Palynological and palaeoecological studies of Palaeocene coal seams in Jarain and Laitrymbai areas, Jaintia Hills, Meghalaya, India. Geophytology 23: 203–207.

Mehrotra RC 2000. Study of plant megafossils from the Tura Formation of Nangwalbibra, Garo Hills, Meghalaya, India. Palaeobotanist 49: 225–237.

Mehrotra RC 2003. Status of plant megafossils during the early Palaeogene in India. *In*: Wing SL, Gingerich PD, Schmitz B & Thomas E (Editors)—Causes and Consequences of Globally Warm Climates in the Early Palaeogene: 413–423. Geological Society of America, Special Paper 309, Boulder, Colorado.

Raja Rao CS 1981. Coalfields of India; coalfields of northeastern India. Bulletin of the Geological Survey of India. Series A (45): 1–76.

Sah SCD, Kar RK & Singh RY 1971. Stratigraphic range of *Dandotiaspora* gen. nov. in the Lower Eocene sediments of India. Geophytology 1: 54–63.

Sah SCD & Singh RY 1974. Palynological biostratigraphy of the Tura Formation in the type area. *In*: Sah SCD & Cross AT (Editors)—Symposium on Stratigraphical Palynology, Special Publication 3: 76–98. Birbal Sahni Institute of Palaeobotany, Lucknow.

Saxena RK, Tripathi SKM & Prasad V 1996. Palynofloral investigation of the Tura Formation (Palaeocene) in Nongwal Bibra area, East Garo Hills, Meghalaya. Geophytology 26: 19–31.

Singh RY 1975. Morphological study of the Retialetes complex from Indian Tertiaries. Geophytology 5: 98–104.

Singh RY 1977a. Stratigraphy and palynology of the Tura Formation in the type area–Part II (Descriptive palynology). Palaeobotanist 23: 189–205.

Singh RY 1977b. Stratigraphy and palynology of the Tura Formation in the type area–Part III: Discussion. Palaeobotanist 24: 1–12.

Singh RY 1982. Development of Palaeogene palynostratigraphy in North–east India. *In*: Cenozoic stratigraphy and palynology in India. The Palaeontological Society of India, Special Publication 1: 37–49.

Tripathi SKM, Saxena RK & Prasad V 2000. Palynological investigation of the Tura Formation (Early Eocene) exposed along the Tura–Dalu Road, West Garo Hills, Meghalaya, India. Palaeobotanist 49: 239–251.

Thanikaimoni G, Caratini C, Venkatachala BS, Ramanujam CGK & Kar RK 1984. Selected Tertiary angiosperm pollen from India and their relationship with African Tertiary pollen. Institut Francais de Pondichéry, Travaux de la Section Scientifique et Techique 19: 1–92.

Venkatachala BS & Kar RK 1969. Palynology of Tertiary sediments of Kutch–1–Spores and pollen from Borehole no. 14. Palaeobotanist 17: 157–278.

Tryon RM & Tryon AF 1982. Ferns and allied plants. Springer–Verlag, Berlin.

Willis JC 1973. A dictionary of the flowering plants and ferns. Cambridge University Press, Cambridge.