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Siwalik Flora from Koilabas Area in the Nepal Himalaya and its Significance on Palaeoenvironment and Phytogeography

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ABSTRACT

The plant fossil assemblages recovered from the Siwalik sediments of Koilabas area (Darwaja and Chorkholi) in the Western part of Nepal are described. An attempt has been made to deduce the palaeoclimate and phytogeography of the area during sedimentation. Based on available data. Low land mixed mesophytic forest communities of broad leaved semievergreen to evergreen trees appeared to be flourishing around Koilabas area during Siwalik period. Analysis of the present distribution of the modern equivalents of the fossils shows that about 80 percent of taxa have disappeared from the area and have got migrated to other suitable regions like northeast India, Bangladesh, Myanmar and Malaya where they have found favourable condition for their longer survival. It indicates a positive change in the climate after Mio-Pliocene times. The study of physiognomic characters of the fossil leaves in relation to climate has been done and based on these characters as well as habit and habitat of comparable taxa, a tropical (warm humid) climate with plenty of rainfall has been deduced.

INTRODUCTION

The uplift and erosion of the Himalaya highlands during the Neogene have resulted in an extension apron of terrestrial sediments deposited at the margin of the mountain front in India, Pakistan and Nepal. These sediments are called the Siwalik Group. Throughout Nepal the Siwalik Group of the sub-Himalaya can be divided into three lithostratigraphic units, the Lower Siwalik, the Middle Siwalik and the Upper Siwalik (Hagen 1959, Kumar and Gupta 1981, West 1984, West and Munthe 1981, Herail et al. 1986, Delcaillau et al. 1987, Chaudhuri 1983, Tokuoka et al. 1986, 1988, and Corvinus 1990). It attains a maximum thickness of about 6,000 m at places. The sediments belonging to this group are exposed continuously as a long the southern hills of Nepal except for a small gap in the central Nepal. The width of outcrop is variable with an average of 20-30 Km. The age ranges from Middle-Miocene to Lower Pleistocene.

The fossil locality of Koilabas (27°42' : 82°20') is situated south of Lamahi in Dang Valley, western Nepal (Fig. 1). This is one of the richest fossiliferous localities in the Himalayan foothills of Nepal. In this

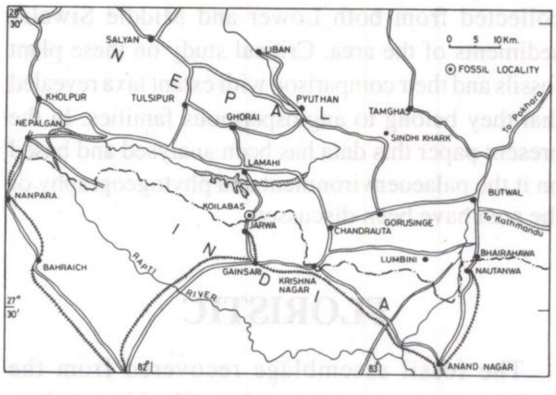

Fig. 1 Map showing the fossil locality (Koilabas)

area the Siwalik sediments are well exposed all along the upstream of Koilabas river and the road cuttings from Koilabas to village Lamahi (Fig. 2). The rocks belonging to Lower Siwalik are exposed in river cuttings from Koilabas to Darwaja (Sharma 1977) and characterized by a alternative sequence of purple clay and pale grey and buff sandstones. Clays are more common in the lower part while in the upper part of the sequence sandstones are dominants. Beyond the Darwaja up to the Chorkholi and onwards the rocks are supposed to belong to Middle

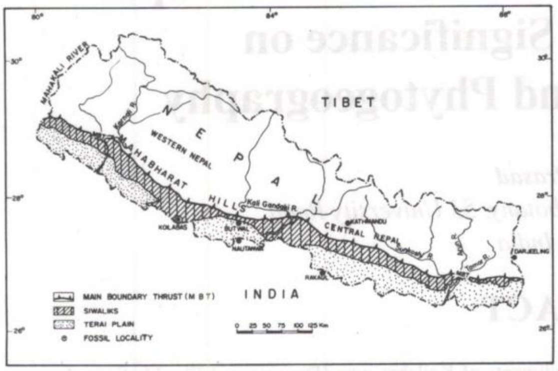

Fig. 2 Map showing the Siwalik rocks around Koilabas area

Siwalik which comprise a monotonous sequence of buff and greyish sandstones punctuated with thin intercalations of clays (Fig. 3).

The plant fossils especially leaf-impressions were collected from both Lower and Middle Siwalik sediments of the area. Critical study on these plant fossils and their comparison with extant taxa revealed that they belong to angiospermous families. In the present paper this data has been analysed and based on it the palaeoenvironment and phytogeography of the area have been discussed.

FLORISTIC

The fossil assemblage recovered from the Koilabas area comprises a variety of leaf-impressions and a legume seed showing close resemblance with extant Entada scandens. All the leaf impressions as well as seed have been compared with the living ones in order to show their botanical affinities. The fossil assemblage includes 55 species and 44 genera and belongs to 24 dicot families (Table 1). Out of these, *Hopea mioglabra, Evodia koilabasensis, Chloroxylon palaeoswietenia, Sabia eopaniculata, Tapiria chorkholiense, Mangifera someshwarica, Cassia miosiamia, Millettia miobramdisia, Entada palaeo secamdens, Terminalia panandhroeresis, Morinda Siwalica, carissa koilabasensis, Anacolosa mioluzoniensis* are recorded from Middle Siwalik (Mid-Pliocene) sediments near Chorkholi while the rest are from Lower Siwalik sediments near Darwaja in Koilabas area. The assemblage is represented by mostly large trees (40 species), shrubs (12 species) and climbers (3 species). The herbs are totally absent. From the floral assemblages (Table 1) provided with comparable extant taxa their distribution and type of forest indicated, it is evident that there are three types of tropical elements: 1) evergreen 2) evergreen and moist deciduous and 3) moist deciduous. The evergreen elements dominate the assemblage which constitute about 47 percent of the total flora. Thus it may be concluded that a tropical evergreen forest was flourishing in the Koilabas area during Mio-Pliocene against the present days mixed deciduous forest.

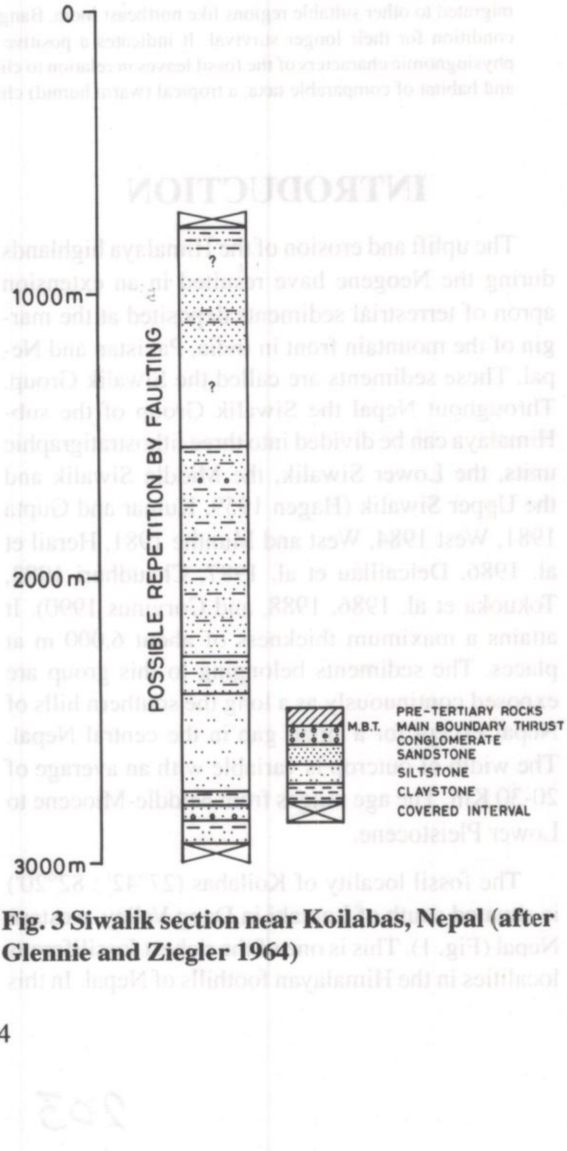

Fig. 3 Siwalik section near Koilabas, Nepal (after Glennie and Ziegler 1964)

Table 1 Present day distribution and fossil types of comparable taxa recovered from the foot hills of Koilabas, Western Nepal

Fossil Taxa	Modern Equivalents	Distribution	Forest Type
Dilleniaceae			
Dillenia palaeoindica Prasad & Prakash, 1984	D. indica Linn.	India, Myanmar	Moist evergreen
Flacourtiaceae			
Ryparosa prekunstelri Prasad, 1990b	R. kunstelri King.	Malaya	Evergreen
Clusiaceae			
Mesua tertiara (Lakhanpal) Prasad, 1990b	M. ferrea Linn.	Northeast India, Myanmar Malaya	Evergreen
Kayea kalagarheansis Prasad, 1994	K. floribunda Wall	Northeast India, Myanmar	Evergreen
Dipterocarpaceae			
Dipterocarpus siwalicus (Lakhanpal and Guleria) Prasad, 1990a	D. tuberculatus Roxb.	Northeast India, Myanmar, Southeast Asia	Evergreen to moist deciduous
Hopea mioglabra Prasad, 1994	H. glabra W. and A.	South India	Evergeeen
Rutaceae			
Evodia koilabasensis Prasad, 1994	E. fraxinifolia Hook. f.	Northeast India, Malaya, Nepal	Evergeeen to Moist deciduous
Murraya khariensis (Lakhanpal and Guleria) Prasad, 1994	N. paniculata (Linn.) Jacq.	Sub himalayan region Myanmar Andman, Sri Lanka, Australia	Moist deciduous to evergreen
Atlantia miocenica Prasad, 1994	A. monophylla Corr.	South and North India Myanmar, Andman	Evergreen
Meliaceae			
Chloroxylono palaeosnietenia Prasad, 1990bRhamnaceae	C. swietenia DC.	India, Sri Lanka	Moist deciduous
Zizyphus miocenica Prasad, 1994c	Z. jujuba Lam.	India, Myanmar	Deciduous
Sapindaceae			
Filiciue koilabasensis			
F. decipience Thw. Prasad, 1994c	South India, Sri Lanka,	Evergreen Tropical Africa	
Euphorea nepalensis Prasad, 1994c	E. longana Lamk.	South and North India, Myanmar, Malaya	Evergreen to moist deciduous
Otophora miocenica Prasad, 1994c	O. fruticosa Blume	Malaya	Evergreen
Sabiaceae			
Sabia eopaniculata Prasad, 1994c	S. paniculata Seem.	Sub-Himalayan region, Myanmar, Malaya	Evergreen to moist deciduous

Table 1 Coontd...

Anacardiaceae			
Bouea koilabasensis Prasad, 1994c	B. burmanica Griff.	South India, Andman, Myanmar	Evergreen
Tapiria chorkholiense Prasad, 1994c	T. hirsuta Hook. f.	Northeast India, Nepal, Bhutan	Moist deciduous
Nangifera someshwarica (lakhanpal and Awasthi) Prasad, 1994	N. indica Linn.	India, Malaya	Evergreen to deciduous
Fabaceae			
Albizia siwalica Prasad, 1990a	A. lebbek Gamble	Northeast India, Myanmar	Moist deciduous
Cassia nepalensis Prasad, 1990b	C. hirsuta Linn.	Central India	Deciduous
C. miosiamea Prasad, 1994c	C. siamea Lam.	India, Myanmar, Malaya	Moist deciduous
C. neosophora Prasad, 1994c	C. sophora Wall	Southeast Asia	Moist deciduous
Dalbergia miosericea Prasad, 1990b	D. sericea Boj.	Sub-Himalayan region, Madagascar	Deciduous
D. siwalika Prasad, 1994c	D. sissoo Roxb.	Sub-Himalayan region,	Deciduous
Millettia siwalica Prasad, 1990b	M. ovalifolia Kurz.	Sub-Himalayan region, Myanmar	Moist deciduous
			M. koilabasensis Prasad,
1990a M.macrostachya Coll.and Hemsl.	Myanmar	Evergreen	
M. miobrandisiana Prasad, 1994c	M. brandisiana Kurz.	Myanmar	Moist deciduous
Ormosia robustoides Prasad, 1990a	O. robustoides Jacq.	Northeast India, Myanmar	Evergreen
Samanea siwalika Prasad, 1994c	S. saman Merr.	Tropical Africa, America	Evergreen
Entada palaeoscandens (Awasthi and Prasad) Prasad, 1994c	E. scandens Benth.		
Combretaceae			
Anogeissus eosericea Prasad and Prakash, 1984	A. sericea Brandis	Central India	Deciduous
Clycopteris floribundaoides Prasad, 1990b	C. floribunda Lam.	Northeast India, Myanmar, Western Peninsula	Deciduous
Terminalia koilabasensis Prasad, 1990b	T. angustifolia Jacq.	Malaya	Evergreen
T. siwalica Prasad, 1990b	T. pyrifolia Kurz.	Myanmar	Evergreen to moist deciduous
T. panandhroensis (Lakhanpal and Guleria) Prasad, 1994c	T. tomentosa W.A.	Sub-Himalayan region, Myanmar	Moist deciduous
Combretum sahnii (Antal and Awasthi) Prasad, 1994c	C. decandrum Roxb.	Sub-Himalayan region, Bangladesh, Central India	Deciduous
Lythraceae			
Lagerstroemia siwalica Prasad, 1994c	L. lanceolata Wall.	Western Peninsula	Moist deciduous
Woodfordia neofruticosa Prasad, 1994c	W. fruticosa Kurz.	Sub-Himalayan region, Tropical Africa, Arabia, Both Peninsula	Moist deciduous

Table 1 Coontd...

Myrtaceae			
Syzygium miocenica Prasad and Prakash, 1984	S. claviflorum roxb.	Northeast India, Andman, Myanmar	Evergreen to moist deciduousCaprifoliaceae
Lonicera mioquinquelocularis Prasad, 1990b	L. quinquelcularis Hardw.	Northwest Himalaya, Nepal, India	Deciduous
Rubiaceae			
Randia miowallichii Prasad, 1990b	R. wallichii Hook. f.	Northeast India, Myanmar, Andman	Evergreen
Mirinda siwalica Prasad, 1994c	M. umbellata Linn.	South and Northeast India, Sri Lanka, Malaya	Evergreen
Ebenaceae			
Diospyros koilabasensis Prasad, 1990b	D. montana Roxb.	India, Myanmar, Sub-Himalayan region	Deciduous
D. pretoposia Prasad, 1990b	D. toposia Ham.	Northeast India, Bangladesh, Sri Lanka	Evergreen
Apocynaceae			
Tabernaemontana precoronaria Prasad, 1990b	T. coronaria Willd.	Sub-Himalayan region, Sri Lanka, Myanmar	Deciduous
Carissa koilabasensis Prasad, 1994c	C. paucinervia A.Dc.	Northeast India, Myanmar	Evergreen
Loganiaceae			
Gaertnera siwalica Prasad, 1990b	G. bieleri (D.Willd.) E.Petit	Tropical Africa	Evergreen
Solanaceae			
Datura miocenica Prasad, 1990b	D. fastuosa Linn.	India, Malaya, Tropical Africa	Deciduous
Oleaceae			
Anacolosa mioluzoniensis Prasad, 1994cVerbinaceae	A. luzoniensis Merr.	Southeast Asia	Evergreen
Vitex prenegundo Prasad, 1990b	V. negundo Linn.	India, Sri Lanka, China	Deciduous
V. siwalica Prasad, 1990b	V. pubescens Vahl.	India, Myanmar	Evergreen
Lauraceae			
Cinnamomum mioinuctum Prasad, 1990b	C. inuctum Meissn.	Myanmar, Malaya	Evergreen to moist deciduous
Moraceae			
Ficus precunia (Lakhanpal) Prasad, 1990b	F. cunia Ham.	Sub-Himalayan region, Assam, Myanmar	Deciduous
F. retusoides Prasad, 1990b	F. retusa Linn.	India, Malaya	Evergreen
F. nepalensis Prasad, 1990b	F. glabrrima Blume	India, Malaya	Evergreen

PALAEOENVIRONMENT

The Siwalik plant fossils are supposed to be good indicators for understanding past environmental conditions as they have been compared with extant taxa. However, the degree of accuracy totally depends upon proper identification of the fossils. As the fossil assemblage comprises mainly leaf-impressions, the physiognomic characters of the fossils also play an important role in inferring the palaeoenvironment of the area. Thus the inferences regarding palaeoenvironment can been drawn by two methods (i) Nearest living relative method and (ii) Foliar physiognomic method.

NEAREST LIVING RELATIVE METHOD

As all the plant fossils recovered from Koilabas area have been identified with modern taxa up to the species level, it would be easy to infer the palaeoclimate of the region. The present day distribution of the recorded taxa (Table 1) shows that they occur mostly in the tropical evergreen and moist deciduous forests of north east India, Bangladesh, Myanmar and Malaysia. Thus it may be concluded that a warm and humid climate prevailed around Koilabas at the time of Siwalik sedimentation in contrast to the present relatively dry climate. From Table 1 it is also evident that the most of the taxa in the floral assemblage are not found in Koilabas area or any where in the Himalayan foothills of Nepal and became extinct due to unfavourable climatic conditions in the area. This change in climate most probably has taken place as the result of rising Himalaya. During these times, the large area previously occupied by Tethys got converted into land with numerous small water basins. Thus the physiography of the area became changed and brought about a progressive change in the climate which affect the entire vegetation in the foothills of the Himalaya. At that time the Indian Plate had already joined with Eurasia and a land connection between Nepal-India and neighbouring continents was formed. Through the land connections several tropical evergreen and semievergreen elements might have come into Indian subcontinent, from southeast Asia probably via Myanmar and then spread all over and ultimately reached the Himalayan foothills. Further change in the physiography of the area took place in the last phase of Himalayan uplift during Early Pleistocene due to which the climatic conditions progressively changed from warm humid to drier and cooler, adversely affecting the vegetation of the Himalayan foot hills. The evergreen elements which had flourished became disappeared from the foothills of this region . Some of them like *Dipterocarpus, Kayea, Hopea, Albizia, Ormosia*, etc. have restricted distribution in the evergreen forest of Assam and Arunachal Pradesh (eastern Himalayan foot hills) where they receive favourable conditions for their proper growth (Gamble 1972, Brandis 1971, Desh 1957, Kanjilal 1928).

FOLIAR PHYSIOGNOMIC METHOD

This is a very useful tool for estimating palaeoclimate in being independent of systematic relationship of the modern taxa. As the plant fossils studied here are mostly leaf impressions, they certainly throw some light on the palaeoenvironment of the area. The important physiognomic features of the leaf impressions having relationship with the climate are leaf margin (Bailey and Sinnot 1916), major venation pattern (Bailey and Sinnot 1916), venation density (Wolf 1969), leaf texture (Wolf 1969) and leaf base shape (Howard 1969).

Leaf margin type (entire versus non entire) is an important physiognomic feature which has direct relation with temperature. It is widely accepted that the woody plants of tropical low lands bear entire margins while in temperate regions they bear nonentire margins (Bailey and Sinnot 1916). It has also been concluded that the percentage of entire margined taxa in tropical rain forest is highest which decreases with decreasing temperature (Wolfe 1969). The floral assemblage obtained from Koilabas area comprises the taxa having entire margin (Fig. 4-6). *Dillenia palaeoindica* (Fig. 4E) and *Datura miocenica* are the only nonentire margined species in the assemblage (Table 2). Thus it may be concluded that the vegetation around Koilabas area was flourishing under tropical climate (warm humid) during Mio-Pliocene times.

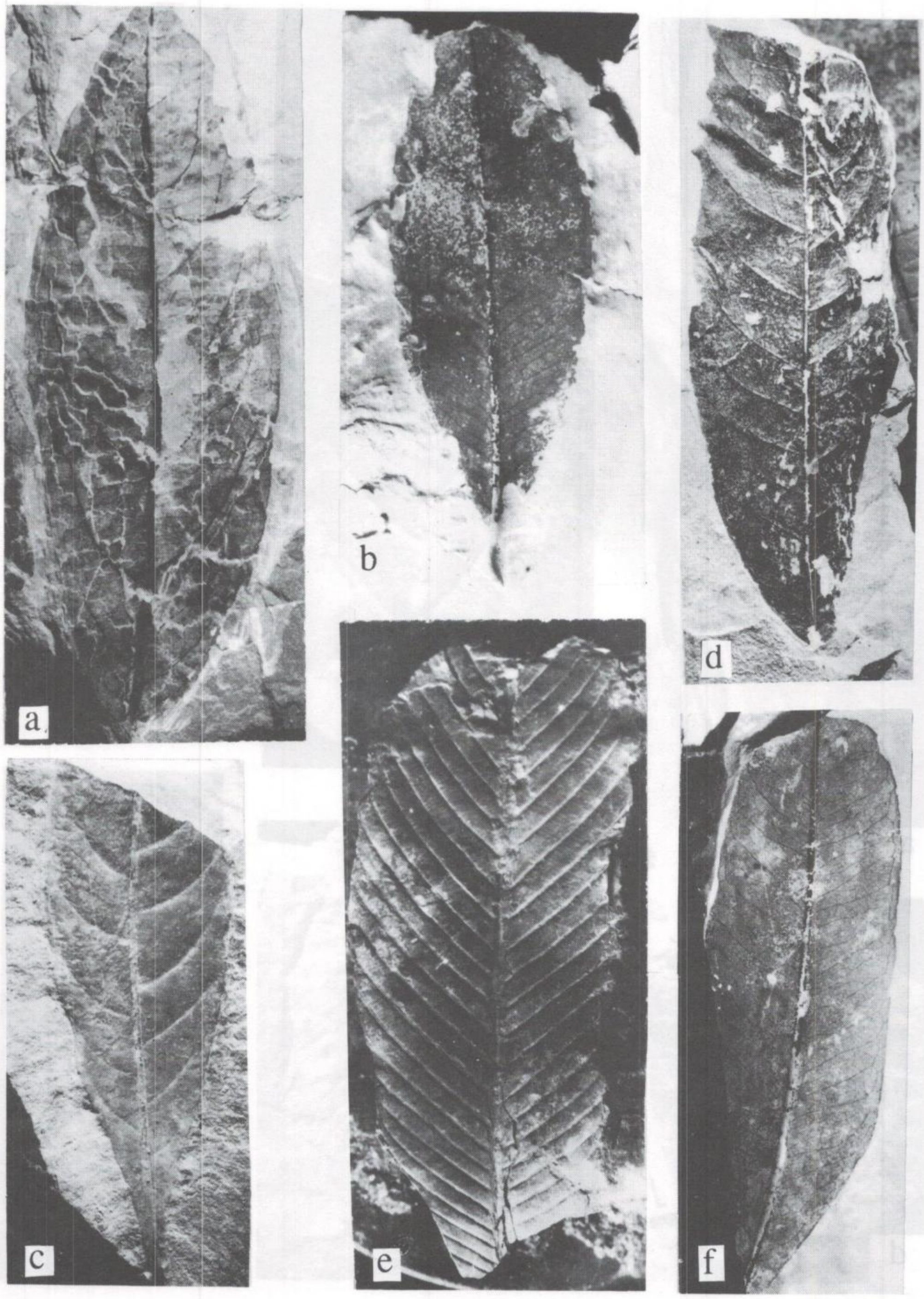

Fig. 4 a) Fossil leaf of *Hopea glabra;* b) Fossil leaf of *Syzygium claviflorum;* c) Fossil leaf of *Randia waallichii* ; d) Fossil leaf of *Mangifera indica;* e) Fossil leaf of *Dillenia indica;* f) Fossil leaf of *Filicium decipiense* (Scale: natural size).

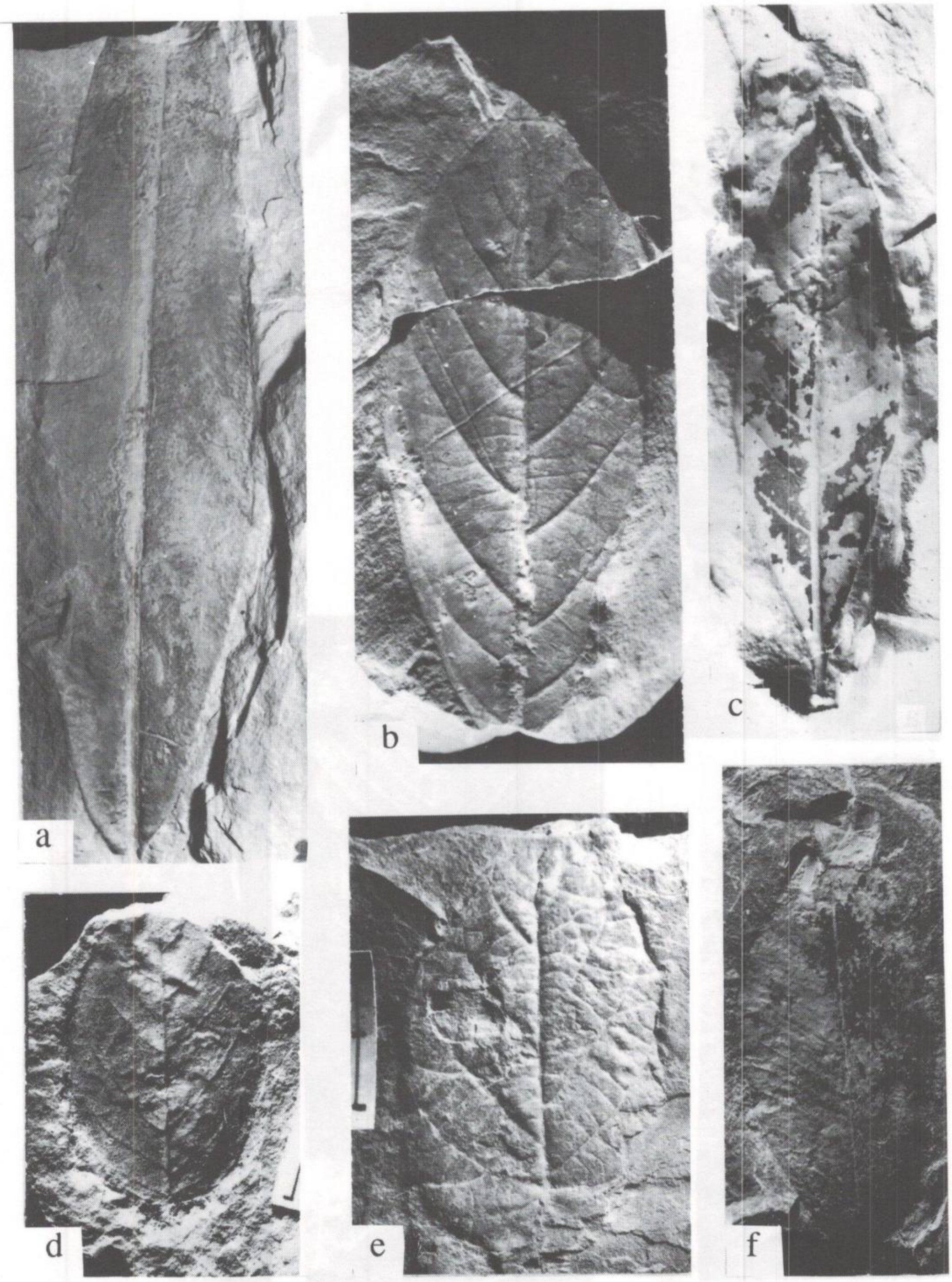

Fig. 5 a) Fossil leaf of *Kayea floribunda;* b) Fossil leaf of *Millittia macrostachya;* c) Fossil leaf of *Tabernaemontana coronaria*; d) Fossil leaf of *Angogeissus sericea;* e) Fossil leaf of *Ficus cunia;* f) Fossil leaf of *Ficus retusa* (Scale: natural size).

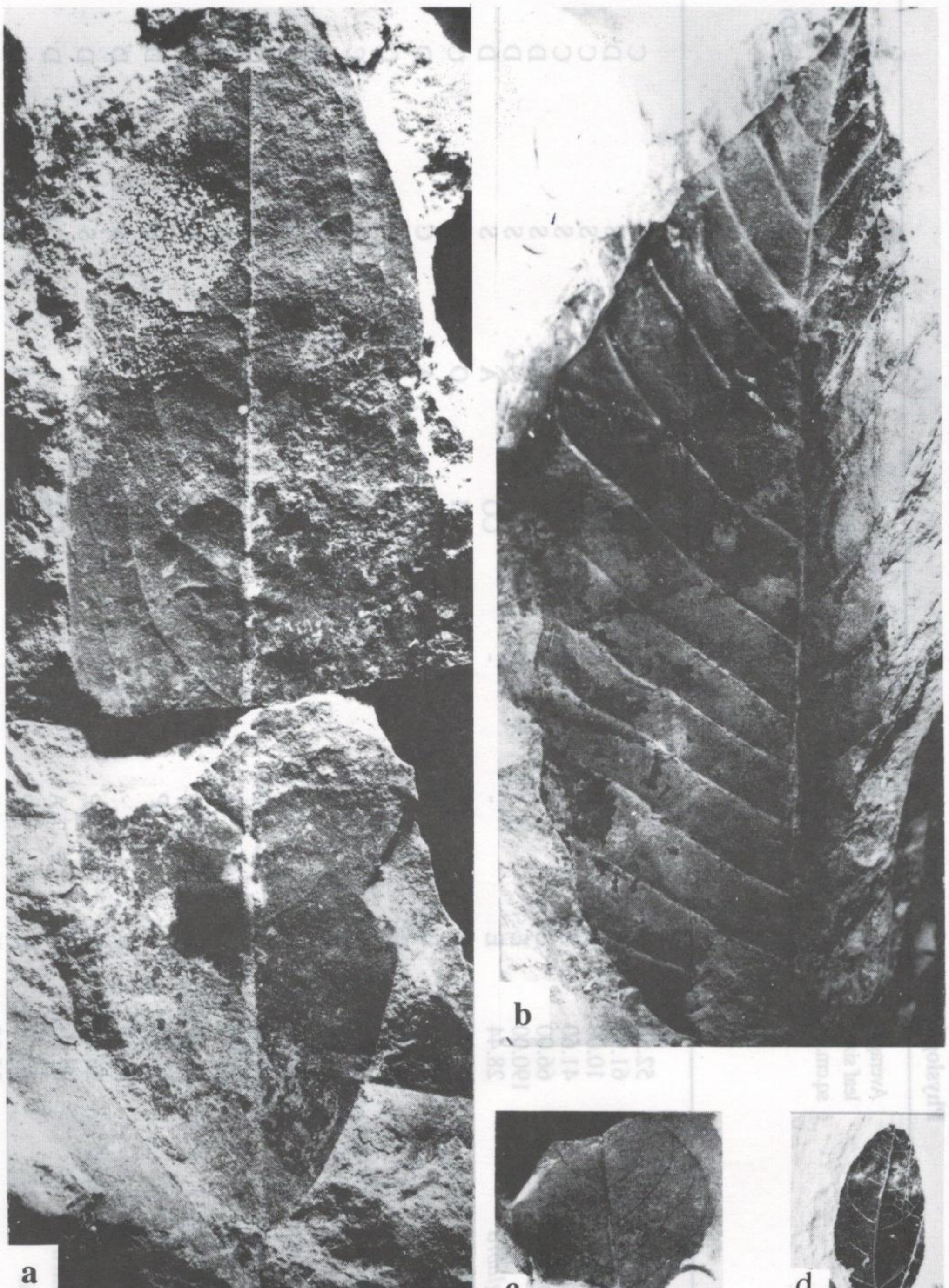

Fig. 6 a) Fossil leaf of *Diospyros toposia;* b) Fossil leaf of *Dipterocarpus tuberculatus;* c) Fossil leaf of *Millettia ovalifolia;* d) Fossil leaf of M. *Brandisiana* (Scale: natural size).

Table 2 Physiognomic characters of the fossil flora recovered from Koilabas area, Western Nepal

	Physiognomic characters							
	Average leaf size sq.cm.	Leaf margin entire (E) nonentire(N) indistinct(-)	Drip tips presence (P) absence (A) indistinct (-)	Nature of petiole swollen (S) normal (N)	Leaf texture chartaceous (CH) coriaceous(CO)	Leaf base shape acute (A) obtuse (O) cuneate(C) cordate(CR) attenuate (AT) indistinct(-)	Leaf organization simple (S) compound (C)	Venation pattern close (C) distant (D)
Dillenia palaeoindica	52.50	N	-	-	CH	-	S	C
Ryparosa prekunstelri	61.92	E	-	N	CO	A	S	D
Mesua tertiara	10.00	E	P	N	CH	A	S	C
Kayea kalagarhensis	41.60	E	-	N	CO	A	S	C
Dipterocarpus siwalicus	66.00	E	P	N	CH	D,CR	S	D
	190.00	E	-	N	CH	O	S	D
Hopea mioglabra	28.44	E	-	-	CO	A	S	D
Evodia koilabasensis	20.90	E	-	-	CH	O	C	C
Murraya khariense	07.30	E	A	-	CO	A	C	D
Atlantia miocenica	05.22	E	-	-	CH	A	C	C
Chloroxylon palaeoswietenia	05.60	E	-	-	CH	A	C	C
Zizyphus miocenica	05.60	E	-	-	CH	O	S	D
Filicium koilabasensis	26.25	E	P	N	CH	A	S	C
Euphorea nepalensis	27.00	E	P	-	CO	A	S	C
Otophora miocenica	14.25	E	A	S	CO	-	S	D
Sabia eopaniculata	21.98	E	P	-	CH	-	S	C
Bouea koilabasensis	12.00	E	P	N	CO	A	S	D
Tapiria chorkholiense	11.25	E	-	-	CO	O	S	D
Mangifera someshwarica	26.40	E	P	N	CH	A	S	D
Albizia siwalica	07.50	E	A	N	CO	A	C	D
C. nepalensis	10.08	E	P	-	CH	O	C	D
C. miosiamea	05.25	E	A	N	CH	O	C	C

Table 2 Coontd...

C. neosophora	03.80	E	A	N	CH	O	C	C
Dalbergia miosericea	14.40	E	A	N	CH	A	C	D
D. siwalika	07.20	E	-	-	CH	O	C	C
Millettia siwalica	06.20	E	A	N	CH	D,A	C	D
M. koilabasensis	28.40	E	P	-	CH	A	C	D
M. miobramdisiana	02.53	E	-	-	CH	O	C	D
Ormosia robustoides	35.00	E	P	-	CH	O	C	C
Samanea siwalica	02.00	E	-	-	CH	O	C	D
Anogeissus eosericea	10.75	E	-	N	CH	O	S	D
Calycopteris floribundoides	12.48	E	P	-	CO	O	S	D
Terminalia koilabasensis	11.20	E	P	-	CH	A	S	D
T. siwalica	35.60	E	P	N	CO	O	S	D
Combretum sahnii	15.75	E	P	-	CH	-	S	D
Lagerstroemia siwatika	42.00	E	-	-	CH	-	S	D
Woodfordia neofruticosa	03.00	E	-	-	CO	CR	C	D
Syzygium miocenicum	24.44	E	-	N	CH	C	S	C
Lonicera mioquinquelocularis	08.75	E	-	-	CH	O	C	D
Randia miowallichii	13.80	E	-	N	CH	C	S	D
Morinda siwalika	07.56	E	P	-	CH	-	S	C
Diospyros koilabasensis	09.00	E	-	-	CH	CR	S	D
D. pretoposia	108.00	E	-	N	CO	O	S	D
Tabernaemontana precoronaria	13.86	E	P	N	CH	C	S	D
Carissa koilabasensis	05.60	E	A	-	CH	A	S	D
Gaertnera siwalica	*12.00*	*E*	-	-	*CH*	*A*	*S*	D
Datura miocenica	59.20	N	P	N	CH	A	S	C
Anacolosa mioluzoniensis	23.12	E	A	N	CO	A	S	D
Vitex prenegundo	20.90	E	P	N	CH	A	S	C
V. siwalica	31.50	E	-	-	CH	-	S	C
Cinnamomum mioinuctum	06.48	E	A	N	CH	C	S	D
Ficus precunia	20.25	E	-	-	CO	CR	S	D
F. retusoides	31.32	E	P	N	CH	A	S	C
F. nepalensis	28.00	E	-	-	CO	O	S	D

According to Raunkiaer (1934) the leaf size distribution in any forest has a correlation with the available moisture/precipitation. He also suggests that the percentage of species with large leaves should be highest in the piedmont. Similarly, Givnish (1976) opined that the species with optimum sized leaves should be greatest in the tropics, decreases in the sub-tropics and increases in the warm temperate forests. While applying this criterion to the present floral assemblage, it has been seen that most of the species possess optimal sized leaves (mesophyll and microphyll). The leptophyll and nanophyll which are the classes of smaller size are totally absent. The macrophyll, a class of large leaves is represented by only two species *Diospyrus petoposia* and *Dipterocarpus siwalicus* (Fig. 6A, 6B, Table 2). Thus the present fossil assemblage indicates the prevalence of tropical humid climate in the foot hills of western Nepal during Siwalik Period.

'Drip tip' is also an significant indicator of past climate which develops on the leaves of many plants in excessive wet condition. It has been generally seen that the species of tropical and subtropical rain forests possess conspicuous drip tips (Dorf 1969, Richards 1952). Obviously, in the present fossil assemblage about 19 species possess drip tips showing evidence of tropical humid climate. Only 10 species do not possess drip tips, however, in other species the tips are either broken or not preserved.

The other physiognomic features which have been cited as being dependent upon climate such as leaf organization, major venation pattern, venation density, leaf texture and leaf base shape are not so significant as leaft margin type, leaf size and drip tips. Sometimes these features are difficult to analyze in the fossil materials.

According to Dolph and Dilcher (1979) the percentage of taxa bearing simple leaves increases from piedmont to both mountains and coastal regions wherever the precipitation is higher. Thus the Koilabas assemblage is also indicative of the presence of somewhat higher precipitation as it possesses simple leaves in a good quantity (Table 2).

PHYTOGEOGRAPHY

One of the important aspects of studying the Siwalik flora of the Himalayan foot hills is to know the past distribution and the migration of vegetation since the Tertiary Period. The different composition of the recent flora as compared to the older vegetation type is the result of a number of factors such as climatic changes, geological events, evolutionary process and varying ecological factors which led to alter the area of distribution of individual taxa.

The Himalayan uplift and the land connection of Indian Plate with other continents are the two main geological events playing important role in the change of vegetation all along the Himalayan foothills. The Indian plate joined Eurasia towards the close of Oligocene establishing land connection with the Asian mainland, Africa and Southeast Asia. This enabled the entry of foreign elements in India and vice versa. *Dipterocarps* and associates which migrated from Malaysia rapidly spread along with Palaeogene elements all over the Indian subcontinent. This brought out significant changes in the floral composition. The total absence of *Dipterocarps* and legumes in the Palaeogene sediments of India and later on their abundant occurrence during Miocene Period all along the Himalayan foothills as well as in other parts of India (Prasad 1994a 1993a, b , Prakash and Tripathi 1992) undoubtedly indicates the change in floral composition due to land connections which may have led to the migration of the plants.

From the floral assemblage recovered from Koilabas area it is evident that about 15 comparable taxa are found to grow both in India and Malaysia regions. They are *Dillenia indica, Meeua Terrea, Dipterocarpus tuberculatus, Evodea fraxinifolia, Euphoria longan, Sabia paniculata, Bouea burmanica, Mangifera indica, Albisia leobek, Caesia siamia, Dalbergia sericea, Morinda umbellata, Cinnamomum innuctum, Ficus retusa, and F. glaserrime* indicating that there was a floral exchange between the two subcontinents.

Moreover, the taxa like *Ryparesa, Kunstalri and Otophora fruticosa* are growing restrictly in Malayan region which suggests that the migration of some plants from Malaysia to Indian subcontinent took place during Miocene (Prasad and Prakash 1987). The occurrence of African elements such as *Uncobia spinosa, Trichilia glabra, Parinari excelsa and Samanea saman* (Prasad 1994b) in the Siwalik sediment of Kathgodam have also migrated from tropical Africa to Indian subcontinent during Miocene.

A significant change in vegetation of western and central Himalayan foothills has taken place after Mio-Pliocene time most probably due to the further rise of the Himalaya. The evergreen taxa which were growing there have therefore been progressively replaced by some other present day moist to dry deciduous taxa. Most of the evergreen taxa of this region shifted toward east (North east India, Myanmar, Bangladesh) and flourished there because of the favourable climatic conditions while others became extinct. Only few of them like *Murraya paniculata, Zizyphus jujuba, Mangifera indica, Dalbergia sissoo, Terminalia tomentosa, Cambretum decandrum, Woodfordia fruticosa, Dispyros montana, Datura fastuosa, Vitex negundo, and Ficus cunia* are found to grow yet there at different altitudes. It suggests that these taxa have susceptibility to adopt the new climatic conditions.

The fossil records of some Australian elements such as *Acronychia baueri and Acacia sericea* from Siwalik sediments of Kathgodam, north India (Prasad 1994b), *Eucalyptus* from both Hardwar and Kalagarh Siwaliks, U.P., India and Koilabas, western Nepal (Prasad 1987 1994a), further suggests the migration of some foreign elements into the Indian subcontinent (Himalayan foothills). These taxa came from Australia to India when the Indian Plate was joined with the Australian Plate through Antarctica about 100 million years back (Bande et al. 1986, Smith and Briden 1979).

MEGAFLORAL COMPARISON

On comparison of the present Koilabas assemblage with other fossil assemblages known from the Siwalik sediments of the Arjun Khola and Surai Khola, western Nepal, it is found that there is no significant difference in their floral composition. Surai Khola is one of the fossiliferous localities in the Himalayan foothills where a complete and uninterrupted sequence of the Siwalik Group is exposed covering a distance of 16 Km from Surai Naka to Rang Sing Khola and divisible into Lower, Middle and Upper Siwalik (Corvinus 1990). In the floral assemblage obtained from the Surai Khola area (Awasthi and Prasad 1990) the genera like *Millettia, Diospyros, Mangifera, Entada. Terminalia., Dipterocarpus, Cinnamomum, Ficus, Cassia, Albizia* are found common to Koilabas assemblage. The Arjun Khola assemblage, which comprises more than 60 taxa is a bigger assemblage so far recorded from the Siwaliks. Of these, *Dillenia, Ryparosa, Dipterocarpus, Albizia, Millettia, Anogiessus, Terminalia, Randia and Cinnamomum* are found common to the present assemblage. It is also interesting to note that the taxa like *Clinogynea grandis, Bauhinia sp., Gluta renghas, Terminalia chebula; Bambusa tulda, Calophyllum polyanthum, Cynometra polyandra* are common in both Arjun Khola and Surai Khola assemblages. However, these are not so far recorded from the Siwalik sediments of Koilabas area.

The overall study on plant megafossils from the Siwalik sediments of both India and Nepal suggests the existence of a tropical forest all along the Himalayan foothills during Mio-Pliocene. Moreover, the plant assemblage recovered from different localities in the foot hills mostly comprises the taxa of Malaysia and South east Asia. Further, the megafossil records indicate that the flora remained unchanged in its overall composition and distribution pattern until the close of Pliocene.

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