Siwalik pollen succession from Surai Khola of western Nepal and its reflection on palaeoecology

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A palynological report dealing with the Siwalik Group of sediments from Surai Khola area of western Nepal is presented. The clay samples collected from six different lithological units of Lower, Middle and Upper Siwalik provide data for palaeoecological interpretations. Significant elements of the palynoflora are: *Zygnema, Mougeotia, Botryococcus, Striatriletes, Lycopodiumsporites, Monoporopollenites, Malvaceaerumpollis* and *Polyadopollenites*. Periodic changes in qualitative and quantitative composition of the palynological spectra show that the vegetational succession reflects changing palaeogeographical conditions. A fresh-water swampy environment is interpreted for the older horizons. Algal remains of *Botryococcus, Pediastrum, Zygnema* and megaspores of *Azolla*, etc., provide cogent evidence for this observation. Gradually swampy conditions seem to have changed to a bottom land habitat which is evidenced by the presence of a number of pteridophytic elements, viz., *Lycopodium, Polypodium, Schizaea*, etc. Palynoassociations depict semi-evergreen vegetational pattern during the time of deposition of the Surai Khola Siwalik sequence in West Nepal.

Key-words—Palynology, Siwaliks, Palaeoecology, Mio-Pliocene (Nepal).

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सारॉंश

पश्चिमी नेपाल में सुराई खोला से शिवालिक परागकण अनुक्रम तथा पुरापारिस्थितिकी पर इसका प्रभाव

समीर सरकार

पश्चिमी नेपाल में सुराई खोला क्षेत्र से शिवालिक अवसादों से सम्बन्धित एक परागाणविक रिपोर्ट प्रस्तुत की गई है। अधरि, मध्य एवं उपरि शिवालिक की छः विभिन्न शैलिकीय इकाईयों से एकत्र मिट्टी के नमूनों से पुरापारिस्थितिकीय निष्कर्षों हेतु आँकड़े उपलब्ध हुए हैं। **जिग्नीमा, मोगिओटिया, बोट्रिओकोकस, स्ट्रिआट्राइलिटीस, लाइकोपोडियमस्पोराइटिस, मोनोपोरोपोलिनाइटिस, माल्वेसियरमपोलिस** एवं **पोलिएडोपोलिनाइटिस** परागाणुवनस्पतिजात के मुख्य अवयव हैं। परागाणविक स्पेक्ट्रम की परिमाणात्मक एवं गुणात्मक संरचना में हुए सामयिक परिवर्तनों से बदलती हुई पुराभौगोलिक परिस्थितियाँ व्यक्त होती हैं। पुराने संस्तरों हेतु स्वच्छ जल वाले दलदली वातावरण का होना सुनिश्चित किया गया है। इस प्रेक्षण के लिए **बोट्रीओकोकस, पैडिआस्ट्रम** व **जिग्नीमा** के शैवालीय अवशेष तथा **ऍंजोला** के गुरुबीजाणु विश्वासप्रद प्रमाण जुटाते हैं। धीरे-धीरे दलदली परिस्थितियों से तलीय स्थल परिवर्तित हुआ प्रतीत होता है जो कि **लाइकोपोडियम, पोलिपोडियम, शाइज़िआ** आदि के बीजाणुओं की उपस्थिति से प्रमाणित होता है। परागाणु साहचर्य से पश्चिम नेपाल में सुराई खोला शिवालिक अनुक्रम के निक्षेपण के समय अर्ध-सदाहरित वनस्पति का होना इंगित होता है।

THE Siwalik Group of sediments are well-developed all along the foot-hills of the Nepal Himalaya. The sediments of this group are mainly characterised by clay, sandstones, grits and conglomerates. At some places lignitic nodules and coal bands have also been observed. So far, palynological investigations of this strata from Nepal have been scantily carried out. Mathur (1973) reported a Lower Siwalik palynofloral assemblage from Tharukhola-Chepang area of Nepal. Recently, Mathur (1984) has also recorded palynofossils from the Lower, Middle and Upper Siwalik sediments from the area in the east of Nepalganj. During the last four years, a rich collection of plant megafossils and palynological samples has been made from the Siwalik sediments of Dang region, western Nepal under a collaborative project with Dr G. Corvinus of University of Erlangen, West Germany. Detailed palynological investigations of the Siwalik sediments of Surai Khola and adjoining areas (see Map 1 in Corvinus, p. 295 of this volume) were carried out to build up a palynofloral succession to understand the

vegetational history, palaeoecology and phytogeography.

Location of samples—The area is situated at about 7 km north-west of Shivpur in the Kapilwastu District of west Nepal. The road section along the Surai Khola stream, between Surai Naka and Rangsing Khola, extends for a distance of 16 km and represents a complete sequence of the Siwalik Group in this region. Sediments of Lower, Middle and Upper Siwaliks are exposed along the road cutting. The basal part is called Bankas Bed. It is seen close to the base of the Surai Naka foot-hill. The top of the Surai Khola sequence is known as the Dhan Khola Bed. Between Bankas and Dhan Khola beds four more beds are present in succession, just south of Rangsing Khola, viz., Paira Khola, Chor Khola, Surai Khola and Dobata (Corvinus, 1988, 1990).

Two field trips were undertaken for collection of material from the Surai Khola sequence. Three hundred and ninety four samples were collected and processed. Samples were mainly taken from the finer clastics. Some coarse grained sandstones from the Surai Khola Bed have also proved to be productive. The slides and negatives of the palynofossil have been deposited in the museum of the Birbal Sahni Institute of Palaeobotany, Lucknow.

RESULTS

Palynofloral assemblage—A rich palynofloral assemblage is recorded from the Surai Khola sequence. Following are the significant constituents of the palynofossils:

a) ALGAL REMAINS
- *Botryococcus braunii* Kützing 1849
- Zygospores of *Mougeotia*
- *Pediastrum* spp.
- Zygospores of *Zygnema*

b) FUNGAL REMAINS
- *Callimothallus assamicus* Kar, Singh & Sah 1970
- *Inapertisporites* spp.
- *Notothyrites amorphus* Kar & Saxena 1976
- *Phragmothyrites eocaenica* Edwards 1922

c) PTERIDOPHYTIC SPORES
- *Azolla* megaspore
- *Cyathidites australis* Couper 1953
- *Crassoretitriletes vanraadshooveni* Germeraad, Hopping & Muller 1968
- *Dictyophyllidites* sp.
- *Lycopodiumsporites* spp.
- *Lygodiumsporites* spp.
- *Polypodiaceaesporites* spp.
- *Polypodiisporites ornatus* Sah 1967
- *Schizaeoisporites* sp.
- *Striatriletes multicostatus* Kar & Saxena 1981
- *Striatriletes paucicostatus* Kar 1985
- *Striatriletes susannae* (Van der Hammen) Kar 1979

d) GYMNOSPERMOUS POLLEN
- *Cycadopites* spp.
- *Pinuspollenites* spp.

e) ANGIOSPERMIC POLLEN
- *Aglaoreidia* sp.
- *Compositoipollenites* sp.
- *Liliacidites* sp.

→

PLATE 1

(All photomicrographs magnified Ca × 500)

1. *Lycopodiumsporites* sp., Slide no. BSIP 10173, coordinates: 31 × 101.
2. *Lycopodiumsporites* sp., Slide no. BSIP 10172, coordinates: 57.5 × 101
3. *Polypodiisporites ornatus* Sah 1967, Slide no. BSIP 10164, coordinates: 52 × 102.5.
4. *Botryococcus braunii* Kützing, 1849; Slide no. BSIP 10176, coordinates: 44.5 × 107
5. *Striatriletes paucicostatus* Kar 1985, Slide no. BSIP 10167, coordinates: 61 × 93.5.
6. *Lycopodiumsporites globatus* Kar 1985, Slide no. BSIP 10175, coordinates: 45.5 × 96.5.
7. *Cycadopites* sp., Slide no. BSIP 10178, coordinates 49.5 × 103.5.
8. *Dictyophyllidites* sp., Slide no. BSIP 10174, coordinates: 57 × 110.

9,20,21 Zygospores of *Zygnema*, Slide no. BSIP 10177, coordinates: 59 × 100.5; Slide no. BSIP 10173, coordinates: 53 × 79.9; Slide no. BSIP 10171, coordinates: 53 × 96.

10,11,16. *Malvacearumpollis* sp., Slide no. BSIP 10165, coordinates: 42 × 98; Slide no. BSIP 10163, coordinates: 57.5 × 100.5; Slide no. BSIP 10166, coordinates: 59 × 112.

12. *Malvacearumpollis grandis* Sah 1967; Slide no. BSIP 10163, coordinates: 45.5 × 99.
13. *Crassoretitriletes vanraadshooveni* Germaraad, Hopping & Muller 1968; Slide no. BSIP 10159, coordinates: 37 × 95.
14. *Phragmothyrites eocaenica* Edwards 1922,; Slide no. BSIP 10174, coordinates: 62.5 × 109.1.
15. *Striatriletes susannae* (Van der Hammen) Kar 1979; Slide no. BSIP 10169, coordinates: 52.5 × 108.
17. *Polyadopollenites myriosporites* Stover & Patridge 1973; Slide no. BSIP 10163, coordinates: 55 × 103.
18. *Striatriletes multicostatus* Kar & Saxena 1981; Slide no. BSIP 10170, coordinates: 45 × 107
19. *Monosulcites* sp., Slide no. BSIP 10168, coordinates: 56.5 × 109.

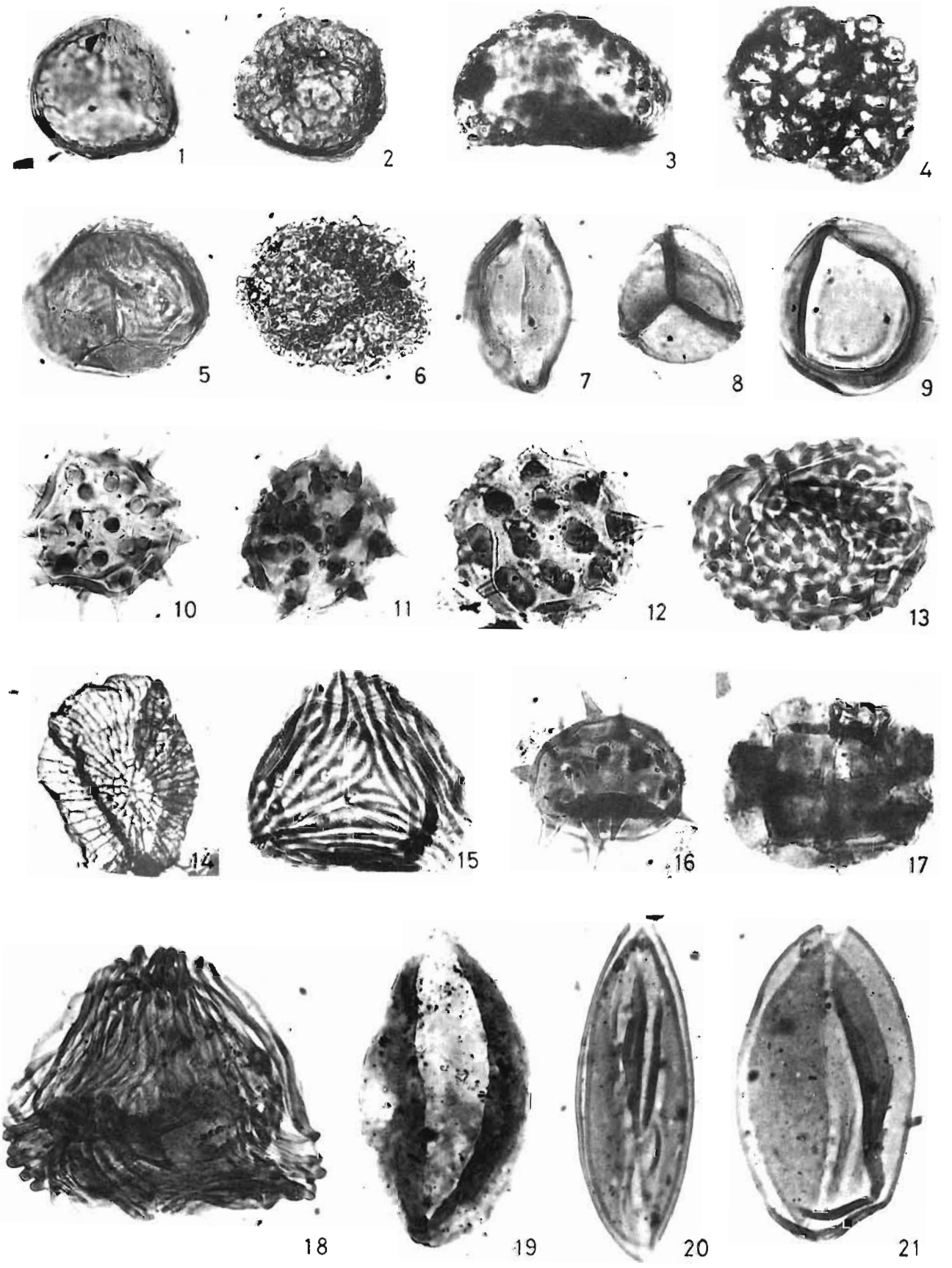

PLATE 1

Malvacearumpollis grandis Sah 1967
Malvacearumpollis sp.
Monoporopollenites kasauliensis Singh & Sarkar 1984
Monosulcites sp.
Nympheacidites sp.
Palmaepollenites sp.
Polyadopollenites myriosporites Stover & Patridge 1973
Tricolpites sp.

Some significant palynofossils have been illustrated in Plate 1

Out of 30 genera a few bryophytic spores have also been recorded. Algal forms are represented throughout the lower part of the Bankas Bed. *Botryococcus, Pediastrum* and *Zygnema* are richly represented. Fungal spores and conidia are poor. Ascostromata of microthyriaceous fungi, viz., *Phragmothyrites* and *Callimothallus*, are common

Pteridophytic spores constitute an important aspect of the assemblage at all levels of the Surai Khola sequence. Ten genera and fifteen species representing seven families, viz., (i) Cyatheaceae, (ii) Schizeaceae, (iii) Parkeriaceae, (iv) Polypodiaceae, (V) Lycopodiaceae, (vi) Matoniaceae, and (vii) Azollaceae, have been recognized, though gymnospermous pollen are qualitatively less, still in some horizons they form a significant group quantitatively Pollen grains of cycadaceous and Pinaceous affinity, viz., *Cycadopites* and *Pinuspollenites* have been recorded respectively.

The angiosperm pollen are represented by nine genera and ten species. The dicotyledonous pollen are assigned to families Compositae, Malvaceae, Cruciferae, Mimosaceae whereas the monocotyledonous pollen grain represent the palmae, Gramineae, Liliaceae, and Typhaceae. A quantitative analysis of the above assemblage reveals the varied representation of pteridophytic spores (35%), gymnospermous pollen (30%), angiospermous pollen (15%), and fungal and algal remains (20%). Among the pteridophytic spores some of the significant forms are *Striatriletes* spp. (33%), *Polypodiaceaesporites* (15%) and *Polypodiisporites* (8%), gymnospermous pollen are represented by *Cycadopites* spp. and *Pinuspollenites* spp. equally. *Malvacearumpollis* spp. (30%) and *Monoporopollenites* spp. (23%) are the most dominant elements among the angiosperm pollen.

STRATIGRAPHIC DISTRIBUTION

From the distributional pattern of the palynofossils it is evident that the older horizon of Surai Khola succession, i.e., the Bankas Bed is dominated by algal elements, whereas the middle part of the sequence, viz., upper part of Paira Khola and Chor Khola beds, are dominated by

Table 1—Distribution of significant palynofossils in Surai Khola Siwalik sequence

Palynofossils (Genera)	Palynofloral assemblage					
	1	2	3	4	5	6
Botryococcus	×	×	0	0	×	
Pediastrum	+	–			–	
Zygnema	×	×			–	
Phragmothyrites	–	–	+	+	0	0
Lygodiumsporites		–	×	–	–	0
Striatriletes		×	×	–	–	
Crassoretitriletes		+	+	0		
Lycopodiumsporites		+	×	–	–	
Polypodiisporites		+	–	+	0	
Dictyophyllidites		+		×		
Cycadopites				×	×	
Malvacearumpollis					+	×
Monoporopollenites						×
Palmaepollenites					+	–
Polyadopollenites				–	–	×
Compositoipollenites					+	–
Liliacidites			–		0	

1. Bankas Bed	×	> 30%
2. Paira khola Bed	+	15-30%
3. Chor Khola Bed	–	5-15%
4. Surai Khola Bed	0	< 5%
5. Dobata Bed		
6. Dhan Khola Bed		

pteridophytic spores and gymnospermous pollen; the upper part of the sequence is dominated by angiospermic pollen. The emergence of algal elements in the Dobata Bed is a striking feature of the assemblage. Distribution of important palynofossils in the Surai Khola sequence is given in Table 1.

PALAEOECOLOGICAL INTERPRETATION

Analysis of the palynofloral assemblage provides valuable information regarding the palaeoecological conditions that might have prevailed during the time of deposition of the Siwalik sediments in the Surai Khola area. The lower part of the Surai Khola sequence (Bankas to Chor Khola beds) indicates the presence of fresh water swamps: *Pediastrum, Botryococcus, Zygnema, Mougeotia, Azolla* and *Ceratopteris* are present. It is possible that areas nearby were swampy lowlands which were inhabited by ferns. The most important evidence of fresh water swamp conditions comes from the lowermost sediments of the succession, i.e. the Bankas Bed.

The swampy condition seems to have changed from the upper part of the Chor Khola Bed onwards to a bottomland habitat. This is evidenced by the presence of a large number of pteridophytic elements, like *Lygodium, Lycopodium, Schizaea* and *Polypodium* along with *Cycas, Hibiscus, Acacia*, etc. At the same time, the high incidence of pollen grain of the members of Malvaceae and Mimosaceae indicates a change from semi-evergreen vegetational pattern, typical of the lower part of the sequence, to a moist deciduous vegetation in Dobata Bed. The middle part of the Surai Khola Bed is distinctly marked by the first appearance of bisaccate gymnospermous pollen perhaps of pinaceous affinity, a feature which is largely in conformity with the middle part of Siwalik sequence exposed elsewhere in the Indian subcontinent (Banerjee, 1968; Lukose, 1969; Nandi, 1972, 1975; Saxena & Singh, 1980, 1981, 1982a, 1982b; Saxena *et al.*, 1984; Singh & Saxena, 1980, 1981). This information may be useful to understand the time and spread of modern conifers in the Indian subcontinent. The topmost part of the succession exhibits abundance of graminaceous pollen along with bisaccate pollen which indicate the onset of much drier conditions in the later period.

The palynofloral assemblage recorded by Mathur (1984) from the Tharukhola-Chepang-Chinji area of Nepal does not compare well with the present assemblage; however, the higher representation of grass pollen in the younger horizons as reflected in the Surai Khola palynofloral assemblage seems to be a common feature between the two.

The modern equivalents of Surai Khola

Table 2—Botanical affinities of Surai Khola palynofossils and their climatic habitats

Palynofossils	Modern comparable taxa	Preferable habitat	Climate
Botryococcus braunii	*Botryococcus braunii*	Aquatic (Freshwater)	Cosmopolitan
Pediastrum	*Pediastrum*	Aquatic ,,	Cosmopolitan
Zygnema	*Zygnema*	Aquatic ,,	Cosmopolitan
Mougeotia	*Mougeotia*	Aquatic ,,	Cosmopolitan
Phragmothyrites	Microthyriaceae	Warm, humid	Tropical-Subtropical
Notothyrites	Microthyriaceae	,, ,,	Tropical-Subtropical
Callimothallus	Microthyriaceae	,, ,,	Tropical-Subtropical
Cyathidites	Cyatheaceae	Humid shady places	Tropical-Subtropical
Lygodiumsporites	*Lygodium*	Leaf climber	Tropical-Subtropical
Striatriletes	*Ceratopteris*	Aquatic (Marshy places)	Tropical-Subtropical
Crassoretitriletes	Schizaeaceae	Moist and shady places	Tropical-Subtropical
Lycopodiumsporites	*Lycopodium*	Moist and shady places	Cosmopolitan
Polypodiaceaesporites	Polypodiaceae	Moist and shady places	Tropical-Subtropical
Schizaeoisporites	*Schizaea*	Moist and shady places	Tropical-Subtropical
Dictyophyllidites	Matoniaceae	Warm, humid	Tropical
Azolla megaspore	*Azolla*	Aquatic	Tropical-Subtropical
Cycadopites	Cycadaceae	Prefers dry places	Tropical-Subtropical
Pinuspollenites	Pinaceae	Prefers dry places	Cosmopolitan.
Malvacearumpollis	*Hibiscus*		Tropical-Subtropical
Monoporopollenites	Gramineae	Prefers dry places	Cosmopolitan
Nympheacidites	*Nymphaea*	Aquatic	Cosmopolitan
Liliacidites	Liliaceae		Cosmopolitan
Palmaepollenites	Palms		Tropical-Subtropical
Polyadopollenites	*Acacia*	Dry plains	Tropical-Subtropical
Aglaoreidia	Typhaceae	Ponds & still water	Cosmopolitan
Compositoipollenites	Compositae		Cosmopolitan

palynofossils denoting their habitats and climates are given in Table 2.

From the above Table it is clear that out of 26 taxa 13 prefer tropical to subtropical climate, the remaining 13 are of cosmopolitan nature. Therefore, it can be inferred that the overall palynofloral contents of the assemblage indicate the prevalence of tropical to subtropical climate during the deposition of Surai Khola sediments.

Data presented in this paper is considered very significant as it throws light on the history of the vegetation through Mio-Pleistocene time and its palaeoecology. Extended investigations are likely to generate a dependable data-base for the reconstruction of the vegetational changes.

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