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PLANT FOSSILS FROM THE DECCAN INTERTRAPPEAN SEDIMENTS OF CHHINDWARA DISTRICT, MADHYA PRADESH, INDIA : THEIR PALAEOCLIMATIC SIGNIFICANCE

M. PRASAD, E.G., KHARE and **S. K. SINGH**

BIRBAL SAHNI INSTITUTE OF PALAEOBOTANY, 53, UNIVERSITY ROAD, LUCKNOW, 226007, INDIA
mahesh_bsip@yahoo.com

ABSTRACT

Investigation on the leaf and fruit impressions collected from Deccan Intertrappean beds of Mohgaon Kalan and Keria in Chhindwara District, Madhya Pradesh, revealed the occurrence of significant taxa like, *Miliusa veluntina* Hook. F. & Th., *Polyalthia simiarum* Benth. & Hook. (Anonaceae), *Kayea floribunda* Wall. (Clusiaceae), *Atlantia monophylla* Correa. (Rutaceae), *Spondias accuminata* Roxb. (Anacardiaceae), *Putranjiva roxburghii* Wall. (Euphorbiaceae), *Ficus ramentacea* Roxb. (Moraceae), *Cocos nucifera* Linn. and *Pinanga insignis* Becc. (Arecaceae) and *Musa sapientum* Linn. (Musaceae). The present day distribution of the above taxa indicates the existence of tropical evergreen to moist deciduous forest during their deposition. Presence of palm plants (*Cocos nucifera*. and *Pinanga insignis*) indicates characteristics of tropical vegetation.

Keywords: Leaf impressions, Mohgaon Kalan, Keria (M.P.), Deccan Intertrappean bed, Tropical vegetation, Climate

INTRODUCTION

The history of angiospermous fossil flora of India logically began with the events of the Late Cretaceous epoch, 70-60 Ma (Lameta Formation/Deccan Intertrappean Series) in Madhya Pradesh. Plant fossils comprising stems, roots, leaves, fruits, seeds, flowers, pollen, spores, etc have been reported from different localities of the Deccan Intertrappean Series of Betul, Seoni, Mandla, Chhindwara of Madhya Pradesh and Nagpur, Yawatmal of Maharashtra state, India (Bande *et al.,* 1988). Most of the fossils reported are petrifactions, while only a few of the fossil represent leaf impressions reported by Bonde (1986a,b), Nambudary (1970), Patil (1975), Prakash *et al.,* (1979), Sheikh and Kohle (1980), Trivedi (1956), Trivedi and Chandra (1971) and Guleria and Mehrotra (1998). Besides, some leaf remains based on petrifaction have also been known from the Deccan Intertrappean Series of Madhya Pradesh (Achuthan, 1968; Bonde, 1986a; Chitaley and Patil, 1970; Dwivedi, 1961; Sheikh and Kohle, 1980 and Verma and Mathur, 1968). The fossil localities, Mohgaon Kalan (22°1'N: 79° 11'E) and Keria (21° 59' N: 79° 10′ E) situated in Chhindwara District, Madhya Pradesh are richest fossiliferous localities of the Deccan Intertrappean deposits of Madhya Pradesh. The study on the leaf impressions collected from both the areas revealed the occurrence of some new, ecologically significant taxa. They resemble 10 extant taxa of both the dicotyledon and monocotyledon families, Anonaceae, Clusiaceae, Rutaceae, Euphorbiaceae, Moraceae, Arecaceae and Musaceae. On the basis of habit, habitat and present-day distribution of the modern comparable taxa, the palaeoclimate and plant diversity of the area have been discussed.

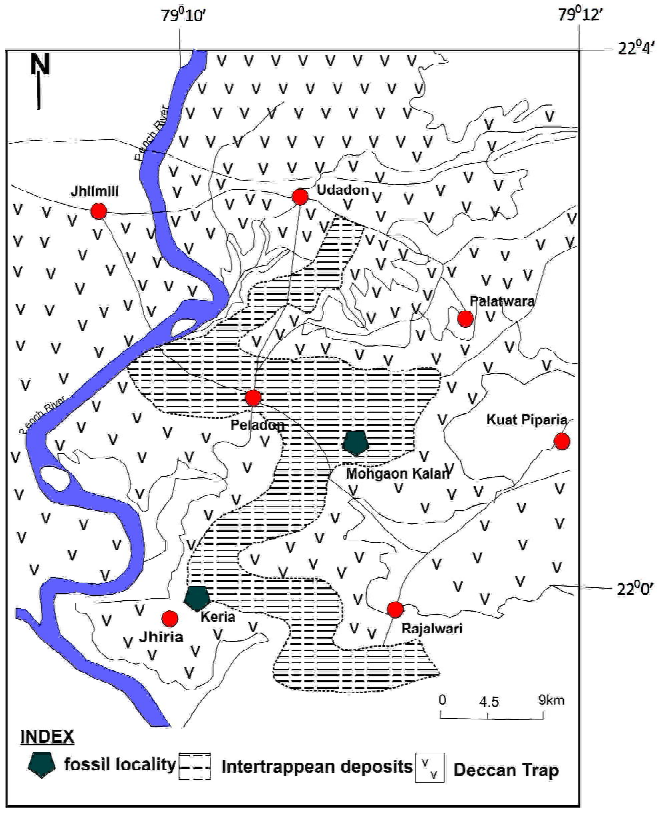

Fig. 1. Geological map of a part of central India showing location of study areas and deposition of Deccan Intertrappean sediments (after Sahni and Rode, 1937).

MATERIAL AND METHOD

About 30 samples of leaf impressions were collected from two Deccan Intertrappean localities, i.e. Mohgoan Kalan and Keria in Chhindwara district, Madhya Pradesh, India (Fig. 1). The leaf impressions were devoid of cuticle. They have been studied with the help of either the hand lens or low-power microscope under reflected light. For identification, the herbarium sheets of different families and genera were examined at the Central National Herbarium, Sibpur, Howrah, West Bengal. The description of these leaf impressions is based on the terminology given by Hickey (1973) and Dilcher (1974). The photographs of the leaf of modern comparable taxa have been taken during their identification and compared with the fossil leaves to indicate similarity. All the figured specimens have been deposited at the Museum of Birbal Sahni Institute of Palaeobotany, Lucknow, India.

GEOLOGICAL SETTING

The Deccan traps exhibit terrace-like profile observed in the area traditionally known as Dakkhan in peninsular India, resulting from a series of volcanic eruptions. The traps formed as a result of successive outpourings of enormous lava flows which spread over a vast area of western, central and southern India. It is believed that the volcanic activity in the Deccan traps started towards close of the Mesozoic Era and continued intermittently until the early Tertiary.

Mohgaon Kalan (22° 1' N: 79° 11' E), situated in the Chhindwara District of Madhya Pradesh, exposes the Deccan Intertrappean series consisting of thin, fossiliferous sedimentary beds which were deposited during comparatively quieter phases of the volcanism. During the quiescent phase, the lake formed over the trap covered areas between the basaltic flows and provided habitat for diverse biota. The palynological assemblage recovered from these Intertrappean beds is characterised by *Azolla cretacea*, *Gabonisporites viguourouxii* and *Aquilapollenites bengalensis* which indicate Maastrichtian age (Mathur and Sharma, 1990; Kar and Srinivasan, 1998 and Kar *et al*., 1998). Srinivasan (1996) reported four types of thin egg shells of dinosaurian and avian affinities from the Lameta Formation of Dongargaon, Maharashtra. The samples were collected from the studied succession exposed about 0.5 km west of the Mohgaon village (22°1' N: 79°11' E). The Intertrappean bed of shale is approximately 1m thick and is marked by the buff-coloured cherts (0.25 m thick) with poorly preserved wood fragments. These are overlain by green shale (0.25 m thick) that contains freshwater bivalve shell fragments. The uppermost part of the shale bed (0.25 m thick) is carbonaceous and occasionally coaly in nature.

SYSTEMATIC DESCRIPTION

Class **Magnoliopsida**

Order **Magnoliales**

Family **Anonaceae**

Genus ***Polyalthia*** **Blume**

Polyalthia palaeosiamiarum Awasthi & Prasad, 1990

(Pl. I, figs. 4,6)

Material: Single fairly preserved and incomplete leaf impression with galls.

*Description***:** Leaf simple, symmetrical, seemingly elliptic; preserved size 4.8 x 3.7 cm; apex and base absent; margin entire; texture thick chartaceous; venation pinnate, eucamptodromous; primary vein (1°) single, prominent, stout, straight; secondary veins (2°) only 6 pairs visible, 0.7 to 1.3 cm. apart, alternate to sub-opposite, uniformly curved up, unbranched, angle of divergence acute (55°- 60°), moderate; tertiary veins (3°) fine, poorly preserved, angle of origin usually RR, percurrent, branched, oblique in relation to midvein, predominantly alternate and close. Insect galls present over the leaf surface mostly near the veins, sometimes 2-3 galls agglomerate and fused to form a cluster, circular to ovoid in shape, 2-4mm in diameter.

Specimen: B.S.I.P. Museum No. 39914 (Pl. I, fig. 4).

Locality: Keria, Chhindwara District, Madhya Pradesh, India.

Horizon and Age: Deccan Intertrappean beds; Early Tertiary to Upper Cretaceous (Maastrichtian- Danian).

*Affinities***:** The diagnostic features of the present fossil leaf are elliptic shape, entire margin, eucamptodromous venation, and acute angle of secondary veins and their course, percurrrent tertiary veins and presence of galls altogether indicate its resemblance with the genus *Polyalthia* Blume of family Anonaceae. A morphological study of modern leaves of all the available species (30 species) of this genus suggests that the leaves of *P. siamiarum* Benth. & Hook. (C.N.H. Herbarium sheet no. 11902; Pl. I; figs 5, 7) show closest affinity with the present fossil leaf.

So far, five fossil leaves resembling the genus *Polyalthia* are known from the Tertiary sediments of India and abroad. Of them, *Polyalthia crassips* Engl. has been described from the Tertiary of Germany (Menzel, 1920) and *P. chaneyi* from the Eocene of North America. Two fossil leaves have been designated as *P. palaeosiamiarum* Awasthi & Prasad from the Siwalik of Suraikhola, Western Nepal and Darjeeling District, West Bengal (Awasthi & Prasad, 1990; Antal & Prasad, 1996) and *P. palaeosumatrana* Tripathi *et al.,* 2002 from the Lower Siwalik of Koilabas, Nepal. On comparison of present fossil leaf with the above known species, it has been concluded that it shows closest similarity with *P. palaeosiamiarum* Awasthi & Prasad and it has been assigned to the same specific name.

The genus *Polyalthia* Blume consists of 100 species distributed in the tropics of old world (Mabberley, 1997). The modern comparable species *P. siamiarum* Benth. & Hook. with which the fossil shows closest resemblance, is a tall tree found in Assam, Chittagong Hills in Bangladesh, Myanmar and Andaman (Brandis, 1971; Gamble, 1972).

Genus ***Miliusa*** Leschen ex. A. DC.

Miliusa pretomentosa n. sp.

(Pl. I, figs. 1, 2)

Material: Two well-preserved leaf impressions. One specimen is almost complete

Description: Leaf simple, symmetrical, narrow to wide elliptic; preserved size 4.6 x 3.7cm. and 4.3 x 2.6cm; apex

EXPLANATION OF PLATE I

1. ***Miliusa pretomentosa*** n. sp. - Fossil leaf showing shape, size and venation pattern. B.S.I.P Museum no. 39915 (Holotype). 2. ***Miliusa pretomentosa*** n. sp. - Another fossil leaf showing shape, size and nature of apex and base. B.S.I.P Museum no. 39916 (Paratype). 3. ***Miliusa tomentosa*** n. sp. Hook. F. & Th. - Modern leaf showing similar shape, size, apex, base and venation pattern. 4. ***Polyalthia palaeosiamiarum*** Awasthi & Prasad - Fossil leaf showing shape, size and venation pattern and presence of galls. B.S.I.P. Museum no. 39914. . 5. ***Polyalthia siamiarum*** Benth. & Hook. - Modern leaf showing similar shape, size and venation pattern and presence of similar galls. 6. ***Polyalthia palaeosiamiarum*** Awasthi & Prasad - A part of fossil leaf (fig-4) showing details of venation and the galls X2. 7. ***Polyalthia siamiarum*** Awasthi & Prasad - A part of modern leaf (Fig-5) magnified to show similar detail of venation and galls X2. 8. ***Kayea kalagarhensis*** Prasad - Fossil leaf showing shape, size and venation pattern. B.S.I.P. Museum no. 39917. 9. ***Kayea kalagarhensis*** Prasad - Another fossil leaf showing nature of apex B.S.I.P Museum no. 39918. 10. ***Kayea floribunda*** Wall.- Modern leaf showing similar shape, size and venation pattern. 11. ***Spondias deccanensis*** n. sp. - Fossil leaf showing shape, size and venation pattern. B.S.I.P Museum no. 39920 (Holotype). 12. ***Spondias acuminata*** Roxb. - Modern leaf showing similar shape, size and venation pattern). 13. ***Atlantia monophylla*** Correa. - Modern leaf showing similar shape, size and venation pattern. with fig. 14. 14. ***Atlantia miocenica*** Prasad - Fossil leaf showing shape, size and venation pattern. B.S.I.P. Museum no. 39919. 15, 18. ***Ficus preramentacea*** n. sp. - Fossil leaves showing nature of base and secondary veins shape, size and venation pattern. B.S.I.P. Museum no. 39922 (Holotype) 39923 (Paratype). 16,17. ***Ficus preramentacea*** n. sp. - fossil leaves showing middle part of lamina with their venation pattern. B.S.I.P. Museum no. 39924, 39925 (Paratype). 19. ***Ficus ramentacea*** Roxb. - Modern leaf showing similar shape, size and venation pattern.

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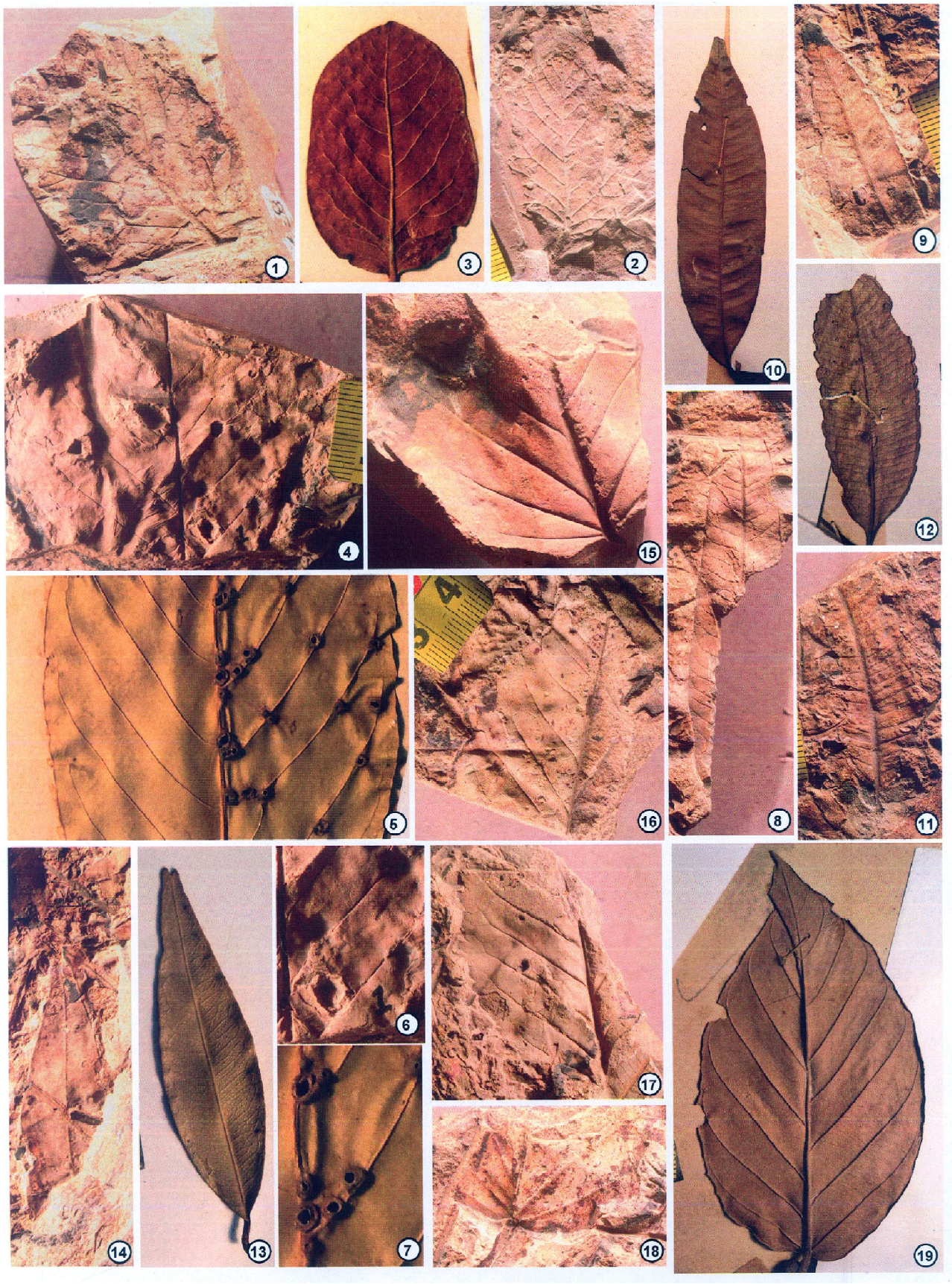
Plate I



indistinct; base obtuse; margin entire; texture thick, chartaceous; venation pinnate, craspedodromous to eucamptodromous; primary vein (1^0) single, prominent, stout, almost straight; secondary veins (2^0) 10-11 pairs visible, 0.2 to 1.0 cm apart, angle of divergence 60^0- 70^0, uniformly curved upward, basal secondary recurved and running upward; alternate to opposite, branched near the margin; intersecondary veins indistinct; tertiary veins (3^0) fine, well preserved, angle of origin usually RR, percurrent, sometime sinuous to recurved, branched, oblique in relation to midvein, alternate to opposite and close.

Specimen: B.S.I.P. Museum no.39915 (Pl. I, fig.1; Holotype) and 39916 (Pl. I, fig. 2; Paratype).

Locality: Keria, Chhindwara District, Madhya Pradesh.

Horizon and Age: Deccan Intertrappean beds, Early Tertiary to Upper Cretaceous (Maastrichtian to Danian).

Derivation of name: By adding the prefix 'Pre' to the name of modern species, *M. tomentosa*.

Affinity: The most important morphological features of the present fossil leaves are narrow to wide elliptic shape, obtuse base, entire margin, craspedodromous to eucamptodromous venation, recurved nature of basal secondary branching near the margin and percurrent and recurved to sinuous tertiary veins. These features are found in the modern leaves of the genus *Miliusa* Leschen ex. A. DC. of the family Anonaceae. A critical survey of modern leaves of all the available species of this genus suggests that the leaves of *M. tomentosa* H. F. & Th. (C.N.H. Herbarium sheet no.269; Pl. I, fig.3) show closest similarity in almost all the morphological features.

Two fossil leaves showing affinity with the genus *Miliusa* Leschen ex. A. DC have been known from the Siwalik sediments. They are *Miliusa siwalika* (Prasad *et al.*, 1999) from the Siwalik of Koilabas area, Western Nepal and *Miliusa miovelutina* Tripathi *et al.*, 2002) from the Siwalik sediments exposed near Jarva in Balrampur District, Uttar Pradesh, India. On comparison with these fossils, it has been observed that *M. siwalika* Prasad *et al.,* 1999 differs from present fossils in having only 3 pairs of secondary veins against 10-11 pairs of secondary veins in the present specimen. However, *M. miovelutina* Tripathi *et al.* (2002) can be easily differentiated from the present fossil leaves in being larger size (9.0 x 7.0 cm.). Thus, in being different from already known species the present fossil leaves have been described as new species.

The genus *Miliusa* Leschen ex. A. DC. comprises 40 species distributed mostly in the Indo-Malayan region and Australia. Only 7 species are found in India. The extant taxon *M. tomentosa* H. F. & Th. is a medium-sized tree distributed throughout Uttar Pradesh, Bihar, central India and Western Ghats. It also occurs in Gujarat and the moist part of Rajputana (Brandis, 1971).

Order **Malpighiales**
Family **Clusiaceae**
Genus ***Kayea*** Wall.
Kayea kalagarhensis Prasad,1993
(Pl. I, figs. 8, 9)

Material: Two well preserved partly incomplete leaf impressions.

Description: Leaves simple, symmetrical, narrow elliptic to oblong; preserved size 4.5 x 1.6 cm. and 8.0x 1.6 cm; apex narrow acute to attenuate; base indistinct; margin entire; texture thick, chartaceous; venation pinnate, eucamptodromous; primary vein (1^0) single, prominent, stout, almost straight; secondary veins (2^0) more than 22 pairs visible, closely placed, alternate to opposite, seemingly unbranched, angle of divergence acute to nearly right angle (70^0- 85^0), lower secondaries are more acute, uniformly curved up, sometimes the secondary joined to the margin directly or showing craspedodromous type of venation; inter secondary veins present, simple; tertiary veins (3^0) fine, poorly preserved, angle of origin usually RR, percurrent, usually oblique in relation to midvein, alternate to opposite and close.

Specimen: B.S.I.P. Museum no.39917 and 39918 (Pl. I, fig. 8, 9).

Locality: Keria, Chhindwara District, Madhya Pradesh.

Horizon and Age: Deccan Intertrappean beds, Early Tertiary to Upper Cretaceous (Maastrichtian to Danian).

Affinity: The characteristic features of the present fossil leaves are narrow elliptic to oblong shape, acute to attenuate apex, entire margin, thick chartaceous, texture eucamptodromous, venation and closely placed, secondary veins with acute to nearly right angle of divergence strongly suggest their close affinity with the leaves of *Kayea floribunda* Wall. (*Kayea paniculata*) of the family Clusiaceae (C.N.H. Herbarium sheet No. 47650; Pl. I., fig.10).

Fossil leaves resembling the genus *Kayea* Wall. have been reported from the Tertiary sediments of India and Nepal. These are *Kayea kalagarhensis* Prasad, 1993 from the Lower Siwalik sediments of Kuwan Sot near Kalagarh, Pauri Garhwal District of Uttarakhand and Neyveli Lignite Deposit, South India (Agarwal, 2002) *Kayea baragolaensis* Awasthi & Mehrotra, 1995 reported from Oligocene sediments of Baragoli, Assam, *Kayea* sp. Mathur & Mathur,1998 from Neogene (Mar Formation) of Bikaner District, Rajasthan) and *Kayea* sp. Mathur *et al.,* 1996 from Kasauli Formation (Lower Miocene) of Solan District, Himachal Pradesh. Among the above-mentioned fossil leaves *Kayea kalagarhensis* (Prasad, 1993, Pl.1, fig.3,4); shows the closest similarity with the present fossil specimens and, therefore, have been kept under the same specific name, *Kayea kalagarhensis* Prasad.

EXPLANATION OF PLATE II

1. ***Putranjiva palaeoroxburghii*** n. sp.-Fossil leaf showing shape, size and venation pattern. B.S.I.P. Museum no. 39921 (Holotype). 2. ***Putranjiva roxburghii*** Wall.- Modern leaf showing similar shape, size and venation pattern and the nature of apex. 3. ***Putranjiva paleoroxburghii*** n. sp. -A part of fossil leaf (fig.1) magnified to show detail of venation X4. 4. ***Putranjiva roxburghii*** Wall.- A part of modern leaf (fig. 2) magnified to show similar detail of venation X4. 5. ***Pinanga palaeoinsignis*** n. sp.- Fossil leaves showing oblong lamina and parallel venation with some distinct veins. B.S.I.P. Museum no. 39926. 6. ***Pinanga insignis*** Becc. - A part of modern leaf showing similar shape, size and venation pattern. 7. ***Amesoneuron cocosii*** n. sp. -Fossil leaf (small portion of leaf) showing nature of plicates and their venation pattern which are divisible into prominent and faint veins. B.S.I.P. Museum no. 39927 (Holotype). 8. ***Cocos palaeonucifera*** n. sp.-Fossil specimen showing 5-6 immature fruits having oval to triangular shape with broken epicarp and mesocarp B.S.I.P. Museum no. 39928 (Holotype). 9,10. ***Cocos nucifera*** Linn.- Modern immature fruits showing similarity with fig.8 having oval to triangular shape. 11. ***Musa intertrappea*** n. sp. - Fossil leaf showing shape, size and venation pattern. B.S.I.P. Museum no. 39929 (Holotype).

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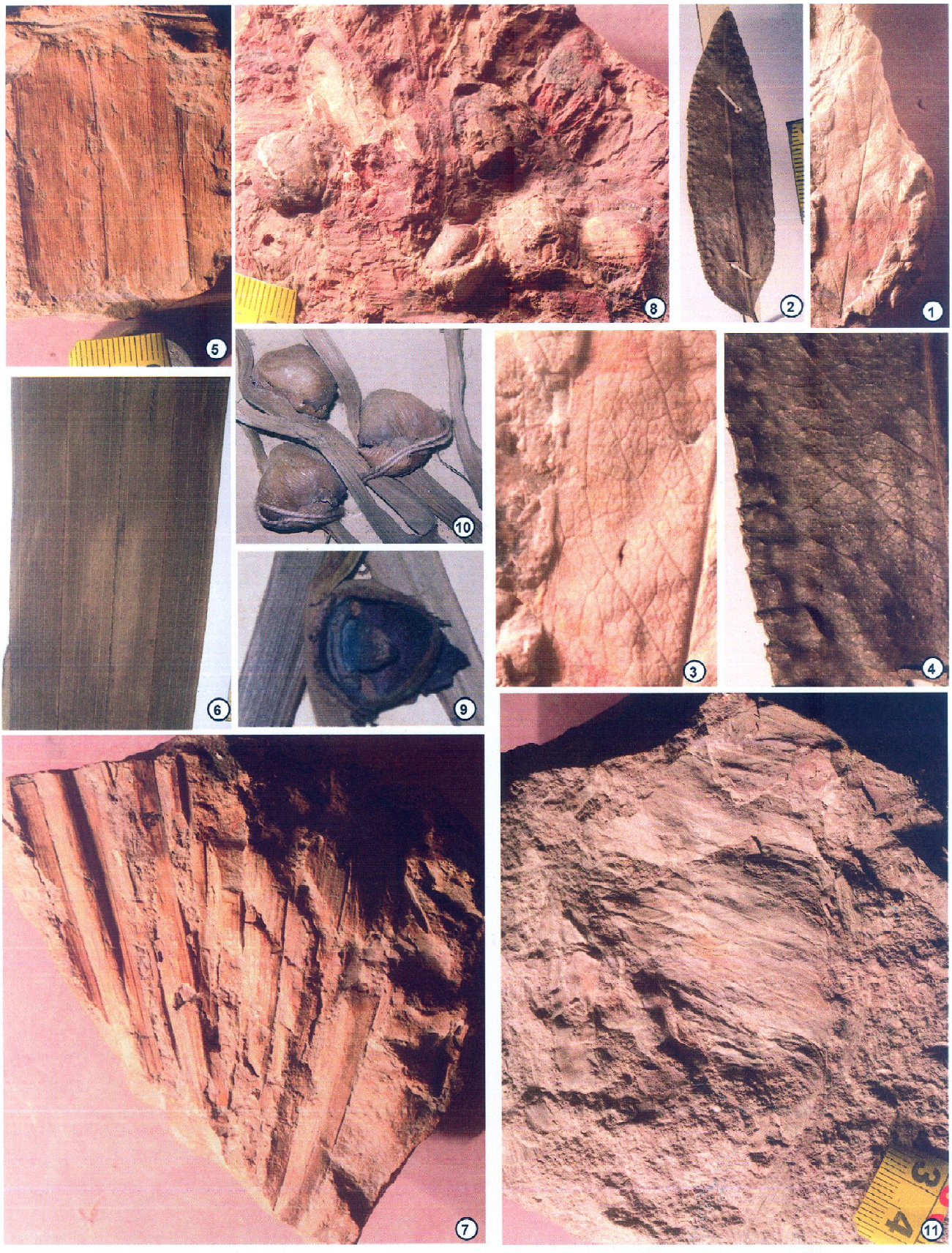
Plate II



The genus *Kayea* Wall. consists of about 40 species distributed in the Indo-Malayan region. The modern comparable taxon, *Kayea floribunda* Wall. (*Kayea paniculata*) with which fossils show affinity, is a medium sized tree growing in the forest of North-east India and Myanmar. (Chowdhury & Ghosh, 1958).

Order **Sapindales**
Family **Rutaceae**
Genus ***Atlantia*** Correa.
Atlantia miocenica Prasad,1994
(Pl. 1, fig.14)

Material: Single, poorly preserved leaf impression, base partly broken.

Description: Leaf simple, slightly asymmetrical at basal part, narrow elliptic; preserved size 4.5 x 1.6 cm; apex attenuate; base slightly broken; margin entire; texture thick, chartaceous; venation pinnate, eucamptodromous; primary vein (1^0) single, prominent; stout, almost straight; secondary veins (2^0) poorly preserved, closely placed, angle of divergence acute (about 60^0), uniformly curved up, intersecondary veins present, poorly preserved. Further details not visible.

Specimen: B.S.I.P. Museum no.39919 (Pl. I, fig.14).

Locality: Keria, Chhindwara District, Madhya Pradesh, India

Horizon and Age: Deccan Intertrappean beds, Early Tertiary to Upper Cretaceous, (Maastrichtian to Danian).

Affinity: Asymmetrical, narrow elliptic shape, attenuate apex, entire margin, eucamptodromous venation, number and nature of secondary veins and presence of intersecondary veins altogether indicate its resemblance with the modern leaves of *Atlantia monophylla* Correa. of the family Rutaceae (C.N.H. Herbarium sheet No. 76387; Pl. I., fig.13).

So far, only two fossil leaves resembling the genus *Atlantia* Correa have been reported from the Tertiary sediments of Indian subcontinent. Of these, *Atlantia miocenica* Prasad, 1994 is known from the Siwalik sediments of Koilabas, Western Nepal and *A. palaeomonophylla* Mehrotra, 2000 reported from Tura Formation (Upper Palaeocene) of East Garo Hills District, Meghalaya. Both the above fossil leaves have been compared with the present fossil and observed that *A. palaeomonophylla* Mehrotra differs from present fossil in being narrow ovate shape possessing only 10 pairs of secondary veins. However, the other fossil leaf, *A. miocenica* Prasad is comparatively smaller in size but has similar venation pattern to the present fossil leaf. Hence the present fossil leaf has been assigned to *A. miocenica* Prasad.

Atlantia Correa. includes 10 species distributed in the tropical regions. The comparable species *A. monophylla* Correa. is an evergreen shrub or small tree growing in Kanara, western Mysore, Nilgiri, Karnataka, Assam, Andamans and Mayanmar (Brandis,1971).

Family **Anacardiaceae**
Sub family **Spondioideae**
Genus ***Spondias*** Linn.
Spondias deccanensis n. sp.
(Pl. I, fig. 11)

Material: It consist of single well preserved leaf impressions.

Description: Leaf simple, symmetrical, narrow elliptic; preserved size 4.0 x 1.8 cm; apex and base slightly broken, seemingly acute; margin indistinct, texture thick chartaceous; venation pinnate; brochidodromous; primary vein (1^0) single, prominent, stout, slightly curved; secondary veins (2^0) more than 16 pairs visible, closely placed, alternate to opposite, angle of divergence wide acute to nearly right angle, 70^0-85^0, uniformly curved up, seemingly unbranched, intersecondary veins present; simple; tertiary veins (3^0) not distinct.

Specimen: B.S.I.P. Museum no. 39920 (Pl. I, fig. 11; Holotype).

Locality: Keria, Chhindwara District, Madhya Pradesh, India.

Horizon and Age: Deccan Intertrappean beds, Early Tertiary to Upper Cretaceous (Maastrichtian to Danian).

Derivation of name: The specific epithet is based on the Deccan Intertrappean beds.

Affinity: The shape, size, venation pattern, and nature of secondary veins indicate that the present fossil leaves closely resemble to the extant leaves of *Spondias accuminata* Roxb. of the family Anacardiaceae (Pl. I, fig.12; C.N.H. Herbarium sheet no. 1123787).

There is single record of fossil leaf of the genus *Spondias* Linn. from the Late Tertiary sediments of Mahuadanr, Jharkhand India. (Bande and Srivastava, 1990) showing close affinity with the extant leaves of *Spondias pinnata* reported under the name *Spondias Pinnata* (Linn. f.) Kurz (Syn. *S. mangifera* Willed.). On comparison it has been observed that the fossil leaf (*S. pinnata*), differs from present specimen in having comparatively larger size and distantly arranged secondary and intersecondary veins. Thus in being different the present fossil leaf have been described under the specific name, *Spondias deccanensis* n. sp.

Spondias Linn. is a small genus consisting of about 6 species widely distributed throughout the tropics of the old and new World. Of these three species are found to grow in India. The comparable species *S. acuminata* Roxb. is a large deciduous tree distributed from Konkan southwards, in Coastal Mysore and Madras (Ghosh and Purkayastha,1963).

Order **Malpighiales**
Family **Putranjivaceae**
Genus ***Putranjiva*** Wall.
Putranjiva palaeoroxburghii n. sp..
(Pl. II, figs1,3)

Material: A single, well preserved and incomplete leaf impression.

Description: Leaf simple, symmetrical, narrow elliptic; preserved size 6.5 x 1.5 cm; apex broken; base slightly indistinct; margin entire to poorly serrate; texture charataceous; venation pinnate, eucamptodromous; primary vein (1^0) single, prominent, almost straight; stout, secondary veins (2^0) 5 pairs visible, 0.8-1.5 cm. apart, uniformly curved up, alternate, branched, angle of divergence about 60^0, acute, moderate; tertiary veins (3^0) fine, well preserved, angle of origin usually RR, rarely AO, percurrent, branched, straight to sinuous, predominantly alternate, close; areoles well developed.

Specimen: B.S.I.P. Museum no.39921 (Pl. II fig. 1; Holotype).

Locality: Mohgaon Kalan, Chhindwara District, Madhya Pradesh.

Horizon and Age: Deccan Intertrappean beds, Early Tertiary to Upper Cretaceous (Maastrichtian to Danian).

Derivation of name: By adding prefix 'Palaeo' to the modern comparable species, *P. roxburghii*.

Affinity: The characteristic features of the present fossil leaf such as, narrow, elliptic shape, asymmetrical base, nature of margin, eucamptodromous, venation, distantly placed secondary veins which running upwards for a little distance, branched,

AO-RR, per current, tertiary veins collectively indicate its resemblance with the modern leaves of *Putranjiva roxburghii* Wall. (C.N.H. Herbarium sheet no. 63538; Pl. II fig.2 & 4) of the family Putranjivaceae in shape, size and venation pattern.

As far as authors are aware, there is no record of fossil leaf resembling the genus *Putranjiva* wall. This is the first record of fossil leaf referable to this genus from Early Tertiary of Mohgaon Kalan, Madhya Pradesh and assigned as *P. palaeoroxburghii* n. sp.

The genus *Putranjiva* Wall**.** comprises 200 species distributed in the tropical region of E. Asia and South Africa (Mabberley,1997). The modern comparable species, *P. roxburghii* Wall. is a moderate sized evergreen trees, distributed in the tropical region of India. It is wild and cultivated from Lower Himalaya in Kumaon, eastward and south ward to Pegu and SriLanka. (Hooker,1885).

Order **Urticales**
Family **Moraceae**
Genus ***Ficus*** Linn.
Ficus preramentacea n. sp.
(Pl. I, figs 15-18)

Material: Four incomplete and fairly preserved leaf impressions.

*Description***:** Leaf simple, symmetrical, wide elliptic, preserved size 5.5 x 5.2 cm, 4.5 x 3.5 cm, 4.5 x 3.5 cm and 2.2 x 4.0 cm; apex broken; base obtuse; margin entire; texture coriaceous; petiole preserved in two specimens, 0.5 to 1.0 cm. long, thick; venation pinnate, eucamptodromous; primary vein (1^0) single, prominent; almost straight; thick toward basal part; secondary veins (2^0) 6-7 pairs visible, 0.5 to 1.3 cm. apart, lowest pair of secondary vein arises very closely, angle of origin 55^0-85^0, lowest pair arise at greater angle, uniformly curved up, usually alternate, unbranched; tertiary veins fine, poorly preserved, angle of origin usually RR, percurrent, branched, straight to sinuous, alternate to opposite, close.

Specimen: B.S.I.P. Museum no.39922 (Pl. I, fig. 15; Holotype), 39923-39925 (Pl. I, figs 16-18; Paratype).

Locality: Mohgaon Kalan, Chhindwara District, Madhya Pradesh.

Horizon and Age: Deccan Intertrappean beds, Early Tertiary to Upper Cretaceous (Maastrichtian to Danian).

Derivation of name: By adding prefix 'Pre' to the modern comparable species *F. ramentacea.*

*Affinity***:** The diagnostic features of the present fossil leaves are symmetrical, elliptic shape, obtuse base, entire margin, coriaceous texture, thick petiole, eucamptodromous venation, nature of basal secondaries and percurrent, straight to sinuous tertiary veins. These features are found common in the modern leaves of the genus *Ficus* Linn. belonging to the family Moraceae. In order to find out its specific affinity a variety of modern leaves of all the available species (37 species) of this genus were critically examined and found that *Ficus ramentacea* Roxb.(C.N.H. Herbarium sheet no.427612, Pl. I, fig.19) show close resemblance with the present fossils.

The genus *Ficus* Linn. is well documented from the Tertiary of India and abroad. The fossil leaves of *Ficus* Linn. have been described under four generic name viz. *Ficus* Linn., *Ficonium* Ett., *Ficophyllum*, Fontaine emend. Edward and *Protoficus* Saporta. More than 390 fossil species of *Ficus* Linn. have been reported from different part of the world (Prasad *et al.*, 2004).

About 28 fossil species of the genus *Ficus* Linn. have been reported from Tertiary and Quaternary sediments of Indian subcontinent (Table-1). These fossil leaves were taken in account for comparison and it was found that none of them shows complete resemblance with the present fossil leaves.

The above taxa mainly differ in the nature of base and venation pattern of secondary and tertiary veins. The present specimens being different from already known fossil leaves of *Ficus* Linn. the fossil leaves have been assigned to new specific name, *Ficus preramentacea* n. sp.

The genus *Ficus* Linn. comprises about 1000 species of trees, shrubs or climbers distributed throughout the tropical of both the hemisphere but particularly abundant in South east Asia and Polynesia (Mabberley,1997). About 70 species occur in Indian subcontinent of which most common species are. *Ficus bengalensis*, *F. religiosa* and *F. elastica.* The modern comparable species, *F. ramentacea* Roxb. with which fossil closely resembles is a powerful epiphyte often eventually a tree and distributed in the Sylhet, Myanmar, Perak and Malaya (Hooker, 1885).

Class **Liliopsida**
Order **Arecales**
Family **Arecaceae**
Genus ***Pinanga*** Blume.
Pinanga palaeoinsignis n. sp.
(Pl. II, fig.5)

Material: A well preserved and incomplete leaf impression.

*Description***:** preserved lamina length 5 cm**.** and width 4 cm; apical and basal part broken; margin appearing entire; texture chartaceous; venation parallelodromous, two veins which are running parallel to each other at distance of 1.6 cm, are thick and prominent like the primary veins. In between these two prominent veins there are 3-4 thin and slightly prominent veins run parallel. Further, in between there are 4-5 veins which joined each other by the cross veins.

Specimen: 39926 (Pl. II, fig. 5; Holotype).

Locality: Mohgaon Kalan, Chhindwara District, Madhya Pradesh, India.

Horizon and Age: Deccan Intertrappean beds, Early Tertiary to Upper Cretaceous (Maastrichtian-Danian).

Derivation of name: By adding prefix 'palaeo' to the name of modern comparable species.

Affinity: The characters exhibited by the fossil leaf such as size, entire margin and nature of venation are found common in the extant leaves of family Poaceae, *Areca triandra* Roxb. *Calamus* sp. and *Pinanga insignis* Becc. A critical study of the leaves of above taxa show that the leaves of Poaceae differ from present fossil in having single prominent vein (midvein). In *Calamus* sp. the prominent veins are comparatively more distinct than present fossil. The modern leaves of *Areca triandra* Roxb. also possess three prominent veins but differ in internal venation pattern and distantly placed. Thus, the leaves of *Pinanga insignis* Becc. show closets affinity with the present fossil in shape, size and venation pattern (C.N.H. Herbarium sheet no. 442181, Pl. II, fig.6).

As far as authors aware, there is no record of fossil leaves resembling the genus *Pinanga* Blume from Tertiary sediments of India. The occurrence of the fossil leaf in Deccan Intertrappean beds forms first report from there and described as *Pinanga palaeoinsignis* n. sp.

The genus *Pinanga* Blume consists of approximately 120 species ranging from the Himalayas and South China to new Guinea with greatest diversity in the wet area of Sunda Shelf. Of these, 40 species are Indo- Malayan (Willis, 2006). The modern

Table 1: Fossil leaf of the genus *Ficus* Linn. known from India and Nepal.

FOSSIL SPECIES	HORIZON/ LOCALITY	REFERENCES
Ficus arnottiana	Quaternary beds, Maharastra	Mahajan & Mahabale, 1973
F. champarensis	Siwalik beds, Bhikhnathoree, Bihar	Lakhanpal & Awasthi, 1984
F. cherrapunjiensis	Palaeocene, Garo Hills, Meghalaya	Ambwani, 1991
F. cunia	Karewa beds, Kashmir Dharmsala beds, Himanchal Pradesh	Puri ,1947; Gupta & Jiwan, 1972
F. foveolata	Late Tertiary deposits of Palamau District, Jharkhand	Bande & Srivastava, 1990
F. glaberrima	Late Tertiary deposits of Palamau District, Jharkhand	Bande & Srivastava, 1990
F. khariensis	Miocene of Katchchh, Gujrat	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, Himanchal 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, Deposite, South India.	Prasad, 1990; Antal & Awasthi, 1993; Agarawal, 2002
F. tomentosa	Late Tertiary deposits of Palamau District, Jharkhand	Bande & Srivastava, 1990
F. benjamina	Quaternary beds of Sirmur District, Himanchal Pradesh; Siwalik sediments of Himanchal Pradesh.	Prasad *et al.,* 2002; Prasad, 2006
F. eomysorensis	Siwalik sediments near Jarwa, U.P.	Tripathi *et al.,* 2002
F. barogensis	Kasauli Formation,Barog, Himachal Pradesh	Mathur, Mishra & Mehra, 1996
F. kasaulica	Kasauli Formation, Barog, Himachal Pradesh	Mathur, Mishra & Mehra, 1996
F kumarhattiensis	Dagshai Formation, Solan District, Himachal Pradesh	Mathur, Mishra & Mehra, 1996
F. precurticeps	Neyveli Lignite, Deposite, South India.	Agarawal, 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, Himachal Pradesh.	Mathur, Mishra & Mehra, 1996
Ficus sp *cf. F. tomentosa* Roxb.	Dagshai Formation, Himachal Pradesh	Mishra & Mathur 1992
F. rumphii Blume	Late Tertiary deposits of Palamau District, Jharkhand	Singh & Prasad, 2008
F. microcarpa var. *nitida* Thumb.	Late Tertiary deposits of Palamau District, Jharkhand	Singh & Prasad, 2008
F. curticeps Corver.	Late Tertiary deposits of Palamau District, Jharkhand	Singh & Prasad, 2008
F. palaeoracemosa	Kasauli Formation, Solan, Himachal Pradesh	Srivastava *et al*., 2011

comparable species *P. insignis* Becc. is a tall tree, grows to heights over 300 ft. and naturally found throughout the open forest of the Philippines.

***Genus Amesoneuron* (Goeppert) Read and Hickey**

Amesoneuron cocosii n. sp.

(Pl.. II, fig. 7)

Material: A single well preserved part of leaf impression.

Description: Preserved lamina size 11.0 x 7.0 cm, shape not clear; apical and basal part broken; margin entire; texture coriaceous; lamina consist of more than 4 plicates fused segment, each about 2.0 cm in width. The segment has slightly prominent vein (midvein) along with 4-5 faint parallel veins connected with cross veins.

Specimen: B.S.I.P. Museum no.39927 (Pl. II, fig. 7; Holotype).

Locality: Keria, Chhindwara District, Madhya Pradesh, India.

Horizon and Age: Deccan Intertrappean beds, Early Tertiary to Upper Cretaceous (Maastrichtian-Danian)

Derivation of name: After the name of comparable extant genus *Cocos*.

Affinity: Shape, size and fused plicate segment having prominent midrib along with faint parallel veins and entire margin undoubtedly suggest that the fossil belongs to the family Arecaceae (Read and Hickey, 1972). In order to compare with the extant leaves, a large number of herbarium sheets of different genera and species have been critically examined and concluded that the present fossil leaf resembles closely with the extant leaves of *Cocos nucifera* Linn. (C.N.H. Herbarium sheet no. 495118).

A number of fossil palm and palm like leaves have been recorded from Tertiary sediments of India and abroad (Guleria & Mehrotra, 1998, Prasad, 2006). The genus *Amesoneuron* was specially created to accommodate the leaves or leaflets which are fragmentary remains of palm leaves considering the evidence of original leaf form (Goeppert) Read and Hickey, 1972). There are six fossil leaves described under form genus *Amesoneuron* from Tertiary sediments of India. These are *A. borassoides* Bonde, 1986 from Deccan Intertrapean sediments of Mohgaon Kalan, India, *A. deccanensis* Guleria & Mehrotra, 1998 from Deccan Intertrappean sediments of Binori Reserved Forest of Madhya Pradesh and Tura Formation of Garo Hills, Meghalaya, *A. sah*nii Guleria *et al.,* 2000 from Lower Miocene of Kasauli Formation, Himachal Pradesh, *A lakhanpalii* Mehrotra 2000 from Tura Formation of Garo Hills, Meghalaya, *A manipurensis* Guleria *et al.,* 2005 from Late Eocene of Imphal, Manipur and *A. siwalika* Prasad, 2006 from Siwalik Sediments of Ranital, Himachal Pradesh, India. After a critical comparison of the present palm fossil leaf with these above mentioned known palm fossil leaves, it has been concluded that none of them shows similarity with the present fossil leaf. They differ mostly in nature and arrangement of prominent and faint parallel veins. Since the present fossil is different from earlier know fossils, it has been described as *Amesoneuron coccosii* n. sp.

The genus *Cocos* Linn. comprises more than 30 species distributed in Tropical region of the World. *Cocos nucifera* with which fossil shows resemblance is a tall tree found to grow in all tropical countries. It grows especially well close to the sea (Hooker, 1885). Cultivated in the hot damp region of India, Myanmar and SriLanka.

Genus ***Cocos*** Linn.

Cocos palaeonucifera n. sp.

(Pl. II, fig.8)

Material: There are 5-6 fruit impressions of different sizes on a piece of chert.

Description: Fruits are immature, oval to spherical or triangular in shape, size varies, 1.8 x 1.8 cm, 1.5x 1.5 cm, 2.0x1.5 cm, the exocarp and mesocarp have been dried and broken before their preservation and hard endocarp part of fruit is seen clearly in two specimen, endocarp is oval elongated in shape, 1.6x 0.9cm and 1.4x 0.6 cm.

Specimen: B.S.I.P. Museum no.39928 (Pl. II, fig. 8; Holotype).

Locality: Mohgaon Kalan, Chhindwara District, Madhya Pradesh, India.

Horizon & Age: Deccan Intertrappean bed, Early Tertiary (Maastrichtian- Danian).

Derivation of name: By adding prefix 'Palaeo' to the modern comparable species, *C. nucifera.*

Affinity: The above mentioned morphological features of the present fossil fruits suggest their affinity with the immature fruits of *Cocos nucifera* Linn.(C.N.H. Herbarium sheet no. 495117, 495120; Pl. II, fig.9,10).

So far, five fossil fruits resembling the genus *Cocos* Linn. have been reported from Tertiary sediments of India and abroad. They are *Cocos sahnii* Kaul, 1951 from Eocene of Kapurdi, Barmer District, Rajasthan, *C. intertrappea* Patil and Upadhye, 1984 from the Tertiary of Mohgaon Kalan, Madhya Pradesh, *Cocos nucifer* like fruit (Tripathi *et al.*,1991), and *Cocos pantii* (Misra, 2004) from the Tertiary of Amarkantak, Madhya Pradesh. Rigby, 1995 also described a fossil fruit of *Cocos nucifera* from the Pliocene of Queensland, Australia.

The fossil fruit of *Cocos nucifera* described earlier are in petrifaction form having their sufficient anatomical structures. They are comparatively larger in size and divisible into different parts. However, the present fossils are immature fruit impression showing only the outline features. In view of this, the present fossil fruits do not resembles any one of them hence these are described as *Cocos palaeonucifera* n. sp. This is first record of immature fruit from Early Tertiary of Madhya Pradesh, India.

Order **Zingiberales**

Family **Musaceae**

Genus ***Musa*** Linn.

Musa intertrappea n. sp.

(Pl. II, fig.11)

*Materia*l: A part of well preserved leaf impression on the chert.

Description: Due to incomplete specimen, the shape is unknown; preserved size 10.5 x 7.5 cm; apex broken; base seemingly obtuse; margin preserved near base, seemingly entire to undulate; texture coriaceous; petiole 3.5 cm long flattened; venation pinnate; craspedodromous, each secondary joined the margin separately; primary vein (1^0) single, prominent, massive, flat, 0.8 cm thick; secondary veins (2^0) numerous, more than 20 pairs visible, 0.4-0.6 cm apart, alternate to opposite, unbranched, angle of origin 75^0, wide acute, recurrent in origin straight to slightly curved and joined to the margin and run almost parallel to each other; intersecondary veins present, simple, 3-4 veins in between two secondary veins. Further detail could not be seen.

Specimen: B.S.I.P. Museum no.39929 (Pl. II, fig. 11; Holotype).

Locality: Mohgaon Kalan, Chhindwara District, Madhya Pradesh, India.

Horizon and Age: Deccan Intertrappean beds, Early Tertiary to Upper Cretaceous (Maastrichtian- Danian)

Derivation of name: After Deccan Intertrappean beds from where sample was recovered.

Affinity: The morphological features exhibited by the present fossil leaf such as massive flattened primary veins along with pinnately arranged numerous secondary and inter secondary veins, entire to undulate margin and presence of long flat petiole indicate its affinity with the extant leaves of family Musaceae. A critical comparison of present fossil with the leaves of many genera and species of this family available at C.N.H. herbarium suggests that the leaves of *Musa sapientum* Linn. (C.N.H. herbarium sheet no.10786, 10605) shows closest affinity with the present fossil leaf in almost all the morphological features.

Fossil leaves belonging to the family Musaceae have been reported under form genus *Musophyllum* Goeppert, 1854. Several species of *Musophyllum* have been recorded from the Tertiary sediments of India and abroad (Pons, 1965, Prakash *et al*., 1979). Of these, only two species resembling the genus *Musa* Linn. known from the Deccan Intertrappean Beds of Madhya Pradesh, India. They are *Musophyllum indicum* Prakash *et al.*, 1979 from Mohgaon Kalan area in Chhindwara District and *Musophyllum* sp. Udhoji & Verma, 1990 from Brangda area in Madhya Pradesh. The present fossil leaf has been compared with these two species of *Musophyllum* known from India and other available species recorded from out side of Indian subcontinents (*M. elegans* Engelhardt, *M. truncatum* Goeppert, *M. bohimicum* Unger, *M. axonense* Watelet, *M. bilinicum* Ettingshausen, *M. complicatum* Lesquereus, *M. styriacum* Ettingshausen, *M. tarkanyense* Bubik). It was observed that none of them shows closet similarity with the present fossil. Most of the fossil leaf does not have their shape and exact size. The comparison has been based only on venation pattern. The present fossil differs mainly in the angle of divergence of secondary and intersecondary veins. Since the present fossil leaf can be differentiated from other species, it has been assigned as *Musa intertrappea* n. sp.

The genus, *Musa* Linn. comprises 35 species distributed in the tropics of Old World (Mabberley,1979). The modern comparable species, *Musa sapientum* Linn. is indigenous in Bihar and Eastern Himalaya ascending to 4000 ft. It is very common in Sri Lanka and Malaya. It is also cultivated throughout India (Hooker, 1894).

DISCUSSION AND CONCLUSIONS

The Deccan Intertrappean sediments were deposited in several shallow reservoirs occupying central India during early Tertiary. Several flowering plants of both the classes (Magnoliopsida and Liliopsida) were found growing luxuriantly in more or less the same proportion. Many of the earlier reports of plant megafossils from the Deccan Intertrappean sediments of central India were based on permineralized fossils. Only a few of them are based on impressions (Prakash *et al.*, 1979;

Table 2: Present day distribution and forest types of modern comparable species recorded from Deccan Intertrappean beds of Madhya Pradesh.

Fossil Taxa	Modern comparable Taxa	Habit	Type of Forest	Present day distribution
Anonaceae				
Polyalthia palaeosiamiarum Awasthi & Prasad	*Polyalthia siamiarum* Benth. & Hooker *Miliusa tomentosa* Hook. F. & Th.	Tree	Evergreen	North east India, Andamans, Bangladesh, Myanmar
Miliusa pretomentosa n. sp.		Tree	Evergreen	Throughout Indian region
Clusiaceae				
Kayea kalagarhensis, Prasad	*Kayea floribunda* Wall.	Tree	Evergreen	North east India, Myanmar
Rutaceae				
Atlantia miocenica, Prasad	*Atlantia monophylla* Correa.	Tree	Evergreen	South India, Assam, Andaman, Myanmar
Anacardiaceae				
Spondias deccanensis n. sp.	*Spondias accuminata* Roxb.	Tree	Evergreen	South India
Euphorbiaceae				
Putranjiva palaeoroxburghii n. sp.	*Putranjiva roxburghii* Wall.	Tree	Evergreen	South India
Moraceae				
Ficus preramentacea n. sp.	*Ficus ramentacea* Roxb.	Tree	Evergreen	North east India, Myanmar and Malaya
Arecaceae				
Pinanga palaeoinsignis n. sp.	*Pinanga insignis* Becc.	Tree	Evergreen	Philippines
Amesoneuron cocosii n. sp.	*Cocos nucifera* Linn.	Tree	Evergreen	Tropical countries specially well close to sea
Cocos *palaeonucifera* n.sp.	"			"
Musaceae				
*Musa intertrappea*n. sp.	*Musa sapientum* Linn.	Tree	Evergreen to moist deciduous	India, Sri Lanka and Malaya

Guleria *et al.,* 1998). The morphotaxonomical study on the well-preserved leaf impressions collected from Keria and Mohgaon Kalan, Chhindwara District, Madhya Pradesh, revealed the occurrence of eleven fossil taxa belonging to eight families of angiosperms. These are *Polyalthia palaeosiamiarum* Awasthi & Prasad, *Miliusa pretomentosa* n. sp., *Kayea kalagarhensis* Prasad, *Atlantia miocenica* Prasad, *Spondias deccanensis* n. sp., *Putranjiva palaeoroxburgii* n. sp., *Ficus preramentacea* n. sp., *Pinanga palaeoinsignis* n. sp., *Amesoneuron cocosii* n. sp., *Cocos palaeonucifera* n. sp. and *Musa intertrappea* n. sp. The modern comparable taxa of the above fossils are found to grow mostly in the tropical evergreen forests of northeast India, Myanmar and Malayan Peninsula (Table 2) which allow us to infer that same type of forest must have been existing around the area during the early Tertiary instead of tropical deciduous forest found there at present.

Occurrence of the genus, *Pinanga* Blume and *Cocos* Linn. of palm family (Arecaceae) is phytogeographically important. This family is a monotypic group having 183 genera and 2364 species and distributed mainly in the tropics. Only 130 palm species grow naturally beyond the tropics (Henderson *et al.*, 1995). The arecaceous fossil records from the Tertiary Period suggest its latitudinal distribution because of suitable warmer climate. The oldest macrofossil has been recorded from the lower Upper Cretaceous of France (Dransfield *et al*., 2008). The records of abundant palm fossils from Deccan Intertrappean beds of India (Lakhanpal *et al.,* 1982; Bonde, 1996a,b) indicate that palms radiated quickly after Cretaceous and were distributed throughout the tropical regions of India. Further, the palms are growing in a typical tropical forest where the temperature and humidity remain high throughout the year. Their occurrence along with the taxa, *polyalthia siamiarun* Benth & Hook., *Kayea floribunda* Wall. and *Ficus ramentacea* Roxb. thriving in evergreen forest of North-east India, the Myanmar and Malayan region, suggest that the climate of the area during the sedimentation must have been more humid than at present day.

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