The Palaeobotanist 57(2008) : 479-495
0031-0174/2008 $2.00

Fossil leaf-impressions from the Late Tertiary sediments of Mahuadanr Valley, Latehar District, Jharkhand, India

SANJAI KUMAR SINGH AND MAHESH PRASAD

Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226007, India.
E-mail: sanjai_sk2002@yahoo.co.in; mahesh_bsip.@ yahoo.com

(Received 19 June, 2007; revised version accepted 05 August, 2008)

ABSTRACT

Singh SK & Prasad M 2008. Fossil leaf-impressions from the Late Tertiary sediments of Mahuadanr Valley, Latehar District, Jharkhand, India. Palaeobotanist 57(3): 479-495.

Morphotaxonomical study of the leaf impressions collected from the Late Tertiary sediments of Mahuadanr Valley, Jharkhand, India has been done. The comparison of morphological features between the fossils and extant taxa revealed the occurrence of 13 species of 5 dicotyledonous families. On the basis of present assemblage the palaeoclimate and phytogeography of Mahuadanr area during the Late Tertiary have been deduced. Present distribution of all the modern comparable species of the fossils indicates that these are presently found to grow in the tropical forests of the Himalayan foot hills, central India, south India and adjoining area of the Mahuadanr Valley, suggesting a mixed, mesophytic type of forest was flourishing in and around the fossil locality during the sedimentation. As most of the comparable species are found now-a-days in the vicinity of fossil locality of Mahuadanr it indicates that same flora has continued till now which suggests that there has been no marked climatic change in the area since the Late Tertiary time.

Key-words—Leaf impressions, Angiosperms, Palaeoclimate, Phytogeography, Late Tertiary, Mahuadanr, Jharkhand (India).

भारत में झारखंड के लातेहार जिले की महुआडाँर घाटी के अंतिम तृतीयक अवसादों से प्राप्त पर्ण-छाप जीवाश्म

संजय कुमार सिंह एवं महेश प्रसाद

सारांश

भारत के झारखंड राज्य की महुआडाँर घाटी के अंतिम तृतीयक अवसादों से संग्रहीत पर्ण छापों (मुद्राश्म) का आकारवर्गिकीय अध्ययन पूर्ण हो चुका है। जीवाश्मों एवं विद्यमान वर्गक में आकारिकीय लक्षणों की तुलना से 5 द्विबीजपत्री परिवारों की 13 जाति की प्राप्ति हुई हैं। अंतिम तृतीयक के दौरान महुआडाँर क्षेत्र की वर्तमान समुच्चयों की पुराजलवायु व पादप भूगोल के आधार पर निगमित की गई हैं। जीवाश्मों के समस्त आधुनिक तुलनीय जाति के वर्तमान वितरण इंगित करते हैं कि ये वर्तमान में हिमालयी गिरिपादों के उष्णकटिबंधीय वनों, मध्य भारत, दक्षिणी भारत एवं महुआडाँर घाटी के आस-पास क्षेत्रों में उगते पाए गए हैं। अवसादन के दौरान जीवाश्म उपबस्ती के आस-पास मिश्रित, मेसोफायटी प्रकार के वनों का विकसित होना प्रस्तावित करता है। इन दिनों महुआडाँर की जीवाश्म उपबस्ती के पड़ोस में तुलनीय जाति पाई गई हैं। इससे यह संकेत मिलता है कि यह वनस्पति जात अब भी मौजूद है जो कि प्रस्तावित करती है कि अंतिम तृतीयक काल से क्षेत्र में कोई उल्लेखनीय जलवायु परिवर्तन नहीं हुआ है।

मुख्य शब्द—पर्ण छापें, आवृतबीजी, पुराजलवायु, पादपभूगोल, अंतिम तृतीयक, महुआडाँर, झारखंड (भारत)।

Changing Scenario in Palaeobotany and Allied Subjects
Editor : J.S. Guleria

INTRODUCTION

MAHUADANR Valley (84°06' N: 23°23' E) lies in the District Latehar of Jharkhand, about 116 km south of Daltenganj (Fig.1). In the valley, the fossiliferous beds are exposed along Birha River and its tributary Jhumari and near Rajdanda Village. The exposed rock mostly consists of sandstone and shale. Puri and Mishra (1982) recorded for the first time fossil bird, fish and plant fossils. Later, a number of leaf, flower and fruit impressions and silicified woods were recorded from this area (Bande & Srivastava, 1990; Prakash *et al.*, 1988; Srivastava & Bande, 1992; Srivastava *et al.*, 1992; Srivastava & Srivastava, 1998; Srivastava, 1998; Singh & Prasad, 2007; Singh & Chauhan, 2008). Out of a large number of leaf impressions collected from the Late Tertiary sediments of Jhumari nala section Mahuadanr Valley, Jharkhand, only a few are found to be well preserved and suitable for their identification. A detailed study on these leaf impressions revealed the occurrence of 13 taxa belonging to 10 genera of 5 dicotyledonous families which have been described and discussed in the present communication.

GEOLOGICAL SETTING OF THE MAHUADANR VALLEY

The part of Jharkhand State which extends from south of the Ganges in the north to the hill ranges on the border of Orissa in the south is structurally divided into two broad tectonic divisions.

1. Gangetic plains
2. Chotanagpur Plateau region

The present fossil locality comes under the Chotanagpur Plateau region (Roy Chowdhury, 1974). The geology of this area has been worked out in detail by Puri and Mishra (1982; Fig. 1).

The geological sequence proposed by Puri and Mishra (1982) for the rocks exposed in the area is as under:

Recent Holocene	Newer Alluvium Older Alluvium	
	Unconformity	
	Shale bed	3.2 m
Upper Tertiary	Sandstone bed	3.0 m
	Conglomerate bed	2.0 m
	Unconformity	
	Pyroclastic rocks	6.0 m
	Unconformity	
Precambrian	Chotanagpur Granite Gneiss	

MATERIAL AND METHOD

About 125 fossil leaf impressions were collected from the Late Tertiary sediments exposed along the Birha River and its tributary Jhumari nala. The fossil locality is easily approachable by road and situated about 4 km from Mahuadanr Village on a road connecting to Daltenganj. The fossil leaf impressions were well preserved on brown clay shales but were mostly devoid of cuticles. These were studied with the help of low power microscope under reflected light. Their identification has been done through the consultation of a number of herbarium sheets of extant taxa at the Herbarium of Central National Herbarium, Sibpur, Howrah and Botanical Survey of India, Allahabad. For the description of leaf impressions, the terminology given by Hickey (1973) and Dilcher (1974) has been followed. For the assignment of these identified leaf impressions the name of comparable extant species has been used to avoid any taxonomical problem. The photographs of both fossil and modern comparable leaves were taken on 35 mm B/W film using SLR (Yashica Camera). The photos of comparable leaves of extant species have been put along with those of fossil leaves in plates to show their close similarity.

All the figured specimens and their photonegatives are kept in the Museum, Birbal Sahni Institute of Palaeobotany, Lucknow.

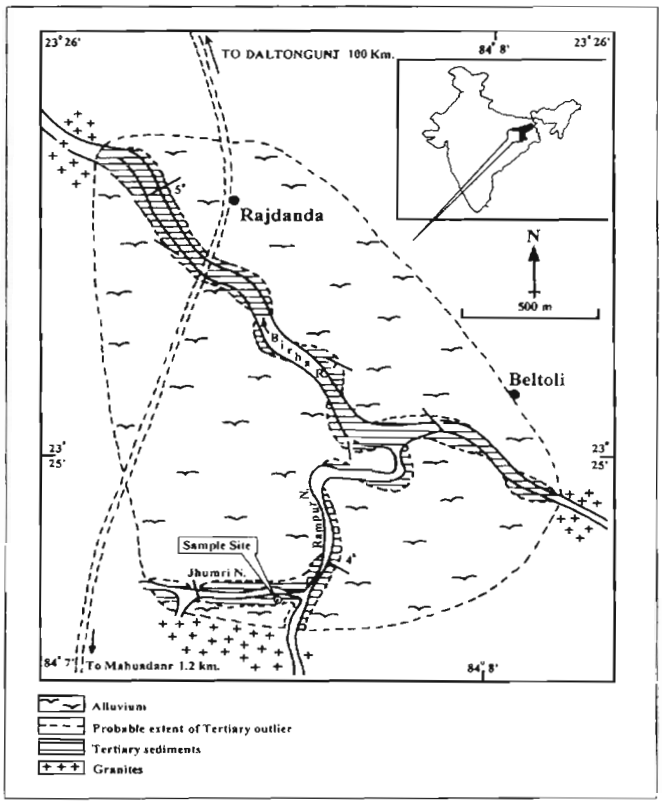


Fig. 1—Geological map of the study area (After Puri & Mishra, 1982).

SYSTEMATICS

Family—Rutaceae

Genus—*Micromelum* Blume

Micromelum pubescens Blume

(Pl. 1.1, 2; Pl. 2.6)

Material—The leaf-impression is without apex. Preservation is fair and enough to reveal the finer details of the leaf architecture.

Description—Leaf simple, asymmetrical, narrow oblong; preserved lamina size 11.6 × 4.5 cm; apex slightly broken; base oblique; margin entire; texture chartaceous; petiole indistinct; venation pinnate, eucamptodromous; primary vein (1º) single, moderate, markedly curved; secondary veins (2º) 12-13 pairs visible, 0.5 to 0.9 cm apart, alternate to opposite, angle of divergence moderately acute (55-65º), angle of divergence more acute on one side of the leaf than on the other, relative thickness of secondary vein, moderate, course curved uniformly, joining superadjacent secondaries at acute angle, intersecondary veins present, simple; tertiary veins (3º) angle of origin usually RR, percurrent, straight to sinuous, right angle to oblique in relation to midvein, predominantly alternate and close.

Discussion—The important distinguishing features of the present fossil are asymmetrical narrow oblong shape, entire margin, eucamptodromous venation, moderately acute angle of secondary veins and presence of intersecondary veins which indicate that the fossil leaf shows affinity with the leaves of the genus *Micromelum pubescens* Blume of the family Rutaceae (C.N.H. Howrah Herbarium Sheet No. 9661; Pl. 1.3).

So far, there is no record of any fossil leaf resembling genus *Micromelum* Blume from the Tertiary sediments of India and Nepal. The present fossil leaf forms its first record from the Late Tertiary sediments of Mahuadanr area.

The genus *Micromelum* Blume includes about 9 tropical species (Mabberley, 1997). *Micromelum pubescens* Blume is distributed in central and eastern Himalaya, Nepal, Sikkim and Assam. It is also common in Bangladesh, Myanmar and Sri Lanka (Hooker, 1872). It is also found in Singbhum, Hazaribagh especially in evergreen forests (Hains, 1910).

Genus-*Citrus* Linn.

Citrus aurantium Linn.

(Pl. 1.4-7)

Material—Two leaf-impressions, one with counterpart.

Description—Leaf almost symmetrical, elliptic; preserved lamina length 6.6 cm and width 3.0 cm; apex obtuse; base obtuse; margin entire; texture coriaceous; petiole winged; venation pinnate, eucamptodromous-brochidodromous; primary vein (1º) single, moderate, straight; secondary veins (2º) 6 pairs visible, distantly placed, about 1.0 to 1.5 cm apart, alternate to opposite, angle of divergence (50º-60º), moderately acute, uniformly curved, joining superadjacent secondary at acute angle, intersecondary veins present; tertiary veins (3º) fine, poorly preserved, angle of origin usually RR, rarely AO, percurrent, seemingly branched, almost straight, oblique in relation to midvein, predominantly alternate and close.

Discussion—The most important characters of the present fossil leaves such as elliptic shape, obtuse base, winged petiole and eucamptodromous-brochidodromous venation, presence of intersecondary veins, percurrent and close tertiary veins, indicate their resemblance with the leaves of *Citrus aurantium* Linn. of the family Rutaceae (C.N.H. Howrah Herbarium Sheet No. 66; Pl. 1.8).

As far as authors are aware there is no record of fossil leaf of *Citrus* Linn. from the Tertiary sediments of India and abroad. This fossil leaf forms its first record from the Mahuadanr area.

The genus *Citrus* Linn. includes about 16 species (Mabberley, 1997). *Citrus aurantium* Linn. is a small tree growing in hot valleys along the foot-hills of Himalaya from Garhwal eastwards to Sikkim and in the Khasia Hills (Hooker, 1872). It is also found in the forest of Chotanagpur region. (Hains, 1910).

Citrus medica Linn.

(Pl .2.1, 3)

Material—Two leaf-impressions. Preservation is good enough to reveal morphological details of the leaf.

Description—Leaf symmetrical, narrow oblong; preserved lamina length 7.5 cm, 4.0 cm and maximum width 3.5 cm, 2.5 cm; apex indistinct; base rounded, normal; margin broken, seemingly non entire; gland not visible; texture chartaceous; petiole not preserved; venation pinnate, eucamptodromous-brochidodromous; primary vein (1º) single, prominent, stout, straight; secondary veins (2º) 7 pairs visible, 0.4 to 1.0 cm apart, alternate to opposite, angle of divergence (45º-65º), uniformly curved joining superadjacent secondaries at acute angle, intersecondary veins present, frequent; tertiary veinss (3º) fine, poorly preserved, angle of origin RR-AO, percurrent, almost straight, alternate to opposite, oblique in relation to midvein, close.

Discussion—The important diagnostic features of the present fossil leaves are narrow oblong shape, normal, rounded base, chartaceous texture with pinnate, eucamptodromous-brochidodromous venation and joining of superadjacent secondaries at acute angle, indicate their resemblance with the genus *Citrus* Linn. of the family Rutaceae in order to find out nearest specific affinity the extant leaves of all the available species of above comparable genus were examined and concluded that the leaves of *Citrus medica* Linn. show closest similarity in shape, size and venation pattern (C.N.H. Howrah Herbarium Sheet No. 552074; Pl. 2.2). The fossil leaves showing resemblance with the genus *Citrus* Linn. described earlier in this text are entirely different from present fossil. The present fossil differs in possessing narrow oblong shape with normal petiole in comparison to elliptic shape with winged petiole in the earlier reported fossil leaves.

The comparable taxon, *Citrus medica* Linn. is found in tropical to subtropical region (Willis, 1973). It grows in waste places especially on the Hazaribagh Plateau and frequently found at the moist places in the Sub-Himalayan zone and in Duars (Haines, 1910). It also grows in the outer valley of Kumaon, Pachmarhi, Garo Hills, Satpura Hills and Western Ghats (Brandis, 1906).

Genus—*Acronychia* Frost

Acronychia laurifolia Blume

(Pl. 2.4, 6)

Material—Single, well preserved leaf-impression.

Description—Leaf almost symmetrical, oblong; lamina 10.7 × 3.1 cm; apex seemingly acute; base acute, normal; margin almost entire; texture chartaceous; petiole normal; venation pinnate, brochidodromous; primary vein (1º) single, prominent, moderate, slightly curved; secondary veins (2º) 9 pairs visible, alternate to opposite, angle of divergence acute, upper more acute than lower, secondaries 0.6 to 1.4 cm apart, moderate, joining superadjacent secondaries at right angle, intersecondary veins present, composite; tertiary veins (3º) fine with angle of origin AO-RR, percurrent, branched, approximately at right angle in relation to midvein, predominantly alternate and close.

Discussion—Almost symmetrical, oblong shape, acute apex, entire margin, pinnate, brochidodromous venation, prominent, moderate, slightly curved primary vein, composite intersecondary veins and fine with angle of origin AO-RR tertiary veins collectively indicate that the present fossil leaf shows its affinity with the leaves of extant genus *Acronychia* Frost. of the family Rutaceae. A critical examination of a number of herbarium sheets of different species of this genus was carried out and found that the modern leaves of *Acronychia laurifolia* Blume. (C.N.H. Howrah Herbarium Sheet No. 10470; Pl. 2.5) show closest similarity with fossil leaf.

The fossil leaf resembling the genus *Acronychia* has been described under *Acronychia siwalica* from the Lower Siwalik sediments of Kathgodam area, Nainital District, Uttaranchal by Prasad (1994). This fossil leaf is small elliptic in shape having closely placed secondaries with 2-3 intersecondaries in between them. Thus the present fossil is entirely different from earlier known fossil, *Acronychia siwalica* Prasad.

The genus *Acronychia* Frost. consists of about 43 species of shrubs and trees (Mabberley, 1997). *Acronychia laurifolia* Blume with which fossil resembles is a small tree growing in Sikkim, Himalaya, Assam, Chittagong, Eastern and Western peninsula (Hooker, 1872; Haines, 1910).

Family—Fabaceae

Genus—*Cassia* Linn.

Cassia nodosa Hamilton

(Pl. 3.3, 5)

Material—Single, almost complete leaflet impression with fair preservation.

Description—Leaf asymmetrical, ovate, length 6.0 cm, width 2.5 cm; lamina and base asymmetrical; apex slightly broken; base normal; margin entire; texture coriaceous; petiole normal, less than 0.2 cm; venation pinnate, eucamptodromous; primary vein (1º) single, moderate, straight; secondary veins (2º) more than 14 pairs visible, closely placed, less than 0.4 cm apart, alternate to opposite, angle of divergence is acute (moderate), uniform, straight, joining superadjacent secondaries at acute angle, intersecondary veins present, simple, frequent; tertiary veins (3º) fine, poorly preserved, angle of origin RR, percurrent, almost straight, sometime branched, oblique in relation to midvein, alternate to opposite and close.

Discussion—Asymmetrical, ovate shape, coriaceous texture, eucamptodromous venation, closely placed secondary veins with acute angle of divergence and percurrent, RR tertiaries are important characters of fossil leaflet which show its similarity with the modern leaf /leaflets of *Syzygium cuminii*, *Cassia fistula*, *Cryptolepis buchananii*, *Cassia nodosa*, *Ochna squamosa* and *Ficus microcarpa*, (Syn. *F. retusa)*. On critical examination of a number of herbarium sheets of above taxa, it is found that the present fossil shows the closest resemblance with the leaflets of *Cassia nodosa* Hamilton of the family Fabaceae (C.N.H. Howrah Herbarium Sheet No. 120620; Pl. 3.4).

The genus *Cassia* is fairly well represented in the Tertiary of Indian subcontinent and known by fossil wood, fruit as well as leaf impressions (Prakash, 1966; Lakhanpal & Guleria, 1982; Navale, 1973; Awasthi, 1979; Acharya & Roy, 1986; Prakash, 1975). The fossil leaflets of the genus *Cassia* so far

PLATE 1

(All figures are of natural size unless otherwise mentioned)

Micromelum pubescens Blume

1. Fossil leaf in natural size; BSIP Specimen no. 39357.
2. Venation pattern of fossil leaf near the margin. x 2.5
3. Modern leaf in natural size.

Citrus aurantium Linn.

4. Fossil leaf in natural size; BSIP Specimen no. 39358.
5. Venation details of fossil leaf (fig. 4) showing venation pattern near margin. x 3.
6. Another fossil leaf in natural size; BSIP Museum Specimen no. 39359.
7. Counterpart of (fig. 4) 39358.
8. Modern leaf in natural size.

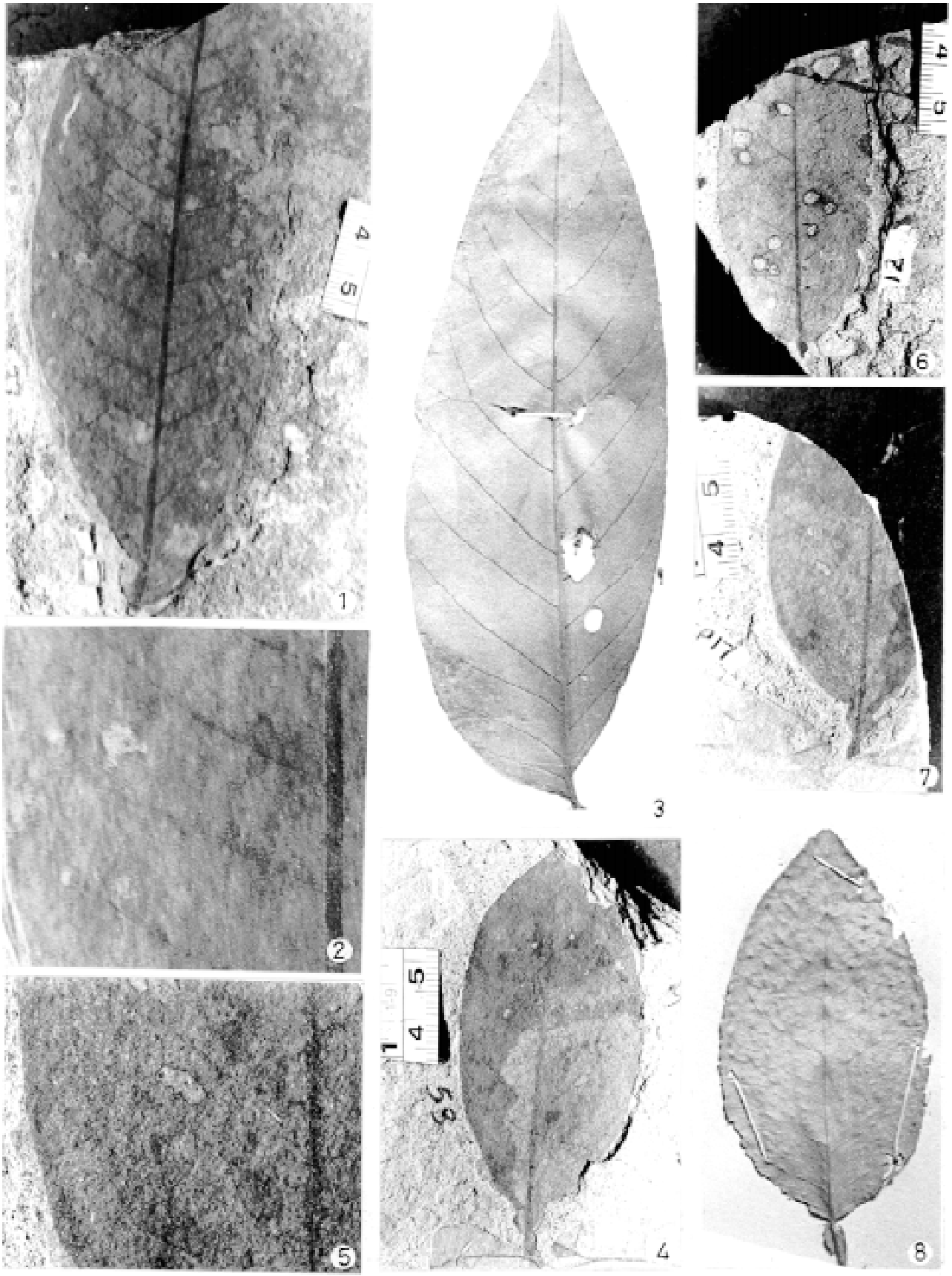


PLATE 1

described from the Tertiary sediments of India and Nepal (Prasad, 2008) are different from the present fossil leaflets either in shape and size or venation pattern.

The genus *Cassia* Linn. consists of 340 species spreading everywhere in tropical and subtropical regions whereas few species are extra tropical. *Cassia nodosa* Hamilton is distributed from eastern Himalaya to Mallucca (Hooker, 1872). It is found in Silhet, Chittagong hill tract, Andamans, and in evergreen forest of Martaban and upper Tenasserim (Brandis, 1906). It is also very common in the forest of Chotanagpur (Wood, 1903; Haines, 1910).

Genus—*Erythrina* Linn.

Erythrina lithosperma Miq.

(Pl. 3.1)

Material—Single, incomplete leaf-impression without basal part. Preservation is fair enough to reveal the finer details of the leaf.

Description—Preserved leaf length 12 cm, width 12 cm; apex acuminate; base not preserved; margin entire; texture chartaceous; petiole not preserved; venation pinnate, eucamptodromous-brochidodromous; primary vein (1º) single, stout, straight; secondary veins (2º) 7 pairs visible, 1.8-2.5 cm apart, alternate to subopposite, angle of divergence acute, (about 60º), moderately thick, curved uniformly, forming loop with superadjacent secondary veins at right angle; tertiary veins (3º) fine, angle of origin usually RR, percurrent, straight to sinuous, relationship with midvein oblique, predominantly alternate and close; quaternary veins (4º) fine, arising at right angle forming orthogonal to polygonal meshes.

Discussion—The important diagnostic features of the present fossil leaf are acuminate apex, chartaceous texture, entire margin, eucamptodromous-brochidodromous venation, with stout, straight primary vein, distantly arranged secondary veins with acute angle of divergence and RR, percurrent and straight to sinuous tertiaries veins indicate that the fossil leaf shows close resemblance with the extant leaves of *Erythrina* Linn. of the family Fabaceae. In order to find out nearest specific affinity, extant leaves of all the available species of *Erythrina* were examined and found that the leaves of *Erythrina lithosperma* Miq. show closest similarity in shape, size and venation pattern (C.N.H. Howrah Herbarium Sheet No. 18841; Pl. 3.2).

The fossil leaf resembling the genus *Erythrina* Linn. was first reported by Bande and Srivastava (1990) from the Late Tertiary sediments of Mahuadanr Valley. This fossil shows closest affinity with the extant taxon *Erythrina suberosa* Roxb. and differs in having less number of secondaries (only 4) instead of about 7-8 pairs in the present fossil.

The genus *Erythrina* Linn. consists of about 112 species (Mabberley, 1997). The exant taxon, *Erythrina lithosperma* Miq. with which the fossil shows closet similarity is a tall tree distributed in Java, Philippines and Myanmar (Hooker, 1872).

Genus—*Butea* Roxb.

Butea frondosa Roxb.

(Pl. 4.1; Pl. 2.7)

Material—Single, well preserved leaf-impression.

Description—Leaflet asymmetrical, ovate; preserved lamina 6.0 x 4.1 cm; apex slightly broken; base obtuse, inequilateral; margin entire; texture chartaceous; petiole not preserved; venation pinnate, craspedodromous, simple; primary vein (1º) single, moderate, straight; secondary veins (2º) 6 pairs visible, alternate to sub opposite, 0.6-1.2 cm apart, angle of divergence moderately acute (about 55º), more acute on one side of leaf than the other side; intersecondary veins not seen; tertiary veins (3º) fine with angle of origin usually RR, percurrent, almost straight, sometimes branched, oblique to nearly right angle in relation to midvein, predominantly alternate and close.

Discussion—The diagnostic features of the present fossil leaf are asymmetrical ovate shape, obtuse inequilateral base, chartaceous texture, craspedodromous venation, moderately acute angle of divergence of secondaries veins which is more acute on one side of leaf than the other. These features collectively indicate that the present fossil leaf shows its affinity with the leaves of extant genus *Butea* Roxb. of the family Fabaceae. On critical examination of the leaf from the herbarium sheets of this genus, it has been seen that the modern leaf of *Butea frondosa* Roxb. (C.N.H. Howrah Herbarium Sheet No. 2877; Pl. 4.2) has the closest similarity with fossil leaf.

So far, there is no fossil record of *Butea* Roxb. leaf from the Tertiary sediments of India and Nepal. The present fossil leaf forms its first record from the Late Tertiary sediments of Mahuadanr area.

PLATE 2

(All figures are of natural size unless otherwise mentioned)

Citrus medica Linn.

1. Fossil leaf in natural size; BSIP Museum Specimen no. 39360.
2. Modern leaf in natural size.
3. Details of venation of fossil near margin. x 2.5.

Acronychia laurifolia Blume.

4. Fossil leaf in natural size; BSIP Museum Specimen no. 39361.
5. Modern leaf in natural size.
6. Details of venation of fossil near margin. x 2.

Butea frondosa Roxb.

7. Venation details of fossil leaf (Pl. 4.1) showing venation pattern near margin. x 2.

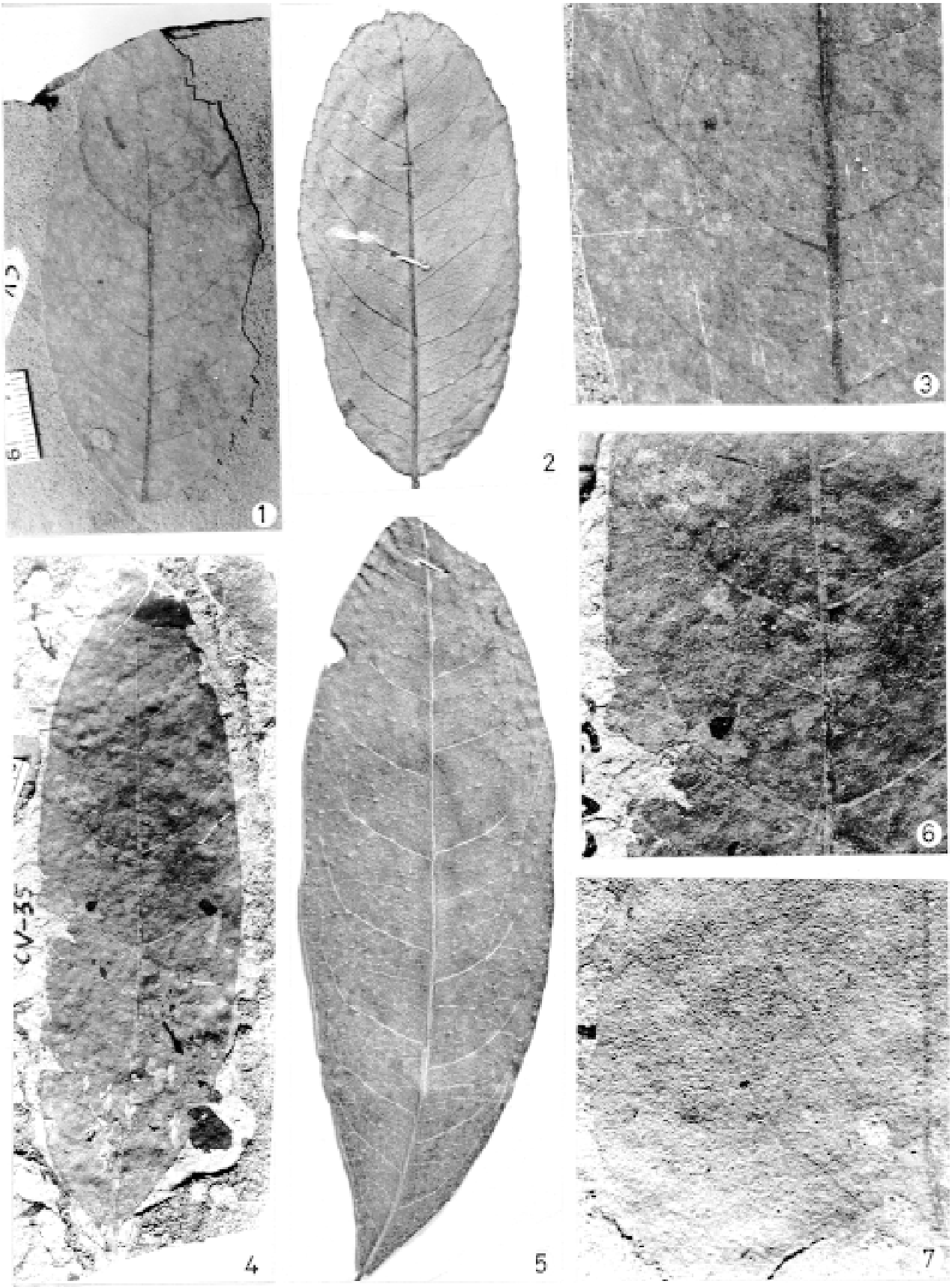


PLATE 2

The genus *Butea* Roxb. consists of about 2 species (Mabberley, 1997). *Butea frondosa* Roxb. is a small tree which occurs in India, Sri Lanka and Myanmar (Hooker, 1872). It is very common in central and southern area of Palamau and Hazaribagh. It is also found subgregariously in some grass lands of North Champaran (Haines, 1910).

Genus—*Mezoneurum* Desf.

Mezoneurum cucullatum Wight. & Arn.

(Pl. 4.3; Pl. 5.7)

Material—The fossil is represented by an impression of almost complete leaflet.

Description—Leaflet symmetrical, ovate, lamina length 5.2 cm, width 2.3 cm; apex attenuate; base obtuse, normal; margin entire; texture coriaceous; petiole not preserved; venation pinnate, eucamptodromous-brochidodromous; primary vein (1º) single, moderate, straight; secondary veins (2º) poorly preserved, about 7 pairs visible, closely placed, angle of divergence moderatly acute, uniform, joining superadjacent secondaries at acute angle; intersecondary veins present, simple; tertiary veins (3º) not clearly seen due to poor preservation.

Discussion—Attenuate apex, obtuse base; entire margin, with eucamptodromous-brochidodromous venation and closely placed secondary veins are the important characters of fossil leaflet which have been seen in the leaflets of *Cicca acida, Mezoneurum cucullatum, Clitoria ternatea.* However, it shows the closest resemblance with the leaflets of *Mezoneurum cucullatum* of the family Fabaceae (F.R.I. Herbarium Sheet No. 897/16413; Pl. 4.4) in shape, size and venation pattern.

As far as the authors are aware, there is no fossil record of the genus *Mezoneurum* from Tertiary sediments of India. The present fossil leaf forms its first record from the Late Tertiary sediments of Mahuadanr area, Jharkhand.

The genus *Mezoneurum* comprises about 10 species distributed in mostly tropical Asia. The comparable taxon, *Mezoneurum cucullatum* is found in eastern Himalayas from Nepal, ascending to 4000 ft, to the Khasi hills, Bihar and the western peninsula (Hooker, 1872). It is also very common in the forest of the Chotanagpur along the streams (Wood, 1903; Haines, 1921).

Family—Olacaceae

Genus—*Olax* Linn.

Olax scandens Roxb.

(Pl. 5. 1, 2)

Material—Single, almost complete and well preserved leaf impression.

Description—Leaf symmetrical, narrow elliptic, length 7.8 cm, width 3.3 cm; apex acute; base rounded; margin entire; texture chartaceous; petiole 0.4 cm, normal; venation pinnate, eucamptodromous- brochidodromous; primary vein (1º) single moderate, straight; secondary veins (2º) about 8 pairs visible, 0.5 to 2.5 cm apart, alternate, seemingly unbranched, angle of divergence moderately acute (about 65º), almost uniform, joining superadjacent secondary at right angle; intersecondary veins present, simple; tertiary veins (3º), fine with angle of origin RR, percurrent, usually straight, oblique in relation to midvein, predominantly alternate and close.

Discussion—Narrow elliptic shape, rounded base, entire margin with eucamptodromous-brochidodromous venation, formation of loop at right angle are the important characters of fossil leaflet which show its near affinity with the modern leaves/leaflets of *Toona ciliata, Clitoria ternatea, Olax scandens, Aglai roxburgii, Salix tetraspermum, Garuga pinnata.* However, on critical examination of the herbarium sheets of above taxa it has been concluded that the present fossil leaflet shows the closest resemblance with that of *Olax scandens* Roxb. of family Olacaceae (C.N.H. Howrah Herbarium Sheet No. 82716; Pl. 5.3).

So far, only one fossil leaf impression showing close resemblance with genus *Olax* is described from the Siwalik sediments of Suraikhola area, western Nepal by Prasad and Pandey (2008) under *Olax banksii*. which shows closest affinity with the leaf of *Olax wightiana* Wall. ex W. & A. *Olax banksii* differs from the present fossil in possessing acute base.

The genus *Olax* Linn. consists of about 25 species, distributed in tropical regions of the world (Mabberley, 1997). *Olax scandens* Roxb. with which fossil leaflet shows similarity is a shrub found in tropical western Himalaya, Kumaon, Bihar, central and southern India, Rohilkhand, Myanmar and Sri Lanka (Hooker, 1872). It is very common in the forest of Chotanagpur region (Wood, 1903).

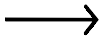
Family—Cucurbitaceae

Genus—*Trichosanthes* Linn.

Trichosanthes palmata Roxb.

PLATE 3

(All figures are of natural size unless otherwise mentioned)



Erythrina lithosperma Miq.

1. Fossil leaf in natural size; BSIP Museum Specimen no. 39362.
2. Modern leaf in natural size

Cassia nodosa Hamilton.

3. Fossil leaf in natural size; BSIP Museum Specimen no. 39363.
4. Modern leaf in natural size.
5. Details of venation of fossil near margin. x 3.

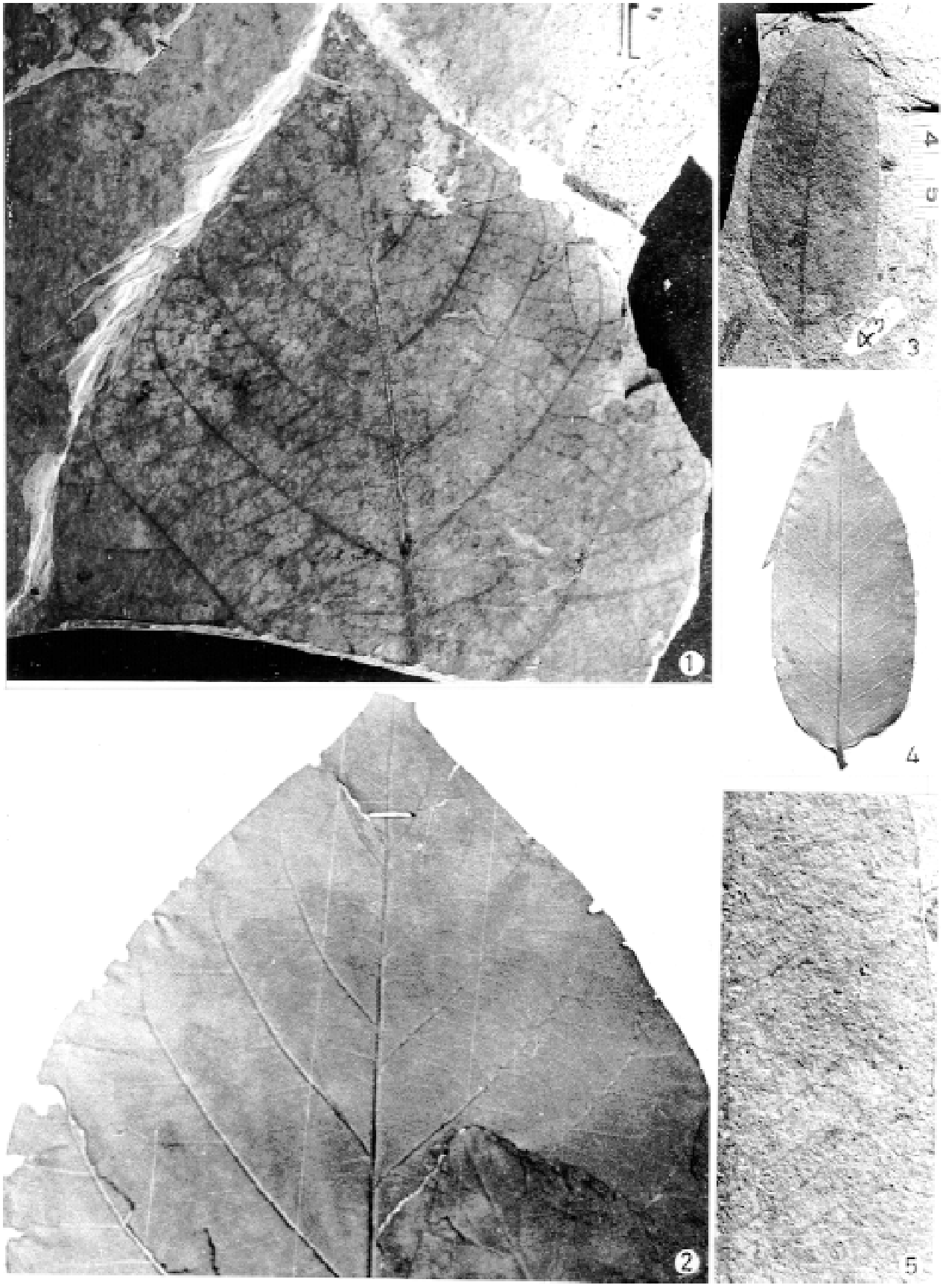


PLATE 3

(Pl. 4.5)

Material—Single, incomplete and well preserved leaf-impression.

Description—Leaf simple, symmetrical, ovate; preserved lamina 10 × 10 cm, lobed, apex not preserved, base auriculate; margin lobed; texture coriaceaous; petiole 1.6 cm long, thick, normal; venation actinodromous, three primary veins arising from the single point, basal; primary vein (1º) three moderate, middle primary almost straight where as lateral primaries markedly curved and branched; secondary veins (2º) arising from all the 3 primary veins, angle of divergence moderately acute, secondaries arising from the lateral primary veins forming loops, intersecondary veins composite; tertiary veins (3º) angle of origin RR, percurrent, straight to sinuous, rarely branched, right angle in relation to midvein, predominantly alternate, close; quaternary veins (4º) arising at right angle, forming orthogonal to polygonal meshes.

Discussion—The diagnostic features of the present fossil leaf such as symmetrical ovate and lobed lamina, auriculate base, lobed margin, coriaceaous texture, actinodromous venation with three basal primary veins, moderately acute angle of divergence of secondary veins and RR, percurrent tertiary veins indicate that the fossil leaf shows close resemblance with the leaves of the genus *Trichosanthes* of the family Cucurbitaceae. In order to find out nearest specific affinity, the extant leaves of all the available species of above genus were examined and concluded that the leaves of *Trichosanthes palmata* Roxb. show closest similarity in shape, size and venation pattern (C.N.H. Howrah Herbarium Sheet No. 513).

As far as the authors are aware, there is no record of fossil leaves of the genus *Trichosanthes palmata* Roxb. from the Tertiary sediments of India and Nepal. The present specimen of the Late Tertiary sediments of Mahuadanr forms its first record.

The genus *Trichosanthes* Linn. consists of about 15 species (Mabberley, 1997). The comparable taxon, *Trichosanthes palmata* Roxb. is a climber found growing all along the Himalaya , Sri Lanka, Singapur, Malaya, China, Japan and North Australia (Hooker, 1872). It is also common in Purneah, Ranchi, Palamau and Singbhum District (Haines, 1910).

Family—Urticaceae

Genus—*Ficus* Linn.

Ficus rumphii Blume

(Pl. 5. 4, 5)

Material—Single, almost complete and well preserved leaf-impression.

Description—Leaf simple, symmetrical, narrow ovate; preserved size 9.5 × 4 .8 cm; apex attenuate; base slightly broken; margin entire; texture chartaceous; petiole not preserved; venation pinnate, craspedodromous to eucamptodromous; primary vein (1º) single, prominent, moderate, straight; secondary veins (2º) 9-10 pairs visible, 0.6 to 1.4 cm apart, alternate to sub opposite, angle of divergence wide acute, uniform, moderate, lower secondaries recurved; tertiary veins (3º) fine, angle of origin usually AO, percurrent, straight to wavy, sometimes branched, oblique in relation to midvein, alternate to opposite and close.

Discussion—Attenuate apex, craspedodromous to eucamptodromous venation, presence of intersecondary veins, percurrent tertiary veins and other morphological details of the fossil leaf indicate its similarity with the various species of *Ficus* Linn. Amongst which it closely resembles the leaves of *Ficus rumbhii* Blume (C.N.H. Howrah Herbarium Sheet No. 425537; Pl. 5.5).

There are abundant and wide spread records of fossil leaves resembling the genus *Ficus.* These have been described under four genera, viz. *Ficus* Linn. *Ficonium* Ett., *Ficophyllum* Fontain emend. Edwards and *Protoficus* Saporta. About three hundred and eighty five species of *Ficus* two species of *Ficonium*, seven species of *Ficophyllum* and six species of *Protoficus* are so far known from different parts of the world, viz. North America, South America, Africa (Ethiopia), Europe, (Belgium, Czechoslovakia, France, Germany, Greenland, Hungary, Italy, Rumania, Yugoslavia, etc.), Asia (Myanmar, China, Egypt, India, Indonesia, Japan) and Australia and New Zealand.

So far, 25 species of fossil leaves showing resemblance with the extant genus *Ficus* Linn. are known from Tertiary as well as Quaternary sequence of the Indian subcontinent. (Fig. 2)

On critical study of the known *Ficus* leaf it has been found that none of them shows similarity with the present fossil. This fossil leaf differs mainly in possessing long attenuate apex.

The genus *Ficus* Linn. comprises about 800 species (Willis, 1973) and widely distributed throughout the tropics of both hemispheres but most abundant in the Island of Indian Archipelago and the Pacific Ocean. A few species are extended beyond the tropics into the southern Florida (U.S.A.), Mexico, Argentina, southern Japan and China, the Canary Island and South Africa. About 70 species are reported to occur in India (Santapau & Henry, 1973). The *Ficus rumphii* Blume distributed on the lower slopes of the mountains of the Punjab and northern, western and central India, Assam, and the Malaya peninsula (Hooker, 1872). It is also found in Northern Champaran, frequent along nalas in the hills of Singbhum, Hazaribagh and other districts of Chotanagpur (Haines, 1921).

Ficus microcarpa var. *nitida* Thunb.

(Pl. 6.4; Pl. 5.8)

Material—Single, well preserved leaf-impression.

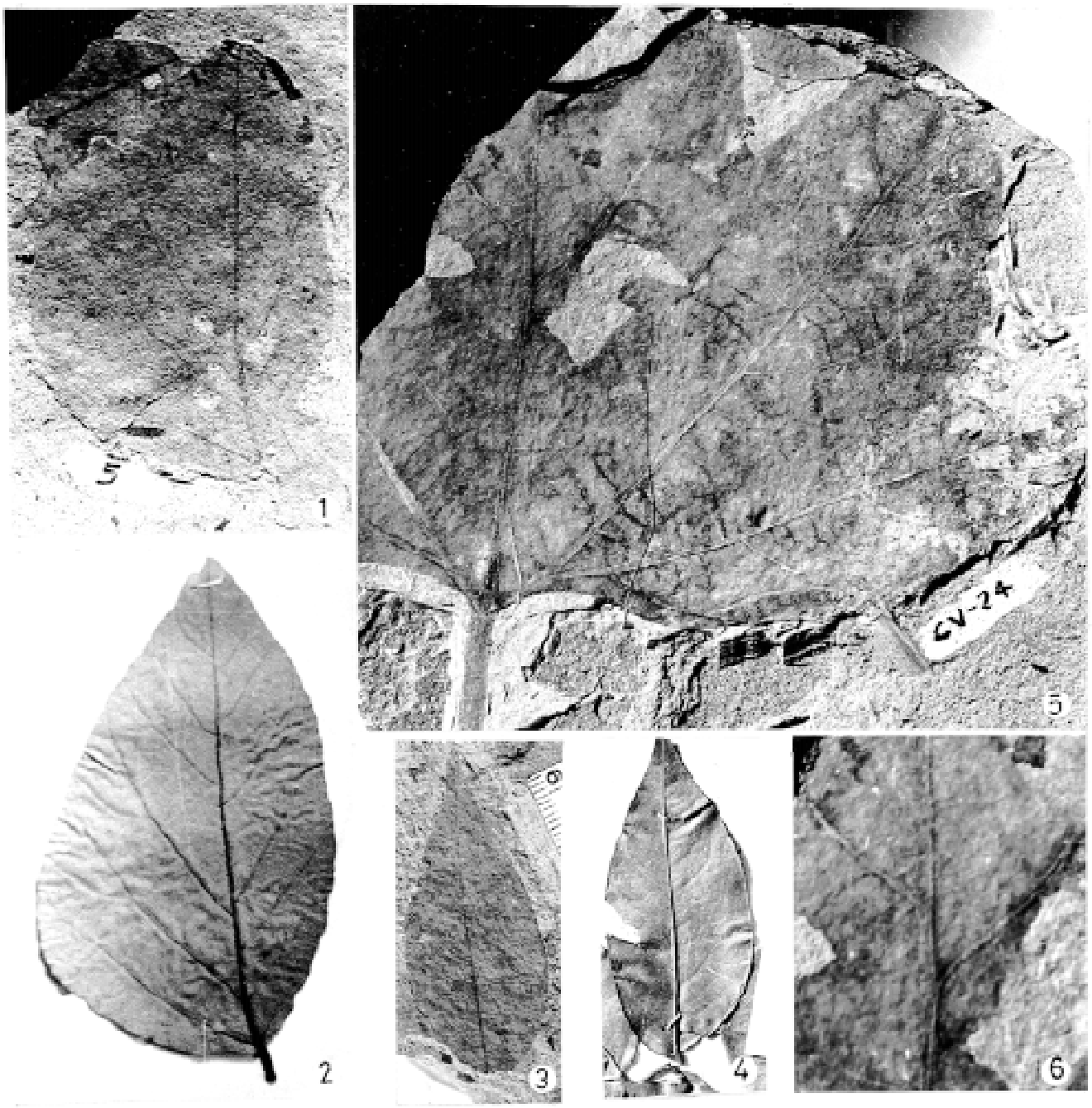


PLATE 4

PLATE 4

(All figures are of natural size unless otherwise mentioned)

Butea frondosa Roxb.

1. Fossil leaf in natural size; BSIP Museum Specimen no. 39364.
2. Modern leaf in natural size

Mezoneurum cucullatum Wight & Arn.

3. Fossil leaf in natural size; BSIP Museum Specimen no. 39365.
4. Modern leaf in natural size.

Trichosanthes palmata Roxb.

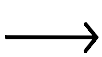
5. Fossil leaf in natural size; BSIP Museum Specimen no. 39366.
6. Details of venation of fossil.

FOSSIL SPECIES	HORIZON/ LOCALITY	REFERENCES
Ficus arnottiana	Quaternary beds, Maharashtra	Mahajan & Mahabale, 1973
F. champerensis	Siwalik beds, Bhikhnathoree	Lakhanpal & Awasthi, 1984
F. cherrapunjiensis	Palaeocene	Ambwani, 1991
F. cunia	Karewa beds, Kashmir Dharmsala beds, Himachal Pradesh	Puri, 1947; Gupta & Jiwan, 1972
F. foveolata	Late Tertiary deposits of Palamau District, Bihar	Bande & Srivastava, 1990
F. glaberrima	Late Tertiary deposits of Palamau District, Bihar	Bande & Srivastava, 1990
F. khariensis	Miocene of Kachchh	Lakhanpal & Guleria, 1982
F.miocenica	Siwalik sediments, western Nepal	Konomatsu & Awasthi, 1999
F. nemoralis	Karewa beds, Kashmir	Puri, 1948
F. nepalensis	Siwalik sediments, Koilabas, western Nepal	Prasad, 1990
F. oodlabariensis	Siwalik sediments, West Bengal	Antal & Awasthi, 1993
F. precunia	Siwalik beds, Jawalamukhi, Himachal Pradesh, Siwalik sediments, Koilabas, western Nepal	Lakhanpal, 1969; Prasad, 1990
F. raptiensis	Siwalik sediments, Suraikhola, western Nepal	Prasad & Awasthi, 1996
F. retusoides	Siwalik sediments, Koilabas, western Nepal, Siwalik sediments, West Bengal, Neyveli Lignite, south India	Prasad, 1990; Antal & Awasthi, 1993; Agarwal, 2002
F. tomentosa	Late Tertiary deposits of Palamau District, Bihar	Bande & Srivastava, 1990
F. benjamina	Quaternary beds of Sirmur District, Himachal Pradesh; Siwalik sediment of Himachal Pradesh.	Prasad *et al.*, 2002; Prasad, 2006
F. eumysorensis	Siwalik sediments near Jarwa, U.P.	Tripathi *et al.*, 2002
F. barogensis	Kasuauli Formation, Barog, H.P.	Mathur *et al.*, 1996
F. kasaulica	Kasuauli Formation, Barog, H.P.	Mathur *et al.*, 1996
F kumarhattiensis	Dagshai Formation, H.P.	Mathur *et al.*, 1996
F. precurticeps	Neyveli Lignite, south India.	Agarwal, 2002
F. prereligiosa	Mar Formation (Neogene), Bikaner District Rajasthan	Mathur & Mathur, 1998
Ficus sp.	Mar Formation (Neogene), Bikaner District Rajasthan	Mathur & Mathur, 1998
Ficus sp. A- C	Dagshai Formation, Solan District, H.P.	Mathur *et al.*, 1996
Ficus sp. cf. *F. tomentosa* Roxb.	Dagshai Formation, H.P.	Mishra & Mathur, 1992

Fig. 2—Fossil leaf of *Ficus* from India and Nepal.

PLATE 5

(All figures are of natural size unless otherwise mentioned)



Olax scandens Roxb.

1. Fossil leaf in natural size; BSIP Museum Specimen no. 39367.
2. Fossil leaf further enlarged to show details of venation. x 4.
3. Modern leaf in natural size.

Ficus rumphii Blume.

4. Fossil leaf in natural size; BSIP Museum Specimen no. 39368.
5. Modern leaf in natural size.
6. Details of venation of fossil near margin. x 3.

Mezoneurum cucullatum Wight & Arn.

7. Details of venation of fossil leaf (Pl. 4.3) near midrib. x 2.5.

Ficus microcarpa var. *nitida* Thunb.

8. Details of venation (Pl. 6.4) near margin. x 2.5.

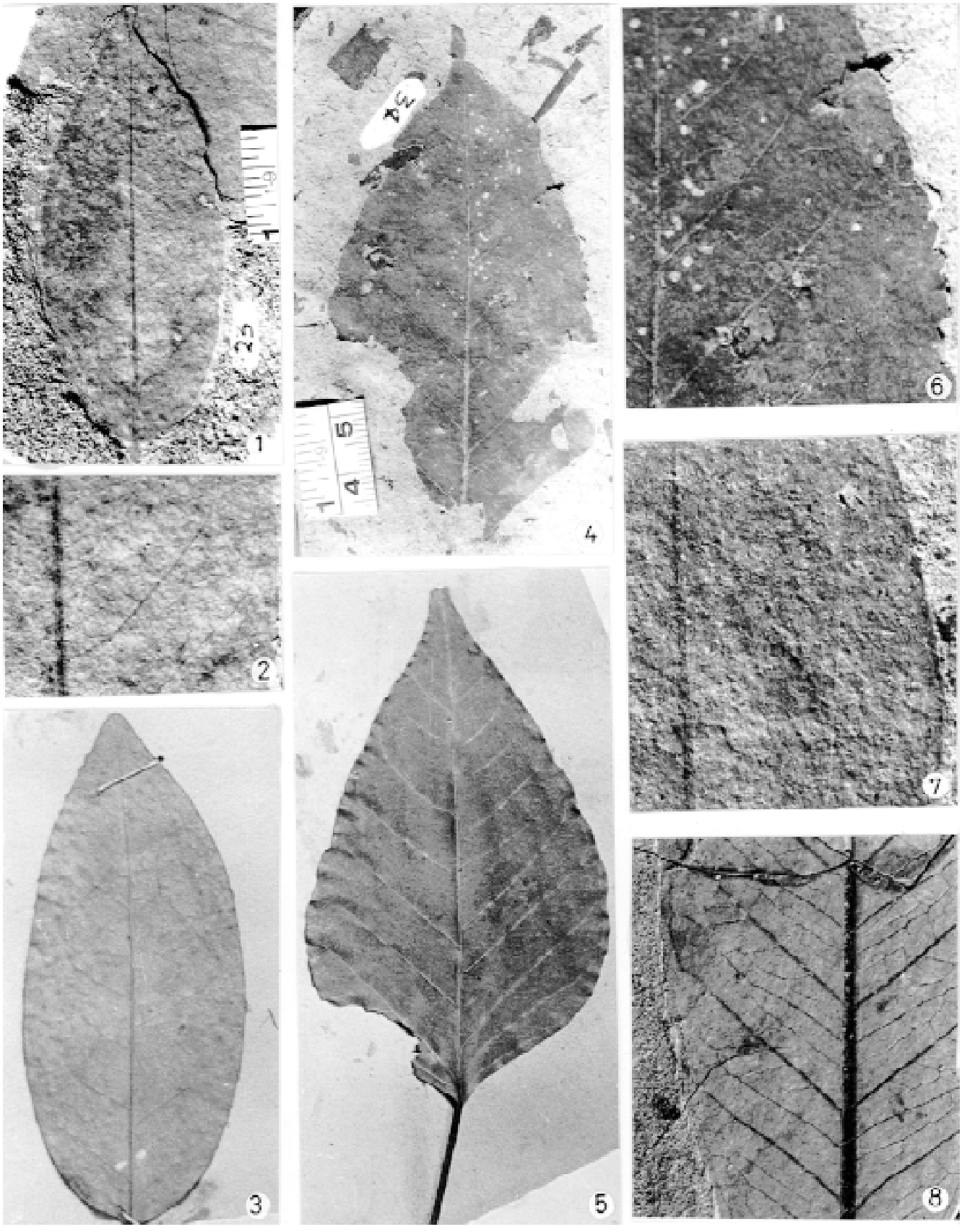


PLATE 5

Description—Leaf simple, symmetrical, narrow elliptic; lamina size 7.2 × 2.7 cm; apex acuminate; base cuneate; margin entire; texture coriaceous; petiole normal; venation pinnate, eucamptodromous-brochidodromous; primary vein (1º) single, almost straight, stout; secondary veins (2º) 7-8 pairs visible, 0.4 to1.3 cm apart, unbranched, angle of divergence moderately acute (about 55º), lowest pair of secondary arises from the base of lamina, loop formation at margin, joining superadjacent secondary at obtuse angle, intersecondary veins present, simple, 2-4 intersecondaries in between two secondary veins; tertiary veins (3º) fine, angle of origin RR-AO, percurrent, almost straight, rarely forked, oblique in relation to midvein, close; quaternary veins (4º) still fine, arising nearly at right angle, forming orthogonal to polygonal meshes.

Discussion—The important diagnostic features of the present fossil leaf are narrow elliptic shape, acuminate apex, cuneate base, eucamptodromous-brochidodromous venation, arising of lowest pair of secondary veins from the base and usually RR, percurrent, tertiaries. These features collectively indicate that the present fossil leaf shows its affinity with the extant leaves of the genus *Ficus* Linn. of family Urticaceae. A critical examination of the modern leaves of more than 20 species of this genus was carried out and found that the modern leaf of *Ficus microcarpa* var. *nitida* Thunb. (C.N.H. Howrah Herbarium Sheet No. 425340; Pl. 6.5) shows the closest similarity with the fossil leaf.

Out of the known fossil leaves of *Ficus*, *F. microcarpa* (*F. retusa*) described from the same bed (Srivastava, 1998) and is resembling with extent *F. microcarpa* Linn. f. as the present fossil, but differs from the present fossil in nature of secondary veins. The secondary veins are more in number (13-14) and arise with greater angle of divergence than in the present fossil.

The modern comparable taxon, *Ficus microcarpa* var. *nitida* Thunb. is an evergreen tree growing in Sub- Himalayan tract from Kumaon eastward and Khasi Hills, Bihar, Chotanagpur, Bundelkhand, Central provinces, Sunderban, Deccan peninsula and Andamans. It also grows commonly in Sri Lanka, Myanmar and Malaya (Hooker, 1872; Brandis, 1906).

Ficus curticeps Corver

(Pl. 6.1, 3)

Material—Single, well preserved leaf-impression.

Description—Leaf simple, symmetrical, obovate; preserved leaf length 9.8 cm, width 4.5 cm; apex obtuse; base acute, normal; margin entire; texture coriaceous; petiole about 2.5 cm in length, thick and curved; venation pinnate, brochidodromous; primary vein (1º) single, straight, prominent, massive; secondary veins (2º) 8-9 pairs visible, 0.8-2.5 cm apart, angle of divergence moderately acute (about 65º), mostly opposite to sub opposite, uniformly curved up, lower pair of secondaries arises from the base with more acute angle, intersecondary veins present, simple, frequent, 3-5 intersecondary veins in between two secondaries; tertiary veins (3º) fine with angle of origin usually RR, percurrent, almost straight, unbranched, predominantly opposite, close, oblique in relation to midvein. Further detail not visible.

Discussion—The diagnostic features of the fossil leaf are symmetrical, obovate shape with obtuse apex, brochidodromous venation, moderately acute angle of divergence of secondary veins of which lowest pair of secondaries arise more acutely and RR, percurrent tertiary veins. These features indicate its resemblance with the leaf of *Ficus* Linn. of the family Urticaceae. In order to find out its specific affinity, a large number of herbarium sheets of the genus *Ficus* Linn. were examined and found that the leaf of the *Ficus curticeps* Corver (C.N.H. Howrah Herbarium Sheet No. 502; Pl. 6.2) shows closest affinity in shape, size and venation pattern.

A comparative study of the present fossil leaf with the already known fossil leaves of the genus *Ficus* Linn. (listed earlier) has been carried out and concluded that the present fossil differs from them mostly in shape and size. *F. precurticeps* described from Miocene beds of Neyveli Lignite, south India (Agarwal, 2002) and also closely resembling *Ficus curticeps* but differs in being smaller in size (24-18 mm) and possessing orbiculate-elliptic size.

Ficus curticeps—Corver is a large evergreen tree found in Assam, Myanmar, Malaya and evergreen forest of northern and southern India (Hooker, 1872)

GENERAL DISCUSSION

The present investigation on the plant megafossils especially leaf impressions collected from the Late Tertiary sediments of Mahuadanr Valley, Jharkhand reveals the occurrence of 13 new taxa from this area, These belong to eight genera, viz. *Micromelum, Citrus, Acronychia* **(**Rutaceae) *Cassia, Erythrina, Butea, Mezoneurum* (Fabaceae), *Olax* (Olacaceae), *Trichosanthes* (Cucurbitaceae) and *Ficus* (Urticaceae) of dicotyledonous families. The maximum number of species belong to family Fabaceae followed Rutaceae. The

PLATE 6

(All figures are of natural size unless otherwise mentioned)

Ficus curticeps Corver

1. Fossil leaf in natural size; BSIP Museum Specimen no. 39369.
2. Modern leaf in natural size.
3. Details of venation of fossil near margin. x 2.

Ficus microcarpa var. *nitida* Thunb.

4. Fossil leaf in natural size; BSIP Museum Specimen no. 39370.
5. Modern leaf in natural size.

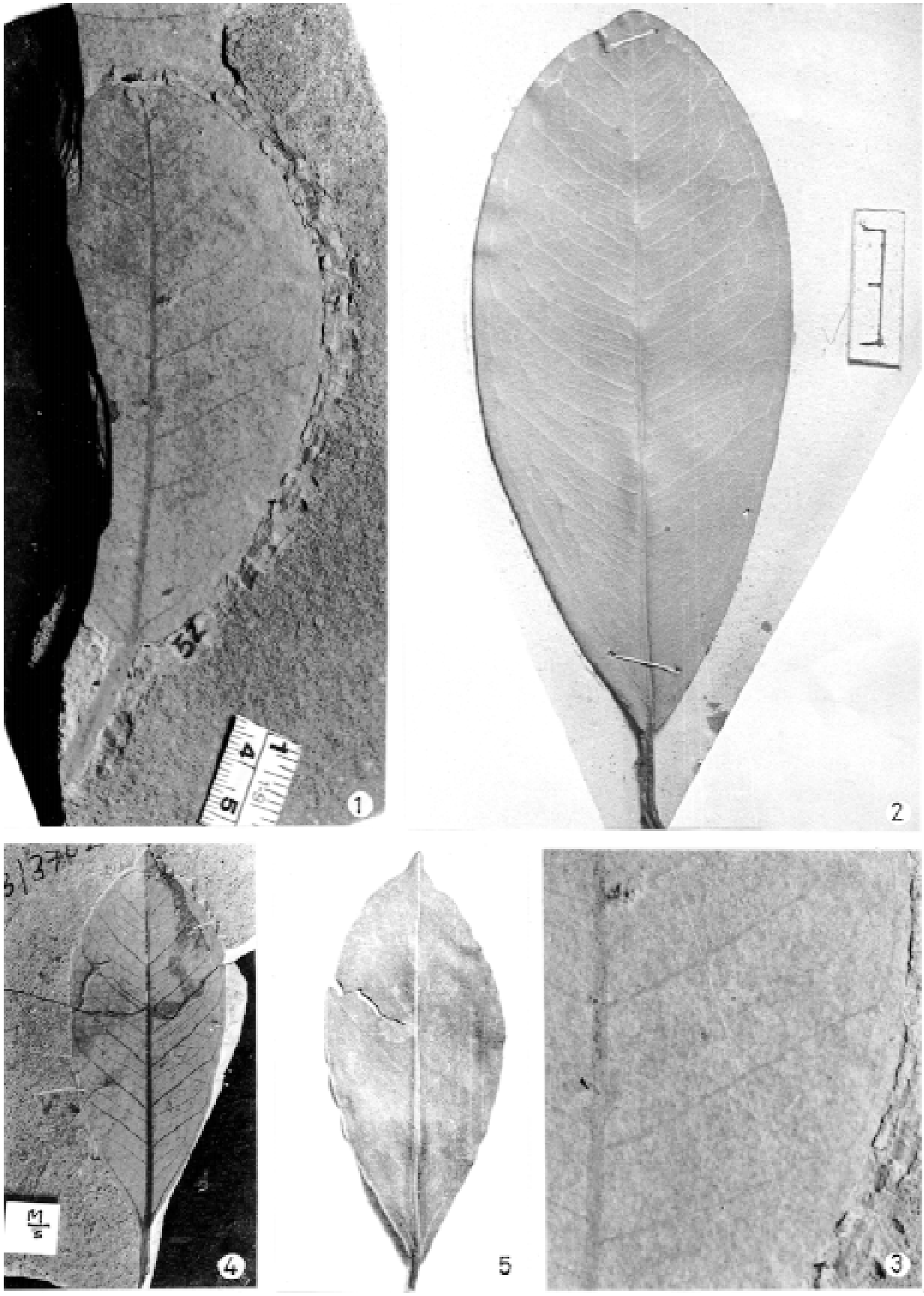


PLATE 6

Recoverd taxa	Forest types	Habit & Habitat	Present Day Distribution
Rutaceae			
Micromelum pubescens Blume.	Moist deciduous to Evergreen	Small tree	Sub-Himalayan tract, south and central India, Khasi Hills, Myanmar, Malucca, Sri Lanka, Nepal, Chotanagpur region.
Citrus aurantium Linn.	Mixed deciduous	Small tree	Along the foot hills of Himalaya, Garhwal, Sikkim, Khasi Hills, Chotanagpur region.
Citrus medica Linn.	Mixed deciduous	Small tree	Sub-Himalayan tract, Pachmarhi Hills, Sikkim, Garo Hills, Satpura Hills, Eastern and Western Ghats, Chotanagpur region.
Acronychia laurifolia Blume.	Moist deciduous to Evergreen	Small tree	Sub-Himalayan tract, Sikkim, Khasi Hills, Assam, Eastern and Western peninsula.
Olacaceae			
Olax scandens Roxb.	Moist deciduous to Evergreen	Shrub	Sub-Himalayan tract, south and central India, Myanmar, Sri Lanka, Chotanagpur region.
Fabaceae			
Cassia nodosa Hamiltan	Mixed deciduous	Small tree	Eastern Himalaya to Malucca, Assam, Andamans, Chotanagpur region.
Erythrina lithosperma Miq.	Moist deciduous to Evergreen	Large tree	Java, Philippines, Myanmar.
Butea frondosa Roxb.	Mixed deciduous	Small tree	Sub-Himalayan tract, central and southern India, Sri Lanka, Myanmar, Chotanagpur region.
Mezoneurum cucullatum Wight & Arn.	Mixed deciduous	Climber	Eastern Himalaya, Nepal, Khasi Hills, Skkim, Andaman, Konkan, Chotanagpur region.
Cucurbitaceae			
Trichosanthes palmata Roxb.	Moist deciduous	Climber	Sub-Himalayan tract, Sri Lanka, Malaya, China, Japan, North Australia.
Urticaceae			
Ficus rumphii Blume	Moist deciduous to Evergreen	Large tree	North East India, Malaya, Chotanagpur region.
Ficus microcarpa var. *nitida* Thunb.	Moist deciduous to Evergreen	Large tree	Sub-Himalayan tract, central India, south India, Malaya.
Ficus curticeps Corver	Moist deciduous to Evergreen	Large tree	North East India, Malaya, south India, Chotanagpur region.

Fig. 3—Present day distribution and forest types of comparable taxa of fossil assemblage recovered from Late Tertiary sediments of Mahaudanr Valley, Jharkhand, India.

present fossil assemblage (Fig. 3) is represented mostly by large to small trees (10 species). Only two climbers and one shrub were recorded. Three types of forest elements are recognized in this assemblage (a) Mixed deciduous (5 species), (b) Moist deciduous (1 species), (c) Moist deciduous to evergreen (7 species). Thus, the present fossil leaf assemblage is dominated by moist deciduous to evergreen elements. Habit and habitat of the comparable taxa reveal that most of them presently occur in the Chotanagpur and nearby areas. Only one comparable species, *Erythrina lithosperma* Miq. is not growing now-a-days in the vicinity of the fossil locality but found to grow in the tropical forests of Malaya, Philippines and Myanmar. As most of the comparable species are presently growing in the vicinity of fossil locality (Chotanagpur, Mahuadanr Valley), this indicates that almost same flora continued till today and also suggests that there is no marked climatic change in this area since the Late Tertiary Period.

Acknowledgements*—The authors are thankful to Dr N.C. Mehrotra, Director, Birbal Sahni Institute of Palaeobotany, Lucknow for providing necessary facilities during progress of the work. We are grateful to Dr G.P. Srivastava, Ex-Scientist 'F', BSIP Lucknow for his kind help during the progress of work. We are also thankful to the authorities of Central*

National Herbarium, Howrah for giving permission to consult their Herbarium for the identification of fossil leaf impressions.

REFERENCES

Acharya S & Roy SK 1986. Fossil woods of Leguminosae from the Tertiary of Tripura, India. Burdwan University Science Journal 3: 127-132.

Agarwal A 2002. Contributions to the fossil leaf assemblage from the Miocene Neyveli Lignite deposits, Tamil Nadu. Palaeontographica 261B: 167-206.

Ambwani K 1991. Leaf impressions belonging to the Tertiary age of North-east India. Phytomorphology 41**:** 139-146.

Antal JS & Awasthi N 1993. Fossil flora from the Himalayan foot-hills of Darjeeling Disrict, West Bengal and its palaeoecological significance. Palaeobotanist 42: 14-60.

Awasthi N 1979. Three new leguminous woods from the Cuddalore Series near Pondicherry**.** Palaeobotanist 26: 157-166.

Bande MB & Srivastava GP 1990. Late Cenozoic plant impressions from Mahuadanr Valley, Palamu District, Bihar. Palaeobotanist 37: 331-366.

Brandis D 1906. Indian Trees. Bishen Singh Mahendra Pal Singh, Dehardun.

Dilcher DL 1974. Approaches to the identification of angiosperm leaf remains. Botanical Review 40: 1-57.

Gupta VJ & Jiwan JS 1972. Plant fossil from the Dharmsala beds of Bilaspur District, H.P. Science & Culture 38: 99.

Haines HH 1910. A forest flora of Chotanagpur. Bishen Singh Mahendra Pal Singh, Dehradun.

Haines HH 1921. The Botany of Bihar and Orissa. Botanical Survey of India Calcutta. Vol. I-III.

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

Hooker JD 1872. The flora of British India I. Kent.

Konomatsu M & Awasthi N 1999. Plant fossil from Arung Khola, Binai Khola Formation of Churia Group (Siwalik), west-central Nepal and their palaeoecological and phytogeographical significance. Palaeobotanist 48: 163-181.

Lakhanpal RN 1969. Fossil *Fissistigma* from the Lower Siwaliks near Jawalamukhi, India. *In:* Santapau H *et al*. (Editors)—Botanical Society. J Sen Memorial Volume : 311-312 Bengal, Culcutta.

Lakhanpal RN & Awasthi N 1984. A Late Tertiary flora form near Bhikhnathoree in Champaran District, Bihar. *In:* Sharma AK (Editor)—Proceedings of the Symposium. Evolutionary Botany and Biostratigraphy: 587-596. Today & Tomarrow Printers & Publ., New Delhi.

Lakhanpal RN & Guleria JS 1982. Plant remains from the Miocene of Kachchh, western India. Palaeobotanist 30: 279-296.

Mabberley DJ 1997. The plant book. Cambridge University Press, Cambridge, U.K.

Mahajan DR & Mahabale TS 1973. Quaternary flora of Maharashtra-I. The Pravera River Basin, District Ahmednagar, Maharashtra. Geophytology 2: 175-177.

Mathur AK, Mishra VP & Mehra S 1996. Systematic study of plant fossils from Dagshai, Kasauli and Dharmsala formations of Himachal Pradesh. Geological Survey of India Palaeontologia Indica (New Series) 50: 1-121.

Mathur UB & Mathur AK 1998. A Neogene flora from Bikaner, Rajasthan. Geoscience Journal 19: 129-144.

Mishra VP & Mathur AK 1992. Biostratigraphic studies of the Lower Tertiary sequence in Dagshai and Kasauli of Himachal Pradesh (Part III). Record Geological Survey of India 125: 197-201 (Abst).

Navale GKB 1973. Some contribution to the palaeobotany of Neyveli Lignite, south India. Palaeobotanist 20: 179-189.

Prakash U 1966. Fossil wood of *Cassia* and *Cynometra* from the Tertiary beds of Mikir hills, Assam. Publication Centre for Advance Study in Geology, Panjab University 3: 93-100.

Prakash U 1975. Fossil woods from Lower Siwalik beds of Himachal Pradesh, India. Palaeobotanist 22: 192-210.

Prakash U, Mishra VP & Srivastava GP 1988. Fossil wood resembling *Sindora* from the Tertiary of Palamu District, Bihar. Record Geological Survey of India 18: 69-73.

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

Prasad M 1994. Siwalik (Middle Miocene) leaf impressions from the foot-hills of Himalayas, India. Tertiary Research 15: 53-90.

Prasad M 2006. Siwalik plant fossils from the Himalayan foot-hills of Himachal Pradesh, India and their significance on palaeoclimate. Phytomorphology 56: 9-22.

Prasad M 2008. Angiosperms fossil leaf from the Siwalik foreland basins and their palaeoclimatic implication. (in press).

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

Prasad M, Chauhan MS & Shah MP 2002. Morphotaxonomical study on fossil leaves of *Ficus* from Late Holocene sediments of Sirmur District, Himachal Pradesh, India and their significance in assessment of past climate. Phytomorphology 52 : 45-53.

Prasad M & Pandey SM 2008. Plant diversity and climate during Siwalik (Miocene-Pliocene) in the Himalayan foot hills of western Nepal. Palaentographica 278:13-70.

Puri GS 1947**.** The occurrence of tropical Fig (*Ficus cunia* Buch. Ham.) in the Karewa beds at Liddar—marg, Pir Panjal Range, Kashmir with remarks on the subtropical forests of the Kashmir Valley during the Pleistocene. Journal of Indian Botanical Society 26: 131-135.

Puri GS 1948. The flora of the Karewa Series of Kashmir and its Phytogeographical affinities with Chapters on the methods in identification. Indian Foresters 24: 105-122.

Puri SN & Mishra VP 1982. On the find of Upper Tertiary- plant, fish and bird fossil near Rajdanda, Palamau, District, Bihar. Record of Geological Survey of India 112: 55-58.

Roy Chowdhury 1974. Geology and mineral resources of the states of India. V- Bihar. Geological Survey of India Miscellaneous Publication 30: 1-34.

Santapau H & Henry AN 1973. A dictionary of the flowering plants of India. New Delhi.

Singh SK & Prasad M 2007. Late Tertiary leaf flora of Mahuadanr Valley, Jharkhand India. Journal of Palaeontological Society of India. 52: 175-194.

Singh SK & Chauhan MS 2008. Fungal remains from the Neogene sediments of Mahuadnar Valley, Latehar District, Jharkhand, India and their palaeoclimatic significance. Journal of Palaeontological Society of India 53: 73-81.

Srivastava AK & Srivastava GP 1998. Gall insect impression of fossil angiosperm leaf. Geophytology 26: 95-97.

Srivastava GP 1998. Impact of Himalayan uplift on the Late Cenozoic flora of India. Geophytology 27: 97-102.

Srivastava GP & Bande MB 1992. Fossil wood of *Terminalia* and *Lagerstroemia* from the Late Cenozoic beds of Mahuadanr, Palamu District, Bihar. Palaeobotanist 39: 333-337.

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

Tripathi PP, Pandey SM & Prasad M 2002. Angiospermous leaf impressions from the Siwalik sediments of Himalayan foot hills, near Jarwa, U.P. and their palaeoclimatic significance. Biological Memoirs 28: 79-90.

Willis JC 1973. A dictionary of the flowering plants and ferns, Cambridge.

Wood JJ 1903. Plants of Chotanagpur including Jaspur and Surguja. Record Botanical Survey of India 2: 1-170.