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# TERTIARY PLANT MEGAFOSSILS FROM THE HIMALAYA — A REVIEW*

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## ABSTRACT

The paper presents a critical review of the Tertiary plant megafossils from the Himalaya falling within the Indian territory. The floral assemblages can be conveniently grouped into two: (i) the pre-Siwalik flora, and (ii) the Siwalik flora. The pre-Siwalik Tertiary plants are poorly preserved and comprise monocotyledonous leaf-impressions assigned to the genera *Sabalites* (palm or palm-like leaves) and *Poacites* (grass-like leaves), and a few dicotyledonous leaves placed under the genus *Dicotylophyllum*. The Siwalik flora, so far known, consists of both monocotyledonous and dicotyledonous leaf-impressions, petrified woods, a few seeds and some fresh water algal remains belonging to Charophyta. The physical conditions around the area of deposition of the plants have been discussed briefly in the light of the distribution of their modern equivalents. The scope and the importance of further studies of fossil plants of the Himalaya have been discussed.

*Key-words* — Megafloristics, Palaeoecology, Tertiary, Himalaya (India).

## साराँश

### हिमालय से तृतीयक युगीन गुरु-पादपाश्म : एक समीक्षा – नीलाम्बर अवस्थी

प्रस्तुत शोध-पत्र में हिमालय के भारतीय-क्षेत्र से प्राप्त तृतीयक युगीन गुरु-पादपाश्मों की समालोचना की गई है। वनस्पतिजात समुच्चयों को सरलता से दो समूहों – (अ) पूर्व-शिवालिक वनस्पतिजात, तथा (आ) शिवालिक वनस्पतिजात – में रखा जा सकता है। पूर्व-शिवालिक के तृतीयक युगीन पादपाश्म कम परिरक्षित हैं। इन पादपाश्मों में सेबॅलाइटिस (ताड़ या ताड़-सदृश पत्तियाँ) एवं पोआसाइटिस (घास-सदृश पत्तियाँ) नामक प्रजातियों से नामांकित एकबीजपत्री पर्ण-छापें तथा डाइकोटिलोफ़िल्लम् प्रजाति के अन्तर्गत् रखी गई कुछ द्विबीजपत्रीय पत्तियाँ सम्मिलित हैं। अभी तक ज्ञात शिवालिक वनस्पतिजात में एकबीजपत्री एवं द्विबीजपत्री पर्ण-छापें, अश्मीभूत काष्ठ, कुछ बीज तथा केरोफ़ाइटा से सम्बन्धित कुछ अलवणी शैवालीय अवशेष सम्मिलित हैं। पादपाश्मों के वर्तमान समतुल्यों का वितरण ध्यान में रखते हुए निक्षेपण के क्षेत्र के आस-पास की भौतिक परिस्थितियाँ संक्षिप्त रूप से विवेचित की गई हैं। हिमालय से प्राप्त पादपाश्मों के और अध्ययन के महत्व एवं सीमा भी विवेचित किये गये हैं।

## INTRODUCTION

IN the Himalaya the Tertiary rocks of all stratigraphic units are found throughout its length, extending from Nanga Parbat in the west to Namcha Barwa Peak in the east. The early part of the sequence (Eocene) consists of marine facies, whereas the later part is characterised by estuarine, fluviatile and lacustrine deposits formed during intervals of different phases of the Himalayan upheaval.

The first information about the occurrence of plant fossils in the Tertiary sediments of

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the Himalaya dates back to 1864 when Medlicott in his memoir on "The sub-Himalayan ranges between Ganges and Ravi" mentioned the occurrence of leaf-impressions in the Kasauli Hills. In subsequent years various other geologists also pointed out the presence of petrified woods and leaf-impressions in the Siwalik beds of the foot-hills. In spite of the sufficient information available, the Tertiary plants of the Himalaya remained almost uninvestigated until quite sometime back. Perhaps this may be due to the fact that the main interest of the earlier workers had been the study of the Deccan Intertrappean flora, being the oldest and the best preserved of the Indian Tertiary.

During the last two decades detailed mapping of the Himalayan region, especially the foot-hills, done by the Oil and Natural Gas Commission for exploration of oil and gas, has provided ample information regarding the occurrence of plant fossils in the Siwalik beds. This was substantiated by various palaeontologists who, in the quest of animal fossils, happened to come across the fossiliferous outcrops from time to time. In recent years attempts have been made successfully to collect and investigate systematically the Tertiary plant megafossils of the Himalaya by various workers. A critical review of the plant megafossils, so far known, is presented in the present paper incorporating all the available information with regard to the fossil localities and plants preserved therein.

## FLORISTIC COMPOSITION

The floral assemblages from the Himalayan Tertiary sediments can be conveniently grouped into two: (i) the pre-Siwalik flora, and (ii) the Siwalik flora.

### Pre-Siwalik Flora

The pre-Siwalik Tertiary sediments in the Lesser Himalayan zone of the western region constitute the lower part of the Cenozoic which includes Subathu, Dagshai and Kasauli formations, ranging in age from Palaeocene to Miocene. The Kasauli Formation in the Dharamsala area of the Kangra District are classified as part of the Dharamsala Group, whereas in the Jammu area these sediments constitute part of the Murree Group. In the Tethys Himalaya they are represented by the Nummulitic Limestone and associated rocks in the Upper Ladakh corresponding to the Subathu Formation (Eocene) overlain by Ladakh Molasse belonging to Oligo-Miocene.

The Early Tertiary sediments belonging to marine facies are poorly represented by plant megafossils. The only fossil plant hitherto known is an alga, *Lithoporella melobisoides* (Foslie) Foslie belonging to the class Rhodophyta, described by Pal and Chatterjee (1978) from the Nummulitic shales and limestones of Palaeocene to Eocene horizon of the Mahe and Nida Valley, Ladakh.

The plant megafossils of the later part of the Pre-Siwalik sediments comprise dicotyledonous and monocotyledonous leaf-impressions which have been reported from the Kasauli Formation. The earliest known fossils are some leaf-impressions of palm, collected by Medlicott (1864) from the Kasauli beds of the type area Kasauli, which were briefly described by Kane (in Medlicott, 1864, pp. 97, 98) as cf. *Flabellaria raphifolia* Stbg. These were later figured and referred to *Sabal major* Heer by Feistmantel (1882, figs 3-5). In a posthumous paper, Sahni (1953) described three ill-preserved dicotyledonous leaf-impressions under the non-committal genus *Dicotylophyllum* and a parallel ribbed impression probably belonging to a fan palm which he collected from near Kasauli club. In the same paper he refigured *Sabal major* (Sahni, 1953, pl. 1, fig. 1). Again in 1964, Sahni renamed the above palm leaves as *Sabalites microphylla* and *Sabalites* sp. (see Table 1).

From Banog Grahat on the left bank of Koshalya River, another fossil locality in the Simla Hills, Chaudhri (1969) described a few badly preserved leaves which he has referred to palms and dicotyledons in general.

There are a few preliminary report on the occurrence of plant-remains in the Dharamsala beds of Himachal Pradesh. Gupta and Jiwan (1972), in a note, reported some leaf-impressions from near Namhol, about 26 km from Bilaspur on Bilaspur-Simla Road. They identified one of the leaves as *Ficus cunea*, but no description and photographs have been given. In his book, Gupta (1976, p. 36) has mentioned that the monocotyledonous leaves (*Palmophyllum* spp.) *Dicotylophyllum* and woody tissues are also

TABLE 1 — PLANT MEGAFOSSILS FROM THE PRE-SIWALIK SEDIMENTS

| Fossil | Locality | Horizon/ Formation/ Series/Stage | Reference |
|---|---|---|---|
| **ALGAE** | | | |
| I. CHAROPHYTA | | | |
| 1. *Grambastichara* cf. *G. cylindrica* (Madler) Horn af Rantz. | Mangunor, near Kargil, Ladakh | Wakka Formation | Tewari & Sharma, 1972b |
| 2. *Grambastichara* cf. *G. tornata* (Reid & Groves) Horn af Rantz. | do | do | do |
| 3. *Harrisichara* cf. *H. vasiformis* (Reid & Groves) | do | do | do |
| II. RHODOPHYCOPHYTA | | | |
| 1. *Lithoporella melobesioides* (Foslie) Foslie | Mahe and Nida Valley, Ladakh | Nummulitic Shale and Limestones (Palaeocene-Eocene) | Pal & Chatterjee, 1978 |
| **ANGIOSPERMS** | | | |
| **Monocotyledons** | | | |
| I. PALMAE | | | |
| 1. *Sabal* sp. | Between Kargil and Leh, Ladakh | Ladakh Molasse | Drew, 1875 (in Tewari, 1964); Sahni & Bhatnagar, 1958; |
| 2. *Sabalites microphylla* (i) Leaf cf. *Flabellaria raphifolia* Stbg. Kane in Medlicott, 1864, pp. 97-99 (ii) *Sabal major* Heer, Feistmantel, 1882, fig. 3; Sahni, 1953 | Kasauli, H.P. | Kasauli | Sahni, 1964 |
| 3. *Sabalites* sp. (i) Leaves (in part) cf. *Flabellaria raphifolia* Stbg. Kane in Medlicott, 1864, pp. 97-99 (ii) *Sabal major* Feistmantel, 1882, figs 1, 2, 4, 5 | Near Chakoti (Kashmir) on the river Jhelum; Kasauli, H.P. | Murree and Kasauli | Sahni, 1964 |
| 4. *Palmophyllum* sp. | Banong Grahat, Koshalya River bank, H.P. | Kasauli | Chaudhri, 1969 |
| 5. Leaf fragment cf. Palm | Kasauli, H.P. | Kasauli | Sahni, 1953 |
| II. INCERTAE SEDIS | | | |
| 6. Plicated parallel veined leaf-impressions | Rajaori, J. & K. | Murree | Sahni, 1953 |
| 7. *Poacites Rajaoriensis* | Under the Bridge at Rajaori, J. & K. | Murree | Sahni, 1964 |
| **Dicotyledons** | | | |
| I. MORACEAE | | | |
| 1. *Artocarpus murreecus* | Liranwali Ban, South of Thanmandi, Rajaori Dist., J. & K. | Murree | Sharma & Gupta, 1972 |
| II. INCERTAE SEDIS | | | |
| 1. *Dicotylophyllum* spp. 1-3 | Kasauli, H.P. | Kasauli | Sahni, 1953 |
| 2. *Dicotylophyllum* spp. 1-3 | Banong Grahat, Koshalya River bank, H.P. | Kasauli | Chaudhri, 1969 |

found in the Upper Dharamsala Sub-group, but he has not given the locality as to where from these plants were collected.

In the Ladakh Himalaya the pre-Siwalik sediments have yielded a few megafossils. Palm leaves referred to *Sabal* sp. were described earlier by Drew in 1875 (in Tewari, 1964). Later, Sahni and Bhatnagar (1958) also reported a similar fan palm leaf referable to *Sabal* sp., along with fresh water molluscs from south-east of Leh and concluded that these fresh water deposits belong to Eocene. However, Tewari (1964) regarded the sequence of these deposits to Ladakh Molasse which are of Miocene in age. Quite recently Sah and Sharma (1980) also reported a palm leaf from Hemis conglomerate (Oligo-Miocene) of Ladakh. From the freshwater deposits of Wakka River Formation near Kargil, Tewari and Sharma (1972) described 3 species of Charophytic gyrogonites and placed them provisionally under the genera *Grambastichara* and *Harrisichara*. These were found in association of gastropods, vertebrate remains and dicot leaf-impressions. On the basis of these fossils they have suggested the age of the beds as Oligo-Miocene.

From the Jammu and Kashmir Himalaya a fragmentary palm-like leaf having several converging parallel veins undoubtedly belonging to fan palm was reported by Sahni (1964) from the Murree Formation (Lower Miocene) near Chakoti (Kashmir) on the River Jhelum, about midway between Rawalpindi and Srinagar. He (Sahni, 1964) also reported grass-like leaf-impressions of unknown affinities from Rajaori and named as *Poacites rajaoriensis* and *Poacites* sp., In 1962, Sharma and Gupta reported a leaf-impression as *Artocarpus murreecus* from the shale beds exposed near Liranwali Ban, south of Thanmandi in Rajaori District.

In the northeastern India the Tertiary rocks of the Arunachal Pradesh Himalaya were considered to be unfossiliferous until sometimes back. However, recently from the Eocene beds of Dihang Valley in Siang District, Tripathi *et al.* (1979) reported the occurrence of a leaf-impression assigned to *Apocynophyllum* sp. and a few fruits referred to *Canavalia*, *Hicoria*, *Grewiopsis* sp. and *Sophora*. Regarding the identification of these fruits nothing can be said since they are not accompanied by description and figures.

## The Siwalik Flora

The Siwalik Group consists of fresh water sedimentary rocks of Middle Miocene to Lower Pleistocene age, massively developed all along the Sub-Himalaya from Potwar Plateau on the north-west to Brahmaputra on the north-east, covering a distance of about 2,400 km in length and 20 to 25 km in width. The stratigraphy of the Siwalik Group has been worked out by several geologists from time to time. Pilgrim (1910) proposed the following classification of the Siwalik Group on the basis of lithology and palaeontology, which has been followed by Sahni and Mathur (1964) and other workers.

| | | |
|---|---|---|
| Upper Siwalik | Boulder conglomerate Stage<br>Pinjor Stage | Pleistocene |
| Middle Siwalik | Tatrot Stage<br>Dhok Pathan Stage<br>Nagri Stage | Pliocene |
| Lower Siwalik | Chinji Stage<br>Kamlial Stage | Middle to Upper Miocene |

The rocks belonging to above stratigraphical units have been found very rich in animal as well as plant fossils.

To begin with the plant fossils of the Siwalik Group the Jammu and Kashmir Himalaya have been taken first. So far only a few taxa are known from this region. Sahni (1931, 1964) reported for the first time two petrified palm woods and placed them under the genus *Palmoxylon*. They were collected from the alluvial boulder deposits (Upper Siwalik conglomerate) near Jammu. He also described a grass-like leaf, *Poacites siwalicus*, from the Lower Siwalik (Palandri Formation = Chinji Formation) near Poonch, Jammu and Kashmir. Since then perhaps no further record of fossil plants has been made from this region.

Of the Siwalik beds extending from north-west to north-east those exposed in the foot-hills of Himachal Pradesh and Uttar Pradesh are perhaps the richest in plant fossils. During the last two decades a number of fossil localities have been explored and valuable contributions made to the knowledge of the Tertiary palaeobotany of the Himalaya by various workers.

From a small patch of Lower Siwalik beds exposed at Balugoloa near Jawalamukhi, Lakhanpal (1965, 1967, 1968, 1969) and Lakhanpal and Dayal (1966) described

TABLE 2 — PLANT MEGAFOSSILS FROM THE SIWALIK SEDIMENTS

| Fossil | Locality | Horizon/ Formation/ Series/Stage | Reference |
|---|---|---|---|
| **ALGAE** | | | |
| CHAROPHYTA | | | |
| 1. *Chara contraia* Brain ex Kuetz. | Near Chandigarh | Pinjor | Bhatia & Mathur, 1978 |
| 2. *C. rantzieni* (Tewari & Sharma) emend. Bhatia & Mathur<br>Synonym:<br>*Grambastichara rantzieni* Tewari & Sharma<br>*Grambastichara bhatiai* Tewari & Sharma<br>*Tectochara pinjorica* Tewari & Sharma<br>*Tectochara* cf. *T. diluviana* Tewari & Sharma | do | Tatrot and Pinjor | do |
| 3. *C. rantzieni silvalensis* sub-sp. | Near Daulatpur, Kangra Dist., H.P. | Dhok Pathan | Bhatia & Mathur, 1978 |
| 4. *C. Surajpurica* (Tewari & Sharma) Bhatia & Mathur<br>Synonym:<br>*Charites surajpurica* Tewari & Sharma | Near Chandigarh and Dhamala, about 6 km NW of Pinjor | Tatrot | do |
| 5. *Chara molassica* (Straub) Horn. af Rantz. | Punyagiri, Tanakpur, U.P. | Kamlial | Lakhanpal *et al.*, 1976 |
| 6. *Chara* sp. | Near Chandigarh | Tatrot | Bhatia & Mathur, 1978 |
| 7. *Charites indica* | Near Chandigarh | Pinjor | Tewari & Sharma, 1972a |
| 8. *Charites siwalikus* | Punyagiri, Tanakpur, U.P. | Kamlial | Lakhanpal *et al.*, 1976 |
| 9. *Hornichara maslovi* | Near Chandigarh and Dhamala, near Pinjor | Pinjor and Tatrot | Bhatia & Mathur, 1978 |
| 10. *Raskyaechara purniagiriensis* | Punyagiri, Tanakpur | Kamlial | Lakhanpal *et al.*, 1976 |
| 11. *Sphaerochara rolli* (Unger) Horn. af Rantz. | Punyagiri, Tanakpur, U.P. | Kamlial | Lakhanpal *et al.*, 1976 |
| 12. *S. tewarii* | Daulatpur, H.P. | Dhok Pathan | Bhatia & Mathur, 1978 |
| 13. *S. pecki* | do | do | do |
| 14. *Sphaerochara* sp. | Triloknath and Bharil, H.P. | Chinji | do |
| 15. *Tectochara meriani meriani* (Papp) Grambast | Daulatpur, Triloknath and Kotla, H.P. | Dhok Pathan and Chinji | do |
| 16. *T. meriani huangi* (Lu) Wang | Triloknath, H.P. | do | do |
| 17. *T. sahnii* | Triloknath, H.P. | do | do |
| 18. *Tectochara* sp. | Triloknath, H.P. | do | do |
| **ANGIOSPERMS**<br>**Monocotyledons** | | | |
| I. PALMAE | | | |
| 1. *Palmoxylon jammuense* | Tawi River, near Jammu | Siwalik conglomerate | Sahni, 1931, 1964 |
| 2. *P. wadiai* | Taranagiri, left bank of Tawi, opposite Jammu | | Sahni, 1931, 1934 |
| II. SMILACACEAE | | | |
| 3. *Smilax* sp. | Balugoloa, near Jawalamukhi, H.P. | L. Siwalik | Lakhanpal & Dayal, 1966 |

— *Continued*

TABLE 2 — PLANT MEGAFOSSILS FROM THE SIWALIK SEDIMENTS — *Contd.*

| Fossil | Locality | Horizon/ Formation/ Series/Stage | Reference |
|---|---|---|---|
| III. INCERTAE SEDIS | | | |
| *Poacites siwalicus* | Garala-Gorah Road, Sudnatti, Poonch, J. & K. | L. Siwalik (Palandri Marl) | Sahni, 1964 |
| *Poacites* spp. A-C | Near Jawalamukhi | Chinji | Mathur, 1978 |
| **Dicotyledons** | | | |
| I. ANNONACEAE | | | |
| 1. *Fissistigma senii* | Balugoloa, near Jawalamukhi, H.P. | L. Siwalik | Lakhanpal, 1969 |
| 2. *Polyalthioxylon indicum* | Kalagarh, U.P. | do | Prakash, 1978 |
| II. DIPTEROCARPACEAE | | | |
| 3. *Anisopteroxylon jawalamukhi* | Khundian, near Jawalamukhi, H.P. | M. Siwalik | Ghosh & Ghosh, 1958 |
| 4. *A. kalagarhensis* | Kalagarh, U.P. | L. Siwalik | Prakash, 1978 |
| 5. *Dipterocarpoxylon sivalicus* | Khokhra, near Nalagarh, H.P. | do | Prakash, 1975 |
| 6. *D. nalagarhense* | do | do | Prakash, 1975 |
| 7. *D. premacrocarpum* | do | do | Prakash, 1975 |
| 8. *D. parabaudii* | Kalagarh, U.P. | do | Prakash, 1978 |
| 9. *D. nungarensis* | Nungarh Nala (Kalagarh), U.P. | do | Trivedi & Ahuja, 1980 |
| 10. *D. surangei* | Kalagarh, U.P. | do | Prakash, 1981 |
| 11. *Dipterocarpoxylon* sp. | Mohand, near Dehradun, U.P. | M. Siwalik | Rawat, 1964 |
| 12. *Shoreoxylon ornatum* (Trivedi & Ahuja) Prakash & Bande | Kalagarh, U.P. | L. Siwalik | Prakash & Bande, 1980; Trivedi & Ahuja, 1979b |
| Synonym: *Pentacmeoxylon ornatum* Trivedi & Ahuja | | | |
| 13. *Vaterioxylon kalagarhense* | Kalagarh, U.P. | L. Siwalik | Trivedi & Misra, 1980 |
| 14. *V. miocenecum* | Kalagarh, U.P. | L. Siwalik | Trivedi & Misra, 1980 |
| III. STERCULIACEAE | | | |
| 15. *Sterculioxylon kalagarhense* | Kalagarh, U.P. | L. Siwalik | Trivedi & Ahuja, 1978a |
| IV. MELIACEAE | | | |
| 16. *Meliaceaephyllum mohagonites* | Bagh Rao, Hardwar, U.P. | Low.Mid. Siwalik | Verma, 1968 |
| 17. *Dysoxydendron kalagarhensis* | Kalagarh, U.P. | L. Siwalik | Trivedi & Misra, 1979 |
| V. RHAMNACEAE | | | |
| 18. *Berchemia balugoloensis* | Balugoloa, near Jawalamukhi, H.P. | L. Siwalik | Lakhanpal, 1967 |
| 19. *Ziziphus sivalicus* | do | L. Siwalik | Lakhanpal, 1967 |
| 20. *Z. champarensis* | Bhikhnathoree, W. Champaran Dist., Bihar | Probably U. Siwalik | Lakhanpal & Awasthi (in Press) |
| 21. *Z. indicus* | 5 km North of Pasighat, Siang Dist., Arunachal Pradesh | Upper Miocene | Singh & Prakash, 1980 |
| VI. ANACARDIACEAE | | | |
| 22. *Dracontomelumoxylon mangiferumoides* Ghosh & Roy | Kalagarh, U.P. | L. Siwalik | Prakash, 1979a, b |
| Synonym: *Dracontomeloxylon palaeomangiferum* Prakash | Kalagarh, U.P. | | |
| 23. *Glutoxylon kalagarhensis* | Kalagarh, U.P. | L. Siwalik | Trivedi & Ahuja, 1978b |
| 24. *Mangifera someshwarica* | Bhikhnathoree, W. Champaran Dist., Bihar | Probably U. Siwalik | Lakhanpal & Awasthi (in Press) |

— *Continued*

TABLE 2 — PLANT MEGAFOSSILS FROM THE SIWALIK SEDIMENTS — *Contd.*

| Fossil | Locality | Horizon/ Formation/ Series/Stage | Reference |
|---|---|---|---|
| VII. LEGUMINOSAE | | | |
| 25. *Albizinium eolebbekianum* | Khokhra near Nalagarh, H.P. | L. Siwalik | Prakash, 1975 |
| 26. *Bauhinioxylon indicum* | Mohand, near Dehradun, U.P. | M. Siwalik | Rawat, 1964-65 |
| 27. *Bauhinia siwalika* | Bhikhnathoree, W. Champaran Dist., Bihar | Probably U. Siwalik | Lakhanpal & Awasthi (in Press) |
| 28. *Cassinium prefistulai* | Khokhra, near Nalagarh, U.P. | L. Siwalik | Prakash, 1975 |
| 29. *C. borooahii* (Prakash) Prakash | Kalagarh, U.P. | do | Prakash, 1978 |
| 30. *Cynometroxylon holdeni* (Gupta) Prakash & Bande Synonym: *Cynometroxylon* sp. cf. *C. indicum* Prakash, *Cynometroxylon siwalicus* Trivedi & Ahuja | Nalagarh, H.P. and Kalagarh, U.P. | do | Prakash & Bande, 1980 |
| 31. *Dalbergia sisso* (Fruit) | Balugoloa, near Jawalamukhi, H.P. | L. Siwalik | Lakhanpal & Dayal, 1966 |
| 32. *Dalbergia* sp. (Leaf) | Bhikhnathoree, W. Champaran Dist., Bihar | Probably U. Siwalik | Lakhanpal & Awasthi (in Press) |
| 33. *Dialiumoxylon kalagarhense* | Kalagarh, U.P. | L. Siwalik | Trivedi & Misra, 1978 |
| 34. *Hopeoxylon eosiamensis* | do | do | Prakash, 1981 |
| 35. *Indigofera prepulchella* | Bhikhnathoree, W. Champaran Dist., Bihar | Probably U. Siwalik | Lakhanpal & Awasthi (in Press) |
| 36. *Millettioxylon pongamiensis* | Nalagarh, H.P. | L. Siwalik | Prakash, 1975 |
| 37. *Pahudioxylon indicum* | do | do | Prakash, 1979b |
| 38. *Papilionid* sp. (Leaf) | Near Jawalamukhi, H.P. | Chinji | Mathur, 1978 |
| VIII. ROSACEAE | | | |
| 39. *Parinarioxylon splendidum* | Kalagarh, U.P. | L. Siwalik | Trivedi & Ahuja, 1979 |
| IX. COMBRETACEAE | | | |
| 40. *Terminalioxylon palaeomanii* | do | do | Prakash, 1981 |
| X. LECYTHIDACEAE | | | |
| 41. *Careyoxylon pondicherriense* Awasthi | Nalagarh, H.P. | do | Prakash, 1979b |
| XI. LYTHRACEAE | | | |
| 42. *Lagerstroemia* sp. (Leaf) | Balugoloa, near Jawalamukhi, H.P. | do | Lakhanpal & Dayal, 1966 |
| XII. APOCYNACEAE | | | |
| 43. *Apocynophyllum* sp. | Dihand Valley, Siang Dist., Arunachal Pradesh | L. Eocene | Tripathi *et al.*, 1979 |
| XIII. EBENACEAE | | | |
| 44. *Diospyros embryopterisites* | Bagh Rao, near Hardwar, U.P. | Lower-Mid. Siwalik | Verma, 1968 |
| 45. *Ebenoxylon miocenicum* | Kalagarh, U.P. | L. Siwalik | Prakash, 1978 |
| 46. *E. siwalicus* | Kalagarh, U.P. | L. Siwalik | Prakash, 1981 |
| XIV. BORAGINACEAE | | | |
| 47. *Boraginocarpus lakhanpalii* | Near Chandigarh | Tatrot | Mathur, 1974 |
| XV. RUBIACEAE | | | |
| 48. *Gardenia palaeoturgida* | Bhikhnathoree, W. Champaran Dist., Bihar | Probably U. Siwalik | Lakhanpal & Awasthi (in Press) |

— *Continued*

TABLE 2 — PLANT MEGAFOSSILS FROM THE SIWALIK SEDIMENTS

| FOSSIL | LOCALITY | HORIZON/ FORMATION/ SERIES/STAGE | REFERENCE |
|---|---|---|---|
| XVI. LAURACEAE | | | |
| 49. *Cinnamomum palaeotamala* | Bhikhnathoree, W. Champaran Dist., Bihar | Probably U. Siwalik | Lakhanpal & Awasthi (in Press) |
| 50 *Cinnamomum tamala* Nee | Mahanadi River Section, near Darjeeling | M. Siwalik | Pathak, 1969 |
| 51. *Litsea prenitida* | Bhikhnathoree, W. Champaran Dist., Bihar | Probably U. Siwalik | Lakhanpal & Awasthi (in Press) |
| 52. *L. polyantha* Juss. | Mahanadi River Section, near Darjeeling | M. Siwalik | Pathak, 1969 |
| 53. *L. bhatiai* | 1.5 km North of Daulatpur Dist., Kangra, H.P. | Tatrot | Mathur, 1978 |
| 54. *Machilus villosa* Hook. | Mahanadi River Section, near Darjeeling | M. Siwalik | Pathak, 1969 |
| 55. *Persea punyagiriensis* | Punyagiri, Tanakpur, U.P. | L. Siwalik | Lakhanpal & Guleria, 1978 |
| XVII. EUPHORBIACEAE | | | |
| 56. *Bridelia stipularis* Bl. | Mahanadi River Section, near Darjeeling | M. Siwalik | Pathak, 1969 |
| 57. *B. verrucosa* Haines | do | do | Pathak, 1969 |
| 58. *Mallotus philippinensis* | do | do | Pathak, 1969 |
| 58a. *Mallotus* sp. | Near Jawalamukhi, H.P. | | Mathur, 1978 |
| XVIII. MORACEAE | | | |
| 59. *Ficus precunia* | Balugoloa, near Jawalamukhi, H.P. | L. Siwalik | Lakhanpal, 1968 |
| 60. *F. champarense* | Bhikhnathoree, W. Champaran Dist., Bihar | Probably U. Siwalik | Lakhanpal & Awasthi (in Press) |
| XIX. ERICACEAE | | | |
| 61. *Rhododendron lepidotum* | Mahanadi River Section, near Darjeeling | M. Siwalik | Pathak, 1969 |
| XX. CUPULIFERAE | | | |
| 62. *Castanopsis tribuloides* ADC | Mahanadi River Section, near Darjeeling | M. Siwalik | Pathak, 1969 |
| XXI. INCERTAE SEDIS | | | |
| 63. *Dicotylophyllum* spp. 1-4 | Koshalya River beds, near Kalka water works, H.P. | Nahan (L. Siwalik) | Dayal & Chaudhri 1967 |
| 64. *Dicotylophyllum dioscoreoides* | 5 km north of Pasighat, Siang Dist., Arunachal Pradesh | Upper Miocene | Singh & Prakash, 1980 |
| 65. *Phyllites* sp. cf. *Phyllites kamrupensis* Seward | Road Cutting, Kimin-Ziro Road, Subansiri Dist., Arunachal Pradesh | Tertiary | Chaudhry *et al.*, 1970 |
| 66. *Eucalyptophyllum raoi* | Bagh Rao, Hardwar, U.P. | M. Siwalik | Verma, 1968 |
| 67. *Croton tegilis* | do | do | Verma, 1968 |
| 68. *Dryoxylon nahanai* | Khokhra, near Nalagarh, H.P. | L. Siwalik | Prakash, 1975 |

some well-preserved dicotyledonous and monocotyledonous leaf-impressions belonging to the families Smilacaceae, Annonaceae, Rhamnaceae, Lythraceae, Moraceae and a fruit of *Dalbergia*.

With regard to the petrified wood from Jawalamukhi area so far only a single wood, *Anisopteroxylon jawalamukhi*, has been described by Ghosh and Ghosh (1958) from the Middle Siwalik beds near Khundian

Village. Further records of fossil woods from this area are lacking.

Rich deposits of plants comprising exclusively of petrified woods have been found in the vicinity of Nalagarh. The rocks in which these fossils occur are attributed to the Nahan beds which correspond to the Chinji Stage. Extensive studies of these petrified woods have been carried out by Prakash (1975, 1979a, 1979b) who described 11 species belonging to the dicotyledonous families, viz., Annonaceae, Dipterocarpaceae, Leguminosae, Anacardiaceae and Lecythidaceae. Similar deposits of petrified dicotyledonous woods have also been found in the Lower Siwalik beds near Dhaula Kuan in Nahan District. Although they have not yet been studied in detail, preliminary examination of the material made by Dr U. Prakash (Personal communication) has revealed that most of the woods belong to the family Dipterocarpaceae and a leguminous genus *Cynometra*. To the east of Nalagarh, near Kalka, from Nahan Formation (=Kamlial-Chinji sequence of Lower Siwaliks) Dayal and Chaudhuri (1967) in a brief note illustrated four dicotyledonous leaves and assigned to a genus *Dicotylophyllum*. These leaves are so badly preserved that they cannot be identified to the generic or family level.

Recently Mathur (1978) has described a few leaf-impressions from the Lower Siwalik (Chinji Formation) near Jawalamukhi and the Upper Siwalik (Tatrot Formation) near Daulatpur, Kangra District. One of the leaves belonging to Upper Siwaliks is complete and shows all the details of venation. He identified it with the leaves of *Litsea* and named *Litsea bhatiai*, whereas those collected from the Lower Siwalik are named as *Papilionid*, *Mallotus* sp. and *Poacites* sp. A, B and C. Since these leaves are incomplete, nothing can be definitely said about their identification. Besides leaves, from Tatrot Formation Mathur (1974) reported a seed as *Boraginocarpus lakhanpalii* of the family Boraginaceae from near Chandigarh.

It has been observed that the charophytic remains are quite commonly found in the Siwalik sediments. Bhatia and Mathur (1970, 1978) and Tewari and Sharma (1972a) have investigated extensively a large number of Charophytic gyrogonites from different localities situated near Chandigarh, Pinjore and in Kangra District. In all they have recognized 15 species belonging to the genera *Chara*, *Hornichara*, *Sphaerochara* and *Tectochara*. Bhatia and Mathur (1970) also highlighted the significance of fossil charophytes in the biostratigraphic subdivision of the Siwalik Group.

In the Himalayan foot-hills of Uttar Pradesh there are a number of fossil localities from which rich collections of plant megafossils have been made in recent years. Rawat (1964, 1964-65) described two dicotyledonous woods, viz., *Dipterocarpoxylon* sp. and *Bauhinioxylon indicum* from the Middle Siwalik beds of Mohand near Dehradun. Another fossil locality exposed at Kalagarh is also very rich in petrified woods. There are a number of streams coming down from the small hills in which the fossil woods occur quite frequently. It is believed that they have been derived from the Lower Siwalik sediments. Systematic study of these woods has been carried out by Prakash (1978, 1981), Trivedi and Ahuja (1978a, 1978b, 1978c, 1979a, 1979b, 1980) and Trivedi and Misra (1978, 1979, 1980) who identified most of them with the modern genera belonging to the families Annonaceae, Sterculiaceae, Dipterocarpaceae, Meliaceae, Anacardiaceae, Leguminosae, Rosaceae Combretaceae and Ebenaceae. As far as their identification is concerned, some of the woods described by Trivedi and Ahuja (1979a) and Trivedi and Misra (1980) do not exhibit the characters of the modern genera or species to which they have been compared. One of them is *Parinarioxylon splendidum* of the family Rosaceae which has been compared with the modern species of *Parinarium*. The anatomical features of this fossil as shown in the photograph do not conform with those of *Parinarium* but appears to be very similar to those of the wood which Prakash (1978) described as *Ebenoxylon miocenicum* of the family Ebenaceae from the same locality. Similarly, two species of *Vateri-oxylon* have been created by Trivedi and Misra (1980). These seem to be either *Anisoptera* or *Dipterocarpus* which are already reported from this area. *Pentacmeo-xylon ornatum* another dipterocarpaceous wood is described by Trivedi and Ahuja (1979b) showing its close resemblance with the woods of *Pentacme*. Anatomically the woods of *Parashorea*, *Shorea* and *Pentacme*

are so similar that they cannot be differentiated from each other, and hence it is very difficult to decide whether the fossil wood described by Trivedi and Ahuja belongs to *Pentacme* or *Parashorea* or *Shorea*. Such fossil woods are usually placed under the genus *Shoreoxylon*. So in view of this Prakash and Bande (1980) treated the genus *Pentacmeoxylon* Trivedi & Ahuja as synonym of *Shoreoxylon* and changed the name of fossil wood from *Pentacmeoxylon ornatum* to *Shoreoxylon ornatum* (Trivedi & Ahuja) comb. nov.

The Siwalik beds near Hardwar, locally known as " Hardwar beds " also comprise plant fossils. Varma, in 1968, described some leaf-impressions belonging to four species. Two of them are *Meliaceaphyllum mohgonites* and *Diospyros embryopterisites* which have been shown to resemble Meliaceae in general and *Diospyros* of Ebenaceae respectively. Out of the remaining two, one is identified with the leaves of *Eucalyptus* and named *Eucalyptophyllum raoi*. This needs reinvestigation as the genus *Eucalyptus* is a native of Australia whose occurrence in the Indian Tertiary is beyond imagination. The leaf described as *Croton* cf. *C. tegelis* also needs critical reinvestigation.

In the foot-hills of Nainital District the Siwaliks are well-exposed along the Kathgodam-Nainital Road, Kathgodam-Bhimtal Road, Ranibagh-Amritpur Road and along the Gola River. From a small patch in front of Ranibagh, recently we collected a few leaf-impressions preserved in the dark grey micaceous shales. These are yet to be studied.

From near Tanakpur, the eastern most part of Kumaon foot-hills just bordering the Sharada River at the Nepalese frontier, Misra and Valdiya (1961) reported the occurrence of leaf-impressions in the road cutting along the river on the southern side of Punyagiri. Preliminary examination of the material collected from this area by the author in 1967, 1968 and 1972 has revealed that there is a great variety of leaves, although so far only one leaf has been described by Lakhanpal and Guleria (1978) as *Persea punyagiriensis* sp. nov. showing close resemblance with *Persea odoratissima* and *P. gamblei* of the family Lauraceae. From the same section exposed along the road cutting Lakhanpal, Jain and Kapoor (1976) described charophytic gyrogonites, recovered from a clay shale band overlain and underlain by fine grained sandstones. In all they have recognised four species belonging to *Charites*, *Chara*, *Raskyaechara* and *Sphaerochara*.

Near Jarwa in Gonda District, Uttar Pradesh from Koilabas village, about 1 km inside the Nepal Territory, recently we also collected some well-preserved angiospermous leaf-impressions. They are found in dark grey shales exposed along the upstream of a small river. The exact stratigraphical position of these fossiliferous beds within the Siwalik Group is not definitely known, though the rock matrix and the leaf-impressions appear preserved therein more or less similar to those of the Lower Siwalik of Tanakpur.

In the foot-hills of Bihar also, the Siwalik beds are exposed all along the Indo-Nepal border. One of the exposures, which lies a few meters on the Nepal side from the National boundary Post No. 35 at Bhikhnathoree, West Champaran District, has yielded about 35 distinct types of angiospermous leaf-impressions belonging to several genera of dicotyledonous families. Of these, Lakhanpal and Awasthi (in Press) have described nine species showing close resemblance with the modern species: *Ziziphus jujuba*, *Mangifera indica*, *Bauhinia corymbosa* and *B. tomentosa*, *Indigofera pulchella*, *Dalbergia* spp., *Gardenia turgida*, *Litsea nitida*, *Cinnamomum tamala* and *Ficus* spp. One of the characteristic features of this floral assemblage is that the leaves in general are smaller than the normal size of their modern equivalents.

From the Middle Siwalik beds of Darjeeling Himalayas Pathak (1969) for the first time reported some leaf-impressions from the Mahanadi section, near Darjeeling, borne on the massive compact, dark coloured carbonaceous shale. The leaves have been assigned to 8 species, viz., *Castanopsis tribuloides*, *Cinnamomum tamala*, *Machilus villosa*, *Litsea polyantha*, *Bridelia stipularis*, *B. verrucosa*, *Mallotus philippinensis* and *Rhododendron lepidotum*. Since most of the specimens are incomplete without base and apex it is difficult or rather impossible to identify such leaves with the modern species and therefore Pathak's identification should be considered as provisional.

The Upper Tertiary rocks of north-east Himalaya (Arunachal Pradesh) have been

correlated with the Siwalik sediments of the western Himalaya. They are known as Lower Subansiri, Upper Subansiri and Kimin. The plant fossils have been reported only from three places. Chaudhury, Das and Ahmed (1970) have described an incomplete leaf, collected from a road cutting near 20 km Post (from Kimin) along the Kimin-Zero Road in the Subansiri District, Arunachal Pradesh. The leaf has been compared with *Phyllites kamrupensis* Seward (1912) described from the Coal Measures of Assam. They have assigned the beds to Middle to Upper Miocene. Recently Singh and Prakash (1980) have reported two well-preserved leaf-impressions resembling *Ziziphus* of Rhamnaceae and *Dioscoria* of Dioscoriaceae respectively, from a Siwalik bed exposed about 5 km north of Pasighat in Siang District.

A few years back Dr S. K. Dutta of Dibrugarh University collected some pieces of petrified woods from the Upper Subansiri of Ghogra River section in Siang District and near Kimin in Subansiri District of Arunachal Pradesh. This small collection, investigated by me, has yielded about 10 forms showing close resemblance with the modern woods of *Shorea*, *Euphoria*, *Gluta-Melanorrhoea*, *Albizia*, *Afzelia-Intsia*, *Cynometra*, *Cassia* and *Sindora*.

## DISCUSSION

Plant megafossils are reliably used in deciphering the ecology and phytogeography of the fossil floras particularly those of the Cenozoic era. This is because of the fact that they are mostly entomed in the sediments not far from the place of their existence. Secondly, the megafossils can be identified in most of the cases in terms of the modern genera and species.

The floral assemblages of the pre-Siwalik Tertiary of the Himalaya are too small to surmise any definite conclusion about the climatic conditions. Most of the plants constituting the assemblages are either palm or palm-like leaves whose exact affinities with the modern species are not known.

From the foregoing review of the plant megafossils of the Siwalik Group it is evident that majority of the taxa are from the Lower Siwalik sediments. The modern species with which they have been identified are: *Smilax* spp., *Polyalthia simiarum*, *Fissitigma wallichi*, *Anisoptera scaphula*, *Dipterocarpus indicus*, *D. dyerii*, *D. macrocarpus*, *S. baudii*, *D. tuberculatus*, *Berchemia floribunda*, *Ziziphus incurva*, *Sterculia* spp., *Gluta-Melanorrhoea* spp., *Dracontomelum mangiferum*, *Dysoxylum* spp., *Albizia lebbek*, *Cassia fistula*, *Cynometra polyandra*, *Dalbergia sisso*, *Millettia prainii*, *Afzelia-Intsia* spp.. *Sindora siamensis*, *Terminalia manii*, *Careya arborea*, *Lagerstroemia indica*, *Diospyros brandisiana*, *D. kurzii*, *D. embryopteris* and *Ficus cunea*. Excepting a few which still survive in the foot-hills, most of these species occur today in the tropical evergreen to semi-evergreen or deciduous forests of Western Ghats, north-east India, Bangladesh, Burma and elsewhere in south-east Asia. On the basis of these plants it has reasonably been concluded by Lakhanpal (1970), Vishnu-Mittre (1979) and Prakash (1979b) that warm humid climate with high precipitation prevailed all along the Himalayan foot-hills during the Lower Siwalik sedimentation. Now the question arises as to how and where from these tropical evergreen plants came in the Himalayan foot-hills. Close similarity of the Lower Siwalik plants with the corresponding floral assemblages of the peninsular India (Awasthi, 1974), Burma (Prakash, 1973) and south-east Asia (Schweitzer, 1958; Kramer, 1974, 1975) as well as with the present day tropical evergreeen flora of south-east Asia provides a supporting evidence to the assumption that the Lower Siwalik plants may have come from south-east Asia. During the Miocene, with the Himalayan upheaval large areas previously occupied by the Tethys sea were converted into land with numerous water basins. This major geographical change brought about significant change in the climatic conditions in this region which became more warm and humid. As a result, the south-east Asian tropical wet evergreen and semi-evergreen plants led by dipterocarps entered the Himalayan foot-hills replacing or dominating over the so-called Murree and Kasauli floras. How long and under what conditions these plants remained there is yet to be definitely ascertained through the study of fossils. But there are some indications about their continuation in the Middle Siwaliks as evidenced by the occurrence of *Dipterocarpus* in the Middle Siwalik beds near Mohand. Recent discovery of some fossil woods in the Upper Subansiri

sediments of Arunachal Pradesh also confirms that warm humid conditions existed in the Himalayan foot-hills of north-east India. In this floral assemblage almost the same elements are present which are reported from the Lower Siwaliks of Uttar Pradesh and Himachal Pradesh.

Regarding the environmental conditions during the Upper Siwaliks there is a consensus of opinion among the various geologists that the fourth upheaval of the Himalaya took place at the onset of the Upper Siwalik sedimentation by which time the warm humid climate had gradually changed into distinctly colder and drier. This might have adversely affected the surviving tropical evergreen forests which eventually disappeared and were replaced by the subtropical or temperate moist deciduous or dry deciduous forests. Evidences in favour of the above view are provided by our recent studies of the leaf-impressions from the Siwalik beds (probably Upper Siwalik) of Bhikhnathoree, Bihar. In a fairly rich assemblage of leaves comprising about 35 distinct forms, there is none to represent the family Dipterocarpaceae which was so dominant at the time of its deposition in the Lower and Middle Siwaliks. Most of the modern equivalents of Bhikhnathoree leaves are found in dry deciduous forests even though some of them may have a wider distribution in moister forests also. Further, the leaves on the whole are smaller in size than their modern counterparts. All these features strongly suggest that dry or arid conditions might have prevailed in this region during the Upper Siwalik sedimentation.

The inferences made above are still considered as generalized and tentative since they are based on sporadic and insufficient records of plant megafossils. From the available information furnished in the foregoing account it is quite evident that there are rich treasures of various kinds of plants in almost all the Tertiary sediments of the Himalaya. Their extensive collection and systematic studies are needed in order to build up complete floristic successions in a chronological sequence and to throw light on the climatic changes that took place with the result of Himalayan upheaval at different intervals since the beginning of the Cenozoic era. The palaeobotanical data thus accumulated can also be successfully used in broad stratigraphical subdivisions and correlations of strata.

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