Vegetational dynamics of Tertiary Himalaya

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Selected palaeobotanical and palynological records published from the Tertiary Period of Himalaya have been examined and a generalized vegetational frame work has been reconstructed. The diverse Palaeogene floras of Himalaya are marked by moist deciduous and wet semi-evergreen forest types growing mostly under tropical climate in varying type of environments. The tropical families register a decline in the Early Miocene time. The Middle Miocene Himalayan orogeny coincides with proliferation of Abietineae and by the appearance of several subtropical floral elements. Development and diversity of forest types are controlled by the altitudinal belts. The Pliocene floral diversification is related to climatic changes and increased continentality. The wet tropical forests disappeared from the low altitudes, whereas wet subtropical and temperate forests were transformed into dry or moist vegetational types. The appearance of semi-arid and cold conditions forced several moisture loving plants, either to migrate or perish. The modern composition of the Himalayan flora reveals that it is a partial continuum of Neogene floras which have been progressively enriched by the appearance of several immigrant elements and also by the changes brought in due to evolutionary processes.

Key-words—Palynology, Palaeobotany, Tertiary, Himalaya (India).

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साराँश

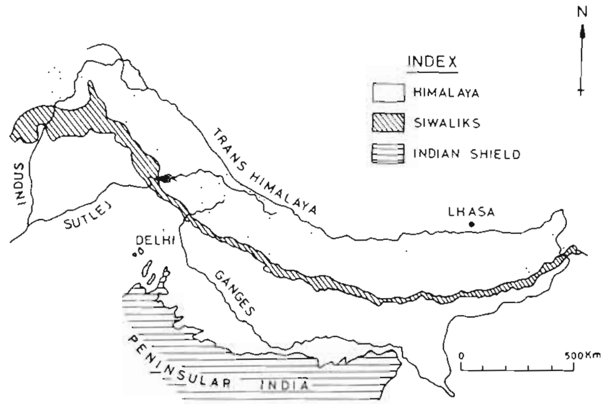
तृतीयक युगीन हिमालय के वनस्पतिक परिवर्तन

हरिपाल सिंह एवं समीर सरकार

हिमालय के तृतीयक कल्प पर प्रकाशित विशेष पुरावनस्पतिक एवं परागाणविक अभिलेखों का अध्ययन किया गया तथा एक व्यापकृत वनस्पतिक स्वरूप की रचना की गई है। हिमालय के पुरानूतन कालीन वनस्पतिजात से नम पर्णपाती एवं आर्द्र अर्ध-सदाहरित वन प्रस्तावित किये गये हैं जो कि अधिकतर विभिन्न प्रकार के वातावरणों में उष्णकटिबन्धीय जलवायु में पाये जाते हैं। प्रारम्भिक मध्यनूतन काल में उष्णकटिबन्धीय कुलों की संख्या में कमी पाई गई है। मध्य-मध्यनूतन काल में हिमालय की उत्पत्ति के समय ही एॅबीटिनी का अत्याधिक विकास एवं अन्य कई उपोष्ण-कटिबन्धीय वनस्पतिजातीय अवयवों का प्रादुर्भाव हुआ। विभिन्न प्रकार के वनों का विकास एवं उनमें विभिन्नतायें उस स्थान की ऊँचाई में परिवर्तन के साथ-साथ विकसित हुई। अतिनूतन वनस्पतिजात में प्रेक्षित विभिन्नता जलवायवी परिवर्तनों एवं महाद्वीपों के बढ़ते आकार से सम्बन्धित है। कम ऊँचाई वाले स्थानों से नम उष्णकटिबन्धीय वन विलुप्त हो गये, जबकि उपोष्णकटिबन्धीय एवं शीतोष्ण वन शुष्क अथवा नमी में रहने वाली वनस्पति में परिवर्तित हो गये। अर्ध-मरुस्थली एवं ठंडी परिस्थितियों के कारण नम स्थानों में पाये जाने वाले कई पौधे या तो वहां से दूसरे उपयुक्त स्थानों पर चले गये अथवा समाप्त हो गये। हिमालयी वनस्पतिजात के वर्तमान स्वरूप से व्यक्त होता है कि यह पश्चनूतन कालीन वनस्पतिजातों की आँशिक अविच्छिन्नता है जो कि कई आवासी अवयवों के प्रादुर्भाव से शनैः शनैः और विकसित होते चले गये।

THE present paper focuses attention on the changes in vegetational pattern through the Tertiary Period in Himalaya and its possible impact on the development of modern flora. Published records of Tertiary palyno and megafossils available from Himalaya have been extensively surveyed and analysed with a view to select dependable taxa for the identification of palaeo-associations and generalized vegetational successions in time and lateral extent. The resultant information has brought out several gaps in our knowledge; however, it has been evaluated and synthesized cautiously to build up vegetational models latitudinally and altitudinally, depicting the role of physical barriers and climatic implications in understanding the developmental processes and evolutionary significance of different forest types.

The Himalayan range runs about 2,400 km and stands as the northern rampart in the Indian subcontinent (Text-figure 1). It is the youngest



Text-figure 1—Extent of Himalayan range in the Indian subcontinent (after West, 1984).

mountain range in the world which was uplifted about 60-70 million years ago. A generalized account deciphering the emergence, radiation and extinction patterns of the Himalayan flora through the Tertiary Period has been discussed. The accrued evidences throw light on some problems related to endemism, regionalism and floral migration in time and lateral extent.

The palaeobotanical data has been tagged with the important geological events in order to have a peep into the glimpses of Tertiary vegetational history of Himalaya. A brief account of the geological history of Himalaya during the Tertiary Period is given below :

GEOLOGICAL HISTORY

Geologically, three major sedimentary zones have been identified in the Himalayan orogenic belts. They are known as (i) the southern most sub-Himalayan zone, (ii) the Lesser Himalayan zone, and (iii) the Tethys Himalayan zone.

The sub-Himalayan zone is mainly represented by Neogene and recent deposits accumulated in a foredeep which is known as the Siwalik Group. Its maximum development has been observed in Jammu and Kashmir and Himachal Pradesh. They progressively thin-out towards the eastern flank of the Himalaya.

The Lesser Himalayan zone consists of two distinct subzones. The first subzone is well represented by unmetamorphosed sediments developed in N-W Himalaya which thins-out progressively towards the east, ranging from Palaeocene to Early Miocene in age. The second subzone is mainly represented by metasediments, the age and stratigraphic position of which is uncertain.

The Tethys Himalayan zone is well exposed in Kumaun, Garhwal, Spiti, Kashmir, Zanskar and Ladakh regions ranging in age from Late Pre Cambrian to Late Cretaceous. The Indus Suture zone exposes the sediments which vary in age from Cretaceous to Mio-Pliocene.

OROGENIC HISTORY

The Himalayan range was uplifted through a series of orogenic pulsations due to the rifting of a large pre-Jurassic Gondwanaland and its subsequent collision with the Eurasiàn Plate. These pulsations continued intermittently till the Pleistocene glaciation started, and uplifted the Himalayan range mostly in Oligocene, Miocene and Pliocene epochs.

The first phase of the Himalayan uplift started during the Late Cretaceous-Early Eocene time due to which the Tethys floor bent at the position of Indus/Tsangpo Suture Zone at Ladakh. This phase of the uplift culminated in the development of a geo anticlinal fold in the basement resulting in the splitting of the Eocene sea into two longitudinal basins. One of these basins developed along the Indus/Tsangpo Zone and the other to the far south which is now known as the lesser and outer Himalaya. The second phase of uplift started towards the end of the Eocene and continued up to the Oligocene. Most of the uplift took place in the Middle Miocene. One of the views is that the third phase of Himalayan orogeny started in the Early Miocene time and continued till to the close of Pleistocene resulting in the rapid sedimentation of Murrees and Siwaliks (Gansser, 1974). The fourth phase started at the end of Pliocene and ended in Pleistocene Epoch and this phase of the uplift caused the development of main boundary thrust which severed the main Himalaya from the newly formed Siwalik mountains. It is believed that the uplift of the Himalaya has been a continuous process even after the Pleistocene time (Sharma, 1984).

The periodic orogeny of the Himalayan range continued to change the climatic, geomorphological and ecological contitions. Thus the rise of Himalaya not only opened several routes for inflow and outflow of floras, particularly from central and west Asia, or even Europe, to east Asia but also dynamically influenced the evolutionary pattern of vegetation in terms of emergence of new taxa and extinction of others. During the course of unstable period of orogeny, the Himalayan range evolved its own characteristic flora which contains tropical, subtropical and temperate constituents, development of which has been controlled by the altitudinal belts. In the beginning, the Himalayan range acted as an important barrier for the temperate climate of the central Asian and European regions which later turned into a favourable ground for the growth of cold-loving plants.

BOTANICAL PROVINCES

Clarke (1898) and Hooker (1906) recognized two botanical regions in Himalaya—the western and the eastern Himalaya, whereas Chaterjee (1939) and Razi (1955) recognised four regions. The additional two regions fall in the central Himalaya and Assam areas. However, we have segregated palaeobotanical data into two botanical regions, the western Himalaya and the eastern Himalaya, the latter includes the flora of the hilly region of Assam and Meghalaya. Altitudinally, the present Himalayan vegetation can be divided into three broad zones: tropical-subtropical (base to 1,200 m), temperate (1,200 to 3,600 m) and alpine at higher altitudes (up to 4,500 m).

The available palaeobotanical and palynological data-base, though scanty, scattered and fragmentary in nature, has been pieced together from the Tertiary Himalaya and a generalised vegetational frame-work (developed in responses to varying altitudinal and palaeogeographic factors) has been reconstructed all along the Himalayan belt. It has been observed that the composition of plant communities has been changing from time to time in the geological past in response to climatic, edaphic, ecological and topographic factors.

The Palaeocene-Eocene landscape of western Himalaya had a low relief which was periodically subjected to elevation in the subsequent periods. Geographic positions of the palynological and palaeobotanical data discussed in the present paper are shown in the Text-figure 2, whereas the data-sources on stratigraphy and flora are given in Table 1. The general pattern of vegetation through the Tertiary Period is discussed below:

TERTIARY VEGETATIONAL PATTERNS IN WESTERN HIMALAYA

Ladakh Himalaya

From the Dras volcanics of Ladakh Himalaya, Palaeocene palynological assemblage (Mathur & Jain, 1980) exhibits the occurrence of a rich coastal type vegetation. Some of the important palynotaxa of the floral composition are : *Nypa, Calamus, Gunnera, Galium, Carya, Carpinus, Fraxinus, Pelliciera, Casuarina*, alongwith the members of the family Ranunculaceae, Fabaceae, Arecaceae, Cycadaceae, etc. A low-salinity assemblage is envisaged by the presence of taxa belonging to the Arecaceae, *Nypa* and *Pelliciera*. Identification of *Rhizophora* pollen does not seem to be authentic. Pollen of *Casuarina, Ephedra* and palms are suggestive of a relatively dry, sandy coastal region. Pollen of Podocarpaceae, *Carpinus, Corylus, Carya* and *Coriara* represent upland vegetation in the assemblage which may be derived from the adjoining higher hills. Floral composition represents tropical and subtropical assemblage of plants.

Text-figure 2—Geographic locations of data sources. For explanation, see Table 1

The Pashkyum Eocene palynofloral assemblage from Ladakh Himalaya (Mathur, 1984) also indicates the continuation of similar palaeoecological conditions which were characteristic of Palaeocene. Tropical elements, like *Calamus, Nypa, Gunnera*, alongwith palms and many other pteridophytic elements, confirm this view.

Bhandari *et al.* (1979) have reported Late Eocene-Miocene assemblage from the Tarums, a ormation of the same area. Some of its important constituents are *Magnastriatriletes, Lycopodiumsporites, Pinuspollenites, Pediastrum, Tricolpites, Caryapollenites, Betulaceoipollenites, Alnipollenites, Juglanspollenites, Polyporina* and *Graminidites*. Composition of the assemblage shows that the Palaeocene coastal semi-evergreen type of vegetation was transformed into moist deciduous type of forests in the Middle Tertiary of Ladaklh Himalaya. The vegetational change denotes the onset of sub-temperate climate. The occurrence of *Prunus* (Kargil Formation) and *Livistonia* (Hemis Conglomerate) has been reported from the Ladakh Himalaya by Guleria *et al.* (1983) and Lakhanpal *et al.* (1983), respectively. Later, Lakhanpal (1988) inferred that *Trachycarpus, Prunus* and possibly

Table 1—Tertiary stratigraphic sequences of floral data sources. Numbers indicated in parentheses refer to geographic locations as shown in Text-figure 2

Chronological Units	Stratigraphic Units			
	Western Himalaya		Eastern Himalaya	References
	Siwalik Group of Jammu		Dihing/Dhekiajuli beds.	Sarkar *et al.*, (20)
Pliocene	and	Siwalik Group		Lakhanpal, 1983 (4)
	Karewas of Kashmir		Tipam Sandstone	Lakhanpal, 1988
			Formation	Corvinus, 1988 (18)
				Du, 1985 (22)
to				Mathur, 1984
				Vishnu-Mittre, 1984 (5)
				Saxena *et al.*, 1984 (13)
				Singh & Sarkar, 1984 (7)
				Awasthi, 1982
				Singh & Saxena, 1981 (12)
				Saxena & Singh, 1980 (15)
				Dutta & Singh, 1980 (30)
				Mathur, 1978
				Nandi, 1975 (14)
				Prakash, 1972, 1979 (15)
Middle Miocene	Kargil (=Liyan)		Bokabil Formation	Lukose, 1969 (19)
	Formation			Banerjee, 1964, 68 (15)
Lower Miocene	Hemisconglomerate	Kasauli Formation	Bhuban Formation/	Singh *et al.*, 1987 (26)
	Horizon		Boldamgiri Formation.	Dogra *et al.*, 1975 (11)
	Murree Group		Renji Formation	Nandi & Sharma, 1984 (29)
	and			Mathur, 1984 (10)
			Jenam Formation	Singh & Sarkar, 1984 (8)
Oligocene	Dharamsala Group	Dagshai		Guleria *et al.*, 1983 (3)
		Formation	Laisong Formation	Singh & Khanna, 1980 (9)
				Mathur & Venkatachala, 1979
				Sahni, 1964 (9)
	Tarumsa Formation	Subathu Formation	Kopili Formation	Sarkar & Singh, 1988 (8)
			Sylhet limestone	Singh & Tripathi, 1987 (28)
			Formation	Mathur, 1984 (5)
				Bhandari *et al.*, 1979 (2)
	Nummulitic lime-			Khanna, 1978 (6)
Eocene	stone of Ladakh,			Dutta & Sah, 1970 (21)
	Subathu Formation			Sah & Dutta, 1968 (23)
	of Jammu			Mathur, 1963, 1964 (7)
				Lakhanpal, 1955 a,b
			Therria/	
Palaeocene			Cherra Formation	Singh & Tripathi, 1987 (28)
	Dras Volcanics			Kar & Kumar, 1986 (27)
			Lakadong Formation	Mathur & Jain, 1980 (1)

also *Populus* immigrated from the mainland of Asia and became a part of the temperate Himalayan flora during the Middle Miocene.

Himachal Himalaya

From Himachal Himalaya, the Subathu Formation (Palaeocene-Eocene) assemblages have generated a rich information (Mathur, 1963, 1964; Khanna, 1978; Singh & Khanna, 1980; Singh *et al.*, 1978; Singh & Sarkar, 1987; Sarkar & Singh, 1988). Dinoflagellate cysts dominate the palynological assemblage. The terrestrial elements are represented by the taxa belonging to Lycopodiaceae, Schizaeaceae, Matoniaceae, Polypodiaceae, Parkeriaceae, Podocarpaceae, Liliaceae, Nympheaceae, Poaceae, Arecaceae, Oleaceae, Fagaceae, Anacardiaceae, Alangiaceae, etc. Algal elements, viz., *Pediastrum* and *Botryococcus* have also been recorded in abundance. The environment of deposition varies from shallow marine to coastal transition with a tropical climate. The vegetational type conforms to a coastal semi-evergreen type and is comparable to that of Ladakh Himalaya.

A Late Eocene-Oligocene palynological assemblage recorded from the Dagshai Formation (Singh & Khanna, 1980), though not copiously diversified, is easily identified by the absence of marine dinoflagellate cysts and by the presence of palm pollen. Gymnospermous pollen are represented by *Inaperturopollenites* and *Podocarpidites*-complex. The high incidences of *Pediastrum* and the presence of palms indicate a coastal transitional type of vegetation for the Dagshai Formation (Singh & Khanna, 1980).

The Oligocene palynoflora of Himachal Pradesh (Mathur, 1984) is mainly represented by herbaceous elements and tree ferns. Some of the important palynotaxa are *Castanea, Galium, Amaranthus* and *Chenopodium*. Mathur (1984) has also reported the occurrence of taxa belonging to Cyatheaceae, Gleicheniaceae, Osmundaceae, Pinaceae, Arecaceae, Haloragidaceae, Fabaceae, Sapotaceae, Buxaceae, Aquifoliaceae, etc.

An Early Miocene palynological assemblage from the Kasauli Formation (Singh & Sarkar, 1984a) having the representatives of modern families, viz., Cyatheaceae, Schizaeaceae, Lindsaeaceae, Polypodiaceae, Pinaceae, Liliaceae, Arecaceae, Bombacaceae, Oleaceae, etc. is inferred to be subtropical and humid type of vegetation. *Pinus* pollen constitute an important aspect of the assemblage. Their presence denotes the earliest record of occurrence of Pinaceae in the Lower Miocene sediments of western Himalaya. It seems likely that temperate elements had started migrating from the West Asian mainland at that time and later found a favourable climate for proliferation in the western Himalaya even before the Middle Miocene orogeny. It appears that the Kasauli Formation had attained sufficient elevation to support the growth of pines in Himachal Himalaya.

The Dharamsala sediments equivalent of Dagshai and Kasauli sediments contain representatives of the following families, viz., Hymenophyllaceae, Schizaeaceae, Polypodiaceae, Lycopodiaceae, Pinaceae, Arecaceae, Aquifoliaceae, Rutaceae, Tiliaceae, Chenopodiaceae, Caprifoliaceae, Ctenolophonaceae, Oleaceae and Pandanaceae (Mathur & Venkatachala, 1979; Mathur, 1984). Freshwater alga *Botryococcus* has also been recorded from these sediments. Taxonomic assignments of Dharamsala palynofossils (Dogra *et al.*, 1985) need confirmation.

Siwalik foot-hills of Himachal Pradesh and Uttar Pradesh

The Miocene vegetational pattern of Himachal Pradesh (Kalka region) and Uttar Pradesh (Dehradun region) based on megafossils (Prakash, 1972, 1979; Awasthi, 1982) shows that some of its important constituents are *Afzelia, Albizzia, Anisoptera, Cassia, Cynometra, Dalbergia, Diospyros, Dipterocarpus, Ficus, Fissistigma, Milletia. Polyalthia* and *Ziziphus*. These assemblages had no representation of gymnosperms. However, the Miocene palynological assemblages from Himachal Pradesh, Punjab and Uttar Pradesh show a wide representation of gymnospermous pollen comparable to *Pinus, Podocarpus, Abies, Cedrus, Picea* and *Tsuga* alongwith other taxa belonging to many families of angiosperms, viz., Arecaceae, Liliaceae, Myricaceae, Juglandaceae, Magnoliaceae, Fabaceae and Moraceae (Banerjee, 1968; Lukose, 1969, 1972; Nandi, 1975; Singh & Saxena, 1981; Saxena & Singh, 1980; Singh & Sarkar, 1984b; Saxena *et al.*, 1984). Lakhanpal (1988) suggested that the temperate pollen occurring in the Siwalik sediments might have been blown in from the surrounding higher hills. Since plant megafossils of temperate climate have not been recovered from these sediments, he has questioned the authenticity of the identification of gymnospermous pollen, particularly of *Pinus, Abies, Cedrus* and *Picea*. The overall palynological evidences from wider regions of Himalaya do indicate that the pines might have been the earliest migrants, pioneering their growth in the Early Miocene times and subsequently attaining a position of dominance after the Middle Miocene orogeny. Gymnospermous megafossils are yet to be recovered from the sediments laid even after the Middle Miocene orogeny.

On the basis of palynological investigations of Mohand Siwaliks (Middle Miocene) Sarkar *et al.* (in press) have identified the occurrence of following families, viz., Arecaceae, Sparganiaceae, Poaceae, Asteraceae, Lentibulariaceae, Malvaceae, Pedaliaceae alongwith gymnospermous pollen, mainly belonging to Pinaceae. The abundance of ferns, together with many angiospermous elements, indicates the existence of a mixed vegetation belonging to moist subtropical climate. Mathur (1984) indicated the prevalence of mangrove swamp and deltaic environment in the Jawalamukhi area of Himachal Pradesh during Middle-Late Miocene Epoch on the basis of occurrence of mangrove swamp trees, like *Sonneratia* and *Rhizophora*. He further observed that the presence of *Crenia, Crudia* and *Phoenix* indicates near-shore conditions whereas *Barringtonia, Sabal*, alongwith dinoflagellate cysts, indicate brackish water condition of environment during Miocene in the Nahan area of Himachal Pradesh. The present authors have extensively worked in these areas and have failed to recover any such elements. Therefore, the identifications of marine or brackish water elements in the Siwalik sediments are not considered authentic. The Siwalik dinoflagellate cysts have been considered to be reworked from the Subathu Formation.

During Pliocene times in the Jammu region, the abundance of palm pollen alongwith grasses representing the palm savana in the Boulder Conglomerate Bed has been observed (Sahni, 1964; Mathur, 1978; Vishnu-Mittre, 1984). Megafossil evidence provided by Lakhanpal and Awasthi (1983) shows the presence of *Ziziphus, Mangifera, Bauhinia, Indigofera, Dalbergia, Litsea, Cinnamomum, Ficus, Gardenia, Toona, Kydia* and members of Fabaceae in the Bhikhnathoree area of west Champaran. Similar evidence has emerged from the Pliocene sediments of Surai Khola area of western Nepal (Corvinus, 1988; Sarkar, in press). The Pliocene palynological assemblages of Siwalik sediments (Singh, 1982) bring out the fact that the cool dry climate had set in, which supported the luxuriant growth of forms, like *Larix, Pinus* and *Pinjoriapollis* (magnoliaceous pollen). Pollen of Poaceae and Arecaceae are also well represented. Some of the important gymnospermous and angiospermous families reported by Saxena and Singh (1980), Singh and Saxena (1981) and Singh and Sarkar (1984b) from the Middle Miocene-Pliocene sediments are Arecaceae, Poaceae, Pinaceae, Fabaceae, Betulaceae, Chenopodiaceae, Euphorbiaceae, Amaranthaceae and Linaceae.

TERTIARY VEGETATIONAL PATTERN OF EASTERN HIMALAYA

Palaeobotanical and palynological information from the Tertiary Period of eastern Himalaya has been developed mainly by Baksi (1962), Banerjee (1964), Sah and Dutta (1968), Dutta and Sah (1970), Kar and Kumar (1986), Prakash (1972), Lakhanpal (1955a, b), Du (1985), Singh and Tripathi (1987), and Singh *et al.* (1987).

A Palaeocene palynoflora typical of tropical affinity is known from the Lakadong Sandstone of Laitryngew and Mawlong, Sohrarim, Shillong-Cherra road and Mowmluh Hill, Meghalaya (Kar & Kumar, 1986). Important families present in this flora are Lycopodiaceae, Schizaeaceae, Cyatheaceae, Polypodiaceae, Matoniaceae, Adiantaceae, Podocarpaceae, Araucariaceae, Arecaceae, Liliaceae, Brassicaceae, Meliaceae, Fabaceae, Olacaceae, Lamiaceae, Oleaceae, Rhizophoraceae, Lentibulariaceae, Proteaceae, Guttiferae, Anacardiaceae, Myricaceae and Droseraceae. These families mostly inhabit tropical to subtropical regions. Gymnospermous pollen are low in number. The overall vegetational pattern is of coastal swamp type. Leaf-impressions of *Nelumbium, Trema, Neolitsea, Grewia*, some members of Bombacaceae have been described from the Eocene sediments of Garo hills (Lakhanpal, 1955a, b). Sah and Dutta (1968) and Dutta and Sah (1970) have reported palynofossils from Cherra Formation, Assam and assigned them to several monocotyledonous and dicotyledonous families in addition to pteridophytic and gymnospermous elements. Most of the families denote tropical to subtropical affinity.

The palynoflora recorded by Singh and Tripathi (1987) from the Palaeocene-Eocene sediments of Meghalaya supports the existence of rich tropical to subtropical vegetation during early Tertiary times. They have recorded rich assemblage of angiospermous pollen taxa belonging to the families, viz., Arecaceae, Liliaceae, Poaceae, Nympheaceae, Nelumboniaceae, Brassicaceae, Oleaceae, Lamiaceae, Chenopodiaceae, Euphorbiaceae, Myricaceae, Magnoliaceae and Aristolochiaceae, along with many pteridophytic spores and dinoflagellate cysts. These palynofloral assemblages give strong support to the views of Lakhanpal (1970).that a tropical vegetation prevailed during the Palaeogene Period in the Indian subcontinent. A higher representation of epiphyllous fungi indicates the prevalence of warm and humid climate during Palaeocene-Eocene times in Meghalaya. The occurrence of palm pollen, along with dinocysts, indicates coastal environment of deposition during Palaeocene-Eocene times in Meghalaya.

The palynofloral assemblages from the Oligocene and Miocene sediments of the same area have also been studied by Singh *et al.* (1987). The taxa belonging to the families Parkeriaceae, Matoniaceae, Gleicheniaceae, Arecaceae and Fabaceae indicates tropical to subtropical climate. The occurrence of Pinus-type pollen in the Oligocene sediments is sporadic but they attain predominance in the Miocene of eastern Himalaya. The high incidence of pinaceous pollen in Miocene indicates the presence of uplands in close proximity to the depositional area. It appears that the surrounding area was much higher in Oligocene in comparison to the Palaeocene-Eocene times. The vegetation was represented by taxa belonging to Arecaceae, Fabaceae, Oleaceae, Araceae, Bombacaceae, Lamiaceae, Potamogetonaceae, Malvaceae, along with many pteridophytic elements. The close of Oligocene witnessed the development of land connections between India and Burma and Malaya through which several tropical plants migrated to the latter countries so as to avoid the harsh climate. *Ctenolophon* and *Sclerosperma* are the notable examples (Srivastava, 1988). It is likely that representatives of Sapotaceae and Fabaceae migrated from Malaya to India. Simultaneously, *Pinus* seems to have made the pioneering venture to invade the

Indian subcontinent, though megafossil evidences are yet to be found to corroborate this view.

Nandi and Sharma (1984) recorded a rich palynofloral assemblage from the Lower Miocene sediments of Garo hills. The presence of pollen taxa *Palmaepollenites, Couperipollis, Striacolporites* along with *Myricipites, Bombacacidites, Araliaceoipollenites* indicates tropical to subtropical climate. Association of pollen related to *Alnus* (*Alnipollenites*), *Chenopodium* (*Chenopodipollis*) and conifers are indicative of an elevated topography during the Early Miocene in Garo hills.

The Miocene flora of Assam and Meghalaya region, represents 65 per cent of tropical deciduous trees as compared to 35 per cent of tropical evergreen trees (Du, 1984). Besides, there are few species which grow in subtropical condition (*Artocarpus* and *Elaeocarpus*). Palynological evidence also indicates the high incidence of deciduous trees in the Neogene vegetation in the Himalayan region. Some fossil taxa comparable to the modern ones are *Calophyllum, Kayea, Anisoptera, Dipterocarpus, Shorea, Sterculia, Elaeocarpus* and *Bursera*. The Miocene flora of Assam region shows great resemblance with the tropical moist deciduous forests. The common elements are *Sterculia, Gluta, Terminalia, Albizia, Diospyros* and *Artocarpus*. Similar forests are still growing in Assam. The landscape seems to have been beset by a number of rivers, swamps and lakes as is indicated by the presence of *Dipterocarpus, Hopea, Bursera, Pometia, Barringtonia* and *Pongamia*. The Tipam flora in certain regions contains *Schleichera, Vitex* and *Phyllanthus* which may indicate the existence of relatively drier conditions.

The Miocene Tipam flora is distinct by the occurrence of some dense tropical forest elements, especially the moist deciduous ones. The deciduous forests had large to medium-sized angiospermous trees mixed with some medium to small-sized evergreen trees, some shrubs, herbs, and climbers. Members of Clusiaceae, Dipterocarpaceae, Anacardiaceae, Fabaceae, Combretaceae, Lythraceae, etc. were well represented. The xerophytic vegetation is speculated to be inhabiting the top of hills. The presence of littoral elements in the flora indicates that the present day Bay of Bengal might have covered areas far further north to the present Assam during Miocene (Lakhanpal, 1970). This observation is also confirmed by the recent palynological studies (Kar & Kumar, 1986). At present, the littoral forests and sea coasts have disappeared. This is perhaps because of the northward drift of the Indian subcontinent. The Pliocene palynological records from eastern Himalayan region are very scanty and hence have not been included for discussion.

DISCUSSION

A general floristic pattern characterizing the Tertiary Period of western Himalaya denotes that the Palaeocene-Eocene landscape was dotted with palms and many tropical angiospermous elements, viz., Clusiaceae, Lecythidaceae, Anacardiaceae, Alangiaceae, Sapotaceae, Bombacaceae, Myristicaceae, etc It is a known fact that these taxa and several others inhabit low relief landscapes and tropical climates. Representatives of Parkeriaceae, Alangiaceae, Juglandaceae and Fagaceae, so far known only from the Neogene Period, have been recorded from the Palaeogene sediments as well. Though the gymnospermous records are scanty, they only relate to the families Podocarpaceae and Araucariaceae. The Palaeogene taxa enumerated in Table 2 provide cogent basis for their segregation into four different forest formation types (*Sensu stricto* Singh & Singh, 1987): (1) submontane, broad-leaf ombrophillous forest, (2) submontane, seasonal broad-leaf forest, (3) submontane, broad-leaf summer deciduous forest, and (4) mid-montane, winter deciduous forest.

Later, the Middle Miocene orogeny of Himalaya brought a radical change in the floristic scenario of the area witnessing a decline in the occurrence of tropical families, appearance and proliferation of gymnospermous elements (Abietinae) and rapid increase in the number of subtropical families, viz., Moraceae, Myrtaceae, Euphorbiaceae, Fabaceae, etc. Further, it is apparent that different vegetational patterns of the Miocene Epoch were adapted to different altitudinal belts. Development of tropical, wet semi-evergreen forests, wet subtropical and humid temperate forests certainly indicates the establishment of different altitudinal belts. As at present, it is surmised that the Tertiary tropical forests inhabited the lower slopes whereas subtemperate to temperate forests were confined to the higher slopes. Besides, the Neogene floras of western Himalaya seem to have been enriched by the immigrating elements from Mediterranean, Sino-Japanese and Malayan regions.

The Neogene palaeobotanical data from western Himalaya broadly identifies itself with the following four forest types: (i) low montane, needle-leaf forest with concentrated summer leaf drops, (ii) low montane, sclerophyllous evergreen broad-leaf forests, (iii) mid-montane, broad-leaf ombrophillous forests, and (iv) mid-montane, needle-leaf evergreen

Table 2—Distribution of plant taxa in the Tertiary of Himalaya

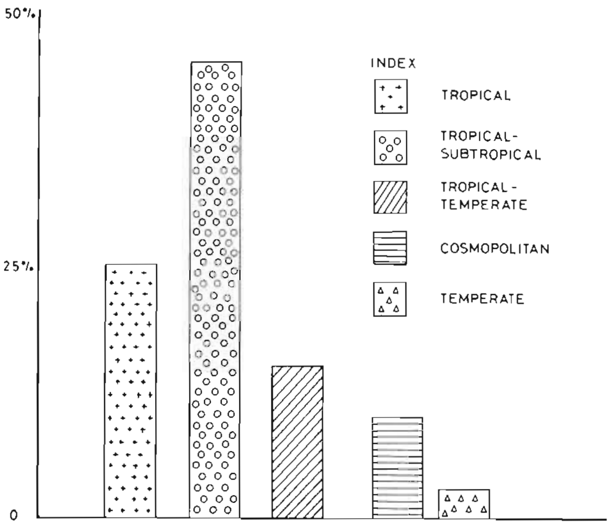
Families	Palaeocene		Eocene		Oligocene		Miocene		Pliocene	
	W.H.	E.H.	W.H.	E.H.	W.H.	E.H.	W.H.	E.H.	W.H.	E.H.
Pteridophytes										
Adiantaceae		+					+		+	
Azollaceae							+	+	+	+
Cyatheaceae		+	+	+				+	+	
Dicksoniaceae			+		+					
Gleicheniaceae			+							
Lycopodiaceae	+	+	+	+	+		+	+	+	+
Matoniaceae		+	+	+		+			+	
Osmundaceae		+	+	+			+		+	
Parkeriaceae			+	+	+	+	+		+	+
Polypodiaceae	+	+	+	+	+			+	+	+
Pteridaceae							+		+	
Schizaeaceae		+	+	+	+		+	+		
Gymnosperms										
Araucariaceae		+	+		+		+		+	
Cycadaceae	+		+				+	+	+	+
Pinaceae					+		+	+	+	+
Podocarpaceae	+	+	+	+	+	+	+		+	
Angiosperms										
Aceraceae				+				+	+	
Alangiaceae				+				+		
Amaranthaceae				+	+	+		+		
Anacardiaceae			+	+			+	+	+	+
Annonaceae					+			+		
Apocynaceae				+			+	+		
Aquifoliaceae						+	+	+		
Araceae					+			+	+	
Berberidaceae										
Betulaceae		+		+		+	+	+		+
Bombacaceae				+				+	+	
Boraginaceae								+	+	
Burseraceae								+		
Caesalpiniaceae		+		+	+					
Caprifoliaceae						+		+		
Casuarinaceae		+								
Celastraceae		+		+			+	+		
Chenopodiaceae				+	+			+		
Combretaceae								+	+	+
Asteraceae							+			
Coriariaceae	+					+				
Brassicaceae		+			+					
Ctenolophonaceae			+							
Dilleniaceae								+		
Dioscoriaceae		+					+	+		
Dipterocarpaceae		+				+	+			
Droseraceae		+								
Ebenaceae						+	+			
Elaeocarpaceae								+		
Euphorbiaceae		+		+	+		+	+	+	
Fabaceae	+	+					+	+	+	
Fagaceae			+					+	+	
Flacourtiaceae				+		+	+		+	
Poaceae			+					+	+	
Clusiaceae		+					+			
Haloragidaceae			+						+	
Juglandaceae	+		+		+		+			
Lamiaceae		+	+	+			+	+	+	+
Lauraceae							+	+	+	
Lecythidaceae		+	+	+					+	

Lentibulariaceae		+		+			+			
Liliaceae		+	+	+			+			
Linaceae			+				+			
Lythraceae			+				+	+		
Magnoliaceae						+	+	+	+	
Malvaceae						+	+	+	+	
Meliaceae		+						+		
Moraceae					+	+	+	+	+	+
Myricaceae		+		+						
Myristicaceae		+								
Myrtaceae		+		+			+			
Nelumboniaceae										
Nympheaceae	+	+		+						
Nyssaceae			+							
Olacaceae		+	+	+						
Oleaceae		+	+	+	+					
Onagraceae				+						
Arecaceae	+	+	+	+	+		+		+	
Pandanaceae	+		+							
Polygalaceae					+					
Polygonaceae					+		+			
Potamogetonaceae					+					
Proteaceae			+	+	+					
Ranunculaceae		+								+
Rhamnaceae							+	+	+	+
Rhizophoraceae			+	+	+			+		+
Rosaceae								+		
Rubiaceae		+						+	+	+
Rutaceae				+	+	+				
Santalaceae		+					+			
Sapindaceae					+			+		
Sapotaceae		+		+				+	+	
Smilacaceae								+		
Sonneratiaceae								+	+	
Sterculiaceae								+	+	
Symplocaceae		+		+						
Theaceae		+		+						
Tiliaceae				+				+		
Ulmaceae								+		
Apiaceae		+			+	+		+		
Urticaceae					+					
Verbenaceae								+		

forests. During this period the palaeobotanical data makes it crystal clear that the Palaeogene tropical moist, deciduous and wet semi-evergreen forests were transformed into moist semi-evergreen and deciduous forests.

The Pliocene floral diversification is related to climatic changes, increased continentality, semi-arid conditions and further uplift of the Himalayan range. In response to these changes, the wet tropical forests disappeared from the low altitudinal areas whereas subtropical and temperate forests were converted into dry or moist forests. The cold and semi-arid conditions forced moisture-loving plants, like *Dipterocarpus* and several others, to migrate or perish. *Cedrus, Picea, Abies, Pinus, Magnolia* and several other cold-loving plants were the significant components of the Pliocene floras, besides grasses, palms, *Alnus, Machilus, Clematis, Mallotus, Juglans, Quercus, Ficus, Rhamnus*, etc.

The eastern Himalayan Palaeocene-Eocene landscape supported mostly mixed type of coastal swamp vegetation as the present Bay of Bengal is believed to have penetrated far deeper into the north-eastern areas. The Oligocene Epoch witnessed major palaeogeographic changes because of the rise of Himalaya, withdrawal of the sea, regression of the Bay of Bengal and development of several land connections with Burma, Malaya and other adjoining areas facilitating inflow and outflow of plant species. It is believed that *Ctenolophon* and *Sclerosperma* made their entry into Malaya at this time. The Oligocene floral components show the abundance of pteridophytes and angiosperms. Gymnospermous records are poor or lacking.



Text-figure 3—Estimated distribution of plants in terms of climatic complexes.

The Miocene floras are chiefly represented by *Calophyllum, Anisoptera, Hopea, Dipterocarpus, Sterculia, Gluta, Albizia, Terminalia, Duabanga, Lagerstroemia*, etc. Composition of these floras mostly conform to tropical to subtropical, moist deciduous vegetational type

These floras have also been enriched by the immigrant species from the Sino-Japanese and Malayan regions, e.g., *Rhododendron, Tsuga, Quercus, Dillenia, Ficus*, etc. Geological, palaeogeographical and climatic events during the Late Tertiary do not seem to have altered overall pattern of vegetational types and far less the ecological conditions. It is surmised that the Middle to Late Miocene climate was warmer and more humid with a relatively higher rainfall than to-day, supporting luxuriant vegetation in which *Podocarpus, Elaeocarpus, Dipterocarpus, Gluta, Diospyros, Sterculia* and *Shorea* remain the significant constituents. The Pliocene floral records are fragmentary and hence have not been discussed. However, the Tertiary Himalayan palaeobotanical data has led to the preparation of an idealized model showing the distribution of plants as related to climatic complexes (Text-fig. 3).

The modern composition of the Himalayan flora reveals that it is a partial continuum of the Neogene floras, which progressively modified due to evolutionary changes and by the appearance of several immigrant elements from the surrounding areas. The modern Himalayan flora exhibits the presence of exotic forms which are believed to be of Euro-Mediterranean, Malayan-Burmese, African and Sino-Japanese origin. Some important immigrants to the western Himalayan flora from the Mediterranean region are *Quercus, Acer, Fraxinus, Alnus* and *Prunus*. The Malesian elements which became part of the Himalayan flora are *Bombax, Syzygium, Terminalia* and *Acacia*. The taxa, viz., *Dalbergia* and *Woodfordia* are the African elements. On the contrary, the eastern Himalayan flora is dominated by the Malayan and Chinese elements, like *Dipterocarpus, Ficus, Dillenia, Cassia, Engelhardtia*, etc. Some Sino-Japanese forms are represented by *Rhododendron, Tsuga, Schima*, etc. The representation of the African elements is very less. However, *Zizyphus mauritiana* is a good example.

The study of migratory pathways and the exact time as to when the immigrant forms became part of the Himalayan flora is a challenge before the palaeobotanists which needs to be met squarely. The present paper, though an initial attempt to build the scenario of Tertiary vegetational dynamics of Himalaya, has identified several intriguing problems which need to be understood precisely by carrying out in-depth studies. Quite often the plant fossil assemblages (micro- and mega) are interpreted without taking into consideration the basic requirements of plants in terms of ecological compatability, range of climatic tolerance, geographic locale and differential altitudinal adaptations. A rethinking on these aspects is likely to avoid several pitfalls which lead to inaccurate conclusions. Conflicting views on the elevation of Siwalik range in the Tertiary Period needs to be resolved. As plants are indicators of climate, the overall palynological data, particularly of gymnospermous affinity, may invoke rethinking in regard to their chronological and spatial invasion during the Tertiary Period in Himalaya. Equally challenging is the problem to understand the differential role of physical barriers which promoted endemism, regionalism, migration and immigration of several plant species during the Tertiary Period of Himalaya.

REFERENCES

Awasthi, N. 1982. Tertiary plant megafossils from the Himalaya: A review. *Palaeobotanist* **30**(3) : 254-267

Baksi, S. K. 1962. Palynological investigation of Simsang River Tertiaries, South Shillong Front, Assam. *Bull. geol. Min. metall. Soc. India* **26** : 1-22.

Banerjee, D. 1964. A note on the microflora from Surma (Miocene) of Garo hills, Assam. *Bull. geol. Min. metall. Soc. India* **29** : 1-8.

Banerjee, D. 1968. Siwalik microflora from Punjab, India. *Rev. Palaeobot. Palynol.* **6** : 171-178.

Bhandari, L. L., Venkatachala, B. S. & Singh, Pratap 1977 Stratigraphy, palynology and palaeontology of Ladakh Molasse Group in the Kargil area. *Proc. IV colloq. Indian Micropalaeont. Stratigr. (1974-75)* : 127-133.

Chatterjee, D. 1939. Studies on the endemic flora of India and Burma. *J. R. asiat. Soc. Bengal, Calcutta* **5** 19-63.

Clarke, C. B. 1898. On the subareas of British India, illustrated by the detailed distribution of the Cyperaceae in that empire. *J. Linn. Soc. Lond., Bot.* **34** : 1-146.

Corvinus, G. 1988. The Mio-Plio Pleistocene litho- and biostrati graphy of the Surai Khola Siwaliks in west Nepal First results. *C R. Acad. Sci. Paris* **306** : 1471-1477

Dogra, N. N., Singh, R. Y & Misra, P. S. 1985. Palynology of Dharamsala beds, Himachal Pradesh. *J. palaeont. Soc. India* **30** : 63-77

Du, N. Z. 1985. Studies on fossil woods from the Neogene of India, Burma and China. *Unpublished Ph.D thesis*, Lucknow, pp. 1-300.

Dutta, S. K. & Sah, S. C. D. 1970. Palynostratigraphy of the Tertiary sedimentary formations of Assam: 5. Stratigraphy and palynology of south Shillong plateau. *Palaeontographica* **B131** : 1-72.

Gansser, A. 1974. *In*: Spencer, A. M. (Ed.)—*Himalaya, in Mesozoic Cenozoic orogenic belts. Data for orogenic studies. Geol Soc. London Spec. Publ.* **4** 267, Scottish Academic Press, Edinburgh.

Guleria, J. S., Thakur, V. C., Virdi, N. S. & Lakhanpal, R. N. 1983. A fossil wood of *Prunus* from the Kargil (= Liyan) Formation, Ladakh. *In* : Thakur, V C. & Sharma, K. K. (eds)—*Geology of Indus Suture Zone of Ladakh* : 187-193. Wadia Institute of Himalayan Geology, Dehradun.

Hooker, J. D. 1906. *A sketch of flora of British India*. London.

Kar, R. K. & Kumar, M. 1986. Palaeocene palynostratigraphy of Meghalaya, India. *Pollen Spores* **28**(2) : 177-218.

Khanna, A. K. 1978. Subathu—Stratigraphic status and nomenclature. *Him. Geol.* **8** 209-223.

Lakhanpal, R. N. 1955a. Recognizable species of Tertiary plants from Damalgiri in the Garo Hills, Assam. *Palaeobotanist* **3** : 27-31

Lakhanpal, R. N. 1955b. On the occurrence of *Nelumbium* in the Tertiary of Assam. *J. Indian bot Soc.* **34**(3) : 222-224.

Lakhanpal, R. N. 1970. Tertiary floras of India and their bearing on the historical geology of the region. *Taxon* **19**(5) : 675-694.

Lakhanpal, R. N. 1988. The advent of the temperate elements in the Himalayan flora. *In* : Aigner *et al.* (eds)—*The palaeoenvironment of East Asia from the Mid-Tertiary, occasional papers and monographs* no. **77** : 673-679. Centre of Asian Studies, Univ. of Hongkong.

Lakhanpal, R. N. & Awasthi, N. 1983. A Late Tertiary florule from near Bhikhnathoree in west Champaran District, Bihar *In* : Sharma, A. K. *et al.* (eds)—*Proc. Symp. Evolut. Bot. & biostratigr* (Prof. A. K. Ghosh commem. vol) : 587-596. Today & Tomorrow Print. & Publ., New Delhi.

Lakhanpal, R. N., Sah, S. C. D., Sharma, K. K. & Guleria, J. S. 1983. Occurrence of *Livistona* in the Hemis Conglomerate horizon of Ladakh. *In* : Thakur, V. C. & Sharma, K. K. (eds)—*Geology of Indus Sutute Zone of Ladakh* : 179-185. Wadia Institute of Himalayan Geology, Dehradun.

Lukose, N. G. 1968. Microfossils from the Middle Siwalik of Bihar, India. *J. Palynol.* **4**(2) : 107-112.

Mathur, A. K. 1978. Some fossil leaves from the Siwaliks. *Geophytology* **8**(1) : 98-102.

Mathur, K. 1963. Occurrence of *Pediastrum* in Subathu Formation (Eocene) of Himachal Pradesh, India. *Sci. Cult.* **29** : 250.

Mathur, K. 1964. On the occurrence of *Botryococcus* in Subathu beds of Himachal Pradesh, India. *Sci. Cult.* **30** : 607-608.

Mathur, Y. K. 1984. Cenozoic palynofossils, vegetation, ecology and climate of the north and Northwestern sub-Himalayan region, India. *In* : White, R. O. (Ed.)—*The evolution of the East Asian environment*, II. *Occasional papers and monographs* no. **59** : 504-551 Centre of Asian Studies, Univ of Hongkong.

Mathur, Y K. & Jain, A. K. 1980. Palynology and age of the Dras volcanics near Shergol, Ladakh, Jammu and Kashmir, India. *Geosci. J.* **1**(1) : 55-74.

Mathur, Y K. & Venkatachala, B. S. 1979. Palynological studies of the Cenozoic sediments of Himalayan foot hills. *Him. Geol Semin Misc Pubs geol. Surv. India* **41**(5) : 103-110.

Nandi, B. 1975. Palynostratigraphy of the Siwalik Group of Punjab. *Him. Geol.* **5** : 411-423.

Nandi, B. & Sharma, R. 1984 Palynology and biostratigraphy of the Boldamgiri Formation, Garo Hills, Meghalaya. *In* : Sharma, A. K. *et al* (eds)—*Proc. Symp. Evolut Bot. Biostratigr.* (Prof. A. K. Ghosh Commem. Vol) 565-580. Today & Tomorrow Print. & Publ., New Delhi.

Prakash, U. 1972 Palaeoenvironmental analysis of Tertiary floras. *Geophytology* **2**(2) : 178-205.

Prakash, U. 1979. Some more fossil woods from the Lower Siwalik beds of Himachal Pradesh. *Him. Geol.* **8** : 61-81.

Razi, B. A. 1955. Some observations on plants of south Indian hill tops and their distribution. *Proc. natn. Inst. Sci. India* **21B** : 79-89.

Sahni, B. 1964. *Revisions of Indian fossil plants.* part **III**—*Monocotyledons* (Monograph 1), pp. 1-89. Birbal Sahni Institute of Palaeobotany, Lucknow.

Sah, S. C. D. & Dutta, S. K. 1968. Palynostratigraphy of the sedimentary formations of Assam-2. Stratigraphic significance of spores and pollen in the Tertiary succession of Assam. *Palaeobotanist* **21**(1) : 42-47

Sarkar, Samir 1990 Siwalik pollen succession in Surai Khola of western Nepal and its reflections in palaeoecology *Palaeobotanist* **38** : 000-000.

Sarkar, Samir & Singh, H. P. 1988. Palynological investigation of the Subathu Formation (Eocene) in the Banethi Bagthan area of Himachal Pradesh, India. *Palaeontographica* **B209**(1-3) : 29-109.

Sarkar, Samir, Bhattacharya, A. P. & Singh, H. P. (in press). Palynology of Middle Siwalik sediments (Upper Miocene) from Bagh Rao, Uttar Pradesh, India. *Pollen Spores.*

Saxena, R. K. & Singh, H. P. 1980. Occurrence of palynofossils from the Pinjor Formation (Upper Siwalik) exposed near Chandigarh. *Curr. Sci.* **49**(12) : 479-480.

Saxena, R. K., Sarkar, Samir & Singh, H. P. 1984. Palynological investigation of Siwalik sediments of Bhakra Nangal area, Himachal Pradesh. *Geophytology* **14**(2) 178-198.

Sharma, K. K. 1984. The sequence of phased uplift of the Himalaya. *In* : White, R. O. (Ed.)—*The evolution of the East Asian environment, Centre of Asian studies occasional papers and Monographs* no. **59** : 56-70. Hong Kong.

Singh, H. P. 1982. Tertiary palynology of the Himalaya: A review. *Palaeobotanist* **30**(3) : 268-278.

Singh, H. P. & Khanna, Ashok K. 1980. Palynology of the Palaeogene marginal sediments of Himachal Pradesh, India. *Proc. IV Int. palynol. Conf., Lucknow (1976-77)* **2** 462-471. Birbal Sahni Institute of Palaeobotany, Lucknow.

Singh, H. P. & Sarkar, Samir 1984a. A Kasauli palynoflora from Banethi area of Himachal Pradesh, India. *Geophytology* **14**(1) : 40-54.

Singh, H. P. & Sarkar, Samir 1984b. Palynological investigations of Ramshahr Well-1, Himachal Pradesh. *Palaeobotanist* **32**(2) : 91-112.

Singh, H. P. & Sarkar, Samir 1987 Palynostratigraphy of Subathu Formation (Eocene) in the Banethi-Bagthan area, Sirmaur District, Himachal Pradesh, India. *Palaeobotanist* **35**(2) : 204-210.

Singh, H. P. & Saxena, R. K. 1981 Palynology of the Upper Siwalik sediments in Una District, Himachal Pradesh. *Geophytology* **11**(2) : 171-179.

Singh, J. S. & Singh, S. P. 1987. Forest vegetation of the Himalaya. *Bot. Rev.* **53**(1) : 80-192.

Singh, H. P. & Tripathi, S. K. M. 1987 Palynology of the Jaintia Group (Palaeocene-Eocene) exposed along Jowai-Sonapur Road, Meghalaya, India (Part II). Data analysis and interpretations. *Palaeobotanist* **35**(3) 301-313.

Singh, H. P., Khanna, A. K. & Sah, S. C. D. 1978. Palynological zonation of the Subathu Formation in the Kalka-Simla area of Himachal Pradesh. *Him. Geol.* **8** : 33-46.

Singh, H. P., Rao, M. R. & Saxena, R. K. 1987 Palynology of the Barail (Oligocene) and Surma (Lower-Miocene) sediments exposed along Sonapur-Badarpur Road Section, Jaintia Hills (Meghalaya) and Cachar (Assam)-Part VII. Discussion. *Palaeobotanist* **35**(3) : 331-341.

Srivastava, S. K. 1988. *Ctenolophon* and *Sclerosperma* palaeogeography and Senonian Indian plate position. *J. Palynol.* **23-24** : 239-253.

Vishnu-Mittre 1984. Floristic changes in the Himalaya (southern slopes) and Siwaliks from the Mid-Tertiary to recent times. *In* : White, R. O. (Ed.)—*The evolution of the east Asian environment*, **2** *Occasional papers and monographs* no. **59** : 483-503. Centre of Asian Studies, Univ. of Hongkong.