Palaeobotanist 49 (2000) : 225-237
0031-0174/2000/225-237 $2.00

Study of plant megafossils from the Tura Formation of Nangwalbibra, Garo Hills, Meghalaya, India

R.C. MEHROTRA

Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India.

(Received 05 April 1999; revised version accepted 07 October 1999)

ABSTRACT

Mehrotra RC 2000. Study of plant megafossils from the Tura Formation of Nangwalbibra, Garo Hills, Meghalaya, India. Palaeobotanist 49(2) : 225-237.

Leaf-impressions collected from the Tura Formation (Upper Palaeocene) of Nangwalbibra, Garo Hills, Meghalaya belong to *Grewia* of Tiliaceae, *Atalantia* of Rutaceae, *Schleichera* of Sapindaceae, *Mangifera* of Anacardiaceae, *Terminalia* as well as *Calycopteris* of Combretaceae, *Syzygium* of Myrtaceae and *Chrysophyllum* of Sapotaceae. In addition, a few palm leaves of uncertain affinities are also described. The modern comparable forms of the fossils indicate a tropical warm and humid climate in the area during the deposition of the beds.

Key-words—Leaf-impressions, Angiosperms, Tura Formation, Garo Hills, Upper Palaeocene.

मेघालय की गारो पर्वत श्रेणियों के नांगवलबिबरा अवस्थित तूरा शैलसमूह से प्राप्त पादप गुरूपादपाश्मों का अध्ययन

राकेश चन्द्र मेहरोत्रा

सारांश

मेघालय की गारो पर्वतश्रेणियों के नांगवलबिबरा में अवस्थित तूरा शैलसमूह (उपरि पेलियोसीन) से पर्ण मुद्राश्म एकत्र किये गये, जो टीलिएसी के *ग्रीविया,* रूटेसी के *अटेलैन्सिया,* सैपिण्डेसी के *स्लीचेरा,* एनाकार्डिएसी के *मैंजीफ़ेरा,* कॉम्ब्रीटेसी के *टर्मिनेलिया* एवं *कैलीकॉप्टेरिस,* मिर्टेसी के *साइज़ीजियम* तथा सैपोटेसी के *क्राइजोफ़िल्लम* से सम्बन्धित हैं. इसके अतिरिक्त अनिश्चित बन्धुता की कुछ खजूर की पत्तियाँ भी अभिलक्षणित की गई हैं. पादपों के आधुनिक तुलनीय रूप से संस्तरों के निक्षेपण के दौरान क्षेत्र में उष्णकटिबन्धीय, आर्द्र एवं उष्ण जलवायु का संकेत मिलता है.

संकेत शब्द—पर्ण मुद्राश्म, आवृतबीजी, तूरा शैलसमूह, गारो पर्वतश्रेणियाँ, उपरि पेलियोसीन.

INTRODUCTION

THE rocks of the Tura Formation are well exposed near Nangwalbibra (25°28' N, 90° 42' E), a town situated near Williamnagar, East Garo Hills District, Meghalaya. The plant bearing beds are located on the right bank of the Nangal stream within an area of 3 km. The fossils are found in greyish-white to buff coloured clay stones ranging 3·05-3·66 m in thickness. The locality map (Fig. 1) and litholog of the area are already given by Bhattacharyya (1983) and Saxena *et al.* (1996).

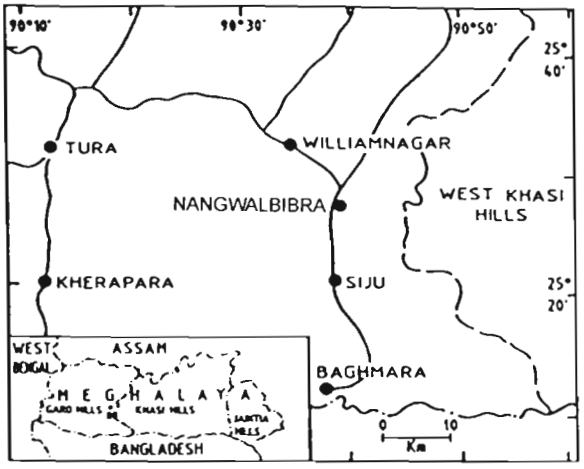


Fig. 1— A map showing the fossiliferous locality near Williamnagar (after Saxena *et al.*, 1996).

however, the general stratigraphic sequence noticed in the area is given below in Fig. 2. As evident from this figure the Tura Formation is considered as Upper Palaeocene in age (Saxena *et al.*, 1996; Mehrotra *et al.*, 1998).

The average annual rainfall in the Garo Hills varies from 250 cm to 320 cm. The climate is moderate during winter, but gradually becomes warmer from middle of March. The monsoon sets in from mid-May and the area is covered with a thick forest of mostly deciduous trees having a thick undergrowth of thorny bushes.

The fossil flora of Nangwalbibra is not well known and only a few plant fossils are described from the area. Lakhanpal (1964) first recorded a palm leaf from this area. Later, Bhattacharyya (1983) described several forms, namely *Nelumbo nagalensis* (Nymphaeaceae), *Litsea* sp., *Phoebe sublanceolata* (Lauraceae), *Artocarpus garoensis* (Moraceae), *Triumfetta rhomboideocarpa* (Tiliaceae), *Heteropanax* sp. (Araliaceae), *Osmanthus eocenicus, Ligustrum turaense, Antholithes oleaceaeformis, A. campanulatus* (Oleaceae), *Nipa sahnii* (Palmae) and *Poacites* sp.

A field excursion was undertaken to ascertain the palaeofloral composition of the Garo Hills, Meghalaya and a large number of plant megafossils were collected from the Tura Formation of Nangwalbibra. Most of the fossils are in the form of leaf-impressions, a few fruits and seeds were also collected from the same locality. Some are complete and well preserved while others are fragmentary in nature.

All the type specimens, negatives etc. of the fossils being described in the paper are deposited in the repository of the Birbal Sahni Institute of Palaeobotany, Lucknow.

The terminology used in describing leaves is after Hickey (1973) and Dilcher (1974). The identification of leaves was done by comparing them with the herbarium sheets at Forest Research Institute (FRI), Dehradun; Central National Herbarium (CNH), Howrah and Birbal Sahni Institute of Palaeobotany (BSIP), Lucknow.

Age	Group	Lithology
Oligocene		Simsang Formation (100 m thick)
Eocene-Palaeocene	Jaintia	Kopili Formation (450 m to 500 m thick)
		Siju Limestone (100 m to 160 m thick)
		Tura Formation (180 m to 250 m thick)
Upper Cretaceous		Coarse grained sandstone and conglomerate (60 m thick)
----------Unconformity----------		
Precambrian		Coarse grained granite ganodiorites, banded gneiss and quartzite

Fig. 2—General stratigraphic sequence of Garo Hills, Meghalaya (after Raja Rao, 1981).

SYSTEMATICS

DICOTYLEDONS

Family—TILIACEAE Bentham & Hooker f.

Genus—GREWIA Linnaeus

Species—GREWIA SAHNII (Lakhanpal) comb. nov.

Pl. 1·1

Neolitsea sahnii

1954 Lakhanpal, p. 28, Pl. 1, figs 3, 4.

Description—Leaf simple, more or less complete, symmetrical, elliptic, about 9·0 x 4·0 cm in length and width respectively; apex slightly broken but appearing acute; base asymmetrical, obtuse, normal; margin entire; texture appearing chartaceous; petiole length and width about 1·3 x 1·5 cm respectively, normal; venation acrodromous, basal, imperfect; primary veins (1°) three in number, mid-rib stout, slightly curved near the apex, a pair of lateral primaries coming off at base at an angle of 25°-30° and running up to the middle of the leaf; secondary veins (2°) arising from the mid-rib at about one third of its length from the base, about 10 pairs visible, alternate, 6-11 mm apart, angle of divergence moderately acute to narrow acute (60°-40°), decreasing gradually towards the apex, abruptly curved near the margin to form loops, joining

superadjacent secondaries at right angle to sometimes at acute angle, moderately thick; intramarginal vein absent; tertiary veins (3°) fine, angle of origin usually RR, pattern percurrent, simple, obliquely placed, predominantly alternate, close, some arising directly from mid-rib to join with the lateral veins; higher order venation present; areoles well developed, oriented, usually quadrangular, medium to small, vein-lets not observed.

Holotype—Specimen no. BSIP 38086.

Occurrence—Tura Formation; Nangwalbibra near Williamnagar, East Garo Hills District, Meghalaya; Upper Palaeocene.

Affinities—The important features of the fossil leaf are : acrodromous basal imperfect venation, asymmetrical base, entire margin, elliptic shape, secondary veins forming loops and percurrent tertiary veins. These characters indicate its affinities with *Grewia* Linnaeus of Tiliaceae. Further identification of the fossil leaf up to specific level is very difficult as there are lot of variations in leaf structure among different species of *Grewia*. The base varies from asymmetrical to symmetrical (*Grewia laevigata* Vahl, Herbarium Sheet Nos FRI 2362, 62203), while the margin varies from serrate to partially serrate to entire (*G. calophylla* Kurz, Herbarium Sheet Nos CNH 80761, 1924).

Though fossil woods (Bande & Srivastava, 1995) and fruit (Paradkar & Dixit, 1984) of *Grewia* are of common occurrence in the Deccan Intertrappean beds of India, its only leaf, *G. foxii* Lakhanpal (1954), is known from the Eocene of Damalgiri, Tura District, Meghalaya. It differs from the present fossil in having serrate-crenate margin, ovate shape, smaller size and twisted petiole. A few years back Srivastava *et al.* (1992) also described a fossil leaf of *Grewia tiliaefolia* Vahl from the Pleistocene beds of Mahuadanr, Palamu District, Bihar. It also differs from the present fossil in having toothed margin.

Lakhanpal (1954) also described a fossil leaf, *Neolitsea sahnii* Lakhanpal, resembling *Neolitsea zeylanica* of Lauraceae from the Damalgiri beds. The venation pattern of this fossil leaf (Lakhanpal, 1954, p. 28, pl. 1, figs 3, 4) appears to be basal acrodromous, while it is suprabasal acrodromous in case of *Neolitsea zeylanica* (Herbarium Sheet Nos BSIP 2664, 2665). Therefore, it cannot be the fossil leaf of *Neolitsea*. As the present fossil is identical to *N. sahnii*, it has been merged with it and both are named as *Grewia sahnii* (Lakhanpal) comb. nov., the revised specific diagnosis of which is given below:

Specific diagnosis

GREWIA SAHNII (Lakhanpal) comb. nov.

Leaf simple, symmetrical, elliptic; apex acute; base asymmetrical, obtuse, normal; margin entire; venation acrodromous, basal, imperfect; primary veins three in number, mid-rib stout, a pair of lateral primaries coming off at base and running up to the middle of the leaf; secondary veins arising from the midrib at about one third of its length from the base, alternate, angle of divergence moderately acute to narrow acute, decreasing gradually towards the apex, abruptly curved near the margin to form loops with the superadjacent secondaries; tertiary veins percurrent, simple, obliquely placed, predominantly alternate, close, some arising directly from the mid-rib to join with the lateral veins.

Species—GREWIA GAROENSIS (Lakhanpal) comb. nov.

Pl. 1·2

Trema garoensis

1954 Lakhanpal, p. 27-28, Pl. 1·1, 2

Description—Leaf more or less complete with slightly broken apex, simple, symmetrical to slightly asymmetrical, narrow ovate; preserved length (including petiole) 11·5 cm, maximum width 4·4 cm; apex appearing acute; base symmetrical; margin serrate, acute, apical side concave to straight, basal side straight; sinuses angular, spacing more or less regular, simple on complete margin; texture seemingly chartaceous; attachment with petiole normal; petiole 2·5 cm in length and 2 mm in thickness; venation acrodromous, imperfect; primary veins three, one straight and moderately thick called mid-rib, two laterals coming off at the base at an angle of 40° and running half way of the lamina length; secondary veins 7 pairs visible, arising slightly above the base, alternate, 0·8-1·6 cm apart, angle of divergence narrow to moderately acute (30°-50°), upper pairs more acute than lower, moderately thick, uniformly curved, sometimes joining superadjacent secondaries; intersecondary veins not present; intramarginal veins absent; tertiary veins percurrent, angle of origin RR-AR, unbranched, obliquely placed, predominantly alternate, close; higher order venation of 4th order; areoles well developed, oriented, quadrangular.

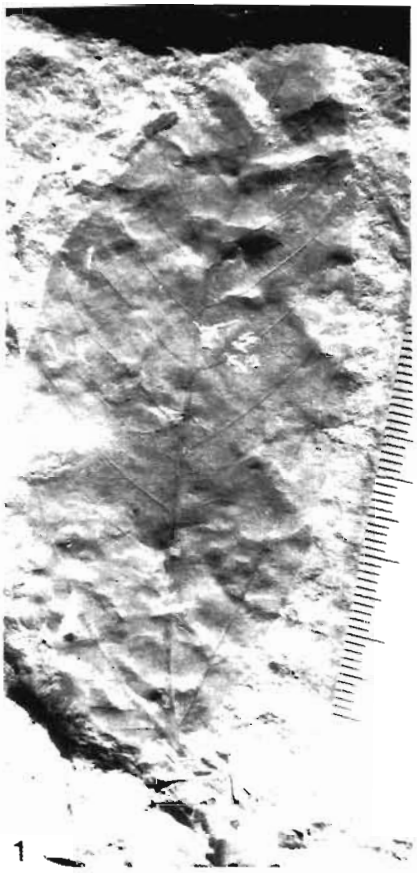
Holotype—Specimen no. BSIP 38087.

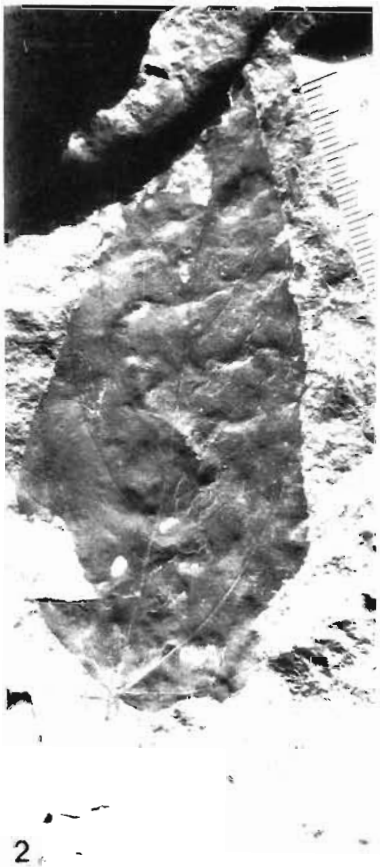
Occurrence—Tura Formation; Nangwalbibra near Williamnagar, East Garo Hills District, Meghalaya; Upper Palaeocene.

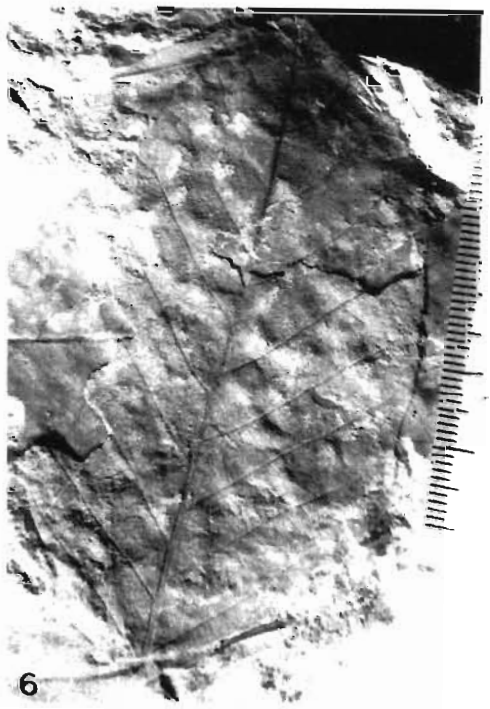
Affinities—The diagnostic features of the fossil, viz., serrate margin, asymmetrical base, narrow ovate shape and acrodromous venation indicate its affinities with that of *Grewia* Linnaeus, especially *G. laevigata* Vahl. (Herbarium Sheet No. CNH 62203) of Tiliaceae.

Grewia foxii Lakhanpal (1954) is the only leaf of *Grewia* known in the fossil state. The present fossil differs from it in size and angle of divergence of lateral primaries.

Lakhanpal (1954) described another fossil leaf, *Trema garoensis* Lakhanpal resembling *Trema orientalis* Blume of Ulmaceae from the Damalgiri beds near Tura (Lakhanpal, 1954, p. 27-28, pl. 1, figs 1, 2). This fossil leaf is exactly similar with the present fossil leaf of *Grewia* . In order to







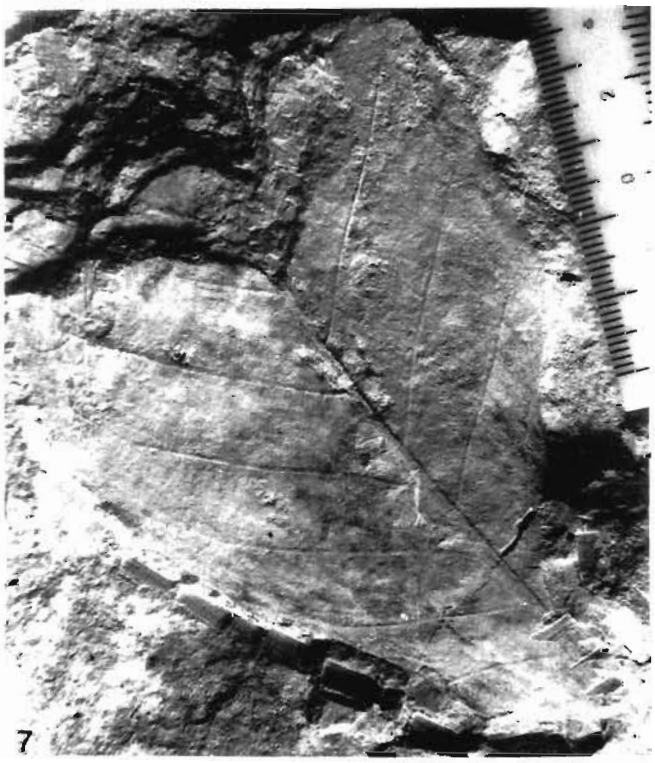


PLATE 1

confirm the identification herbarium sheets of *Trema orientalis* (Herbarium Sheet Nos BSIP 11829-11831) were critically examined and it was observed that secondary veins in *T. orientalis* are mostly straight and are not forming loops whereas in *T. garoensis* the secondary veins are uniformly curved forming loops. It does not appear to be the leaf of *Trema*. As the present fossil leaf of *Grewia* is identical to *T. garoensis* Lakhanpal, it has been merged with it and both are named as *Grewia garoensis* (Lakhanpal) comb. nov., the revised specific diagnosis of which is given below:

Specific diagnosis

GREWIA GAROENSIS (Lakhanpal) comb. nov.

Leaf simple, symmetrical to slightly asymmetrical, narrow ovate to oblong; apex acute; base symmetrical to asymmetrical; margin serrate; venation acrodromous, imperfect; primary veins three, one straight called mid-rib, two laterals coming off at the base and running half way of the lamina length; secondary veins arising slightly above the base, alternate, angle of divergence narrow to moderately acute, upper pairs more acute than lower, moderately thick, uniformly curved, sometimes joining superadjacent secondaries to form loops; tertiary veins percurrent, close.

Family—RUTACEAE Bentham & Hooker f.

Genus—ATALANTIA Correa

Species—ATALANTIA PALAEOMONOPHYLLA sp. nov.

Pl. 1·3,5

Description—Leaf narrow ovate, symmetrical, preserved lamina length 4 cm, maximum width 1·6 cm; apex broken; base obtuse, normal; margin entire; texture membranaceous; venation brochidodromous; primary vein stout, more or less straight; secondary veins more than 10 pairs visible, alternate, 1-3 mm apart, angle of divergence moderately acute (50°-60°), uniform, abruptly curved to form loops, moderately thick; intersecondaries frequently present, simple to composite; tertiary veins fine, random reticulate; areoles well developed.

Etymology—From *Atalantia monophylla*.

Holotype—Specimen no. BSIP 38088.

Occurrence—Tura Formation; Nangwalbibra near Williamnagar, East Garo Hills District, Meghalaya; Upper Palaeocene.

Affinities—The diagnostic features of the fossil are small size, narrow ovate shape, entire margin, membranaceous texture, brochidodromous venation, closely placed secondaries with moderately acute angle of divergence, frequent intersecondaries and random reticulate tertiaries. These characters indicate its close resemblance with *Atalantia* Correa of Rutaceae. Among its various species the fossil shows maximum resemblance with *A. monophylla* (Roxburgh) Decandolle (Herbarium Sheet No. FRI 21320).

This is the first record of a fossil leaf of *Atalantia* though the fossil woods resembling *Atalantia* are known from the Deccan Intertrappean beds of Mandla District, Madhya Pradesh (Lakhanpal *et al.*, 1978). The present fossil leaf is being named as *Atalantia palaeomonophylla*, the specific epithet indicating its resemblance with *A. monophylla*.

The genus *Atalantia* consists of 20 species of which only five are found in India. They are usually evergreen shrubs. *A. monophylla* with which the present fossil shows maximum similarities, is found in South India (Santapau & Henry, 1973).

Specific diagnosis

ATALANTIA PALAEOMONOPHYLLA sp. nov.

Leaf narrow ovate, symmetrical; base obtuse, normal; margin entire; texture membranaceous; venation brochidodromous; primary vein stout, straight; secondary veins alternate, angle of divergence moderately acute, uniform, abruptly curved to form loops, moderately thick; intersecondaries frequently present, simple to composite; tertiary veins random reticulate.

Family—SAPINDACEAE Bentham & Hooker f.

Genus—SCHLEICHERA Willd.

Species—SCHLEICHERA PALAEOTRIJUGA sp. nov.

Pl. 1·7

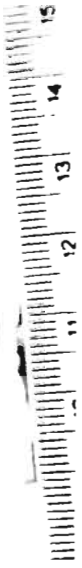
Description—Lamina well preserved, elliptic, symmetrical; preserved length 8·6 cm, maximum width 5 cm; apex slightly broken but appearing acute; base seemingly obtuse, normal; margin entire; texture chartaceous; venation eucamptodromous; primary vein moderate, straight; secondary veins 9

←

PLATE 1

(All figures are in natural size unless otherwise mentioned)

1. A fossil leaf of *Grewia sahnii* (Lakhanpal) comb. nov. showing shape, size and venation pattern; Specimen no. BSIP 38086.
2. A fossil leaf of *Grewia garoensis* (Lakhanpal) comb. nov. showing shape, size and venation pattern; Specimen no. BSIP 38087.
3. A fossil leaf of *Atalantia palaeomonophylla* sp. nov. showing shape and size; Specimen no. BSIP 38088.
4. A modern leaf of *Atalantia monophylla* showing similar shape, size and venation pattern.
5. A portion of *Atalantia palaeomonophylla* sp. nov. enlarged to show details of venation; Specimen no. BSIP 38088. x 3.
6. A fossil leaf of *Schleichera palaeotrijuga* sp. nov. showing shape, size and venation pattern; Specimen no. BSIP 38089.
7. A fossil leaf of *Terminalia palaeocatappa* Awasthi and Mehrotra showing shape, size and venation pattern; Specimen no. BSIP 38091.



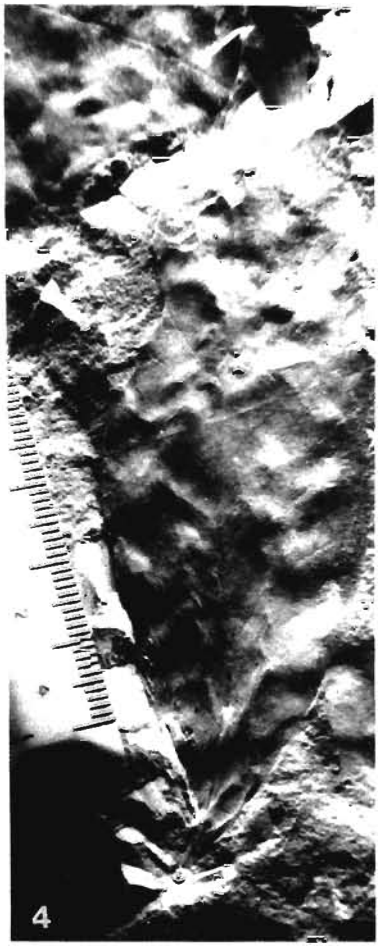


PLATE 2

pairs visible, each 8-12 mm apart, alternate, angle of divergence moderately acute (45°-50°), upper pairs more acute than lower, moderately thick, uniformly curved; intersecondary veins observed near apex; intramarginal veins absent; tertiary veins percurrent, fine, simple to forked, sometimes recurved also, oblique, close, predominantly alternate; further details not visible.

Etymology—From *Schleichera trijuga*.

Holotype—Specimen no. BSIP 38089.

Occurrence—Tura Formation; Nangwalbibra near Williamnagar, East Garo Hills District, Meghalaya; Upper Palaeocene.

Affinities—The important features of the fossil, viz., elliptic shape, entire margin, eucamptodromous venation, moderately acute angle of divergence of secondary veins, presence of intersecondary veins and percurrent tertiaries indicate its affinities with *Schleichera trijuga* Willd. of Sapindaceae.

There is no previous report of the fossil leaf of *Schleichera* from India though its woods are known from Kankawati Series of Gujarat (Awasthi *et al.*, 1982). Therefore, it is being described here as a new species of *Schleichera, S. palaeotrijuga* sp. nov.

Schleichera trijuga is a tree found in dry forests of North west Himalayas, throughout Central and Northern India, Myanmar and Sri Lanka.

Specific diagnosis

SCHLEICHERA PALAEOTRIJUGA sp. nov.

Lamina elliptic, symmetrical; apex acute; base obtuse, normal; margin entire; texture chartaceous; venation eucamptodromous; primary vein moderate, straight; secondary veins alternate, angle of divergence moderately acute, upper pairs more acute than lower, moderately thick, uniformly curved; intersecondary veins present; tertiary veins percurrent, fine, simple to forked, sometimes recurved also, oblique, closely placed.

Family—ANACARDIACEAE Bentham & Hooker f.

Genus—MANGIFERA Linnaeus

Species—MANGIFERA SOMESHWARICA Lakhanpal & Awasthi, 1984

Pl. 2·3

Description—Leaf incomplete without apex, symmetrical, lorate, preserved length 16·5 cm, maximum width 3·5 cm; apex broken; base symmetrical, appearing obtuse; margin entire; texture chartaceous; venation eucamptodromous; primary vein stout, straight; secondary veins about 14 pairs visible, alternate, 5-10 mm apart, angle of divergence acute (70°-85°), uniformly curved, moderately thick; intersecondary veins present; tertiary veins percurrent forked, sometimes recurved also; areoles well developed; intra-marginal veins absent.

Figured Specimen—Specimen no. BSIP 38090.

Occurrence—Tura Formation; Nangwalbibra near Williamnagar, East Garo Hills District, Meghalaya; Upper Palaeocene.

Affinities—The important characters of the fossil, viz., bigger size, lorate shape, entire margin, eucamptodromous venation, stout primary vein, presence of intersecondaries, wide acute angle of divergence of secondary veins and percurrent tertiaries with well developed areoles indicate its affinities with *Mangifera* Linnaeus especially *M. indica* Linnaeus (Herbarium Sheet No. CNH 10564) of Anacardiaceae.

Most of the Indian fossil leaves resembling *Mangifera* are described as *Mangifera someshwarica* Lakhanpal and Awasthi (1984). Another leaf resembling *Mangifera* was recently described as *Eomangiferophyllum damalgiriensis* Mehrotra *et al.* (1998). After a detailed comparison it was found that the present fossil is similar to the former and therefore, has been placed under the same.

The genus *Mangifera* presently consists of about 40 species distributed in South east Asia and Indo Malayan region (Willis, 1973). Out of them only four are found in India. *M. indica*, with which the fossil shows maximum resemblance, is found in all the forests of the plains of India and in Sub-Himalayan tracts. It is also found in Bangladesh, Myanmar, Thailand, Vietnam and Malaya Peninsula (Gamble, 1972).

Family—COMBRETACEAE Bentham & Hooker f.

Genus—TERMINALIA Linnaeus

Species—TERMINALIA PALAEOCATAPPA Awasthi & Mehrotra, 1995

Pl. 1·6

←

PLATE 2

(All figures are in natural size unless otherwise mentioned)

1. A fossil leaf of *Chrysophyllum tertiarum* sp. nov. showing shape, size and venation pattern; Specimen no. BSIP 38094.
2. A modern leaf of *Chrysophyllum cainito* showing similar shape, size and venation pattern.
3. A fossil leaf of *Mangifera someshwarica* Lakhanpal and Awasthi showing shape, size and venation pattern; Specimen no. BSIP 38090.
4. A fossil leaf of *Calycopteris palaeofloribunda* sp. nov. showing shape, size and venation pattern; Specimen no. BSIP 38092.
5. A fossil leaf of *Syzygium nangwalbibrensis* sp. nov. showing shape, size and venation pattern; Specimen no. BSIP 38093.
6. A portion of *Syzygium nangwalbibrensis* sp. nov. enlarged to show intramarginal vein; Specimen no. BSIP 38093. x 2.

Description—Leaf incomplete, symmetrical, narrow obovate, preserved lamina length 8 cm, maximum width 6·5 cm; apex broken; base broken; margin entire; texture chartaceous; venation eucamptodromous; primary vein stout, straight; secondary veins 6 pairs visible, alternate, 8-16 mm apart, uniformly curved but upturned near the margin, angle of divergence moderately acute to wide acute (45°-80°), lower pairs more obtuse, moderately thick; intersecondaries not observed; intramarginal veins absent; tertiary veins indistinct, appearing percurrent.

Figured Specimen—Specimen no. BSIP 38091.

Occurrence—Tura Formation; Nangwalbibra near Williamnagar, East Garo Hills District, Meghalaya; Upper Palaeocene.

Affinities—The identifying characters of the fossil are narrow obovate symmetrical leaf, entire margin, eucamptodromous venation, stout primary vein, moderate acute to wide acute angle of divergence of secondaries and percurrent tertiary veins. These features indicate its affinities with *Terminalia* Linnaeus in general and *T. catappa* Linnaeus (Herbarium Sheet Nos CNH 66, 16334) in particular.

Among the various fossil species of *Terminalia* known so far (Awasthi & Mehrotra, 1995) the present fossil is almost identical to *T. palaeocatappa* Awasthi and Mehrotra (1995) and therefore, has been placed under the same species. As this species was described from the Oligocene sediments of Makum Coalfield, its occurrence in Nangwalbibra traces its antiquity up to Upper Palaeocene.

T. catappa is a tall tree found in the beach forests of Andamans and the Malayan Peninsula. It is a widespread littoral species within the tropics (Brandis, 1971).

Genus—CALYCOPTERIS Lamarck

Species—CALYCOPTERIS PALAEOFLORIBUNDA

sp. nov.

Pl. 2·4

Description—Leaf symmetrical, narrow elliptic, preserved lamina length 9 cm, maximum width about 3 cm, apex broken; base symmetrical, normal acute; margin entire; texture chartaceous; attachment with petiole normal, petiole size 5 x 1 mm; venation brochidodromous to eucamptodromous; primary vein moderate, straight; secondary veins 6 pairs visible, alternate, 1-1·8 cm apart, angle of divergence 40°-50°, more or less uniform, moderately thick, uniformly curved and running parallel to the margin, some of them joining superadjacent secondaries at right angles to form loops; intersecondaries observed; tertiary veins indistinct, percurrent, angle of origin RR, fine, close.

Etymology—From *Calycopteris floribunda* .

Holotype—Specimen no. BSIP 38092.

Occurrence—Tura Formation; Nangwalbibra near Williamnagar, East Garo Hills District, Meghalaya; Upper Palaeocene.

Affinities—The identifying characters of the fossil leaf are narrow elliptic shape, entire margin, brochidodromous to eucamptodromous venation, narrow to moderately acute angle of divergence of secondary veins and percurrent tertiary veins. These features indicate its affinity with *Calycopteris floribunda* Lam. (Herbarium Sheet No. CNH 81122) of Combretaceae.

Prasad (1990) described *Calycopteris floribundoides* Prasad, the only known fossil leaf of *Calycopteris* from the Siwalik sediments of Koilabas, Nepal. It differs from the present fossil in having narrow ovate shape, smaller size, craspedodromous venation and closely placed secondaries. In the light of the above facts the present fossil leaf is described here as *Calycopteris palaeofloribunda* sp. nov., the specific name signifies its resemblance with that of *C. floribunda*.

Calycopteris is a monotypic genus represented by *C. floribunda* which is a large scandant shrub growing in deciduous forests of Western Peninsula, Assam, Chittagong and Lower Myanmar (Brandis, 1971).

Specific diagnosis

CALYCOPTERIS PALAEOFLORIBUNDA sp. nov.

Leaf symmetrical, narrow, elliptic; base symmetrical, normal acute; margin entire; texture chartaceous; attachment with petiole normal; venation brochidodromous to eucamptodromous; primary vein moderate, straight; secondary veins alternate, angle of divergence narrow to moderately acute, moderately thick, uniformly curved and running parallel to the margin, some of them forming loops with superadjacent secondaries; intersecondaries present; tertiary veins percurrent, fine, close.

Family—MYRTACEAE Bentham & Hooker f.

Genus—SYZYGIUM Gaertner

Species—SYZYGIUM NANGWALBIBRENSIS sp. nov.

Pl. 2·5, 6

Description—Leaf incomplete without base, symmetrical, preserved lamina length 7·7 cm, maximum width 3·2 cm, appearing narrow elliptic to narrow oblong; apex acuminate; base broken; margin entire; texture chartaceous; venation eucamptodromous; primary vein stout, straight to curved near the apex; secondary veins alternate, 4-7 mm apart, angle of divergence 40°-50°, uniformly curved forming an intramarginal vein, intersecondary veins commonly present, simple; tertiary veins fine, random reticulate.

Etymology—From Nangwalbibra.

Holotype—Specimen no. BSIP 38093.

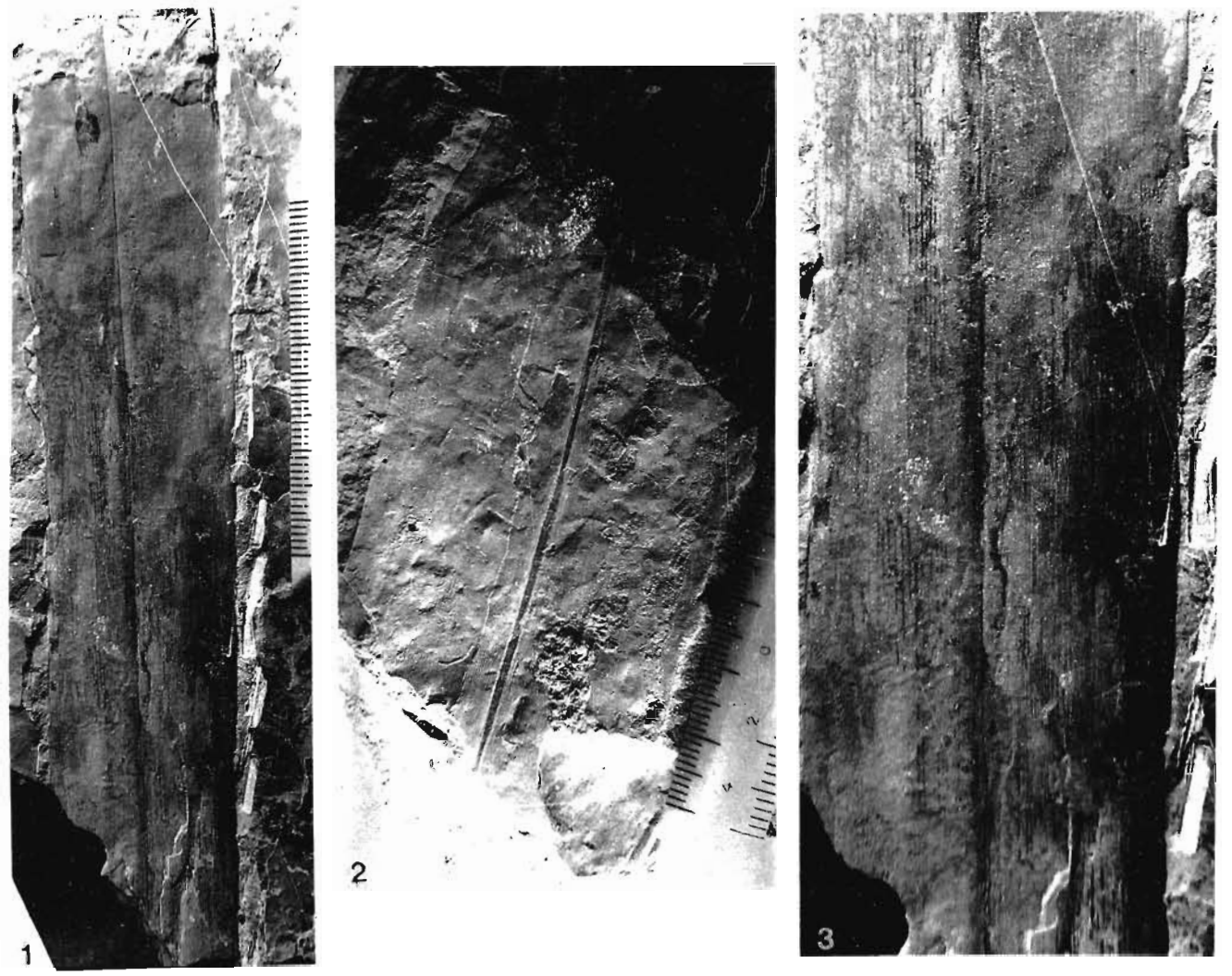


PLATE 3

(All figures are in natural size unless otherwise mentioned)

1. A leaf of *Amesoneuron lakhanpalii* sp. nov. showing shape and size: Specimen no. BSIP 38095.
2. A leaf of *Amesoneuron deccanensis* Guleria and Mehrotra showing shape and size: Specimen no. BSIP 38096.
3. An enlarged portion of *Amesoneuron lakhanpalii* sp. nov.; Specimen no. BSIP 38095. x 2.

Occurrence—Tura Formation; Nangwalbibra near Williamnagar, East Garo Hills District, Meghalaya; Upper Palaeocene.

Affinities—The characteristic features of the fossil, viz., presence of intramarginal vein, narrow elliptic shape, entire margin, presence of intersecondary veins and random reticulate tertiary veins indicate its close resemblance with *Syzygium* Gaertner of Myrtaceae. Its further identification is very difficult due to homogenity in leaf structure observed among various species of *Syzygium*.

Recently Manchester *et al.* (1998) have questioned the identification of isolated fossil leaves known from North America to extant genera of Myrtaceae. However, they (probably unknowingly) have not made any reference of the already known fossil leaves of *Syzygium* from India. Their new combination *Syzygioides* Manchester *et al.* is similar to some extant with the species of *Syzygium* in leaf architecture but differs in fruit morphology. So far only 4 species of *Syzygium* are known from various Tertiary sediments of India. These are *S. kachchhense* Lakhanpal and Guleria (1981) from the Eocene of Kachchh, *S. miocenicum* Prasad and Prakash (1984) from the Siwalik beds of Koilabas, Nepal, *S. palaeobracteatum* Awasthi and Lakhanpal (1990) from the Siwalik sediments of Bhikhnathoree, Bihar and

S. palaeocuminii Prasad and Awasthi (1996) from the Siwalik of Surai Khola, Nepal. The first one though resembling the above fossil very closely differs from it in having asymmetrical leaf. *S. miocenicum* is different due to oblanceolate shape and closely placed secondary veins while *S. palaeobracteatum* differs in having hyphodromous venation and smaller size. The last one *S. palaeocuminii* possesses acute apex and closely placed secondary veins and is thus also different from the present fossil leaf where apex is acuminate and secondary veins are comparatively distantly placed. As the present fossil is distinct from all the species known so far from India, it is being described here as *S. nangwalbibrensis* sp. nov., the specific name is after its locality Nangwalbibra.

Syzygium is represented by about 500 species of trees, shrubs or rarely climbers (Willis, 1973). Brandis (1971) has listed 79 species of it from India of which atleast 76 are indigenous. Most of the species are water loving and occur along the banks of rivers. They are found in all the types of tropical forests (Champion & Seth, 1968).

Specific diagnosis
SYZYGIUM NANGWALBIBRENSIS sp. nov.

Leaf symmetrical, narrow elliptic to narrow oblong; apex acuminate; margin entire; texture chartaceous; venation eucamptodromous; primary vein stout, straight to curved near the apex; secondary veins alternate, angle of divergence narrow to moderately acute, uniformly curved forming an intramarginal vein, intersecondary veins commonly present, simple; tertiary veins fine, random reticulate.

Family—SAPOTACEAE Bentham & Hooker f.

Genus—CHRYSOPHYLLUM Linnaeus

Species—CHRYSOPHYLLUM TERTIARUM sp. nov.

Pl. 2·1

Description—Leaf basal 3/4th part preserved, symmetrical, preserved lamina length (including petiole) 6 cm, maximum width about 4 cm, elliptic; apex broken; base rounded; margin entire; texture chartaceous; attachment with petiole normal to inflated; petiole length and width about 7 mm and 2 mm respectively; venation eucamptodromous; primary vein stout, straight; secondary veins more than 10 pairs visible, alternate, 5-6 mm apart, angle of divergence moderately acute to wide acute (55°-70°), upper pairs more acute than lower, moderately thick, usually uniformly curved but showing abrupt curving near the margin; intersecondary veins present; intramarginal vein not observed; tertiary veins ill preserved, fine, appearing percurrent.

Etymology—From Tertiary.

Holotype—Specimen no. BSIP 38094.

Occurrence—Tura Formation; Nangwalbibra near Williamnagar, East Garo Hills District, Meghalaya; Upper Palaeocene.

Affinities—The diagnostic characters of the fossil are : elliptic shape, rounded base, entire margin, eucamptodromous venation, moderate to wide acute angle of divergence of secondary veins, stout primary vein and presence of intersecondary veins. These features indicate the affinities of the fossil leaf with that of *Chrysophyllum* Linnaeus of Sapotaceae. Its identification up to specific level is not possible due to absence of well preserved tertiaries in the present fossil leaf. However, the only species available for comparison, *C. cainito*, shows close resemblance with the fossil.

As this is the first record of a fossil leaf of *Chrysophyllum*, it is being described here as *Chrysophyllum tertiarum* sp. nov.

The genus *Chrysophyllum* is a tree, consisting of about 150 species of which only 2 are found in India. *C. roxburghii* is found in Assam and Meghalaya while *C. lanceolatum* occurs in West Coast (Hooker, 1872-1897; Santapau & Henry, 1973).

Specific diagnosis
CHRYSOPHYLLUM TERTIARUM sp. nov.

Leaf symmetrical, elliptic; base rounded; margin entire; texture chartaceous; attachment with petiole normal to inflated; venation eucamptodromous; primary vein stout, straight; secondary veins alternate, angle of divergence moderately acute to wide acute, upper pairs more acute than lower, moderately thick, usually uniformly curved but showing abrupt curving near the margin; intersecondary veins present; tertiary veins fine, percurrent.

MONOCOTYLEDONS

Family—PALMAE Bentham & Hooker f.

Genus—AMESONEURON (Goeppert) Read & Hickey, 1972

Species—AMESONEURON LAKHANPALII sp. nov.

Pl. 3·1, 3

Specific diagnosis—Leaf incomplete without base and apex; preserved lamina length 8 cm, width about 5 cm; margin entire; texture coriaceous; venation parallelodromous; primary vein stout, straight; secondary veins numerous, fine, very closely placed (maximum 0·5 mm apart), running parallel to each other, cross bars or commissures indistinct; further details not visible.

→

Fig. 3 — Present day distribution of the modern comparable taxa of the fossils known from the Tura Formation of Nangwalbibra and nearby areas.

Name of the fossil taxa	Modern comparable form	Present day distribution	References
Nymphaeaceae			
Nelumbo nagalensis Bhattacharyya	*Nelumbo nucifera*	An erect large perennial water herb distributed throughout India	Bhattacharyya, 1983
Tiliaceae			
Grewia sahnii (Lakhanpal) comb. nov.	*Grewia*	Hotter regions of the world especially in tropical moist deciduous forests	
G. garoensis (Lakhanpal) comb. nov.	*G. laevigata*	In moist deciduous forests of eastern and southern India, Meghalaya, Sikkim, Martaban and Nepal	
Triumfetta rhomboideocarpa Bhattacharyya	*Triumfetta rhomboidea*	Throughout tropical and sub-tropical India and Sri Lanka ascending up to 4,000 ft in the Himalaya	Bhattacharyya, 1983
Rutaceae			
Atalantia palaeomonophylla sp. nov.	*Atalantia monophylla*	In tropical deciduous and thorn forests of south India, Sylhet, Meghalaya and Sri Lanka	
Sapindaceae			
Schleichera palaeotrijuga sp. nov.	*Schleichera trijuga*	In almost all the types of tropical forests from north west Himalayas from Sirmor to throughout central and southern India, Myanmar and Sri Lanka	
Anacardiaceae			
Mangifera someshwarica Lakhanpal & Awasthi	*Mangifera indica*	An evergreen tree of all the forests of plains of India	Lakhanpal & Awasthi, 1984; Present paper
Combretaceae			
Terminalia palaeocatappa Awasthi & Mehrotra	*Terminalia catappa*	Beach forests of Andamans and Malayan Peninsula	Awasthi & Mehrotra, 1995; Present Paper
Calycopteris palaeofloribunda sp. nov.	*Calycopteris floribunda*	In tropical moist deciduous forests of Western Peninsula, Assam, Chittagong and Lower Myanmar	
Myrtaceae			
Syzygium nangwalbibrensis sp. nov.	*Syzygium*	Water loving plants found throughout India	
Araliaceae			
Heteropanax sp.	*Heteropanax fragrans*	In subtropical Himalayas, Assam, Bengal, Andamans, Myanmar, Java and China	Bhattacharyya, 1983
Sapotaceae			
Chrysophyllum tertiarum sp. nov.	*Chrysophyllum*	West Coast, Assam, Meghalaya, Sylhet and Malacca	
Oleaceae			
Ligustrum turaense Bhattacharyya	*Ligustrum*	Temperate Himalayas at 1200-2200 m in height	Bhattacharyya, 1983
Osmanthus eocenicus Bhattacharyya	*Osmanthus suavis*	Evergreen shrub of sub-alpine Himalayas, Sikkim, East Nepal and Bhutan	Bhattacharyya, 1983
Antholithes oleaceaeformis Bhattacharyya	*Osmanthus suavis*	Evergreen shrub of sub-alpine Himalayas, Sikkim, East Nepal and Bhutan	Bhattacharyya, 1983
A. campanulatus Bhattacharyya	-	-	Bhattacharyya, 1983
Lauraceae			
Phoebe sublanceolata Bhattacharyya	*Phoebe lanceolata*	In swampy and semi-evergreen forests of Meghalaya, South Deccan, subtropical Himalayas from Shimla eastwards and Myanmar	Bhattacharyya, 1983
Litsea sp.	*Litsea salicifolia*	In evergreen bush or small tree of northern and eastern India, Assam, Bangladesh and Pegu	Bhattacharyya, 1983
Moraceae			
Artocarpus garoensis Bhattacharyya	*Artocarpus chaplasa*	Tropical evergreen forests of transgangetic India, from Bengal, Sikkim and Assam to Myanmar and Andaman Islands	Bhattacharyya, 1983
Palmae			
Nipa sahnii Lakhanpal	*Nipa fruiticans*	Sunderbans southwards to Kanyakumari and the Andamans in estuarine or swampy water	Lakhanpal, 1952; Bhattacharyya, 1983
Amesoneuron lakhanpalii sp. nov.	-	-	
A. deccanensis Guleria & Mehrotra	-	-	Guleria & Mehrotra, 1999; Present paper

Etymology—After a well known Indian Palaeobotanist Dr R.N. Lakhanpal.

Holotype—Specimen no. BSIP 38095.

Occurrence—Tura Formation; Nangwalbibra near Williamnagar, East Garo Hills District, Meghalaya; Upper Palaeocene.

Affinities—The coriaceous texture and typical parallelodromous venation of the fossil leaf suggest its affinities with Palmae (Read & Hickey, 1972). However, due to the absence of base and apex its further comparison is not possible.

Read and Hickey (1972) have given a key for the identification of palm-like leaves. Accordingly the above specimen has been placed under the form genus *Amesoneuron* (Goeppert) Read and Hickey. Recently, Guleria and Mehrotra (1999) have given a detailed list of the fossil palm and palm-like leaves known so far from the Tertiary sediments of India. After a detailed comparison with all of them it was concluded that the present fossil leaf is different from them. Therefore, it is being described here as a new species of *Amesoneuron*, *A. lakhanpalii* sp. nov. The specific name is in the honour of Dr R.N. Lakhanpal, a well known Indian Palaeobotanist.

Species—AMESONEURON DECCANENSIS Guleria & Mehrotra, 1999

Pl. 3·2

Description—Leaf incomplete without apex and base; preserved lamina length 13·5 cm, width about 3 cm; strap shaped; margin entire; texture coriaceous; venation parallelodromous; primary vein moderately thick-walled, straight; secondary veins many, very closely placed, fine, running parallel to each other, cross bars or commissures absent; further details not visible.

Figured Specimen—Specimen no. BSIP 38096.

Occurrence—Tura Formation; Nangwalbibra near Williamnagar, East Garo Hills District, Meghalaya; Upper Palaeocene.

Affinities—In having coriaceous texture, parallelodromous venation and entire margin the fossil shows affinities with *Amesoneuron* (Goeppert) Read and Hickey (1972). Only 3 species of the genus are known so far from India. These are *Amesoneuron borassoides* Bonde (1986), *A. deccanensis* Guleria and Mehrotra (1999) (both from the Deccan Intertrappean sediments) and *A. lakhanpalii* (Present paper). As the present fossil is identical to *A. deccanensis* in almost all the morphological characters such as shape, size and venation, it has been placed under the same species.

DISCUSSION

A perusal of the Fig. 3 indicates that most of the modern comparable forms of the fossils were growing in tropical evergreen to moist deciduous forests of India during Upper Palaeocene. The occurrence of *Terminalia catappa* and *Nipa fruiticans*, the typical beach forest elements, suggests the presence of estuarine conditions with large amount of swampy vegetation in the area during the period. This shows that the climate was warm and humid with much higher rainfall than today. This view is also supported by palynological studies (Saxena *et al.*, 1996). The occurrence of *Nelumbo nucifera* indicates the existence of ponds around Nangwalbibra during the deposition of beds. However, certain forms for e.g., *Ligustrum nepalense* and *Osmanthus suavis* which occur in temperate or subalpine Himalayas, are against the general nature of the flora which is definitely tropical as evidenced by the other forms. Therefore, these taxa need critical re-investigation as their affinities appear to be doubtful in the light of the above facts.

Acknowledgements—*The author is thankful to N. Awasthi for his great help during the collection of the material. He is also thankful to the Head, Botany Branch, Forest Research Institute, Dehra Dun and Dy. Director, Central National Herbarium, Howrah for allowing him to consult their Herbarium. Lastly, the author is also grateful to Prof Anshu K Sinha, Director, Birbal Sahni Institute of Palaeobotany, Lucknow for necessary facilities and permission to publish this work.*

REFERENCES

Awasthi N, Guleria JS & Lakhanpal RN 1982. Two new fossil woods of Sapindaceae from the Tertiary of India. Palaeobotanist 30 : 12-21.

Awasthi N & Lakhanpal RN 1990. Additions to the Neogene florule from near Bhikhnathoree, West Champaran District, Bihar. Palaeobotanist 37 : 278-283.

Awasthi N & Mehrotra RC 1995. Oligocene flora from Makum Coalfield, Assam, India. Palaeobotanist 44 : 157-188.

Bande MB & Srivastava R 1995. *Grewia* type of fossil woods from the Deccan Intertrappean beds of India. Geophytology 24 : 131-135.

Bhattacharyya B 1983. Fossil plants from the Tura Formation (Eocene) in the Garo Hills, Meghalaya. Indian Journal of Earth Sciences 10 : 1-10.

Bonde SD 1986. *Amesoneuron borassoides* a borassoid palm leaf from the Deccan Intertrappean bed at Mohgaonkalan, India. Biovigyanam 12 : 89-91.

Brandis D 1971. Indian Trees. Bishen Singh Mahendra Pal Singh, Dehra Dun : 767.

Champion HG & Seth SK 1968. A revised survey of the forest types of India. Manager of Publications, Delhi : 404.

Dilcher DL 1974. Approaches to the identification of angiosperm leaf remains. Botanical Review 40 : 1-157.

Gamble JS 1972. A Manual of Indian Timbers. Bishen Singh Mahendra Pal Singh, Dehradun : 856.

Guleria JS & Mehrotra RC 1999. On some plant remains from Deccan Intertrappean localities of Seoni and Mandla districts of Madhya Pradesh, India. Palaeobotanist 47 : 68-87.

Hickey LJ 1973. Classification of the architecture of dicotyledonous leaves. American Journal of Botany 60 : 17-33.

Hooker JD 1872-1897. The Flora of British India. 1-7. L. Reeve and Company, Kent.

Lakhanpal RN 1952. *Nipa sahnii*, a palm fruit in the Tertiary of Assam. Palaeobotanist 1 : 289-294.

Lakhanpal RN 1954. Recognizable species of Tertiary plants from Damalgiri in the Garo Hills, Assam. Palaeobotanist 3 : 27-31.

Lakhanpal RN 1964. A new record of angiospermic leaf impressions from the Garo Hills, Assam. Current Science 33 : 276.

Lakhanpal RN & Awasthi N 1984. A late Tertiary florule from near Bhikhnathoree in West Champaran District, Bihar. *In:* Proceedings of the Seminar on Evolutionary Botany and Biostratigraphy, Calcutta (1979), Prof. A.K. Ghosh Commemoration Volume : 587-596.

Lakhanpal RN & Guleria JS 1981. Leaf impressions from the Eocene of Kachchh, Western India. Palaeobotanist 28-29 : 353-373.

Lakhanpal RN, Prakash U & Bande MB 1978. Fossil dicotyledonous woods from the Deccan Intertrappean beds of Mandla District in Madhya Pradesh. Palaeobotanist 25 : 190-204.

Manchester SR, Dilcher DL & Wing SL 1998. Attached leaves and fruits of myrtaceous affinity from the Middle Eocene of Colorado. Review of Palaeobotany and Palynology 102 : 153-163.

Mehrotra RC, Dilcher DL & Awasthi N 1998. A Palaeocene *Mangifera*-like leaf fossil from India. Phytomorphology 48 : 91-100.

Paradkar SA & Dixit VP 1984. *Grewia mohgaoensis*-a new petrified dicotyledonous fruit from the Deccan Intertrappean beds of Mohgaonkalan, Madhya Pradesh, India. *In:* Proceedings of Vth Indian Geophytological Conference, Lucknow (1983), Special Publication : 155-162.

Prasad M 1990. Fossil flora from the Siwalik sediments of Koilabas, Nepal. Geophytology 19 : 79-105.

Prasad M & Awasthi N 1996. Contribution to the Siwalik flora from Surai Khola sequence, Western Nepal and its palaeoecological and phytogeographical implications. Palaeobotanist 43 : 1-42.

Prasad M & Prakash U 1984. Leaf impressions from the Lower Siwalik beds of Koilabas, Nepal. *In:* Proceedings of the Vth Indian Geophytological Conference, Lucknow (1983), Special Publication : 246-256.

Raja Rao CS 1981. Coalfields of north eastern India-I. Bulletin of the Geological Survey of India 45 A : 1-76.

Read RW & Hickey LJ 1972. A revised classification of fossil palm and palm-like leaves. Taxon 21 : 129-137.

Santapau H & Henry AN 1973. A dictionary of the flowering plants in India. Publication & Information Directorate, New Delhi : 198.

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

Srivastava GP, Mishra VP & Bande MB 1992. Further contribution to the Late Cenozoic flora of Mahuadanr, Palamu District, Bihar. Geophytology 22: 229-234.

Willis JC 1973. A dictionary of the flowering plants and ferns. Cambridge University Press, Cambridge : 1245.