Oligocene flora from Makum Coalfield, Assam, India

N. Awasthi & R.C. Mehrotra

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The coal-bearing Oligocene sediments exposed in the Makum Coalfield, Assam contain rich assemblage of mega-plant remains. Out of a large number of leaves and fruits collected from the associated sediments at Baragolai, Ledo-Tirap and Tipongpani collieries of the Makum Coalfield, 24 species of dicotyledonous taxa have been identified. Of these, 22 are represented by leaves belonging to the genera *Saccopetalum* (Anonaceae); *Calophyllum, Garcinia, Kayea* (Clusiaceae); *Pterygota* (Sterculiaceae); *Santiria* (Burseraceae); *Heynea* (Meliaceae); *Nephelium* (Sapindaceae); *Lannea, Mangifera, Parishia* (Anacardiaceae); *Rhizophora* (Rhizophoraceae); *Terminalia* (Combretaceae); *Memecylon* (Memecylaceae); *Avicennia* (Avicenniaceae); *Alstonia* (Apocynaceae); *Myristica* (Myristicaceae), *Apollonias* (Lauraceae) and *Bridelia* (Euphorbiaceae). The remaining two taxa are based on fruit/seed comparable to those of *Dalbergia* and *Entada* of Fabaceae.

The distribution pattern of comparable modern taxa of fossils and keeping in view the great amount and variety of plants preserved in the sediments, it is inferred that thick tropical evergreen to moist deciduous forest existed in this part of northeast India during Oligocene. Occurrence of *Avicennia, Rhizophora* and *Terminalia catappa* suggests deltaic, mangrove or lagoonal deposition of coalseams and associated sediments in the Makum Coalfield.

Key-words— Megafossils, Angiosperms, Fossil leaves and fruits, Oligocene, Makum Coalfield, Assam.

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साराँश

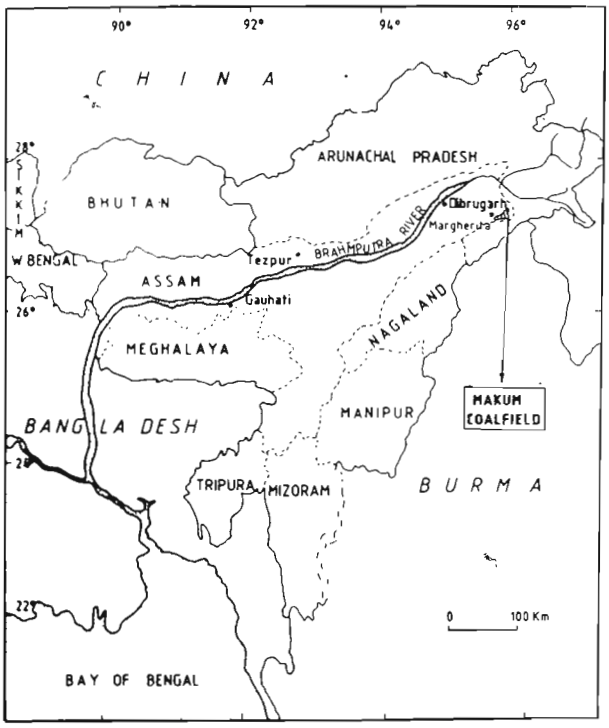
असम (भारत) में माकुम कोयला-क्षेत्र से अल्पनूतन कालीन वनस्पतिजात

नीलाम्बर अवस्थी एवं राकेश चन्द्र मेहरोत्रा

असम के माकुम कोयला-क्षेत्र में अनावरित कोयला-धारक अल्पनूतन अवसादों में गुरुपादपाश्म प्रचुर मात्रा में मिलते हैं। इस क्षेत्र में बारागोलाई, लीडो-तिराप एवं तिपाँगपानी से एकत्रित किये गये पादपाश्म संग्रह में से द्विबीजपत्रीयों की 24 जातियाँ अभिनिर्धारित की गई हैं। इनमें से 22 वर्गकों *सैक्कोपैटेलम* (एनोनेसी), *कैलोफिल्लम* , *गार्सीनिआ, कैइआ* (क्लूसिएसी), *टेरीगोटा* (स्टरकुलिएसी), *सैन्टीरिया* (बर्सेरेसी), *हेनिआ* (मिलीएसी), *निफेलियम* (सैपिन्डेसी), *लैन्नीआ, मेंजिफेरा, पेरीशिआ* (एनाकार्डिएसी), *राइजोफोरा* (राइजोफोरेसी), *टर्मिनेलिआ* (कोम्ब्रीटेसी), *मेमेसाइलोन* (मेमेसाइलेसी), *एविसेन्निआ* (एविसेन्निएसी), *आल्सटोनिआ* (एपोसाइनेसी), *मिरिस्टिका* (मिरिस्टिकेसी), *एपोलोनिआस* (लॉरेसी) एवं *ब्राइडेलिया* (यूफोर्बिएसी), की पर्ण-छापें वर्णित की गई हैं तथा शेष दो वर्गक फल/बीज पर आधारित हैं जो कि *डेल्बर्जिया* एंव *ऐन्टाडा* न ामक प्रजातियों से तुलनीय हैं।

उपलब्ध पादपाश्मों से तुलनीय वर्तमान वर्गकों के आधार पर उत्तर पूर्व भारत के इस क्षेत्र में सघन उष्ण-कटिबन्धीय सदाहरित से नम पर्णपाती वनों का होना सुनिश्चित किया गया है। *एविसेन्निआ, राइजोफोरा* एवं *टर्मिनेलिआ कटापा* की उपस्थिति से माकुम कोयला-क्षेत्र में कोयला सीमों एवं सहयुक्त अवसादों का निक्षेपण डेल्टीय, मैंग्रोव अथवा लैगूनी परिस्थितियों में होना प्रस्तावित किया गया है।

THE Makum Coalfield lies between latitude 27°15' to 27°75' N and longitude 90° 40' to 90°55' E along the outermost flank of the Patkoi range, Tinsukia District, Assam (Text-figure 1). The coalfield houses the largest Tertiary coal deposit of India. The Makum Coalfield, apart from being the most important for coal resources in northeastern India, the area is equally important for palaeobotanical studies as the coal-bearing Oligocene sediments exposed there have a rich assemblage of mega-plant remains. In fact, there is no other Oligocene sedimentary basin in India which contains such a rich and diversified Oligocene flora. The present systematic study of plant fossils from this Coalfield has been undertaken in order to fill the gap in our existing knowledge of the Oligocene floristics and its environment in the Tertiary floral history of India.



Text-figure 1— Map showing location of Makum Coalfield (after Awasthi *et al.*, 1992).

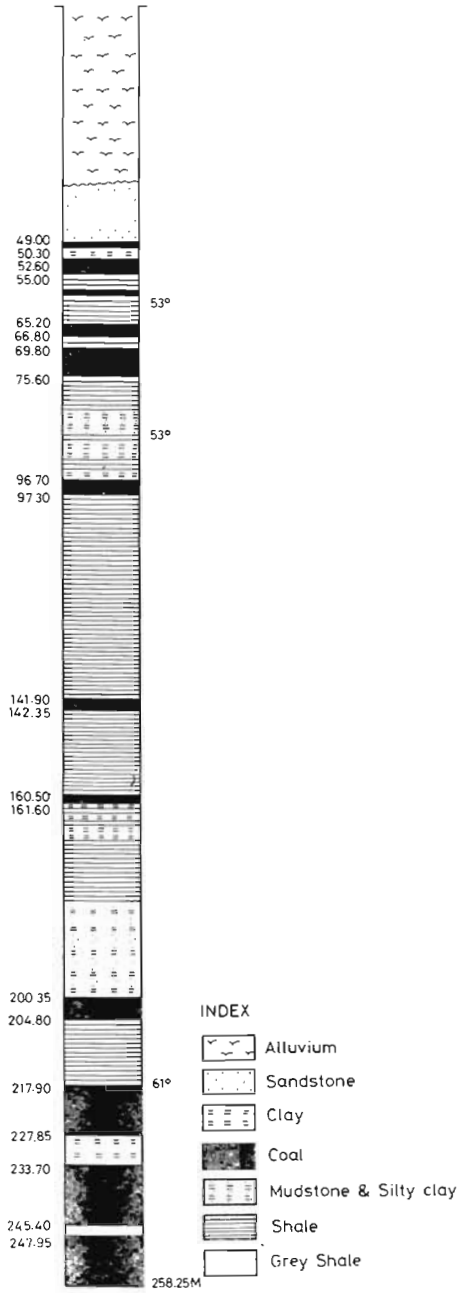
GENERAL GEOLOGY

The Makum Coalfield encompasses Baragolai, Tikak, Ledo-Tirap and Tipong collieries which are well served by roads and railways. The National Highway No. 38 passes through this coalbelt and continues further east up to Myanmar border. The following lithostratigraphic sequence of sediments exposed in the area has been given by Raja Rao (1981) and later modified by Misra (1992a).

AGE/GROUP	FORMATION	LITHOLOGY
Recent-Pleistocene	Alluvium	Alluvium and high level terraces
Dihing Pliocene		Alternating pebble beds, coarse bluish green felspathic and ferruginous sandstone and grey to brown clay.
Tipam Miocene	Girujan Clay Formation	Variegated clay, silty clay, bluish green and grey sandstone (+ 470 m) coarse, gritty and massive bluish green to grey felspathic and micaceous sandstone.
	Tipam Sandstone Formation	Variegated clay, sandy clay, shale, coaly streaks, silicified woods and conglomeratic sandstone (+ 1000m)
Barail Oligocene	Tikak Parbat Formation	Hard and light coloured quartose sandstone. Alternations of siltstone, sandy shale, shale, mudstone, carbonaceous shale and thin impersistent coal seams (+ 409m). Alternations of siltstone, mudstone carbonaceous shale, clay and workable coal seams. Occasional clayey sandstone, clay and sandy shale (+ 200 m)
	Baragolai Formation	Alternations of buff, bluish green and grey coloured sandstone, sandy shale, carbonaceous shale, sandy clay, clay and thin impersistent seams of coal and shaly coal. Herd massive and floggy, grey micaceous and ferruginous sandstone and oilsand (± 2743 m)
	Naogaon Formation	Hard compact and floggy dark grey fine-grained sandstone and interbeds of grey splintery shale (± 1525 m)
Disang Eocene		Dark grey splintery shale with interbeds of dark grey and finegrained sandstone (± 300 m).

The present study is concerned with the coal-bearing Tikak Parbat and Baragolai formations of Barail Group (Oligocene) (Text-figure 2). The Tikak Parbat Formation has five coal seams confined within the basal 200 m section (Misra, 1992a).

Seam no. 5 (2.4 m/8 ft thick	1.3-2.5m abondoned
Parting	30.0-40.0m
Seam no. 4 (1.5 m/5ft thick)	1.2-1.8m/ often merges with seam no. 3 abondoned
Parting	3.0-18.0m
Seam no. 3(6 m/20 ft thick) composite seam	2.0-7.5m worked out in 2 sections
Parting	38.0-68.0m



Text-figure 2— Litholog of Makum Coalfield (Tirap) (provided by Coal India Limited, Northeastern Coalfield, Margherita, Assam).

Seam no. 2		
(New Seam)		
2.1 m/7ft thick	.....	1.5-2.6 m
Parting	.....	5.0-20.0m
Seam no. 1		
(18 m/60 ft thick	.....	10.0-20.8 m/worked
(Composite seam)		out in 2 or 3 sections

Of the five seams only Seam nos 1 and 3 are exploited throughout the field. According to Evans (1932) the 18 m seam (Seam no. 1) is demarcating horizon between the Tikak Parbat Formation and the underlying Baragolai Formation (Text-figure 3). The Baragolai Formation has several thin to very thin coal bands of highly impersistent nature.

The Tikak Parbat Formation comprises alternations of sandstone, siltstone, mudstone, shale, carbonaceous shale, clay and coal seams (Misra, 1992a). Although the occurrence of plant-remains in grey carbonaceous shales and sandy shales in the field is known since long, they remained practically uninvestigated until recently. In early 1989 the present authors made an extensive collection of plant fossils comprising mostly leaves, a few fruits and seeds, with a view to reconstruct the Oligocene plant communities which served as source for coal formation besides, deducing palaeoclimate and depositional environment of the Oligocene sediments. From this collection, recently Awasthi *et al.* (1992) described leaves of *Podocarpus* of Podocarpaceae and a leaf and fruit of *Mesua* of Clusiaceae. Of the remaining large number of fossils, an account of two fruits *Entada* and *Dalbergia* and twentytwo dicotyledonous leaves belonging to 20 genera, distributed among 15 families is presented in the present paper.

The Terminology used in describing the leaves is after Hickey (1973) and Dilcher (1974). The identification of leaves and fruits was done by comparing them with the herbarium sheets at the Forest Research Institute, Dehradun; Central National Herbarium, Howrah and the National Botanical Research Institute, Lucknow.

All the type and duplicate specimens of fossils are deposited in the Museum, Birbal Sahni Institute of Palaeobotany, Lucknow.

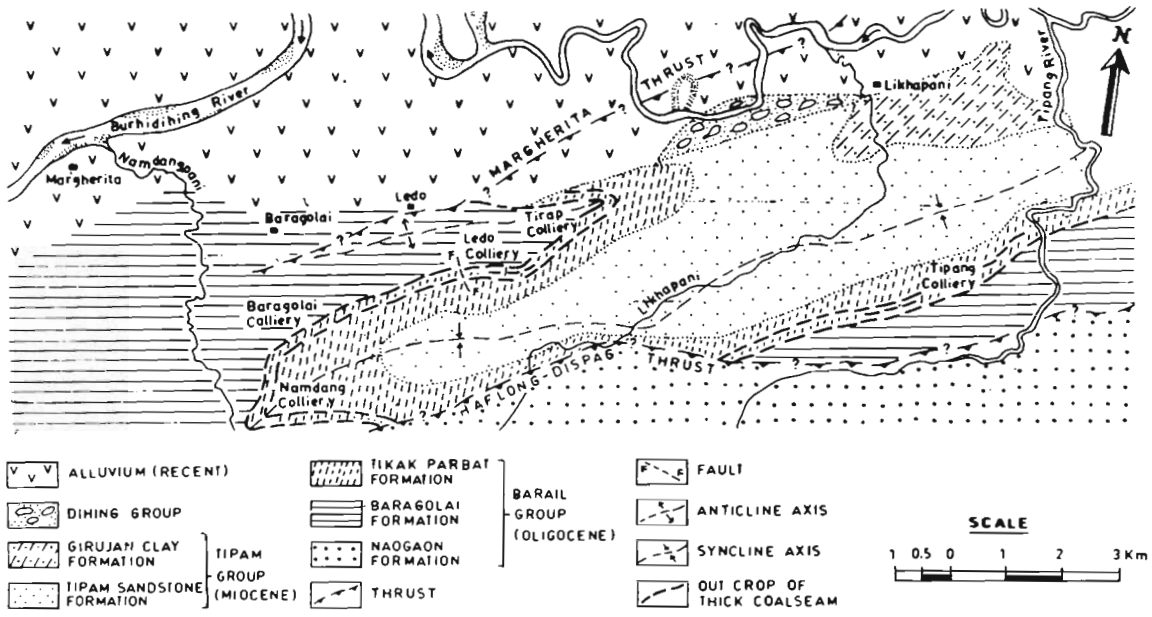
SYSTEMATIC DESCRIPTION

Family — Anonaceae

Genus — *Saccopetalum* Benn.

Saccopetalum palaeolongiflorum sp. nov.
Pl. 1, fig. 1

Description— Leaf symmetrical, seemingly elliptic to wide elliptic, preserved length about 18 cm, width of one side of midrib about 6 cm; apex broken; base broken; margin entire; texture chartaceous; venation pinnate;



Text-figure 3— A geological map of Makum Coalfield (after Misra, 1981)

brochidodromous; primary vein seemingly moderate in thickness, more or less straight; secondary veins 9 pairs visible, each 1.4-2.5 cm apart, angle of divergence moderately acute (50°-65°), more or less uniform, moderately thick, curving sharply before reaching the margin and joining superadjacent secondary veins at acute to right angles; intersecondary veins prominent, simple; tertiary veins percurrent, angle of origin AA-AR, close, mostly alternate, oblique, simple.

Holotype — Specimen no. BSIP 37085.

Locality — Ledo-Tirap colliery, Tinsukia District, Assam.

Affinities — The important characters of the fossil leaf, such as large lamina, entire margin, brochidodromous venation, presence of intersecondary veins and percurrent tertiaries show close similarity with the leaves of *Saccopetalum longiflorum* Hk. f. & Th. (FRI Herbarium sheet no. 915) of Anonaceae (Pl. 2, fig. 1). Since there is no record of fossil leaf resembling this extant taxon, the present fossil leaf is named as *Saccopetalum palaeolongiflorum* sp. nov. The specific name signifies the antiquity of *Saccopetalum longiflorum.*

Saccopetalum is a genus of moderate-sized to large tree distributed in tropical Asia and Australia (Chowdhury & Tandon, 1958). Baillon included this genus in *Miliusa* Leschen. ex A.Dc. though Hutchinson kept them in two distinct genera (Santapau & Henry, 1973). It consists of 5 species. *Saccoptealum longiflorum*, with which the fossil shows resemblance, is found in Eastern Bengal near Purneah (Hooker, 1872)

Family — Clusiaceae

Genus — *Calophyllum* Linn.

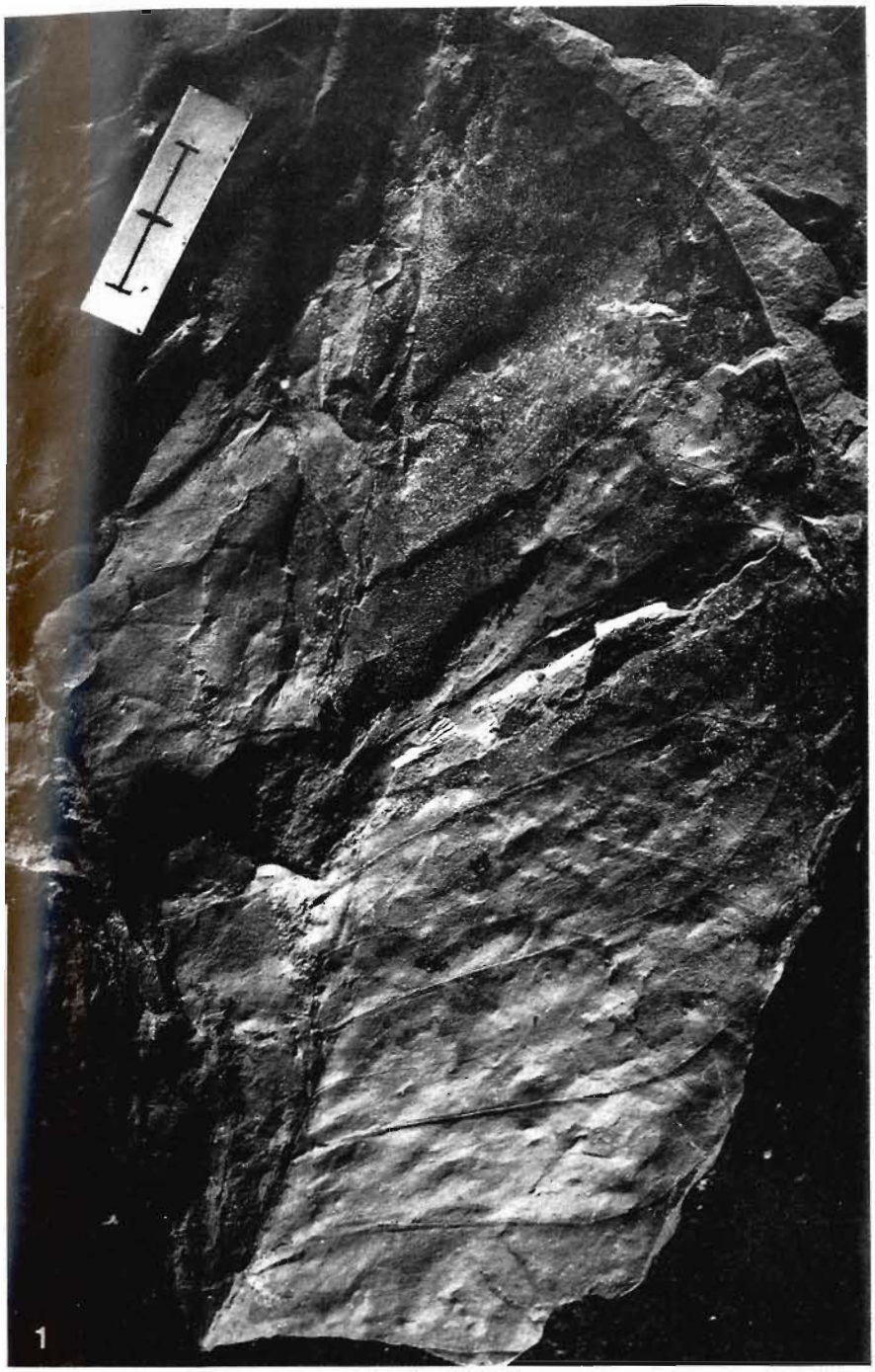
Calophyllum suraikholaensis Awasthi & Prasad 1990
Pl. 1, fig. 2; Pl. 3, fig. 1

Description— Leaf complete, symmetrical, narrow elliptic to elliptic, about 9.5 x 3.7 cm in length and width; apex acuminate; base symmetrical, acute to cuneate; margin entire; texture seemingly chartaceous or coriaceous; petiole normal, flattened dorsiventrally, about 1 cm in length; venation pinnate, eucampto-dromous to craspedodromous; primary vein moderately thick, nearly straight; secondary veins numerous, very closely placed, about 0.5 mm apart, alternate or opposite; angle of divergence moderately acute to wide acute (45°-75°), secondaries in the apical part more acute than in the basal part, fine, parallel to each other, gently curving towards margin, unbranched; tertiary veins not seen.

Figured specimen — Specimen no. BSIP 37086.

Locality — Tipong colliery near Ledo, Tinsukia District, Assam.

Affinities — Elliptic shape, acuminate apex and numerous, very close and evenly placed parallel secondary



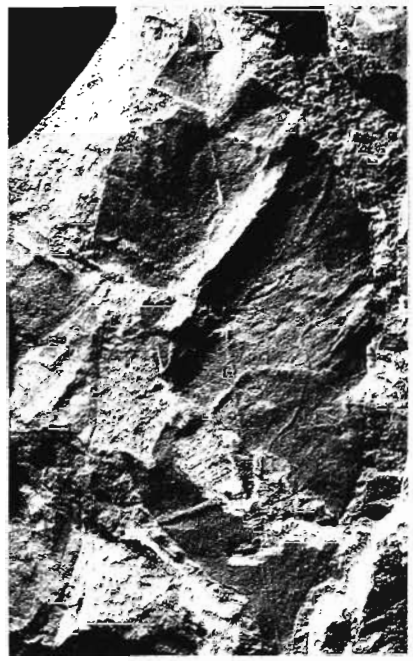


PLATE 1

(All photographs are of natural size unless otherwise mentioned)

1. *Saccopetalum palaeolongiflorum* sp. nov. — a fossil leaf showing shape, size and venation pattern; specimen no. BSIP 37085.
2. *Calophyllum suraikholaensis* Awasthi & Prasad — a fossil leaf showing shape and size; specimen no. BSIP 37086.
3. *Calophyllum polyanthum* — a modern leaf showing similarity with the fossil.

veins indicate that the fossil leaf belongs to the genus *Calophyllum* (Pl. 1, fig. 3) and shows close resemblance with that of *C. polyanthum* Wall. (Herb. sheet no. FRI 605). It differs from the leaves of other species of *Calophyllum* in their shape and size.

Among the fossil leaves of *Calophyllum*, so far known from different parts of the world (see Awasthi & Prasad, 1990), the present fossil from the Oligocene deposits is very similar to *Calophyllum suraikholaensis* Awasthi & Prasad described from the Siwalik sediments of Suraikhola sequence of Nepal and Darjeeling District, West Bengal (Antal & Awasthi, 1993), Warkalli beds of Kerala Coast (Awasthi & Srivastava, 1992) and Palaeocene of Cherrapunji (Ambwani, 1992). There is hardly any noticeable difference between these two types of fossil leaves belonging to different geological epochs and geographical locations. We therefore, place it in the same species, i.e., *Calophyllum suraikholaensis* Awasthi & Prasad.

The genus *Calophyllum* includes over 120 species, distributed in the tropical regions of both the hemispheres, but the majority are grouped in tropical Asia and the East Indies (Pearson & Brown, 1932; Santapau & Henry, 1973). Fourteen species of this genus grow in India. *Calophyllum polyanthum* with which the fossil shows close resemblance, is a large evergreen tree of Eastern Bengal, Khasi Hills, the Chittagong Hill and Myanmar.

Genus — *Garcinia* Linn.

Garcinia palaeoluzoniensis sp. nov.
Pl. 3, fig. 2

Description— Leaf incomplete, 3/4th apical part present, symmetrical, seemingly oblong to elliptic, 6 x 2.5 cm in length and width respectively; apex acuminate; base broken; margin entire; texture chartaceous; venation pinnate, eucamptodromous; primary vein moderately thick, markedly curved towards apex; secondary veins numerous, alternate, closely placed (.5-1.0 mm apart), angle of divergence moderately acute (45^{o}-65^{o}), fine, uniformly curving up towards margin, unbranched; intersecondary veins not seen; intramarginal veins observed in the apical part; tertiary veins not clearly seen.

Holotype — Specimen no. BSIP 37087.

Locality — Ledo-Tirap colliery, Tinsukia District, Assam.

Affinities — The important characters of the fossil, such as oblong to elliptic shape, acuminate apex, entire margin eucamptodromous venation, curved primary vein, numerous and closely placed secondary veins having moderately acute angle of divergence collectively suggest its close resemblance with the leaves of *Garcinia* Linn. in general and *G. luzoniensis* Merr. in particular (Herb. sheet no. CNH 47109).

In view of its close similarity with the leaf of *Garcinia luzoniensis*, the present fossil leaf is assigned to a new species of *Garcinia, G. palaeoluzoniensis*. The specific name indicates the antiquity of *Garcinia luzoniensis*.

Garcinia neyveliensis the only known fossil leaf from Neyveli Lignite deposits, India (Agarwal, 1992), is different from our fossil leaf in shape, size and venation pattern.

Garcinia is a genus of trees or shrubs and includes about 400 species found in Asia and South Africa. *G. luzoniensis* is found in Indonesia.

Genus — *Kayea* Wall.

Kayea baragolaensis sp. nov.
Pl. 4, fig. 1

Description— Leaf incomplete having 2/3rd basal part, symmetrical, elliptic, about 8 cm and 3.3 cm in length and width respectively; apex broken; base symmetrical, acute, normal, margin entire; texture chartaceous; petiole normal, incomplete, length about 5 mm; venation pinnate, eucamptodromous; primary vein stout, straight; secondary veins more than 20 pairs visible in the available part, alternate, 3-7 mm apart, angle of divergence moderately acute to right angle (55^{o}-90^{o}), right angle more prominent on one side of midrib, moderately thick, uniformly curving up towards margin and merging with intramarginal vein paralleling closel to it, unbranched; intersecondary veins present, simple; tertiary veins random reticulate.

Holotype — Specimen no. BSIP 37088.

PLATE 2 ⟶

1 *Saccopetalum longiflorum* — a modern leaf to show similarity with the fossil.

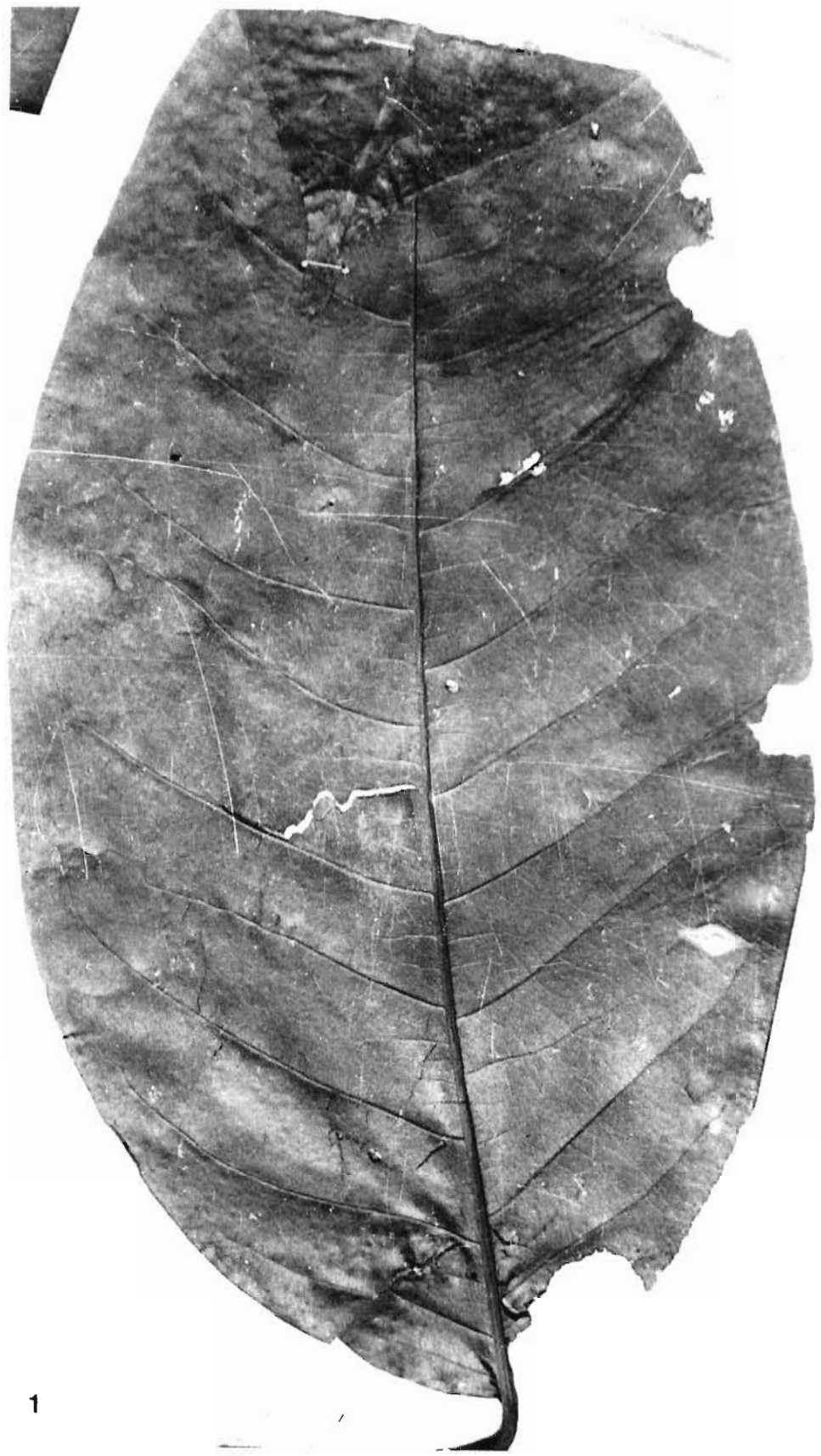


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PLATE 2

Locality — Baragolai colliery near Margherita, Tinsukia District, Assam.

Affinities — In having elliptical shape, entire margin, eucamptodromous venation with intramarginal vein, stout primary vein, mostly wide acute to right angle of divergence of secondary veins and presence of intersecondary veins the fossil leaf shows resemblance with that of *Kayea* Wall. of Clusiaceae. Among the species of *Kayea*, the fossil is closely comparable to the leaves of *Kayea floribunda* Wall. (Herbarium sheet no. 47570) though the size of the fossil leaf is slightly smaller (Pl. 4, fig. 4).

Recently, Prasad (1993) described a fossil leaf as *Kayea kalagarhensis* from the Siwalik sediments of Kalagarh, U.P. and compared it with those of *Kayea floribunda*, the same species with which our fossil leaf also resembles most. However, our fossil differs from *Kayea kalagarhensis* in having distinct reticulate tertiary veins whereas in the latter they are percurrent.

Kayea is a tropical genus of small to medium-sized tree and comprises 35 species, distributed in south and Southeast Asia. Three species occur in India (Tandon & Purkayastha, 1958; Santapau & Henry, 1973). *Kayea floribunda* with which the fossil shows maximum similarity, is found in Sikkim, Assam and Myanmar.

Family — Sterculiaceae

Genus — *Pterygota* Schott & Endl.

Pterygota cordata sp. nov.
Pl. 4, fig. 3

Description— Leaf incomplete with 2/3rd basal part, seemingly wide ovate, length of available part 7 cm, width 7 cm; apex broken; base symmetrical, cordate; margin entire; texture chartaceous; venation actinodromous, basal, perfect; midvein nearly straight, moderately thick, two pairs of lateral primaries arising from the base of midvein, the outer lateral vein on each side thin, arising at right angle and then gently curving upward and reaching the margin, inner lateral primaries one on each side stout, arising at an angle of 50°-60°, curving upward and running up to seemingly half of the length of lamina; secondary veins arising from primaries fine, angle of divergence narrow acute (45°), 1.5-2 cm apart, uniformly curving and turning upward to join superadjacent secondaries; tertiary veins not clearly seen.

Holotype — Specimen no. BSIP 37089.

Locality — Baragolai colliery near Margherita, Tinsukia District, Assam.

Affinities — The characteristic features of the fossil leaf, such as, cordate base, actinodromous venation with prominent midrib and two pairs of lateral primary veins suggest its similarity with the leaves of *Pterygota alata* (Roxb.) R. Br. (syn. *Sterculia alata* Roxb.) of Sterculiaceae (Herb. sheet nos. FRI 3330; CNH 58076). Hence, the fossil leaf is described here as a new species, *Pterygota cordata*. The specific name signifies the cordate base of the leaf.

A few years back, Bande and Srivastava (1990) also described a fossil leaf of *Pterygota alata* from Pleistocene-Holocene beds (Puri, 1976) of Palamu District, Bihar. Close similarity of fossil taxa up to specific level within the modern forms suggests that these beds are not of great antiquity (Bande & Srivastava, 1990).

The genus *Pterygota* consists of about 20 species, distributed throughout the tropics of Old World (Willis, 1973), out of which only one species, *Pterygota alata,* is found in India (Santapau & Henry, 1973). *P. alata* is a tree found in the evergreen forests of northeast India, particularly Assam and in Western Ghats but reaches its best development in Chittagong, Myanmar and Andamans (Ramesh Rao, 1958).

Family — Burseraceae

Genus — *Santiria* Blume

Santiria oligocenica sp. nov.
Pl. 3, fig. 3

Description— Leaf symmetrical, elliptic to narrow oblong, preserved length about 16 cm, maximum width 6.5 cm; apex broken; base symmetrical, acute-obtuse, normal; margin entire; texture chartaceous; petiole nor-

PLATE 3 →

1. *Calophyllum suraikholaensis* Awasthi & Prasad — a fossil leaf magnified to show details of venation, x 2.
2. *Garcinia palaeoluzoniensis* sp. nov. — a fossil leaf showing shape, size and venation pattern; specimen no. BSIP 37087.
3. *Santiria oligocenica* sp. nov. — a fossil leaf showing details of venation; specimen no. BSIP 37090.
4. *S. laevigata* — a modern leaf showing similar venation pattern.
5. *S. laevigata* — another specimen of modern leaf showing similar base.

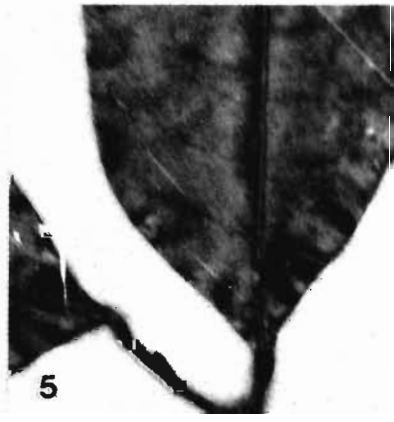


PLATE 3

mal, preserved length about 6 mm; venation pinnate, brochidodromous; primary vein stout, slightly curving towards apex; secondary veins about 13 pairs visible, alternate, each 4-17 mm apart, almost uniform, angle of divergence moderately acute to right (60^{o}-90^{o}), abruptly curving and joining superadjacent secondaries at acute angle, moderately thick; tertiary veins percurrent, simple to convex, predominantly alternate, close, obliquely placed, angle of origin AR-AA.

Holotype — Specimen no. BSIP 37090.

Locality — Ledo-Tirap colliery, Tinsukia District, Assam.

Affinities — Elliptic-oblong shape, obtuse base, brochidodromous venation, stout primary vein, moderately acute to right angle of divergence of secondary veins and percurrent tertiary veins are the important characters of the fossil leaf which shows its resemblance with the leaves of *Santiria* Blume in general and *Santiria laevigata* Blume (Pl. 3, figs 4-5) in particular, belonging to the family Burseraceae. It has been observed that the angle of divergence of secondary veins is variable in the modern leaf. It varies from moderately acute to right (Herbarium sheet nos. FRI 65794, 81892; CNH sheet no. 78628).

As there is no record of fossil leaf resembling those of *Santiria*, the present fossil specimen is described as *Santiria oligocenica* sp. nov. The specific name indicates the occurrence of leaf in the Oligocene sediments.

Santiria is a genus of about 25 species found mostly in Malayan Archipelago. *S. laevigata* is a species of large trees found in Malacca (Santapau & Henry, 1973; Willis, 1973).

Family — Meliaceae

Genus — *Heynea* Roxb. ex Sims

Heynea trijugoides sp. nov.
Pl. 5, figs 2, 4

Description— Leaves incomplete, basal half preserved, asymmetrical, seemingly ovate, preserved length about 5 cm, width 6 cm; apex broken; base oblique, one side forming acute angle and other side rounded; margin entire; texture chartaceous-coriaceous; venation pinnate, eucamptodromous; primary vein stout, curving from the base; secondary veins 5 pairs visible, alternate, 7-11 mm apart, angle of divergence usually narrow acute to sometimes wide acute especially in the basal portion on one side of midvein, 45^{o}-80^{o}, fine, uniformly curving upward, occasionally appearing to join superadjacent secondaries; tertiary veins ill-preserved, seemingly percurrent.

Holotype — Specimen no. BSIP 37091.

Paratype — Specimen no. BSIP 37092.

Locality— Ledo-Tirap colliery, Tinsukia District, Assam.

Affinities — Asymmetrical leaf with oblique base, primary vein markedly curved at the base and eucamptodromous venation are the important characters of the fossil leaf. These together with other features suggest its affinities with the leaves of *Heynea trijuga* Roxb. (Herb. sheet nos. FRI 14372, 2978) of Meliaceae. (Pl. 5, fig. 5).

Since the fossil leaf is closely comparable with that of *Heynea trijuga*, it is named as *Heynea trijugoides* sp. nov.

Heynea is very small genus of trees or shrubs confined to Indo-Malayan region. *H. trijuga*, the only species occurring in India, grows in the sub-Himalayan tract up to 1500 m elevation from Kumaon eastwards to North Bengal; in the plain and hill forests of Assam ascending to 600 m; Chota Nagpur, in the Eastern Ghats up to 1,400 m and in the Western Ghats where it is common from Mysore to Travancore up to 1,80 m. In Myanmar, it occurs in the hill forests at an elevation of about 600-1200 m (Ghosh, Purkayastha & Lal, 1963).

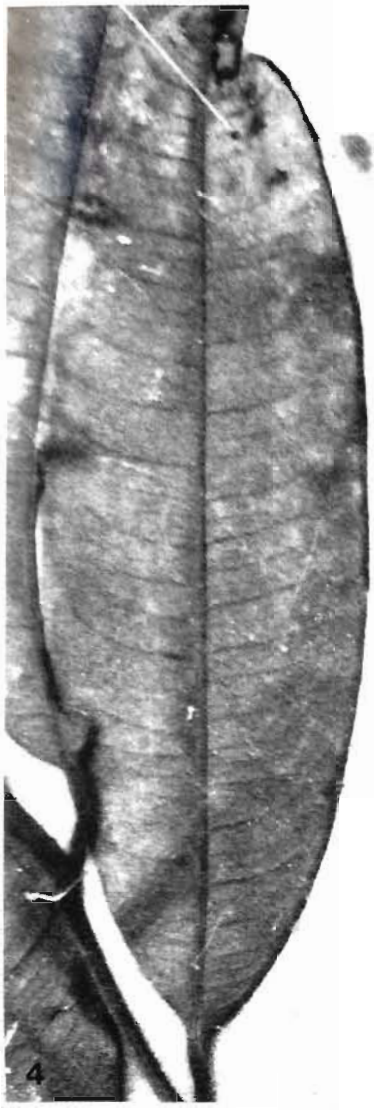
Family — Sapindaceae

Genus — *Nephelium* Linn.

Nephelium oligocenicum sp. nov.
Pl. 4, fig. 2; Pl. 5, fig. 1

PLATE 4

1. Kayea baragolaensis sp. nov. — a fossil leaf showing details of venation pattern; specimen no. BSIP 37088.
2. *Nephelium oligocenicun* sp. nov. — a fossil leaf showing shape, size and venation; specimen no. BSIP 37093.
3. *Pterygota cordata* sp. nov. — a fossil leaf showing details of venation; specimen no. BSIP 37089.
4. *Kayea floribunda* — a modern leaf showing similar details of venation as in the fossil.
5. *Nephelium rubescens* — a modern leaf showing similar shape and size as observed in the fossil.
6. *Pterygota alata* — a modern leaf showing similar venation pattern as in fossil.



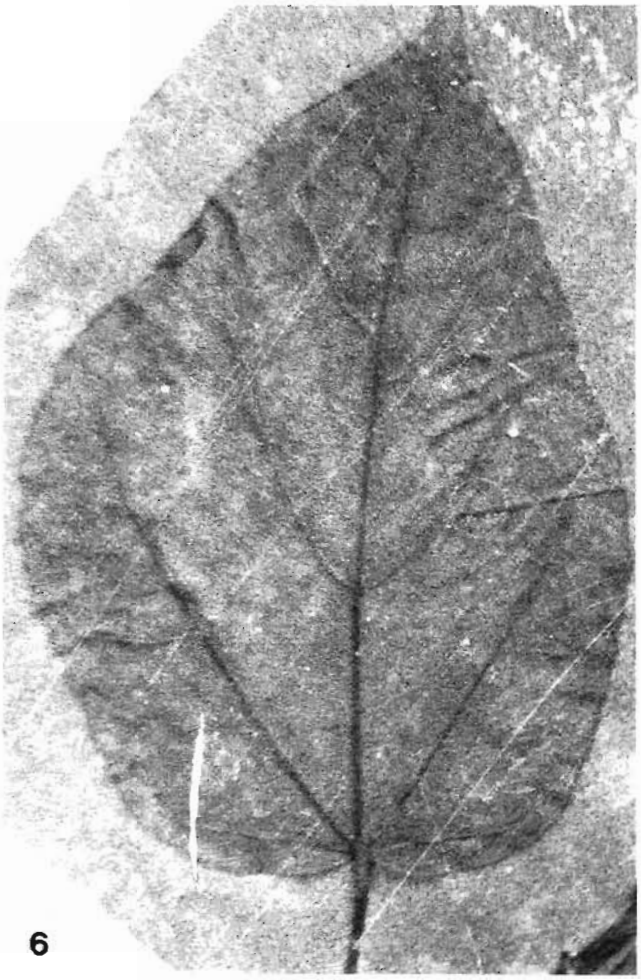


PLATE 4

Description — Leaflets symmetrical, narrow oblong to lorate, about 7 cm in length and 2 cm in width; apex broken; base symmetrical, seemingly obtuse, normal; margin entire; texture chartaceous-coriaceous; petiolule normal, about 5 mm; venation pinnate, eucamptodromous; primary vein stout, curving upward; secondary veins 11 pairs visible, each 4-8 mm apart, alternate, angle of divergence moderately acute to wide acute (55^{o}-85^{o}), uniformly curved, moderate in thickness, unbranched; intersecondary veins present, fine; tertiary veins not clearly visible.

Holotype — Specimen no. BSIP 37093.

Paratype — Specimen no. BSIP 37094.

Locality — Ledo-Tirap colliery, Tinsukia District, Assam.

Affinities — The above characters of the fossil leaflet collectively indicate its resemblance with those of *Nephelium longana* Camb. (Herbarium sheet no. CNH 97187) and *N. rubescens* Hiern (Herb. sheet no. FRI 66338) (Pl. 4, fig. 5).

Fossil leaves resembling *Nephelium* are known since long as *Nephelium jovis* Unger (1867) and *N. verbeerkianum* Geyler (1875) from the Tertiary of Europe and Borneo respectively. Our fossil leaflet is different from these species in their shape and size, therefore, we place it under a new species, *Nephelium oligocenicum.*

Nephelium is a genus of about 30 species which are either trees or shrubs distributed in Indian Archipelago, S. China and Australia (Hooker, 1872). *N. longana* is found in west side of the Peninsula, in evergreen forests from the Konkan southwards, Khasi hills and Myanmar, while *N. rubescens* is known from Martaban, Singapore and Malacca (Brandis, 1971).

Family — Anacardiaceae

Genus — *Lannea* A. Rich

Lannea oligocenica sp. nov.
Pl. 6, fig. 1

Description— Leaf incomplete, 3/4th basal part preserved, symmetrical, wide elliptic, length about 7.2 cm and width about 5.6 cm; apex broken; base somewhat rounded; margin entire; texture chartaceous; petiole about 7 mm, normal; venation pinnate, seemingly, brochidodromous; primary vein moderate, straight; secondary veins 5 pairs visible, 16-19 mm apart, alternate, angle of divergence moderately acute (45^{o}-65^{o}), almost uniform, abruptly curving upward and joining superadjacent secondaries at acute angle, moderately thick; tertiary veins random reticulate, distantly placed.

Holotype — Specimen no. BSIP 37095.

Locality — Ledo-Tirap colliery, Tinsukia District, Assam.

Affinities —

The leaf is wide elliptic with somewhat rounded base, seemingly brochidodromous venation and moderately acute angle of divergence of secondary veins. These features collectively indicate its affinity with those of *Lannea* A. Rich. of Anacardiaceae. Among the modern species of *Lannea, L. coromandelica* (Pl. 6, fig. 2) is the only Indian species available for comparison. The above features of the fossil leaf suggest its affinity with those produced by *L. coromandelica* (Herb. sheet no. CNH 97622). Since there is no other record of fossil leaf resembling *Lannea*, the present fossil leaf from Oligocene of Assam is named as *Lannea oligocenica* sp. nov.

The genus *Lannea* consists of about 70 species of small to medium-sized trees, found mostly in tropical Africa. *L. coromandelica,* the only Indian species, occurs throughout India (Santapau & Henry, 1973; Willis, 1973).

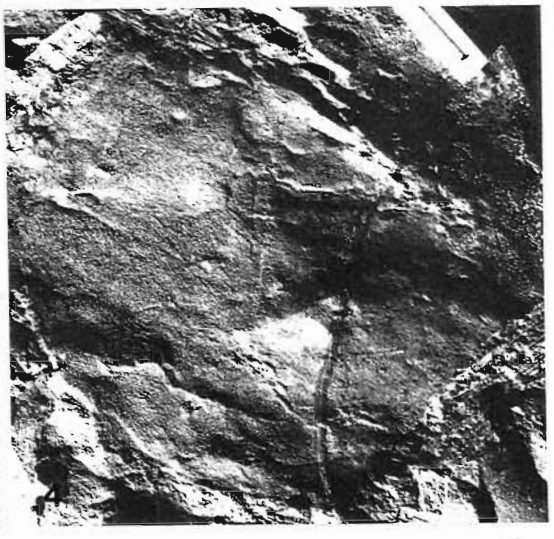
Genus —*Mangifera* Linn.

Mangifera someshwarica Lakhanpal & Awasthi 1984
Pl. 6, fig. 4; Pl. 7, fig. 1

Description — Leaf incomplete without tip, symmetrical, narrow elliptic, length 14.6 cm, width about 4.5

PLATE 5 ⟶

1. *Nephelium oligocenicum* sp. nov. — another specimen of fossil leaf showing details of venation x 2; specimen no. BSIP 37094.
2. *Heynea trijugoides* sp. nov. — a fossil leaf ; specimen no. BSIP 37091
3. *Parishia palaeoinsignis* sp. nov. — an incomplete specimen of fossil leaf; specimen no. BSIP 37098.
4. *Heynea trijugoides* sp. nov. — another specimen of fossil leaf ; specimen no. BSIP 37092.
5. *Heynea trijuga* — a modern leaf.
6. *Parishia palaeoinsignis* sp. nov. — another specimen of fossil leaf showing shape and size; specimen no. BSIP 37097.
7. *P. insignis* — a modern leaf showing similar shape and size.
8. *P. palaeoinsignis* sp. nov. — fig. 6 enlarged to show details of venation, x 2.



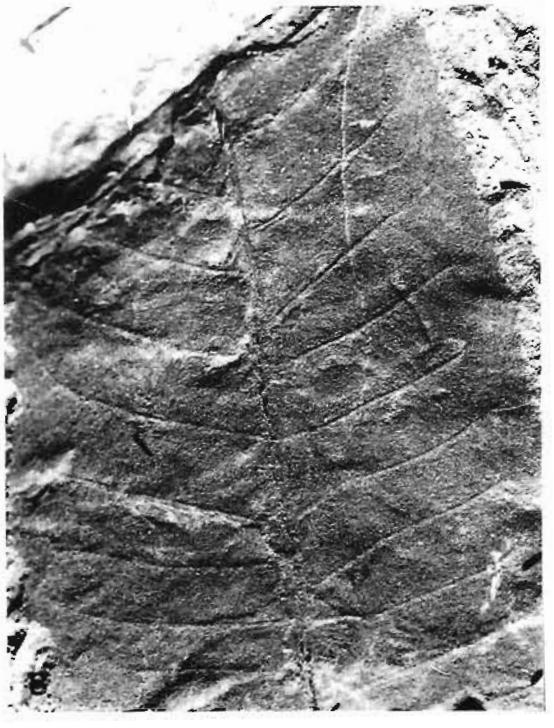


PLATE 5

cm; apex broken; base symmetrical, acute, normal; margin entire; texture seemingly coriaceous to chartaceous; petiole about 5 mm in length, normal; venation pinnate, eucamptodromous; primary vein stout, straight; secondary veins about 14 pairs visible, alternate, 5-12 mm apart, angle of divergence wide acute (70^0-85^0), lower pairs nearly at right angle, moderately thick, uniformly curved; intersecondary veins present, simple; tertiary veins percurrent, angle of origin RA-RR, sinuous, oblique, predominantly alternate, close.

Figured specimen — Specimen no. BSIP 37096.

Locality — Ledo-Tirap colliery, Tinsukia District, Assam.

Affinities — The above features clearly show that the fossil leaf belongs to the genus *Mangifera* (Pl. 6, fig. 3) of Anacardiaceae. *Mangifera* is a moderately large genus having about 41 species, distributed throughout the Indo-Malayan region.

In connection with the identification of this fossil leaf a number of species of *Mangifera* were critically examined and it was found that there is not much difference in their leaf morphology (i.e. shape, size and venation pattern). Therefore it is very difficult to suggest which of the species is closer to the fossil though in overall features the present fossil leaf from Assam appears to be similar to *Mangifera indica* Linn. as well as *M. sylvatica* Roxb. (Herbarium sheet no. FRI 39612).

Fossil leaves resembling *Mangifera* particularly *M. indica* are already reported from the Siwalik sediments of Bihar and Nepal (Lakhanpal & Awasthi, 1984; Awasthi & Prasad, 1990) as *Mangifera someshwarica*. Since our fossil specimen too is closely comparable to the leaves of *M. indica* with which the known fossil leaves have been compared, it is placed under the same species, *Mangifera someshwarica* Lakhanpal & Awasthi.

Mangifera sylvatica grows in Nepal, Sikkim, North Bengal and in Khasi Hills. It is sporadic in the evergreen forests of Upper Assam, Surma Valley and Bangladesh and rare in Andaman Islands and Myanmar (Ghosh & Purkayastha, 1963), whereas *M. indica* is found in all the forests of the plains of India and in sub-Himalayan tracts. It also grows in Bangladesh, Myanmar, Thailand, Vietnam and Malaya Peninsula (Gamble, 1972).

Genus — *Parishia* Hk. f.

Parishia palaeoinsignis sp. nov.
Pl. 5, figs 3, 6, 8

Description — Leaves symmetrical, narrow ovate, length 6.7 cm, width about 3 cm; apex acute; base asymmetrical, obtuse, normal; margin entire; texture chartaceous; petiole broken; venation pinnate eucamptodromous to weakly brochidodromous; primary vein moderate, straight; secondary veins about 16 pairs visible, alternate, 2-4 mm apart, angle of divergence moderate to wide acute (70^0-85^0), abruptly curving upward, sometimes joining superadjacent secondaries at acute to right angles at the margin, moderately thick; intersecondary veins not seen; tertiary veins fine, occasionally seen, percurrent.

Holotype— Specimen no. BSIP 37097.

Paratype— Specimen no. BSIP 37098.

Locality— Baragolai colliery near Margherita, Tinsukia District, Assam.

Affinities— The above characters of the fossil leaves collectively show their similarity with those of *Parishia* in general (Pl. 5, fig. 7) and *P. insignis* Hook. f. in particular (Pl. 5, fig. 7; Herb. sheet no. FRI 22059). These also show resemblance with *Spondias acuminata* and *S. mangifera* Willd. in shape, size and venation pattern but differ in the absence of intra marginal vein.

As this is the first record of fossil leaf of *Parishia*, it has been placed under the genus *Parishia* and named as *P. palaeoinsignis* sp. nov.

The genus *Parishia* consists of about 10 species of tall, evergreen trees, distributed from the Andamans and Myanmar through the Malayan Peninsula to Philippine Islands (Ghosh & Purkayastha, 1963; Santapau & Henry, 1973). *P. insignis* with which the fossil shows near resemblance, is common in Andaman Island and Myanmar.

Family—Fabaceae

Genus—*Entada* Adans.

Entada palaeoscandens Awasthi & Prasad 1990
Pl. 6, fig. 5

Description— Seed more or less rounded having a shallow depression at one end, large, 5.9 cm in length and 4.3 cm in width; seed coat present, visible as dark layer.

TABLE I

FOSSIL SPECIES	ALLIED MODERN SPECIES	PRESENT DISTRIBUTION
Annonaceae		
Saccopetalum palaeolongiflorum sp. nov	*Saccopetalum longiflorum*	Bangladesh
Clusiaceae		
Calophyllum surakholaensis Awasthi & Prasad	*Calophyllum polyanthum*	Evergreen tree of Bangladesh, Chittagong Hill tracts, Khasi Hills and Myanmar.
Mesua antiqua Awasthi *et al.*	*Mesua ferrea*	Evergreen tree of Himalaya, Eastern and Western Peninsula, Andamans
Garcinia palaeoluzoniensis sp. nov.	*Garcinia luzoniensis*	Indonesia
Kayea baragolaensis sp. nov.	*Kayea floribunda*	Sikkim, Assam and Myanmar
Sterculiaceae		
Pterygota cordata sp nov.	*Pterygota alata*	Evergreen forests of north-east India (Assam), Western Ghats, Chittagong, Myanmar and Andamans.
Burseraceae		
Santiria oligocenica sp. nov.	*Santiria laevigata*	Malacca
Meliaceae		
Heynea trijugoides sp.nov.	*Heynea trijuga*	In the sub-Himalayan tract up to 1,500 m elevation from Kumaon eastwards to north Bengal; in the plain and hill tracts of Assam ascending to 600 m; Chota Nagpur, in the Eastern Ghats up to 1,400 m, Western Ghats, in the hill tracts of Myanmar at an elevation of about 600-1,200 m.
Sapindaceae		
Nephelium oligocenicum sp nov.	*Nephelium longana & N. rubescens*	Western side of the Peninsula, in the evergreen forest from Konkan southwards, Khasi Hills and Myanmar, Martaban, Malacca and Singapore.
Anacardiaceae		
Lannea oligocenica sp. nov.	*Lannea coromandelica*	Throughout India
Mangifera someshwarica Lakhanpal & Awasthi	*Mangifera indica*	Evergreen tree in all the forests of the plains of India
	Mangifera sylvatica	Nepal, Sikkim, North Bengal and in Khasi Hills from 300-1, 300 m elevation; sporadic in evergreen forests of Upper Assam, Burma Valley, Chittagong hill tracts of Bangladesh; rare in the Andaman Islands and Martaban hills of Myanmar
Parishia palaeoinsignis sp. nov.	*Parishia insignis*	Evergreen tree of Andaman Island and Myanmar
Fabaceae		
Entada palaeoscandens Awasthi & Prasad	*Entada phaseoloides*	Central and Eastern Himalayas, Nepal ascending to 4,000 ft in Sikkim, western Peninsula, SriLanka, and Malacca; found with Mangrove associations and the jungle immediately behind tropical beaches.
Leguminocarpon dalbergioides sp. nov.	*Dalbergia sissoo*	Deciduous tree of plains of India, ascending to 5,000 ft in the central Himalayas, Afghanistan and Pakistan.
Rhizophoraceae		
Rhizophora coriacea sp. nov.	*Rhizophora mucronulata*	Tidal marshes of Sindh, western peninsula, Sunderbans, Andmans and Myanmar.
Combretaceae		
Terminalia palaeochebula	*Terminalia chebula*	Deciduous tree of sub-Himalayan tract from Sutlej eastwards ascending to 5,000 ft, common in deciduous forests of both peninsulas.
T. obovata sp. nov.	*T. crenulata*	Deciduous tree of south India from Travancore to Malabar, Coorg and Coimbatore, extending northwards to Kanara, Khandesh, Central Provinces, Bihar and Orissa.
T. panandhroensis Lakhanpal & Guleria	*T. coriacea*	Dry Hills of the Kurnool and Cuddapah districts of Andhra Pradesh.
T. palaeocatappa sp. nov.	*T. catappa*	Beach forests of Andamans and Malayan peninsula.

contd.

FOSSIL SPECIES	ALLIED MODERN SPECIES	PRESENT DISTRIBUTION
Memecylaceae		
Memecylon amplexicaulensis sp. nov.	*Memecylon amplecicaule*	Evergreen tree of Penang.
Avicenniaceae		
Avicennia obovata sp. nov.	*Avicennia officinalis*	Throughout India in salt marshes and tidal creeks; specially found in the Sunderbans.
Apocynaceae		
Alstonia oligocenica sp. nov.	*Alstonia neriifolia*, *A. venenatus*, *A scholaris*	Plains of lower hill forests of north Bengal, evergreen forests of Western Ghats from north Kanara southwards, East Nepal, Bhutan and Sikkim; deciduous forests from Yamuna eastwards through Uttar Pradesh, Bengal, Assam.
Myristicaceae		
Myristica lorata sp. nov.	*Myristica sylvestris*	Molucca
Lauraceae		
Apollonias litseoides sp. nov.	*Apollonias arnottii*-*Litsea glabrata*	Evergreen forests of Western Ghats.
Euphorbiaceae		
Bridelia oligocenica sp. nov.	*Bridelia retusa*	Deciduous tree found throughout India except the very dry regions and the hills above 3,500 ft.
Podocarpaceae		
Podocarpus oligocenicus sp. nov.	*Podocarpus neriifolius*	Tropical Himalaya, Nepal, Sikkim, Khasi Hills, Andaman Island, Myanmar and Malay Peninsula.

Figured specimen— Specimen no. BSIP 37099.

Locality— Ledo-Tirap colliery, Tinsukia District, Assam.

Affinities— The above characters clearly show that the fossil seed belongs to *Entada phaseoloides* Benth. Herbarium sheet no. (FRI 489/117189; BSIP 1806) of Fabaceae (Pl. 6, fig. 6).

Recently, Awasthi and Prasad (1990) described seeds of *Entada* as *E. palaeoscandens* resembling *E. phaseoloides* from the Siwalik sediments, Surai Khola, Nepal. In its shape and size our fossil seed is more or less similar to it. Therefore, it is placed in the same species. Recently this species has also been reported from Siwalik sediments of West Bengal (Antal & Awasthi, 1993).

The genus *Entada* consists of about 30 species, chiefly distributed in tropical America and Africa. In India, it is represented by a single species, *E. phaseoloides* (Hooker, 1879 ; Santapau & Henry, 1973). It is a climber found in Central and Eastern Himalayas, Nepal, ascending to 4,000 ft. in Sikkim, Western Peninsula, Sri Lanka and Malacca. It is distributed by Ocean currents and found with mangrove associations and the jungle immediately behind tropical beaches.

Genus— *Leguminocarpon* Goeppert

Leguminocarpon dalbergioides sp. nov.
Pl. 6, fig. 7

Description— Fruit pod, thin, flat, oval to strap shaped, about 4 cm in length and 1 cm in width, having a slight constriction in the middle, seemingly 2-seeded, reticulate striations visible at places.

Holotype— Specimen no. BSIP 37100.

Locality— Baragolai colliery near Margherita, Tinsukia District, Assam.

Affinities— The above characters of the fossil fruit show that it belongs to the family Fabaceae. Among legumes, the fossil is comparable with the fruits produced by *Dalbergia sissoo* Roxb. (Herb. sheet no. FRI 73/9986) (Pl. 6, fig. 8).

For naming the fossil fruits of Fabaceae, the genus *Leguminocarpon* instituted by Goeppert (1855) is widely accepted. Since the present fossil fruit is a pod and shows close resemblance with those produced by *Dalbergia*, especially *D. sissoo*, it is named as *Leguminocarpon dalbergioides* sp. nov.

As far as the record of fossil fruit of *Dalbergia* is concerned, Lakhanpal and Dayal (1966) reported an ill-preserved impression of a fruit from the Siwalik sediments (Middle Miocene) of Balugoloa, Himachal

TABLE 2 —Tropical forest types

Taxa	Wet evergreen forests (1)	Semi-evergreen forests (2)	Moist deciduous forests (3)	Littoral and swamp forests (4)	Dry deciduous forests (5)	Thorn forests (6)	Dry evergreen forests (7)
Saccopetalum longiflorum			+		+		
Calophyllum polyanthum	+						+
Garcinia	+	+					
Kayea floribunda	+						
Pterygota alata	+	+	+				
Heynea trijuga			+				
Nephelium	+	+					
Lannea coromandelica			+		+		
Mangifera	+	+	+		+		
Parishia insignis			+				
Entada phaseoloides		+	+				
Dalbergia sissoo			+		+		
Rhizophora mucronulata				+			
Terminalia chebula	+		+	+	+		
T. crenulata		+	+				
T. coriacea					+		
T. catappa							
Memecylon amplexicaule	+			+			
Avicennia officinalis				+			
Alstonia	+	+					
Myristica sylvestris	+						
Apollonias arnottii	+						
Litsea glabrata	+						
Bridelia retusa		+	+		+		

Pradesh. They called it *Dalbergia sissoo*- like fruit. Bande and Srivastava (1990) also reported a single seeded fruit cf. *Dalbergia sissoo* from Late Cenozoic deposits (Probably Pleistocene or Holocene) of Palamu District, Bihar.

Dalbergia sissoo is a deciduous tree found in the plains throughout India, ascending to 1600 m in the Central Himalayan, Afghanistan and Baluchistan (Hooker, 1879; Brandis, 1971).

Family— Rhizophoraceae

Genus— *Rhizophora* Linn.

Rhizophora coriacea sp. nov.
Pl. 7, figs 2,3

Description— Leaves incomplete, more than half basal part present and apical part missing, symmetrical, elliptic, length of available about 5 cm and width 5.2 cm; apex missing; base symmetrical, obtuse, normal; margin entire; texture coriaceous; petiole length about 1 cm, attachment normal; venation pinnate, brochidodromous; primary vein stout, straight; secondary veins more than 6 pairs visible, alternate, up to 6 mm apart, angle of divergence moderately acute (about 55°), abruptly curving and joining superadjacent secondaries, fine, intersecondary veins not clearly seen; intramarginal veins and higher order of venation not observed.

Holotype— Specimen no. BSIP 37101.

Paratype— Specimen no. BSIP 37102.

Locality— Tirap colliery near Ledo, Tinsukia District, Assam.

Affinities— Although the leaves are incomplete, the available basal part showing elliptic shape, obtuse base and thick coriaceous stout midrib with brochidodromous venation pattern suggests their affinities with those of

Rhizophora Linn. (Pl. 7, fig. 5) of Rhizophoraceae. *R. mucronulata* Lamarck (Herb. sheet no. CNH 9109), the only species available for comparison, appears very similar to our fossil leaves.

Leaves of *Rhizophora* are known to occur in the Tertiary of North America (Lamotte, 1952). Unfortunately, the concerned literature is not available for comparison. Under the circumstances the fossil is named as *Rhizophora coriacea* sp. nov.

Rhizophora is a genus of evergreen glabrous shrubs or middle-sized trees and consists of 7 species, found in the tropical coasts. *R. mucronulata* is found in tidal marshes in Sind, Western Peninsula, Sunderbans, Andamans and Myanmar (Brandis, 1971; Willis, 1973).

Family—Combretaceae

Genus—*Terminalia* Linn.

Terminalia palaeochebula Awasthi & Prasad 1990
Pl. 7, fig. 4

Description— Leaf symmetrical, elliptic, length about 8 cm and width 4.7 cm; apex broken; base symmetrical, obtuse, normal; margin nearly entire to slightly wavy; petiole length about 1 cm; venation pinnate, eucamptodromous; primary vein stout, nearly straight; secondary veins more than 9 pairs visible, alternate, 5-9 mm apart, angle of divergence moderately acute (55°-65°), uniform, moderately thick, curving up towards margin; tertiary veins percurrent, sinuous, sometimes recurved also, angle of origin RR-AR, oblique in relation to midvein, closely placed, predominantly alternate; quaternary veins seemingly orthogonal, areoles well developed.

Figured specimen— Specimen no. BSIP 37103.

Locality— Ledo-Tirap colliery, Tinsukia District, Assam.

Affinities— The above characters of the fossil show its similarity with that of *Terminalia chebula* Retz. (Herbarium sheet no. FRI 66110 of Combretaceae (Pl. 7, fig. 6).

A large number of fossil leaves of *Terminalia* are known from different parts of the world (Lakhanpal & Guleria, 1981; Awasthi & Prasad, 1990; Bande & Srivastava, 1990; Prasad, 1990; Ambwani, 1992; Lakhanpal & Awasthi 1992). Among the fossil leaves described from Indian Tertiary sediments our fossil leaf shows similar features as that of *Terminalia palaeochebula* Awasthi & Prasad described from Siwalik sediments of Surai Khola, Nepal. There is another record of fossil leaf of *T. chebula*, viz. *T. kachchhensis* Lakhanpal *et al.* (1984) from the Tertiary of Kachchh. This leaf is incomplete having only the middle part. Since its basal and apical parts are missing it does not display all the features of *Terminalia chebula*.

Terminalia is a genus of large trees distributed in tropics of the world (Brandis, 1971). It consists of 250 species, out of which 12 are found in India (Santapau & Henry, 1973). *T. chebula*, with which the fossil shows maximum similarity, is a deciduous tree found in sub Himalayan tract from the Sutlej eastwards, ascending to 5,000 ft., common in deciduous forest of both peninsulas.

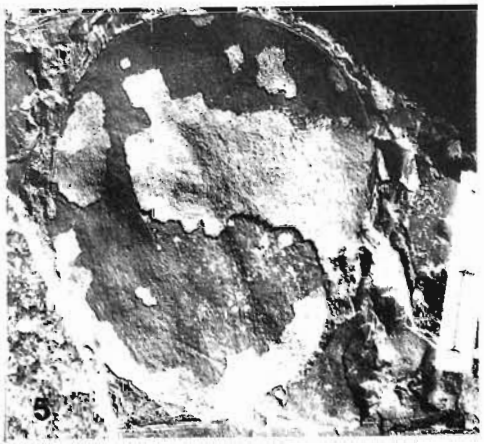
Terminalia obovata sp. nov.
Pl. 9, fig. 4

Description— Leaf symmetrical, narrow obovate, 9.5 cm in length and about 4.5 cm in width; apex rounded; base broken; margin more or less entire; texture chartaceous; venation pinnate, eucamptodromous; primary vein stout, straight; secondary veins about 9 pairs visible, alternate, 9-12 mm apart, angle of divergence moderately acute (45°-65°), almost uniform, moderately thick, uniformly curving and upturned near the margin; tertiary veins seen at places, percurrent, simple and recurved, angle of origin seemingly AR, oblique, alternate, close.

Holotype— Specimen no. BSIP 37104.

PLATE 6 →

1. *Lannea Oligocenica* sp. nov. — a fossil leaf showing venation pattern; specimen no. BSIP 37095.
2. *Lannea coromandelica* — a modern leaf showing similar venation pattern.
3. *Mangifera sylvatica* — a modern leaf.
4. *Mangifera someshwarica* Lakhanpal & Awasthi — a fossil leaf showing shape, size and venation; specimen no. BSIP 37096.
5. *Entada palaeoscandens* Awasthi & Prasad — a fossil seed; specimen no. BSIP 37099.
6. *Entada phaseoloides* — a modern seed.
7. *Leguminocarpondalbergioides* sp. nov. — a fossil fruit; specimen no. BSIP 37100.
8. *Dalbergia sissoo* — a modern fruit.



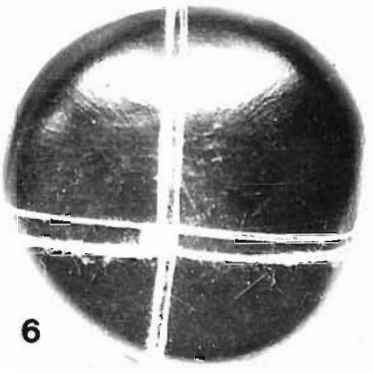


PLATE 6

Locality— Ledo-Tirap colliery, Tinsukia District, Assam.

Affinities— Narrow obovate shape with rounded apex, eucamptodromous venation and percurrent tertiaries are the important features of the fossil leaf. In these features it shows resemblance with leaves produced by *Terminalia crenulata* Heyne ex Roth (Herbarium sheet no. FRI 73291; Pl. 9, fig. 2).

This fossil leaf, in its being obovate shape, is different from all the known fossil leaves assigned to the genus *Terminalia*. Therefore, it is being described as a new species, *Terminalia obovata*.

T. crenulata is distributed in south India from Travancore to Malabar, Coorg and Coimbatore, extending northwards to Kanara and Khandesh, the Central Provinces, Bihar and Orissa (Parkinson, 1937).

Terminalia panandhroensis Lakhanpal & Guleria 1981
Pl. 8, fig. 1; Pl. 9, fig. 1

Description— Leaves (two, incomplete), symmetrical, varying from wide elliptic to suborbiculate, preserved length and width, about 14.5 x 11.5 cm and 10 x 8.5 cm respectively; apex broken; base symmetrical to slightly asymmetrical, nearly rounded; margin entire; attachment with petiole appearing normal; texture coriaceous; venation pinnate, eucamptodromous; primary vein stout, slightly curved; secondary veins about 9 pairs visible, alternate, 6-20 mm apart, angle of divergence wide acute to right (70^{o}-90^{o}), right angle in the basal part and wide acute in the apical part, moderately thick, uniformly curved; intersecondary veins present, fine; tertiary veins percurrent, angle of origin AR-RR, sinuous, occasionally recurved, predominantly alternate, closely placed, oblique in relation to midvein.

Figured specimens— Specimen nos. BSIP 37105, 37106 (reduced into powder due to gypsum formation).

Locality— Tirap colliery near Ledo, Tinsukia District, Assam.

Affinities— The above characters of the fossil, especially the wide elliptic to suborbiculate shape, more or less rounded base, entire margin, eucamptodromous venation, wide acute to right angle of divergence of secondary veins and percurrent tertiaries suggest close similarity of the fossil with the leaves of *Terminalia coriacea* (Roxb.) Wight & Arn. (Herb. sheet nos FRI 55820, 55821).

Fossil leaves resembling *T. coriacea* are already known as *T. panandhroensis* Lakhanpal & Guleria 1981 from the Eocene of Kachchh, Siwalik sediments of Nepal (Awasthi & Prasad, 1990) and Palaeocene of Cherrapunji (Ambwani, 1992). Our present fossil leaves from Oligocene of Assam are very similar to these Known fossil leaves in all the morphological characters and hence placed in the same species. *T. coriacea* is distributed in the dry hills of the Kurnool and Cuddapah districts, Andhra Pradesh (Parkinson, 1937).

Terminalia palaeocatappa sp. nov.
Pl. 10, fig. 1; Pl. 11, figs 1,2,5

Description— Leaves symmetrical, narrow obovate, preserved length and width about 13 x 8.5 cm, 13 x 7.5 cm respectively; apex obtuse to rounded; base symmetrical, obtuse, normal; margin entire; texture chartaceous; petiole about 1 cm in length, attachment normal; venation pinnate, eucamptodromous; primary vein stout, slightly curved; secondary veins about 12 pairs visible, alternate, 7-17 mm apart, angle of divergence usually wide acute (70^{o}-80^{o}), more or less uniform, moderately thick, uniformly curved, rarely bifurcated to join superadjacent secondaries; tertiary veins occasionally seen, seemingly percurrent.

Holotype— Specimen no. BSIP 37107.

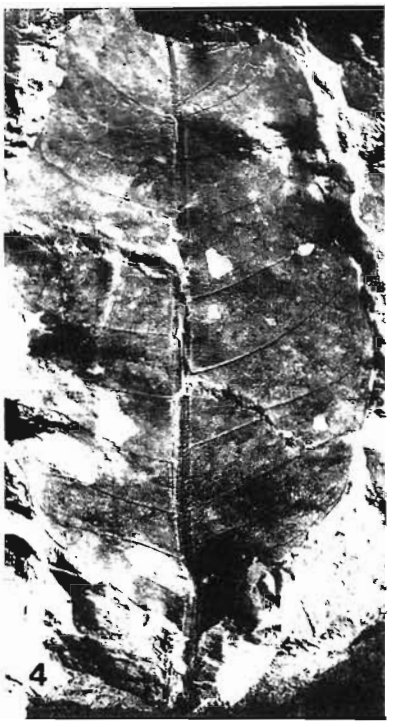
Paratype— Specimen no. BSIP 37108 (reduced into powder due to gypsum formation).

Locality— Ledo-Tirap colliery, Tinsukia District, Assam.

Affinities— In overall characters, such as shape, size and venation pattern the fossil leaves are comparable to those of *Terminalia*. Amongst the species of *Terminalia*,

PLATE 7 →

1. *Mangifera someshwarica* Lakhanpal & Awasthi — fossil leaf enlarged to show details of venation, x 1.5.
2. *Rhizophora coriacea* sp. nov. — a fossil leaf , specimen no. BSIP 37101
3. *R. coriacea* sp. nov. — another specimen of fossil leaf ; specimen no. BSIP 37102.
4. *Terminalia palaeochebula* Awasthi & Prasad — a fossil leaf showing shape, size and venation; specimen no. BSIP 37103.
5. *Rhizophora mucronulata* — a modern leaf.
6. *Terminalia chebula* — a modern leaf showing similar shape, size and venation pattern.



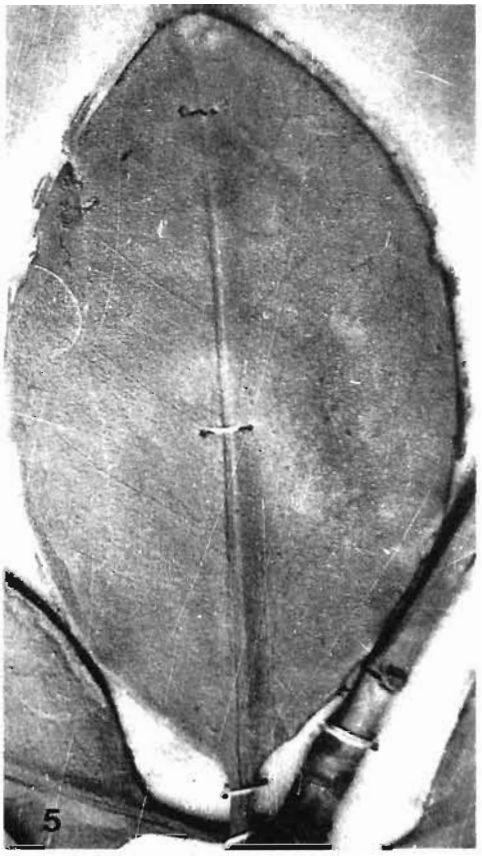


PLATE 7

considering all the morphological details, the fossil leaves are very similar to those produced by *Terminalia catappa* Linn. (Pl. 10, fig. 2) (Herbarium sheet nos FRI 13960, 2361) and differ from all other species. Therefore, they are being named as *Terminalia palaeocatappa* sp. nov.

A fossil leaf of *Terminalia*, cf. *T. catappa* Linn. is known from the Eocene of Halle (listed in Nemejc, 1975). Since the original literature pertaining to this fossil is not available for comparison, it is not possible to make comments on its identification, etc.

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

Family—Memecylaceae

Genus—*Memecylon* Linn.

Memecylon amplexicaulensis sp. nov.
Pl. 8, fig. 6

Description— Leaf symmetrical, narrow ovate, 7.6 cm in length and 4.1 cm in width; apex acute; base symmetrical, rounded, margin entire; texture coriaceous; venation pinnate, brochidodromous; primary vein moderately thick, markedly curved; secondary veins poorly preserved, angle of divergence moderately acute (50°-65°), 4-5 mm apart, alternate, fine, abruptly curved, joining superadjacent secondaries at acute angle; tertiary veins ill-preserved, seemingly reticulate.

Holotype— Specimen no. BSIP 37109 (reduced into powder due to gypsum formation).

Locality— Baragolai colliery near Margherita, Tinsukia District, Assam.

Affinities.— The above characters of the fossil especially coriaceous texture, brochidodromous venation and curved primary vein indicate its similarity with the leaves of *Memecylon amplexicaule* Roxb.

(Herbarium sheet nos FRI 30781/99669) of Memecylaceae (Pl. 8, fig. 7).

As this is the first record of fossil leaf of *Memecylon*, it has been placed under the genus *Memecylon* and named *M. amplexicaulensis* sp. nov.

Memecylon is a genus of evergreen trees or shrubs having over 300 species (Santapau & Henry, 1973), distributed in Southeast Asia and its Islands, Polynesia, Australia and tropical Africa. *M. amplexicaule* with which the fossil shows near resemblance, is found in Penang (Hooker, 1879; Brandis, 1971).

Family—Avicenniaceae

Genus—*Avicennia* Linn.

Avicennia obovata sp. nov.
Pl. 8, fig. 2

Description— Leaf symmetrical, wide obovate, length 5.1 cm, width 3.9 cm; apex broken; base symmetrical, acute, normal; margin entire; petiole 7mm in length, attachment normal; texture chartaceous; venation pinnate, brochidodromous; primary vein moderately thick, more or less straight; secondary veins about 6 pairs visible, alternate, 5-8 mm apart, angle of divergence usually narrow acute to moderately acute (40°-55°), almost uniform, fine, abruptly curving up towards margin and joining superadjacent secondaries at acute angle; intersecondary veins present, simple to composite; tertiary veins not well-preserved, reticulate.

Holotype— Specimen no. BSIP 37110.

Locality— Baragolai near Margherita, Tinsukia District, Assam.

Affinities— In its shape, size, details of venation pattern, the fossil leaf is typically an *Avicennia* Linn. type (Pl. 8, fig. 3). Among the species of *Avicennia*, the fossil leaf is closely comparable to *Avicennia officinalis* Linn.

Fossil leaves of *Avicennia* were described as *Avicennia eocenica* and *A. nitidaformis* from Lower Eocene of southeastern North America (Berry, 1916), *A. nitida* Jacquin from Pleistocene of Trinidad (Berry, 1925) and *A. miocenica* from Miocene of Colombia (Berry, 1936). The literature on most of these species is not available

PLATE 8 →

1. *Terminalia panandhroensis* Lakhanpal & Guleria — an incomplete specimen of fossil leaf; specimen no. BSIP 37105.
2. *Avicennia obovata* sp. nov. — a fossil leaf showing shape and size; specimen no. BSIP 37110.
3. *A. officinalis* — a modern leaf.
4. *Bridelia oligocenica* sp. nov. — a fossil leaf; specimen no. BSIP 37115.
5. *Bridelia retusa* — a modern leaf showing similar venation.
6. *Memecylon amplexicaulensis* sp. nov. — a fossil leaf showing shape and size; specimen no. BSIP 37109.
7. *M. amplexicaule* — a modern leaf.

PLATE 8

for comparison. However, it is being described here as *Avicennia obovata* sp. nov., the specific name indicates obovate shape of the leaf.

The genus *Avicennia* consists of 12 species, distributed on the sea coast within the tropics of both hemispheres (Brandis, 1971; Santapau & Henry, 1973). *A. officinalis*, the living counterpart of the fossil, is a large evergreen shrub or tree which grows especially in the Sunderbans. It is usually found throughout India in salt marshes and tidal creeks.

Family—Apocynaceae

Genus—*Alstonia* R. Brown

Alstonia oligocenica sp. nov.
Pl. 11, fig. 3; Pl. 12, fig. 1

Description— Leaves symmetrical, very narrow elliptic, preserved length about 15 cm and width 3 cm; apex acuminate; base broken; margin entire; texture chartaceous; venation pinnate, eucamptodromous; primary vein moderate, straight to markedly curved especially in the apical region; secondary veins numerous, alternate, closely placed (2-4 mm apart), wide acute to right angle (70^{o}-90^{o}), fine, uniformly curved, unbranched; intersecondary veins occasionally present, simple; intramarginal vein observed; tertiary veins not preserved.

Holotype— Specimen no. BSIP 37111.

Paratype— Specimen no. BSIP 37112.

Locality— Baragolai colliery near Margherita, Tinsukia District, Assam.

Affinities— As described above, the fossil leaves are very characteristic in their being very narrow elliptic in shape with numerous secondary veins mostly arising at 80^{o}-85^{o} from the midvein and forming intramarginal vein. These features suggest their affinities with the leaves of the genus *Alstonia* R. Brown (Pl. 17, fig. 4) of Apocynaceae. Detailed comparison with the leaves of *Alstonia scholaris* Brown, *A. neriifolia* Don (Herbarium sheet no. CNH 289897) and *A. venenatus* Br. (Herbarium sheet no. CNH 289789) revealed that the fossil leaves show resemblance with all these species. However, unlike fossil leaves, the leaves of *A. scholaris* are generally obovate with obtuse apex, while in *A. neriifolia* and *A. venenatus* they are narrow elliptic with acuminate apex. The fossil leaves slightly differ from these in their shape, i.e., the basal part is wider, and the apical part is much narrower. However, in overall features the present fossil leaves are closer to *A. neriifolia* and *A. venenatus* than *A. scholaris*. Therefore, they are being assigned to a new species, *Alstonia oligocenica*.

Fossil leaves of *Alstonia*, those comparable to *Alstonia scholaris* are already known from the Siwalik sediments of foot-hills of Darjeeling District (Antal & Awasthi, 1993) and Late Cenozoic sediments of Palamu District, Bihar (Bande & Srivastava, 1990). However, in shape and size both are different from our fossil leaves.

The genus *Alstonia* consists of 30 species of trees, rarely shrubs, distributed in the Indo-Malayan region extending to Australia and Polynesia. *A. neriifolia* is found in East Nepal, Bhutan and Sikkim while *A. venenatus* occurs in the evergreen forests of Western Ghats. *A. scholaris* is distributed mostly in deciduous forests from Yamuna eastwards through Uttar Pradesh, Bengal, Assam, scarce in Bihar, Orissa and Chota Nagpur but common in West Coast (Pearson & Brown, 1932; Brandis, 1971).

Family—Myristicaceae

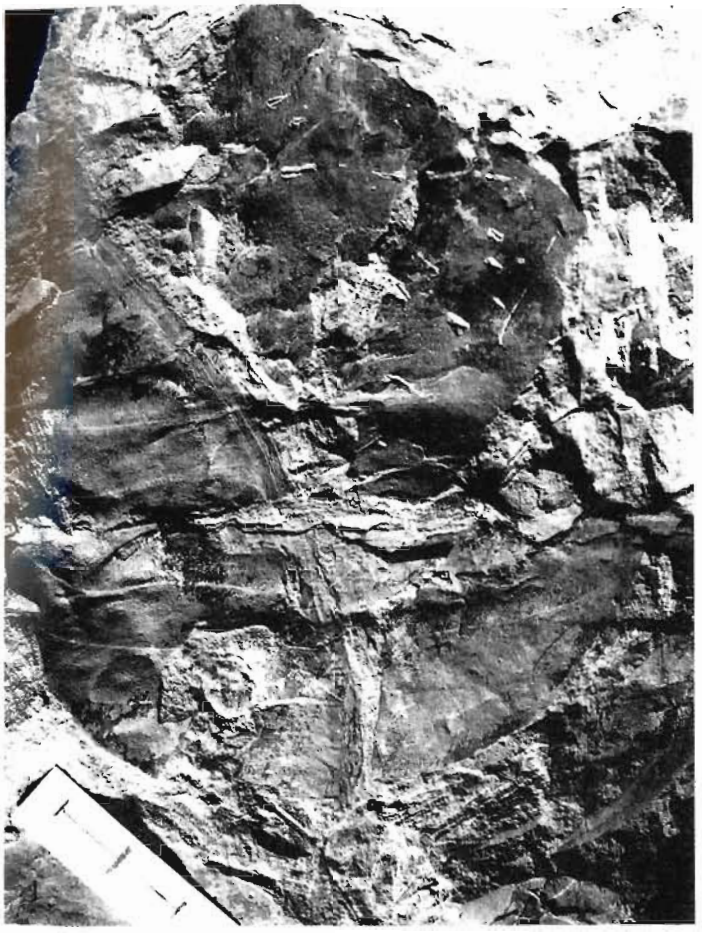
Genus—*Myristica* Linn.

Myristica lorata sp. nov.
Pl. 12, fig. 2

Description— Leaf nearly complete, symmetrical, lorate, length 14.7 cm, width about 3 cm; apex seemingly acute; base symmetrical, seemingly obtuse, normal; margin entire; texture chartaceous; attachment with petiole normal; venation pinnate, brochidodromous; primary vein stout, markedly curved; secondary veins more than 26 pairs visible, alternate, each 4-9 mm apart, angle

PLATE 9

1. *Terminaliapanandhroensis* Lakhanpal & Guleria—another specimen of fossil leaf; specimen no. BSIP 37106.
2. *T. crenulata* — a modern leaf.
3. *Apollonias lutseoides* — a fossil leaf showing shape, size and venation pattern; specimen no. BSIP 37114.
4. *Terminalia obovata* sp. nov. — a fossil leaf; specimen no. BSIP 37104.
5. *Apollonias arnottii* — a modern leaf showing similar shape and size.



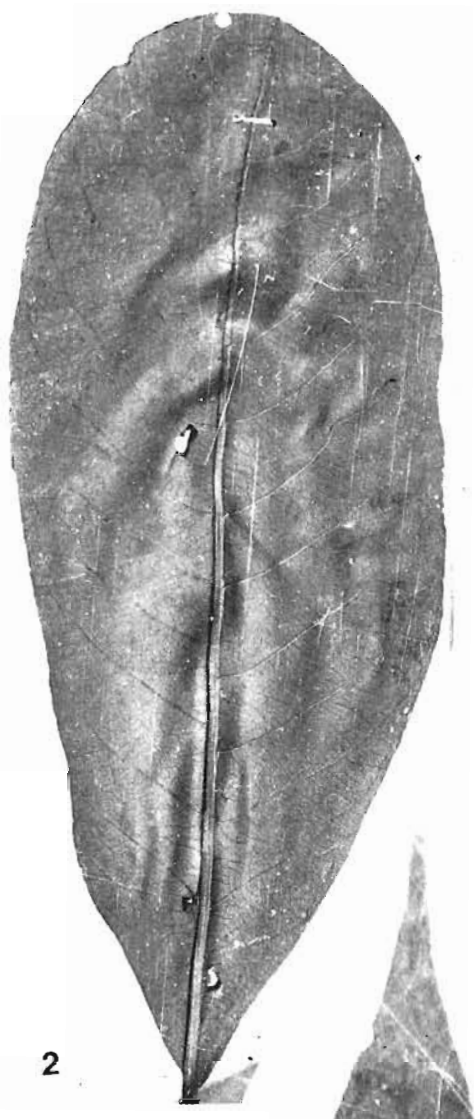


PLATE 9

of divergence moderately acute to wide acute (65°-85°), moderately thick, abruptly curving and joining superadjacent secondaries at acute to right angles; intersecondary veins present, simple; tertiary veins percurrent, simple, oblique, angle of origin RR, close, predominantly alternate.

Holotype— Specimen no. BSIP 37113.

Locality— Tripong colliery, Tinsukia District, Assam.

Affinities— The important features, such as, lorate shape, obtuse base, entire margin, brochidodromous venation and curved primary vein suggest the affinities of fossil leaf with that of *Myristica sylvestris* Houtt. (Herbarium sheet no. FRI 2208) of Myristicaceae (Pl. 12, fig. 3).

Geyler (1887) instituted the genus *Myristicophyllum* for fossil leaves of Myristicaceae and described two species as *M. minus* from the Eocene of Borneo (Geyler, 1887) and *M. penamense* from Oligocene of North America (Berry, 1919). Later, *Myristica fossilis* Engelhardt, a fossil leaf of *Myristica*, was also described from the Tertiary of Argentina. However, according to Berry (1938) the affinities of this fossil leaf are doubtful. Unfortunately, Geyler and Berry's publications are not available for comparison. The only record of fossil leaf of *Myristica* from the Indian Tertiary sediments is *Myristica palaeoglomerata*. It was described by Awasthi and Prasad (1990) from the Siwalik sediments of Nepal. Our fossil leaf shows marked difference from *M. palaeoglomerata* in shape, size, and the number of secondary veins which are two times more. Therefore, it is named as *Myristica lorata* sp. nov. The specific name is after the Lorate shape of the leaf.

The genus *Myristica* consists of 120 species, distributed throughout the tropics of both hemispheres (Pearson & Brown, 1932; Santapau & Henry, 1973). *M. sylvestris*, with which the fossil shows near resemblance, is an evergreen tree found in Molucca.

Family—Lauraceae

Genus—*Apollonias* Nees

Apollonias litseoides sp. nov.
Pl. 9, fig. 3

Description— Leaf complete, symmetrical, narrow elliptic to lanceolate, length 10.3 cm, width 2.4 cm; apex broken; base symmetrical, acute, normal; margin entire; texture membranous; attachment with petiole normal; petiole small, preserved length 3 mm; venation pinnate, eucampotodromous; primary vein stout, nearly straight; secondary veins 12 pairs visible, alternate, 6-12 mm apart, angle of divergence narrow acute (40°-45°), almost uniform, moderately thick, uniformly curving upward and running along the margin; intersecondary veins occasionally present, short and simple; tertiary veins percurrent, forked, sometimes recurved also, angle of origin RR to AR, predominantly alternate, oblique in relation to midvein, closely placed.

Holotype— Specimen no. BSIP 37114.

Locality— Tipong colliery, Tinsukia District, Assam.

Affinities— The above features of fossil leaf show its resemblance with those of *Apollonias* Nees (Pl. 9, fig. 5) and some species of *Litsea* of Lauraceae. From a careful study of venation pattern it is evident that the fossil leaf is closer to *Apollonias arnottii* Nees (Herb. sheet no. FRI 20607) and *Litsea glabrata* Wall. (Pascal & Ramesh, 1987, Pl. 76, fig. 219). Therefore, it is named as *Apollonias litseoides* sp. nov. Fossil record of *Apollonias* leaves are not known so far. However, fossil leaves comparable to *Litsea* have been described as *Litsea polyantha* Juss. from the foot-hills of Darjeeling District (Pathak, 1969) and *Litsea prenitida* Lakhanpal & Awasthi (1984) from the Siwalik sediments of Bhikhnathoree, Bihar-Nepal border. Both the known fossil leaves are different from our specimen.

Apollonias, a small genus of evergreen trees, consists of only two species out of which only one *A. arnottii* is found in India. It is distributed in the evergreen forests of Western Ghats (Santapau & Henry, 1973). *Litsea glabrata* is a small to medium-sized tree found in Travancore.

Family—Euphorbiaceae

Genus—*Bridelia*

Bridelia oligocenica sp. nov.
Pl. 8, fig. 4

Description— Leaf incomplete, about 1/4th apical part missing, symmetrical, elliptic, preserved lamina length of available part about 5 cm, width about 2.5 cm; apex missing; base symmetrical, wide acute, normal; margin entire; texture seemingly chartaceous; petiole broken; venation pinnate, eucamptodromous; primary

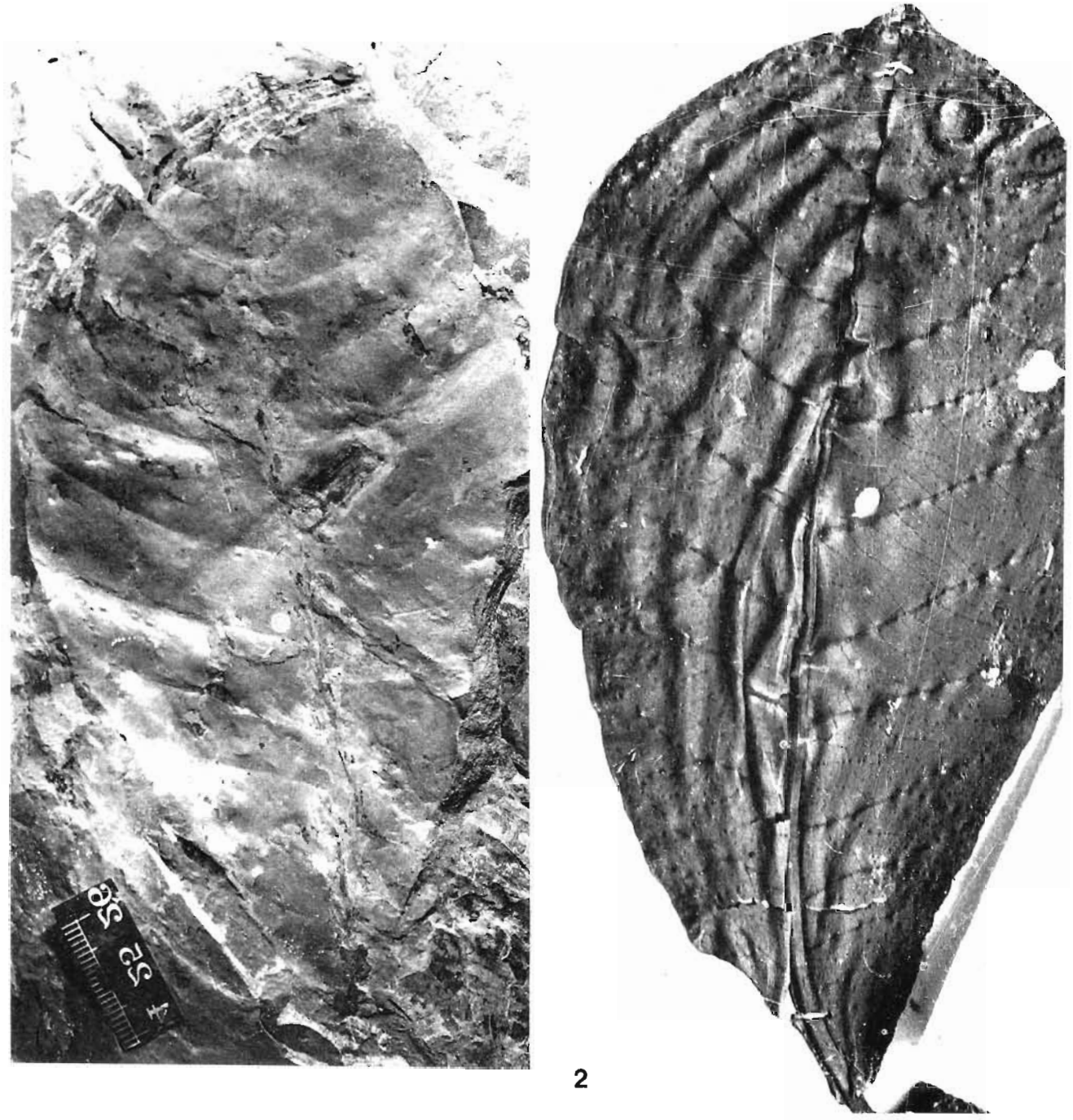


PLATE 10

1 *Terminalia palaeocatappa* sp. nov. — a fossil leaf showing shape, size and venation pattern; specimen no. BSIP 37107.

2. *T. catappa* — a modern leaf showing similar shape, size and venation pattern.

vein stout, straight; secondary veins 9 pairs visible, alternate, 4-6 mm apart, angle of divergence narrow acute (35^{o}-45^{o}), uniform, moderately thick, uniformly curved; tertiary veins not well preserved, seemingly percurrent.

Holotype— Specimen no. BSIP 37115.

Locality— Tirap colliery near Ledo, Tinsukia District, Assam.

Affinities— The fossil leaf shows close resemblance with that of *Bridelia*, especially with *B. retusa* Spreng. (Herb. sheet no. CNH 4440) of Euphorbiaceae (Pl. 8, fig. 5).

Fossil leaves of *Bridelia*, namely *B. stipularis* Bl. and *B. verrucosa* Haines are already described by Pathak (1969) from the Siwalik sediments of Mahanadi River beds, Darjeeling District, West Bengal. Both are different from our fossil leaf especially in shape, size and angle of origin of secondary veins. In view of these differences the present fossil leaf is placed under a new species *Bridelia oligocenica*.

Bridelia is a genus of trees, shrubs or staggling climbers, comprising 60 species, found in Africa and Asia (Gamble, 1972; Willis, 1973). *B. retusa* is a large deciduous tree found throughout India except the very dry regions and the hills above 1,200 m.

GENERAL DISCUSSION

The present study is the first systematic work on megafossils from the Oligocene sediments of India. The floral assemblage of Makum Coalfield including the two species *Podocarpus Oligocenicus* and *Mesua antigua*, described by Awasthi *et al.* (1992), consists of 21 genera and 26 species belonging to 16 families of dicotyledons. The monocotyledonous leaves also commonly occur in the sediments but they are yet to be studied. Considering the extent and thickness of the Oligocene sediments exposed in Makum Coalfield and the amount of plant material preserved therein, the assemblage reported presently is relatively small, therefore, it is too early to reconstruct a comprehensive vegetational scenario and to interpret the palaeoecology and depositional environment. Nevertheless, on the basis of some significant taxa, broad inferences can be deduced.

The comparable extant taxa of fossil plants from Makum Coalfield (Table 1) are *Podocarpus neriifolius, Saccopetalum longiflorum, Calophyllum polyanthum, Garcinia luzoniensis, Kayea floribunda, Pterygota alata, Santiria laevigata, Heynea trijuga, Nephelium longana - N. rubescens, Lannea coromandelica, Mangifera indica - M. sylvatica, Parishia insignis, Entada phaseoloides, Dalbergia sissoo, Rhizophora mucronulata, Terminalia chebula, T. crenulata, T. coriacea, T. catappa, Memecylon amplexicaule, Avicennia officinalis, Alstonia neriifolia - A. venenatus, Myristica sylvestris, Apollonias arnottii - Litsea glabrata* and *Bridelia retusa*.

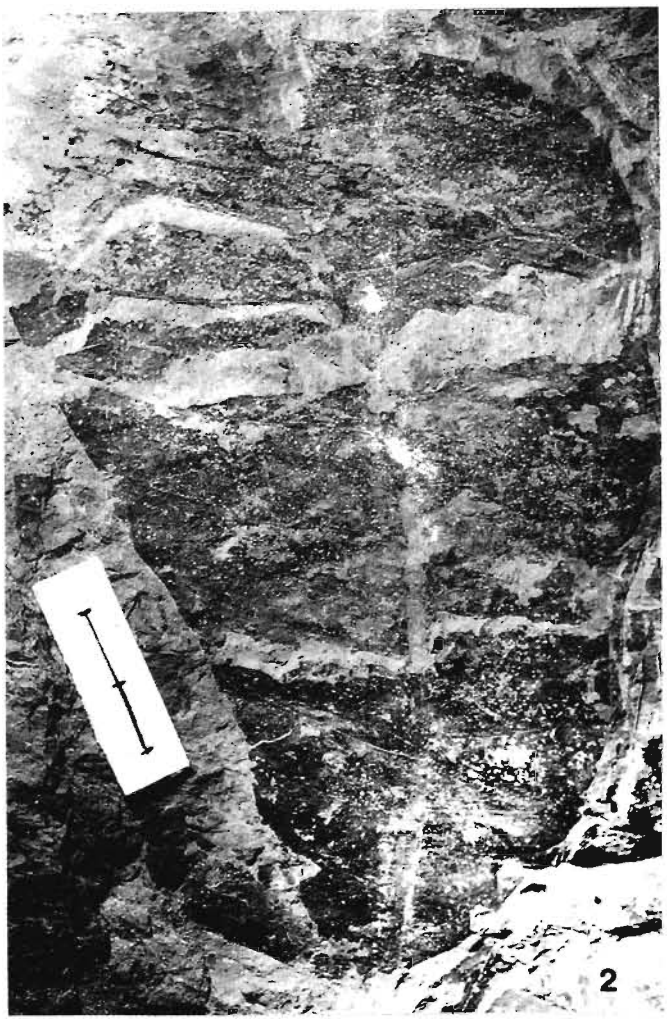
Most of the megafossil genera are reported either from early Tertiary or from Miocene - Pliocene sediments of India. However, there are a few other genera, viz., *Saccopetalum, Santiria, Rhizophora, Memecylon, Avicennia* and *Apollonias* which are being reported for the first time from the Indian Tertiary rocks as megafossills.

In an assemblage of 21 genera, based on megafossils, the family Clusiaceae is represented by *Calophyllum, Mesua* and *Kayea*. The family Anacardiaceae also consists of three genera, viz., *Mangifera, Lannea* and *Parishia*. The genus *Terminalia* of Combretaceae is represented by four species, *T. chebula, T. coriacea, T. crenulata* and *T. catappa* respectively as the nearest modern equivalents of fossil leaves. Fossil record of all these tropical elements provides evidence of their wider distribution in India throughout the Tertiary period.

A perusal of the distribution pattern of equivalent modern species of fossils (Tables 1, 2) and keeping in view the great amount and variety of plants preservd in the sediments, it is inferred that thick tropical evergreen to moist deciduous forest existed in this part of northeast India during Oligocene. Occurrence of *Avicennia*,

PLATE 11 →

1. *T. palaeocatappa* sp. nov. — a portion of the fossil leaf (Pl. 10, fig.1) enlarged, x 1.5.
2. *T. palaeocatappa* sp. nov.— another specimen of fossil leaf; specimen no. BSIP 37108.
3. *Alstonia oligocenica* sp.nov. — a fossil leaf showing details of venation; specimen no. BSIP 37111
4. *Alstonia neriifolia* — a modern leaf showing similar details of venation.
5. *Terminalia palaeocatappa* — a portion of leaf of fig. 2 enlarged to show details of venation, x 1.2.



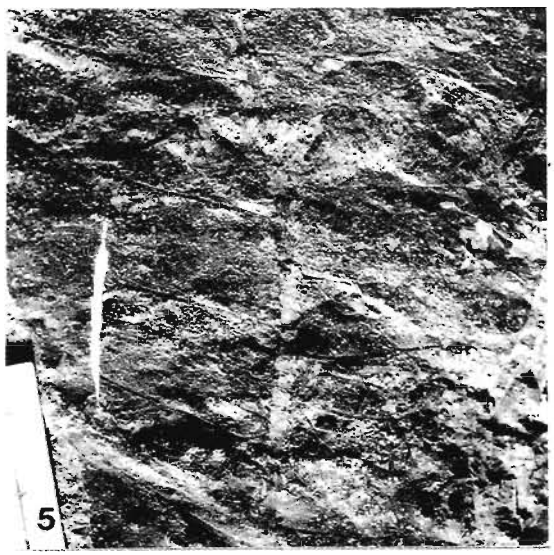


PLATE 11

PLATE 12

1 *Alstonia oligocenica* sp.nov. — another specimen of fossil leaf; specimen no. BSIP 37112.

2. *Myristica lorata* sp. nov. — a fossil leaf showing shape, size and venation; specimen no. BSIP 37113.

3. *Myristica sylvestris* — a modern leaf showing similar details.

Rhizophora and *Terminalia catappa* are very significant from the view point of depositional environment. These taxa are highly suggestive of deltaic, mangrove or lagoonal deposition of coal seams and associated sediments in the Makum Coalfield. This view also gets support from Misra's (1992a, b) work on Makum coals. He has also reported the presence of pollen referable to *Nypa, Rhizophora, Barringtonia, Heliospermopsis* to salt glands of mangrove leaves. According to him (Misra, 1992a, b) the vitrinite-rich, sporinite-poor bright, non-banded nature of coal seams and frequent associations of fungal remains indicate a tropical humid climate with high annual precipitation which facilitated the growth of luxuriant coastal to near shore mangrove mixed forest vegetation with prolific undergrowth during the deposition of coal bearing sediments.

The present climate of the area is tropical and warm humid with heavy rainfall due to summer monsoon. The annual rainfall varies from about 254-320 cm with 150-180 rainy days. The temperature and relative humidity during the year vary between 6-36°C and 80- 95 per cent respectively (Rao, 1981; Raja Rao 1981). Since there has been no major change in the annual precipitation, the area is still covered with dense forest and prolific undergrowth of lycopods, ferns and several varities of herbs and shrubs. But there is much difference between the floristic composition of today and that of Oligocene time. Out of 26 species recovered from the Makum Coalfield, *Saccopetalum longiflorum, Garcinia luzoniensis, Santiria laevigata, Nephelium pubescens, Parishia insignis, Entada phaseoloides, Rhizophora mucronulata, T. crenulata, T. coriacea, T. catappa, Memecylon amplexicaule, Avicennia officinalis, Alstonia venenatus, Myristica sylvestris* and *Apollonias arnottii* no more occur in the area but are confined to Myanmar, Bangladesh, Andaman Islands, Western Ghats and elsewhere in Southeast Asia.

During last 30 million years eversince coal seam and associated sediments were deposited in the Makum Coalfield several major physiographic changes took place in the Indian subcontinent from time to time greatly affecting the vegetation patterns. The advent of northern temperate elements in the Himalayan region and Malaysian and African elements in the peninsular India during post Oligocene epoch caused tremendous increase in the floral diversity and thus bringing about the changes in their distribution pattern and migration. Another important factor of disappearance of *Rhizophora, Avicennia, Terminalia catappa* and other near shore or coastal element from this region is caused by shifting of shoreline hundreds of kilometer south to the present shore line of Bangladesh and West Bengal.

ACKNOWLEDGEMENTS

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