Journal of the Palaeontological Society of India
Volume 64(2), December 31, 2019: 184-226

ISSN 0552-9360

AN EARLY EOCENE FLORAL ASSEMBLAGE FROM THE CAMBAY SHALE (TARKESHWAR LIGNITE MINE) FORMATION, GUJARAT: PALAEOCLIMATIC AND PHYTOGEOGRAPHICAL IMPLICATIONS

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ABSTRACT

A macro and micro fossil study of the early Eocene sequence is reported in a new fossil locality, Tarkeshwar Lignite Mine, located in between the village Tarkeshwar and Mandavi (Lat 21 º 22' 35" N and Long 73 º 07' 35" E), Surat District, Gujarat, India. Plant mega fossils recovered from this area comprises fossil woods, leaves, fruits, seeds and leaf cuticles. The study revealed the occurrence of several phytogeographically significant taxa such as *Walsura piscidia* (Meliaceae), *Ziziphus xylopyrus* (Rhamnaceae), *Saurauia napaulensis* (Actinidiaceae), *Calophyllum inophyllum* (Clusiaceae), *Schleichera oleosa, Drimycarpus racemosus* (Sapindaceae), *Diospyros pilosula* (Ebenaceae), *Terminalia tomentosa, T. bellerica,Combretum decandrum* (Combretaceae), *Lagerstroemia macrocarpa* (Lythraceae) and taxa probably belonging to the Cyperaceae, while the palynofloral assemblage comprising mainly angiosperm pollen including *Proxapertites microreticulatus, Proxapertites cursus, Acanthotricolpites bulbospinosus, Spinizonocolpites prominatus, Longapertites* sp., *Matanomadhiasulcites maximuss, Matanomadhiasulcites kutchensis, Tricolporopollis matanomadhensis, Barringtoniapollenites retipilatus, Lakiapollis ovatus,* and *Ctenolophonidites costatus.* The pteridophytes are represented by *Cyathidites minor, Todiosporites kutchensis, Dandotispora telonata, Lygodiumsporites lakiensis, Lycopodiumsporites palaeocenicus, Dictyophillidites granulates* and *Laevigatosporites lakiensis*. Besides, a few fungal remains including *Callimothallus assamicus*, *Callimothallus* sp., *Phragmothyrites eocenica* and *Notothyrites setiferus,* are also present in the assemblage. Dinoflagellate cysts have also been recovered. Insect feeding damage on early Eocene Cambay Shale Formation fossils leaves is reported for the first time. Even though not abundant and with low diversity, but overwhelmingly made by specialized feeders rather than genera list herbivores. The overall floral assemblage suggests a prevailing tropical warm and humid climate with moist deciduous to evergreen forest, during the deposition of the Cambay Shale. The floral assemblage also points to the proximity of the shoreline. The dinoflagellate cysts along with foraminiferal linings clearly indicate a marine environment.

Keywords: Eocene forests, floristic assemblages, mega and microfossils, palaeoclimate, palaeogeography, Cambay basin, Gujarat, India.

INTRODUCTION

Amongst the various Palaeocene-Eocene sequences in India, the early Eocene Cambay Shale Formation is unique for its highly diversified faunal and floral assemblages. The Cambay Shale biota recovered from the lignites and associated sediments in the lignite mines of Tarkeshwar, Vastan, Mangrol, and Valia is of great interest, particularly for the terrestrial fossil records (Figs. 1, 2). These lignite deposits are important in Cambay basin for the generation of thermal power plants and are the use of several industries. Previously, diverse faunal (fishes, mammals, reptilea, amphibians, birds, mollusca, foraminifers, ostracodes, and diverse insects entombed in amber) and floral (leaves, woods, fruits, seeds, flowers, pollen and spores) remains have been recorded, mainly only from the Vastan Lignite mine (Singh *et al*., 2009). The Lignite exploitation in this area is basically for thermal power generation. In view of their biostratigraphic importance and thermal power potential, these associated sedimentary sequences are highly significant (Rust *et al*., 2010). The Lignitic deposits at Tarkeshwar mine are part of the Cambay Shale Formation (Early Eocene). The present study locality is situated in between the village Tarkeshwar and Mandavi (21°22' 35" N and 73° 07' 35"E), Surat District, Gujarat. Prior to this, a very little work on palaeobotany (Singh *et al.,* 2014, 2016), petrology (Singh *et al.* 2012), and other palaeobiota (Nagori *et al*., 2013; Rust *et al*., 2010; Grimaldi *et al.,* 2013; Engel *et al*., 2011a, b, 2013) was carried out in this area. Here we report on the macro and micro (marine and non-marine) floral assemblages from the Tarkeshwar Lignite Mine (Figs. 1, 2) and discuss their palaeoclimatic and phytogeographic significance. During the last decade our amber collaborative team (Indian-German-American) has studied rich faunal and floral inclusions from Cambay basin Gujarat. In Cambay basin the Tarkeshwar vertebrate fauna is also highly significant (Smith *et al*., 2016). Tarkeshwar lignite mine is an existing opencast mine and is operated by Gujarat Mineral Development Corporation Ltd.). This mine plays an important role in the generation of promising fossil life forms for reconstructing the different palaeobotanical inferences of the study area.

Geology of the Area

The western part of the Indian province (Gujarat and Rajasthan) mainly consists of Mesozoic-Cenozoic rocks (Merh, 1995) and the whole province is largely covered by alluvial and fluvial sediments. The Cambay rift basin is a narrow elongated rift graben extending from Surat in South to Sanchor in the North. It tectonically continues beyond Sanchor to pass into the Barmer Basin of Rajasthan (Mathur *et al*., 1968). Structurally, the Cambay Basin is a NNW-SSE trending intra-cratonic graben. The Basin flanked on the northeast by the Arawali Swell-Arawali-Delhi Supergroup of rocks (Precambrian) on the east by the Deccan craton, and on the southeast and west by the Saurashtra craton. Nearly, almost complete Cenozoic sequences are present underlying the alluvial (Quaternary sediments) covered plains overlying the Deccan traps. The Deccan traps form the basement of the Cambay Basin and are overlain by

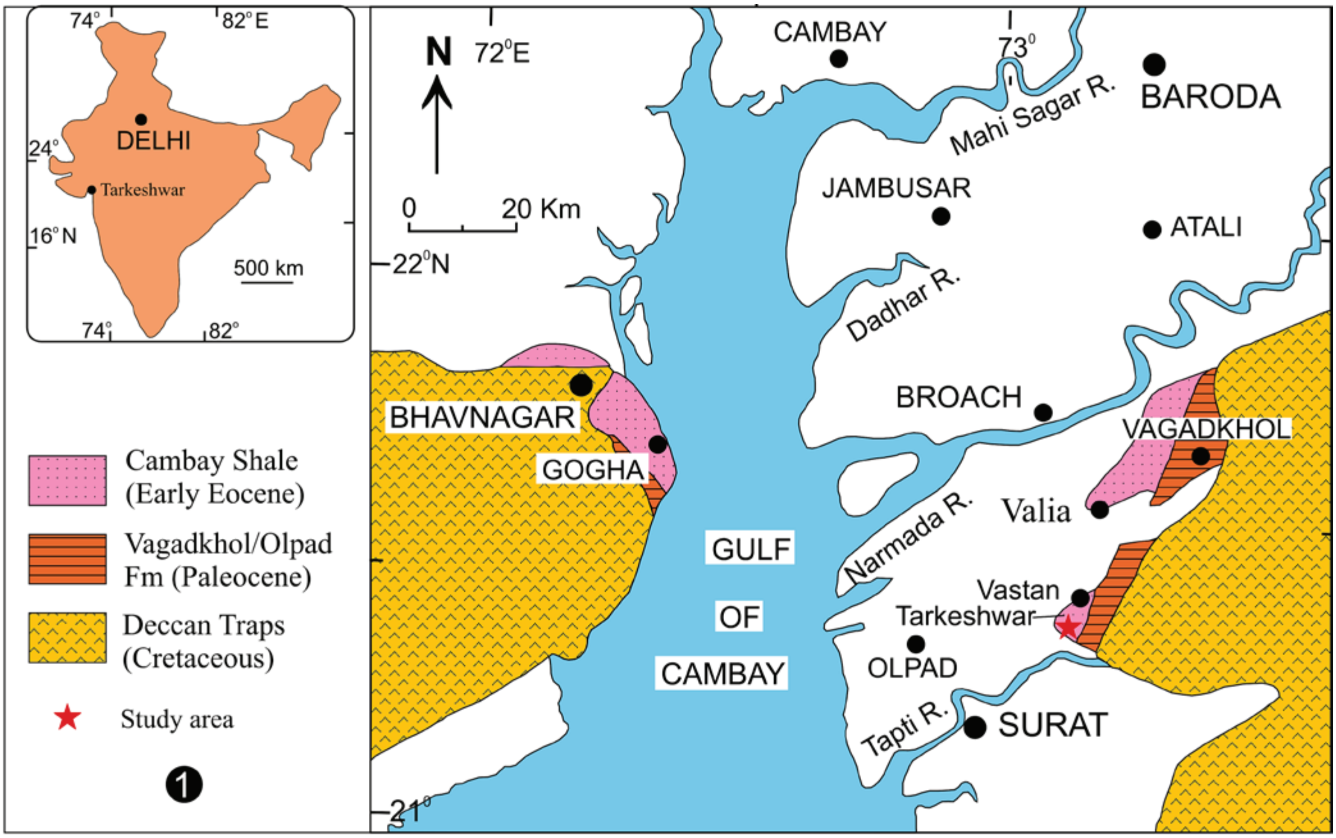


Fig. 1. Geological map of the Cambay Basin, Gujrat showing location of study area (after Rana *et al*., 2004).

the Olpad Formation (Paleocene). The Cambay black shale (Paleocene-Early Eocene) overlies the Olpad Formation. The Kadi Formation of early Eocene is seen with in Cambay black shale and the Kalol Formation of middle Eocene conformably overlies the Cambay black shale. Lastly, the Bhroach (Pliocene) and Jambusar (Pleistocene) formations overlie the Miocene sequence. The subsurface lignite-bearing sequence in southern Cambay (Tarkeshwer, Vastan, Mangrol, Valia, Rajpardi, etc.) is referred as the Cambay shale or Tarkeshwer Formation. The Tarkeshwer Formation consists of sandstones bentonitic and carbonaceous clays and lignite beds. It has different lithologic sequence like, Lignite, carbonaceous clay; lenses of sandstones carbonaceous clay, lignite and grey clay and the rests are Nummulite Formation without any distinction. The early Eocene lignite deposit in the study site is restricted to lower Clay bed of Tarkeshwer Formation (Fig. 2).

MATERIAL AND METHODS

Macro and microfossils described and illustrated in this paper were collected from the early Eocene subsurface shale and lignite beds of the Cambay Shale Formation of Tarkeshwar Lignite Mine (Main Lignite Seam, Shale beds, and Top Lignite Seams) situated 50 km NE of Surat city and 29 km ENE of Kim town, Gujrat, India (Figs. 1, 2). The fossil woods consist of 20 specimens and are highly carbonized but few of them are with the preservation of secondary xylem. These were sectioned along transverse (TS), tangential longitudinal (TLS), and radial longitudinal (RLS) planes. Wood slides were prepared by the standard method of grinding, polishing and mounting in Canadabalsam (Lacey, 1963). The anatomical terms used in describing these fossil woods are those adopted by Wheeler *et al*. (1989) and the International Association of Wood Anatomists, IAWA (1989).

The leaf impressions (about 35 specimens) were mainly collected from shale beds of the same Lignite Mine. Some of the leaves are preserved with cuticle. The morphology of leaf specimens was studied with a hand lens and low power microscope under reflected light. The identification of the fossil leaves and fruits have been carried out at the Central National Herbarium, Sibpur, Howrah, West Bengal, India. For morphological description of leaf impressions, the terminology given by Hickey (1973), Dilcher (1974) and Ash *et al*. (1999) was followed. The cuticles were prepared by sequential maceration in HNO_3 and KOH solution and studied and photographed under a high power microscope. For the systematics of the cuticles, the terminology and methodology given By Dilcher (1974), Roselt and Schneider (1969), and Kovack and Dilcher (1984) were adopted.

Fifty-four palynological samples were collected from the Lignite and associated Shale beds. Almost all the study samples yielded abundant palynofossils. The standard maceration technique of Traverse (2007) has been followed for the recovery of Pollen, spore, fungal & Dinoflagellates. The crushed samples were therefore consequently treated with HF, HCL and concentrated HNO_3 (Lignite only) acids for 3–4 days with intermittent washing after each treatment. The acid-free sieved samples (using 500 mesh sieves) were treated with 10-20% KOH solution for the recovery of clean palynomorphs. The morphographic observation of pollen-spores has been performed on prepared slides (using polyvinyl alcohol and Canada balsam) under a Leica microscope DM 300. The point-to-point and line-to-line distance has been maintained for the counting of pollen-spores. The presence/absence and relative density of recovered pollen/spores have been taken into consideration for interpreting in terms of floral analysis and climatic conditions.

SYSTEMATIC PALAEOBOTANY

Leaf taxa

Family **Actinidiaceae** Gilg and Werdermann, 1925
Genus ***Saurauia*** Willd., 1801

Saurauia eocenica n. sp.
(Pl. II, figs. 1, 2)

Diagnosis: Leaf simple; symmetrical; wide ovate; size 17.5x6.8cm; apex acute; margin entire; venation pinnate, brochidodromous; primary vein moderately thick; secondary veins 17-18 pairs visible, alternate to opposite, secondaries uniformly curved up and joined their super secondaries towards the margin, angle of divergence moderately acute; tertiary veins with angle of origin AR-RR, percurrent, predominantly opposite and close.

Description: Leaf simple, symmetrical; seemingly wide ovate; preserveded size 17.5x6.8cm; apex acute; base broken; margin entire; texture chartaceous; venation pinnate, brochidodromous; primary vein (1^0) single, almost straight, moderately thick; secondary veins (2^0) 17-18 pairs visible, alternate to opposite, 1.0 to 1.6cm apart, secondaries uniformally curved up and joined their super secondaries towards the margin, angle of divergence 55^0-$60^{0,}$ moderately acute, unbranched; tertiary veins (3^0) fine with angle of origin AR-RR, percurrent, straight to sinuous, forked, oblique in relation to mid vein, predominantly opposite and close.

Material: BSIP Museum specimen no. 40791 (Holotype).

*Localit***y**: Tarkeshwar Lignite Mine, District Surat, Gujrat, western India.

Horizon and Age: Cambay shale Formation, Early Eocene.

Etymology: This species is named after the epoch 'Eocene' to which fossil locality belongs.

Remarks: Most characteristic features of the present fossil leaf are wide acute shape, entire margin brochidodromous venation, more than 18 pairs of secondary veins with moderately acute angle of divergence, predominantly opposite, AR-RR, percurrent tertiary veins. A critical survey of a variety of herbarium belonging to different families of Dicotyledons shows that such features are found common in the extant leaves of *Duabanga sonneratioides* Buch.-Ham. of family Lythraceae, *Cannarium* sp. of family Burseraceae, *Terminalia crenulata* (Heyn) Roth and *T. tomentosa* (Roxb.) Wight and Arn. of family Combretaceae and *Saurauia napaulensis* DC. of the family Actidinaceae. Of these the leaves of *D. sonneratioides* Buch.-Ham. differs from present fossil leaf in being narrow in width and the curvature of secondary veins is not so pronounced as in fossil. In the leaves of *Cannarium* sp. the serration of the margin is very distinct. The leaves of *T. tomentosa* (Roxb.) Wight and Arn and *T. crenulata* (Heyn) Roth differ in possessing greater angle of divergence towards basal portion of lamina and secondary veins joined to their superadjascent secondary not forming prominent loop as the fossil. Thus, the leaves of *S. napaulensis* DC. (CNH Herbarium sheet no 49013; Pl. II, figs. 3, 4) are only with which the present fossil shows closest affinity in shape, size and venation pattern.

As far as aauthors aware, there is no record of fossil leaves of the genus *Saurauia* Willd. from Cenozoic sediments of India. It is first report from Eocene sediments of Western India and thus it has been named as *Saurauia eocenica* n. sp.

The genus *Saurauia* Willd. comprises 250 species distributed in the tropics and subtropics of Asia and South and central America. *S. napaulensis* DC. which closely resembles the fossil leaf. Its habits range from small trees or large shrubs growing commonly in the evergreen forests of North Vanlaiphan and Pharphak in Mizoram and Assam.

Family **Clusiaceae** (Calophyllaceae) Enger and Keller, 1925
Genus ***Calophyllum*** Linn., 1737

Calophyllum eocenicum n. sp.
(Pl. III, figs. 1, 2, 4)

Diagnosis: Leaf simple; symmetrical; seemingly elliptic; size 3.7x3.4cm; base obtuse, margin entire; texture coriaceous; venation pinnate, eucamptodromous; primary vein single, prominent; secondary veins numerous, opposite to alternate, angle of divergence right angle, almost straight, unbranched.

Description: Leaf simple, seemingly symmetrical; seemingly elliptic; preserved size 3.7x3.4cm; apex broken; base obtuse, normal; margin entire, texture coriaceous; venation pinnate, eucamptodromous; primary vein (1°) single, prominent, stout, straight; secondary veins (2°) numerous, opposite to alternate, angle of divergence 90°, right angle, almost straight, unbranched, further details not clearly seen.

Material: BSIP Museum specimen no. 40792 (Holotype).

Locality: Tarkeshwar Lignite Mine, District Surat, Gujrat, western India.

Horizon and Age: Cambay shale Formation, Early Eocene.

Etymology: This species is named after the epoch 'Eocene' to which fossil locality belongs.

*Remarks***:** The important features of the present fossil leaf such as elliptic shape, obtuse base, entire margin, closely placed, almost parallel secondary veins and craspedodromous type of venation undoubtedly indicate its resemblance with the extant leaves of *Calophyllum* sp. of the family Clusiaceae. Considering the shape, size and angle of secondary veins of the fossil leaf it has been observed that the leaves of extant species, *C. inophyllum* Linn. (CNH sheet no. 20250; Pl.III, figs. 3, 5,) come closest to it.

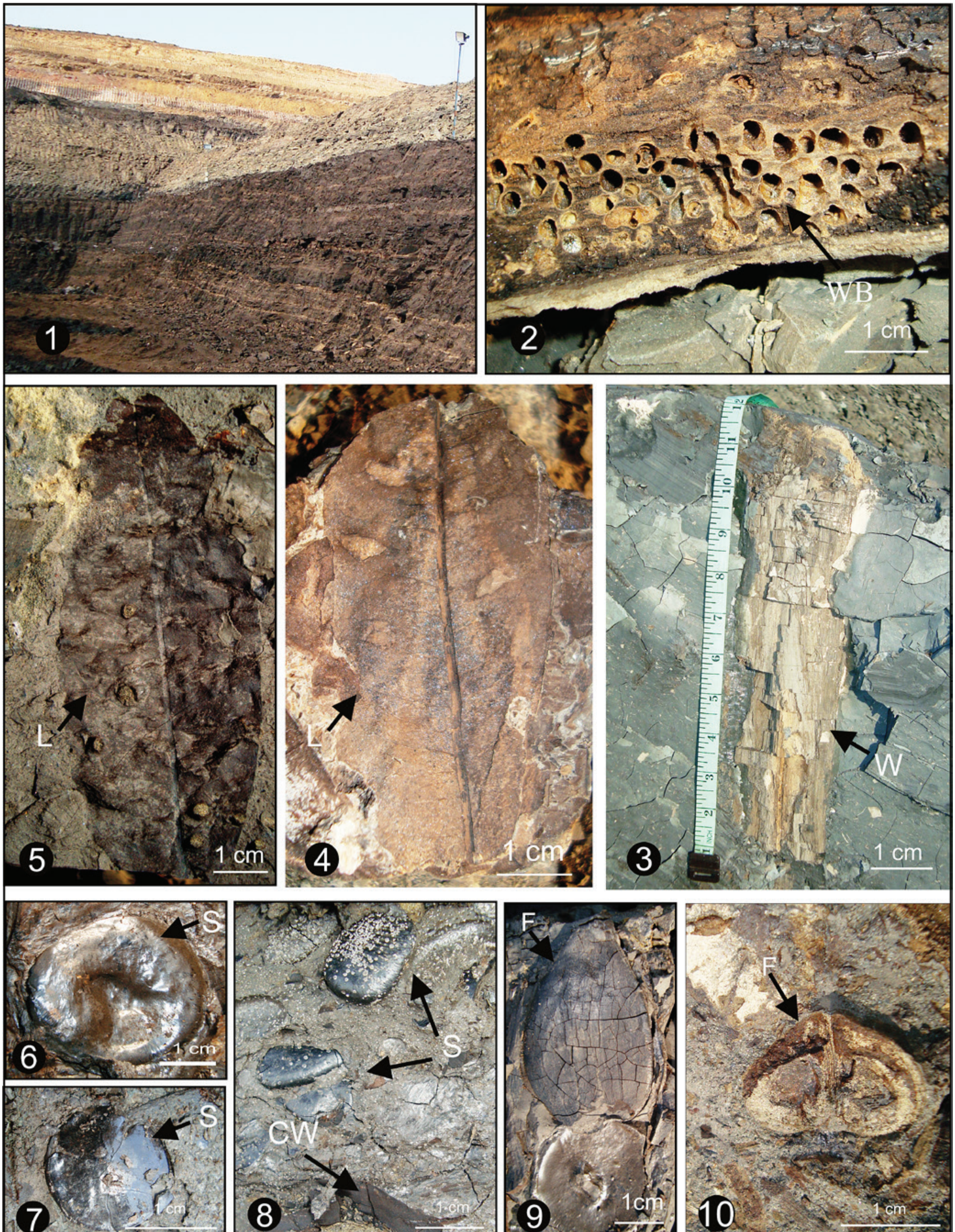
So far, six species of the genus *Calophyllum* Linn. have been reported from the Cenozoic sediments of India and abroad. These are *Calophyllum pliocenicum* Krasser (1903) from Ouricanga

EXPLANATION OF PLATE I

Field photograph showing Tarkeshwar Lignite Mines with some *in situ* fossil occurrence. Symbals indicating: WB- Wood bored, L-Leaf, W- Wood, S-Seed, CW-Carbonized wood, F-Fruit.

Journal of the Palaeontological Society of India
Volume 64(2), December 31, 2019

Plate I



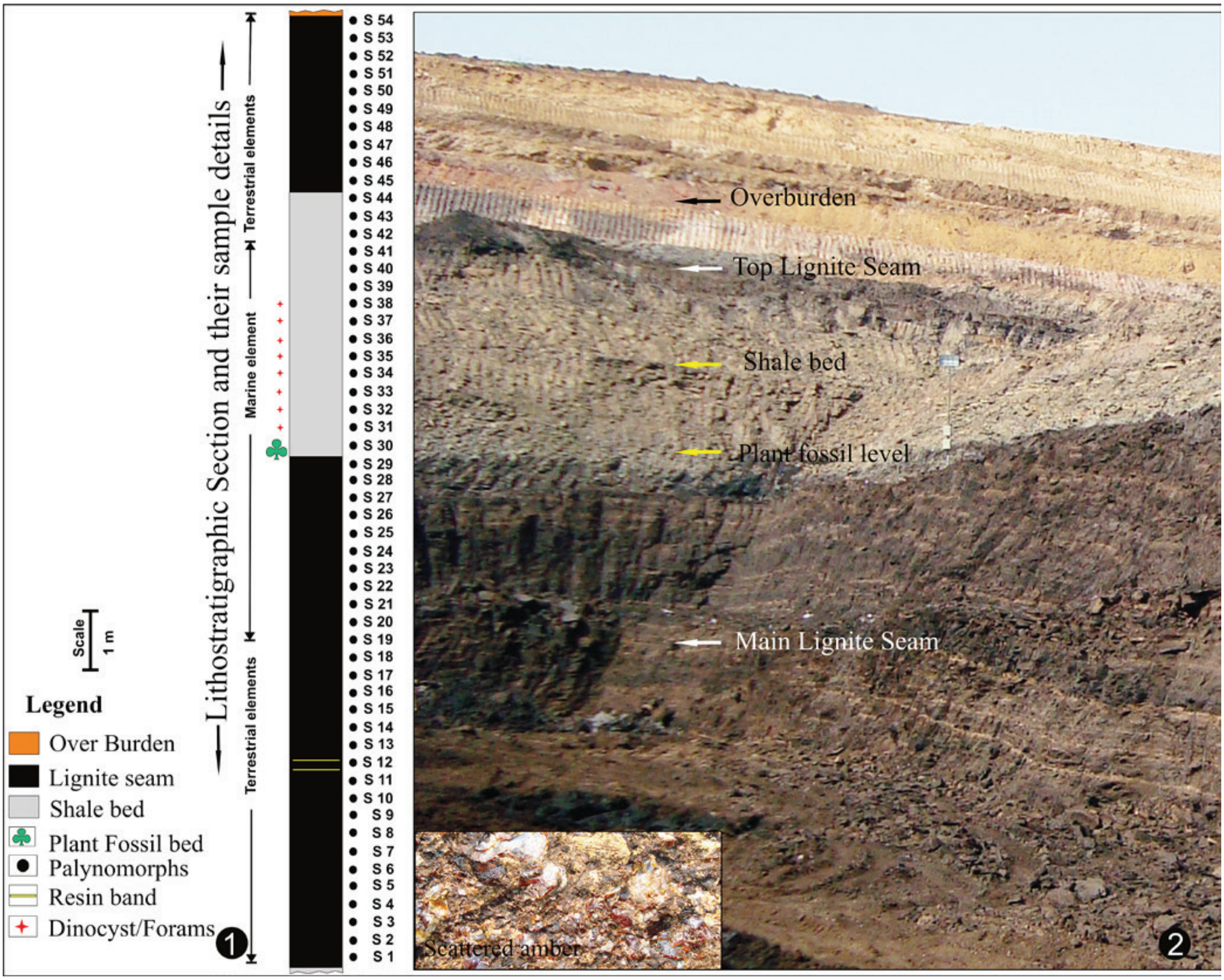


Fig. 2. Field photograph of Tarkeshwar Lignite Mines showing plant bearing beds from where fossil specimens were collected.

Brazil, *C. nathorstii* (Geyler) Krausal and *Calophyllum* sp. Kräusel (1929) from Sumatra, *Calophyllum masensis* Pons (1978) from Colombia and *C. suraikholaensis* from the Siwalik sediments of Surai Khola, Nepal (Awasthi and Prasad, 1990), Oodlabari, West Bengal (Antal and Awasthi, 1993), Kathgodam, Uttarakhand (Prasad, 1994b), Kerala Coast (Awasthi and Srivastava, 1992), Palaeocene of Cherapunji (Ambwani, 1991), Oligocene of Makum Coalfield, Assam (Awasthi and Mehrotra, 1995). A comparative study of the above known fossil leaves shows that present fossil leaf differs mainly in shape and size. Most of the fossil leaves are compared with extant species, *C. polyanthum* Wall, having narrow oblong shape, as compared to elliptic shape in the present fossil. Thus, in being different from already known species the Tarkeshwar fossil leaf has been described as a new species, *C. eocenicum.*

The genus *Calophyllum* Linn. comprises about 187 species of trees distributed in both the hemispheres. *C. inophyllum* Linn. with which fossil resembles closely is presently growing in the evergreen forests of western peninsula from Konkan and south wards Sri Lanka and eastern peninsula from Pegu southwards, Andaman Islands, East Africa, Malaya archipelago, Australia and Polynesia (Hooker, 1875).

Family **Anacardiaceae** Lindley, 1830
Genus ***Drimycarpus*** Hook. f., 1862

Drimycarpus tarkeshwarensis n. sp.
(Pl. IV, figs. 1, 2)

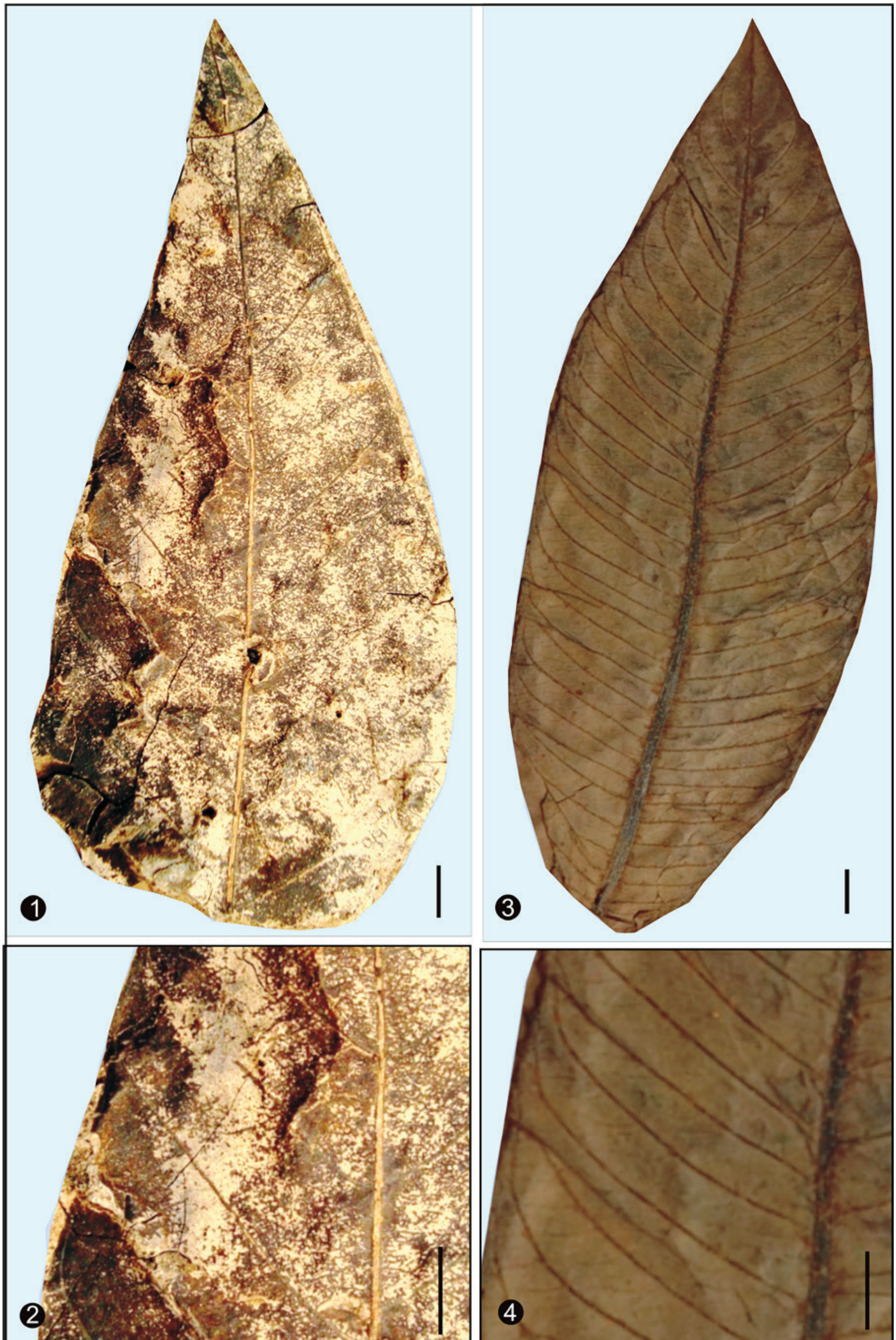
Diagnosis: Leaf simple, symmetrical; oblong; size 12.2x 6.0cm; margin entire; texture chartaceous; venation pinnate, eucamptodromous; primary vein single, prominent, moderately thick; secondary veins 9 pairs visible, 1.0 to 1.2cm apart, alternate, unbranched, angle of divergence wide acute, almost straight to slightly curved; tertiary veins angle of origin usually

EXPLANATION OF PLATE II

Fig. 1. ***Saurauia eocenica*** n. sp. Fossil leaf showing shape, size and venation pattern, BSIP Museum no. 40791 (Holotype); 2. A part of fossil leaf (Fig.1). Magnified to show details of venation; Fig. 3. ***Saurauia napalensis*** DC. Modern leaf showing similarity in shape size and venation pattern with the fossil leaf; 4. A part of modern leaf (Fig. 3). Magnified to show similar detail of venation pattern (Scale bar equal to 10mm).

Journal of the Palaeontological Society of India
Volume 64(2), December 31, 2019

Plate II



RR, percurrent, branched, alternate to opposite, oblique in relation to mid vein, close.

Description: Leaf simple, seemingly symmetrical; shape oblong; preserved size 12.2x 6.0cm; apex broken; base broken; margin entire; texture chartaceous; petiole not preserved; venation pinnate, eucamptodromous; primary vein (1°) single, prominent, stout, straight, moderately thick; secondary veins (2°) 9 pairs visible, 1.0 to 1.2cm apart, alternate, unbranched, angle of divergence 70°-80°, wide acute, almost straight to slightly curved; tertiary veins (3°) poorly preserved, angle of origin usually RR, percurrent, branched, almost straight, alternate to opposite, oblique in relation to mid vein, close.

Material: BSIP Museum specimen no. 40793 (Holotype).

Locality: Tarkeshwar Lignite Mine, District Surat, Gujrat, western India.

Horizon and Age: Cambay shale Formation, Early Eocene.

Etymology: This species is named after the name of fossil locality, 'Tarkeshwar' from where fossil specimen was collected.

Remarks: The diagnostic characters of the fossil leaf like, its oblong shape, entire margin, eucamptodromous venation, nearly right angle of divergence of secondary veins which have pronounce curvature near the margin, RR, percurrent, straight to sinuous tertiary veins collectively indicate that the present fossil leaf resembles very closely with the extant leaves of *Drimycarpus racemosus* Hook. f. (C.N.H. Herbarium sheet no. 99958; Pl. IV, figs. 3, 4) of the family Anacardiaceae. The present fossil has also been compared with some other anacardiaceous taxa showing near resemblance with the fossils like, *Semicarpus anacardium* Linn., *Gluta renghas* Linn., *G. trvancorea* Bedd., *G. usitata* (Wall.) Ding-Hou, *Mangifera indica* Linn., *M. sylvatica* Roxb., *Swintonia floribunda* Grifth. and *S. schwenckii* Teysm. and Bennend. and concluded that these differ in being either different shape size or secondary and tertiary venation pattern. The leaves of *S. anacardium* Linn differ from the fossils in having larger size with different pattern of secondary and tertiary venation pattern. The few basal secondary veins arise at right angle and are recurved and closely placed. The leaves of two species of *Gluta* Linn. (*G. travancorea* Bedd., *G. usitata* (Wall.) Ding-Hou) are almost similar in shape, size and venation pattern. These differ from present fossil in being possessing greater number of comparatively closely placed secondary veins and the intersecondary veins are in distinct and not frequently occur as in the present fossil leaves. The leaves of *Gluta renghas* Linn. are narrow lanceolate in shape with more acute angle of divergence of basal secondary veins. *Mangifera indica* Linn. and *M. sylvatica* Roxb. differ mainly in the angle of divergence of secondary veins which arise usually at acute angle in comparison to acute to nearly right angle in the present fossils. Moreover, the intersecondary veins are frequently (2-3 veins in between two secondary veins) occur in the leaves of *Mangifera*. The leaves of *Swintonia floribunda* Grifth. and *S. schwenckii* Teysm. and Bennend. can be differentiated in being closely placed secondary veins and AO-RR angle of origin of tertiary veins.

So far, there is only one record of fossil leaves of the genus *Drimycarpus* Hook f. as *D. siwalicus* from the Siwalik sediments of Tanakpur area, Uttarakhand, India (Prasad *et al*., 2017). The comparative study shows that the above siwalik fossil is narrow (4.2cm in width) and the intersecondary veins are not seen in it. Thus, in being different, the present fossil leaf has been described here as *Drimycarpus tarkeshwarensis* n. sp.

The genus *Drimycarpus* Hook. f. consists of more than two species of trees and distributed in the Indo-Malayan region. The extant taxon, *D. racemosus* Hook. f. with which the fossil shows resemblance, is an evergreen tree growing in north-east India, Bangladesh and Bhutan (Brandis, 1906; Hooker, 1879).

Family **Lythraceae** Koehne, 1903
Genus ***Lagerstroemia*** Linn., 1759

Lagerstroemia palaeomacrocarpa n. sp.
(Pl. VI, figs. 1, 2)

Diagnosis: Leaf simple, symmetrical; wide elliptic: size 14.0 x 8.0cm: apex acute to acuminate; base obtuse; margin entire; venation pinnate; eucamptodromous; primary vein single, straight, moderately thick; secondary veins 6 pairs visible, 0.8 to 1.5cm apart, alternate to opposite, basal pairs of secondary veins closely placed, angle of divergence acute, moderate; tertiary veins with angle of origin RR, per current, oblique in relation to mid vein, straight to sinuous, predominantly alternate and close.

Description: Leaf simple, symmetrical; wide elliptic: presumed size 14.0 x 8.0cm: apex acute to acuminate; base obtuse, normal: margin entire; texture chartaceous; petiole not preserved; venation pinnate; eucamptodromous; primary vein (1°) single; stout, straight, moderately thick; secondary veins (2°) 6 pairs visible, 0.8 to 1.5cm apart, alternate to opposite, basal pairs of secondary veins closely placed as compare to middle portion, uniformly curved up towards the margin, angle of divergence about 60^0 , acute, moderate, unbranched; tertiary veins (3°) poorly preserved, angle of origin RR, per current, oblique in relation to mid vein, branched, straight to sinuous, predominantly alternate and close.

Material: BSIP Museum specimen no. 40794 (Holotype).

Locality:Tarkeshwar Lignite Mine, District Surat, Gujrat, western India.

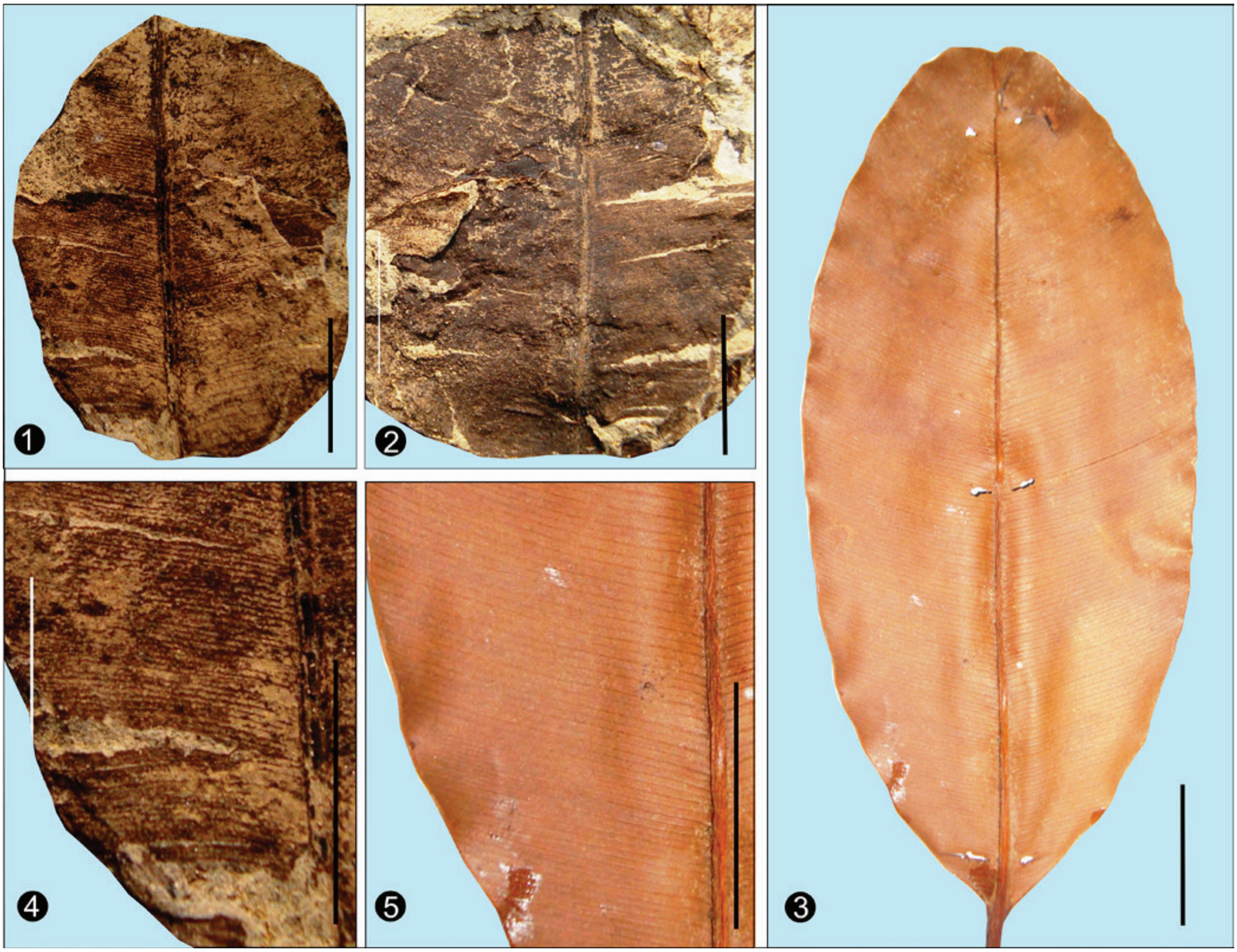
Horizon and Age: Cambay shale Formation, Early Eocene.

Etymology: By addition of prefixed 'palaeo' to the extant comparable species, *L. macrocarpa*

Remarks: The most important features exhibited by the present fossil leaf are: wide elliptic shape, acute to acuminate apex, obtuse base, entire margin, eucamptodromous venation, moderately acute angle of divergence of secondary veins which joined to their superadjacent secondary, absence of inter secondary veins and RR, percurrent, alternate and close tertiaries. These features are found common in the extant leaves of the genus *Lagerstroemia* Linn. of the family Lythraceae. A critical observation of a number of herbarium sheets of different species of this genus indicates that the present fossil leaves show closest affinity with the extant leaves of *Lagerstroemia macrocarpa* Wall. C.N.H. Herbarium sheet no.177095 (Pl. VI, figs. 3, 4).

So far, ten authentic fossils leave resembling the genus *Lagerstroemia* Linn. have been described from the Tertiary sediments of India. They are *Lagerstroemia patelii* from the Eocene of Kachchh, Gujarat (Lakhanpal and Guleria, 1981), from Siwalik sediments of Darjeeling District, West Bengal (Antal and Awasthi, 1993), from Kathgodam, Uttarakhand, India (Prasad,1994b) and Siwalik of Arjunkhola, Nepal (Prasad *et al*., 2019); *L. imamurae* Tanai and Uemura (1991) from Oligocene of Honshu, Japan; *L. siwalica* from Siwalik sediments of Koilabas, Nepal (Prasad, 1994b) and Miocene of Neyveli lignite deposits, Tamil Nadu (Agarwal, 2002); *L. neyveliensis* from Neyveli Lignite Mine-1, South Arcot district, Tamil Nadu (Agarwal, 2002); *L. jamraniensis* from Lower

Plate III



EXPLANATION OF PLATE III

Figs. 1-2. ***Calophyllum eocenicum* n. sp.** Fossil leaves showing shape, size and venation pattern, BSIP Museum no. 40792 (Holotype), 40792a (Paratype); Fig. 3. ***Calophyllum inophyllum* Linn**. modern leaf showing similarity with the fossil leaves; Fig. 4. A part of fossil leaf (Fig. 1). magnified to show detail of venation; Fig. 5. A part of modern leaf (Fig. 3) magnified to show similarity with the fossil leaf (Scale bars equal to 10mm).

Siwalik sediments of Jamrani, Kathgodam, Uttarakhand (Prasad *et al*., 2004), *L. mioparviflora* and *L. eomicrocarpa* from Siwalik sediments of Koilabas area, western Nepal (Dwivedi *et al*., 2006); *L. himalayaensis* (Srivastava *et al.,* 2015) from Lower Siwalik of Kathgodam, Nainital district, Uttarakhand; *Lagerstroemia prakashii* from Siwalik sediments of Darjeeling District, West Bengal (Prasad *et al*., 2015); *L. corvinusii* from Upper Miocene (Siwalik) of Arjun Khola area, western Nepal (Prasad, 2013).

On comparison of the present fossil leaf with the above known species, it has been observed that none of the fossil species of *Lagerstroemia* shows similarity in shape and size. They also differ in nature of either base or arrangement of secondary and tertiary veins. Thus, in being different from already known species of *Lagerstroemia* Linn., the present fossils have been assigned to a new species, *Lagerstroemia palaeomacrocarpa.*

The genus *Lagerstroemia* Linn. comprises about 53 species distributed in the tropical Africa, Asia, Polynesia and pacific region. *L. macrocarpa* Wall. with which fossil leaf shows resemblance is a large evergreen tree presently found in Myanmar and Malayan Peninsula (Ridley, 1922).

Genus ***Lagerstroemia*** Linn., 1759

Lagerstroemia patelii Lakhanpal and Guleria, 1981
(Pl. V, figs. 1, 3,4)

Description: Leaf simple, symmetrical; narrow elliptic; preserved size 9.3 x 3.5cm and 13.2 x 4.8cm; apex acute; base wide acute to obtuse, normal; margin entire; texture chartaceous; venation pinnate; eucamptodromous; primary vein (1˚) single, prominent, slightly curved, stout; secondary veins (2˚) about 12 pairs visible, o.4 to .8 cm apart, alternate to sub opposite, angle of divergence about 60˚, moderate, uniformly curved up and joined to the upper adjacent secondary, unbranched; inter secondary veins present, simple; tertiary veins (3˚) fine, angle of origin RR, per current, straight to sinuous, oblique in relation to mid vein predominantly alternate; close to nearly distant.

Material: BSIP Museum specimen no. 40795, 40796.

Locality: Tarkeshwar Lignite Mine, District, Surat, Gujarat, western India.

Horizon and Age: Cambay Shale Formation, Early Eocene.

Remarks: The diagnostic features such as symmetrical, narrow elliptic shape, acute apex, wide acute base, entire margin, eucamptodronous venation, moderate angle of divergence of secondary veins, percurrent, straight to sinuous and close to distant tertiary veins undoubtedly suggest its affinity with the modern leaves of *Lagerstromia flosregine* Retzius of the family Lythraceae (CNH Herbarium sheet no. 42769; Pl. V, figs. 2, 5).

Several fossil leaves have been referred to the genus *Lagerstromia* Linn from Cenozoic sediments of India and Nepal. They are listed earlier in this text. The comparative study of these fossil leaves with those of the present fossils suggest that *Lagerstroemia patelii* Lakhanpal and Guleria described from the Eocene of western India (Lakhanpal and Guleria 1981, Singh *et al.,* 2011) shows closest similarity with the present fossil leaves. Therefore, the fossil leaves from Tarkeshwar is also referred to *L. patelii* Lakhanpal and Guleria.

Most of the extant species of *Lagerstroemia* Linn are tree and are distributed in the tropical forest region of Africa, Asia, Polynesia and Pacific regions. The comparable species, *L. flosregine* Retz. occurs in the evergreen to deciduous forests along the banks of the streams in the hill tracts of Assam and Western Ghat, Chittagong, Lower Myanmar, Sri Lanka and Malaya Peninsula.

Family **Combretaceae** Brandis, 1893
Genus ***Terminali**a* Linn., 1767

Terminalia sahnii n. sp**.**
(Pl. VII, figs. 1, 2)

Diagnosis: Leaf simple, narrow ovate; size 22.0x10.7cm; margin entire; venation pinnate, eucamptodromous; primary vein single, prominent, moderately thick; secondary veins 16 pairs visible, 0.9 to 1.3cm apart, alternate to opposite, angle of divergence right angle, uniformly curved; angle of origin of tertiary veins RR, percurrent, branched, sinuous, oblique in relation to mid vein, sometimes right angle near the margin, alternate to opposite and close.

Description: Leaf simple, narrow ovate; preserved size 22.0x10.7cm; apex slightly broken; base broken, margin entire; texture chartaceous; petiole not preserved; venation pinnate, eucamptodromous; primary vein (1°) single, prominent, straight, moderately thick, running up to the length of leaf, stout; secondary veins (2°) 16 pairs visible, 0.9 to 1.3cm apart, unbranched, alternate to opposite, angle of divergence 85° to 90°, right angle, uniformly curved towards the margin, and joined to their superadjacent secondary veins; tertiary veins (3°) poorly preserved, angle of origin RR, percurrent, branched, sinuous, oblique in relation to mid vein, sometimes right angle near the margin, alternate to opposite and close.

Material: BSIP Museum specimen no. 40797 (Holotype).

Locality: Tarkeshwar Lignite Mine, District Surat, Gujrat, western India.

Horizon and Age: Cambay shale Formation, Early Eocene.

Etymology: This species is named after Ashok Sahni, an eminent palaeontologist.

*Remarks***:** Diagnostic features of the present fossil leaf are almost symmetrical, narrow ovate shape, entire margin, number and nature of secondary veins with angle of divergence 85° to 90°, eucamptodromous venation, RR, percurrent, straight to sinuous tertiary veins. A comparative study of herbarium sheets of different families and genera show that these features are found common in the modern leaves of the genus *Terminalia* Linn. of the family Combretaceae. After critical examination of the extant leaves of all the available species of this genus it has been concluded that the present fossil leaves shows its close affinity with the leaves of *T. tomentosa* (Roxb.) Wight and Arn.; C.N.H. Herbarium sheet no. 5886, Pl. VII, figs. 3, 4).

So far, 36 fossil leaves resembling the genus *Terminalia* Linn. have been reported under three generic name viz., *Terminalia* Linn., *Terminaliphyllum*, Velenovsky and *Terminaliophyllum* Geyler from Cenozoic- Cretaceous sediments of India and abroad. These are listed in (Table 1).

The present fossil leaf has been compared with all the above known available fossil species (Table 2) and found that it does not match any of them. Only four species, *Terminalia estimina* MacGnite, *T. miocenica* Unger, *T. radobojana* Unger, and *Terminalia* sp. possess ovate shape but differ in being smaller size. The secondary veins are up to 10 pairs with more acute angle of divergence. Other species differ mainly in the course and arrangement of secondary and tertiary veins. In view of this the present fossil leaf has been assigned to new species *Terminalia sahnii.*

The genus *Terminalia* Linn. consists of 150 species of large trees and widely distributed in the Tropics of the world (Mabberley, 1997). *T. tomentosa* (Roxb.) Wight and Arn. mainly distributed in Sub-Himalayan tract, Nepal, Sikkim ascending 4000ft. It is also found in the Deccan region and Sri Lanka and very common in Myanmar (Hooker, 1879).

2. Wood taxa

Family **Meliaceae** De Jussieu, 1789
Genus ***Walsura*** Roxb, 1814

Walsura tarkeshwarensis n. sp.
(Pl. VIII, figs. 1-6)

Diagnosis: *Wood* diffuse porous. *Growth ring* distinct due to presence of terminal parenchyma. *Vessels* usually small to medium sized, t.d. 40–125µm, r.d. 45–140µm, solitary as well as in radial multiples of 2–4, circular to oval, evenly distributed, pits bordered. P*arenchyma* terminal and apotracheal in 1–4 seriate, wavy bands. *Xylem rays* 1–3 (4) seriate, heterogeneous. *Fibres* libriform, 8–12µm in diameter.

Description: Wood diffuse-porous. *Growth ring* present, demarcated by a thin band of terminal parenchyma (Pl. VIII, figs. 1). *Vessels* small to medium sized, t.d. 40–125µm, r.d. 45–150µm, solitary as well as in radial multiples of 2-4, circular to oval when solitary, with flat intervascular walls when in radial multiples, evenly distributed, filled with dark contents

EXPLANATION OF PLATE IV

Fig. 1. ***Drimycarpus tarkeshwarensis* n.sp**. Fossil leaf showing shape, size and venation pattern, BSIP Museum no. 40793 (Holotype); Fig. 2. A part of fossil leaf (Fig.1) magnified to show details of venation; Fig. 3. ***Drimycarpus racemosus* Hook**. f. Modern leaf showing similarity with the fossil leaf. Fig. 4. A part of modern leaf (Fig. 3) magnified to show similar details of venation as fossil (Fig.2) Scale bars equal to 10mm.

Plate IV

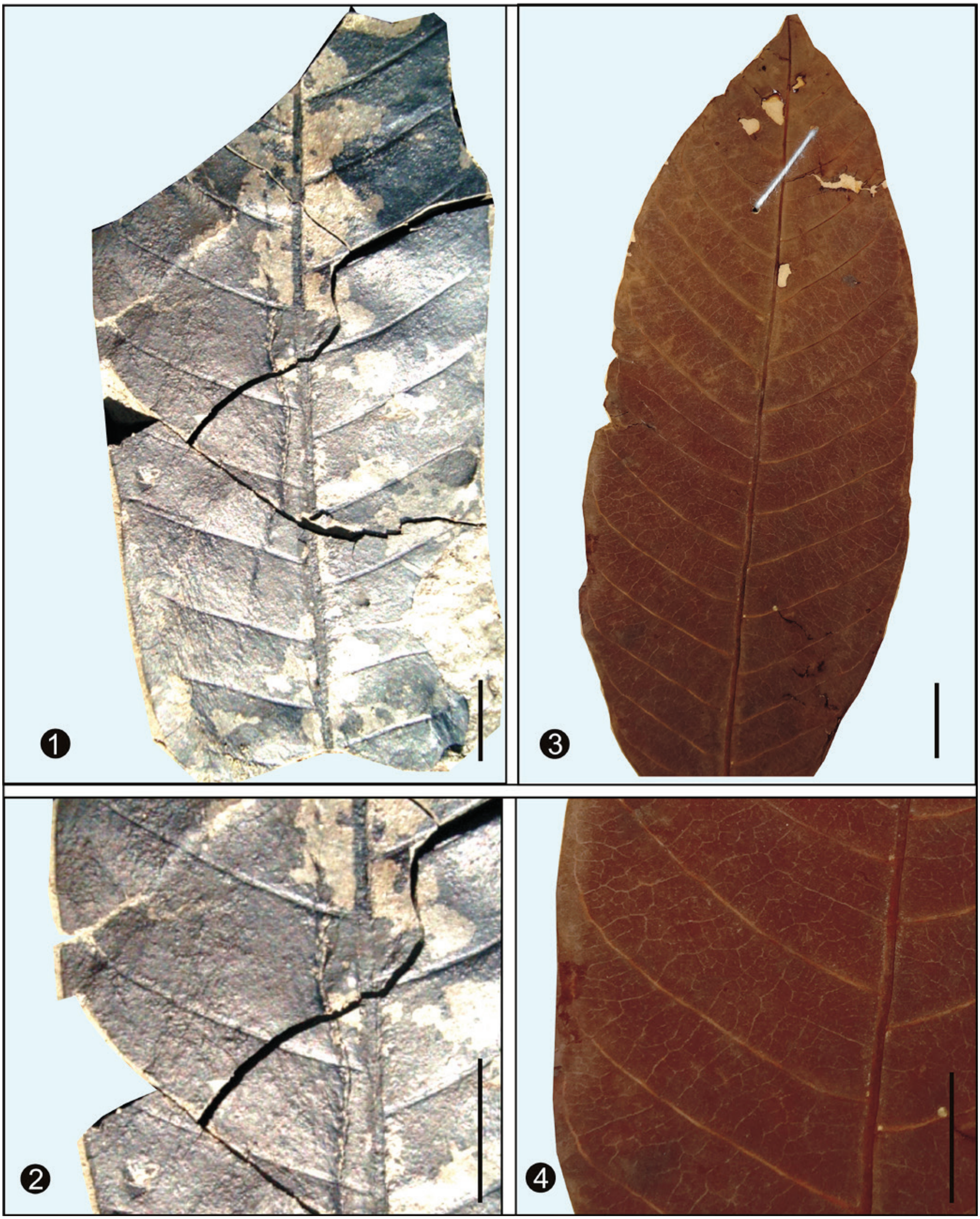
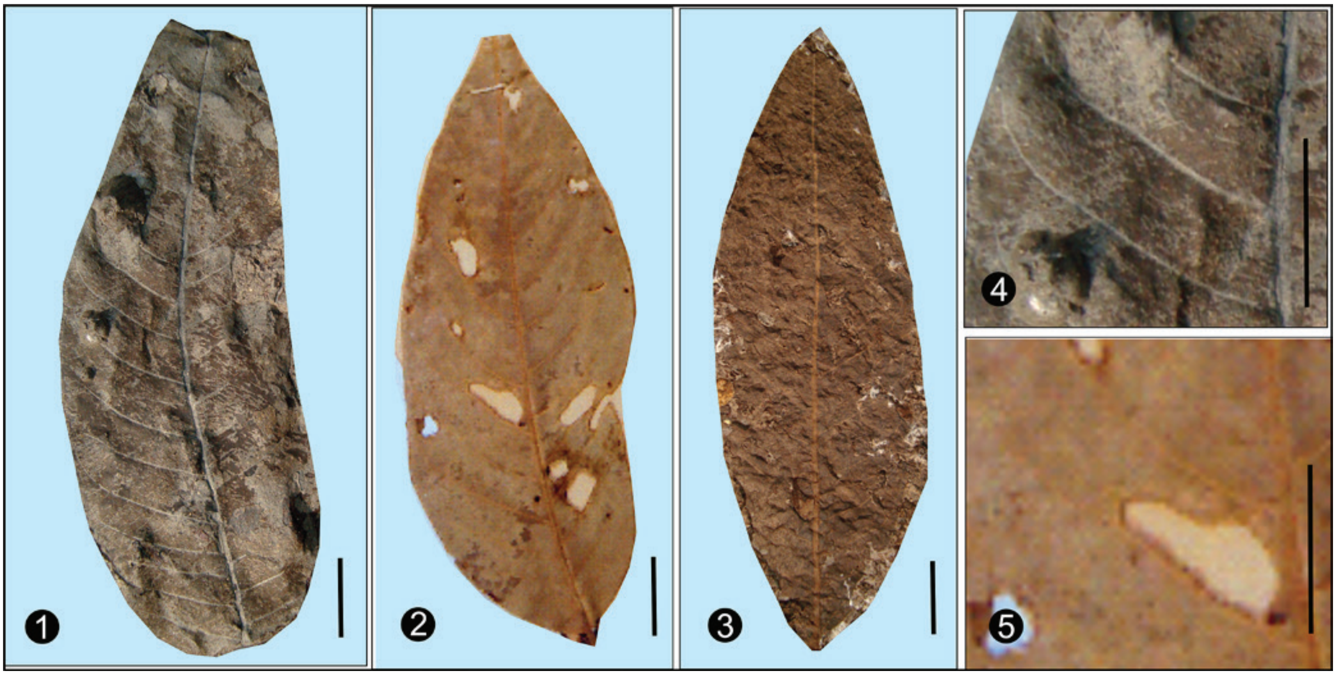


Table 1. Fossil leaves resembling the genus *Terminalia* Linn. recorded from India and abroad.

Species	Locality/Period	Reference
Terminaliphyllum rectinervis	Upper Cretaceous of Bohemia	Velenovsky, 1884, 1889
Terminaliophyllum sp.	Eocene of Borneo	Geyler, 1887
T. keayi	Post Eocene of Nigeria	Puri, 1966
T. faggei	Post Eocene of Nigrria	Puri, 1966
Terminalia cf. *T. catapa*	Tertiary of Czeckoslovakia	Nemejc, 1975
Terminalia claibornensis Berry	Eocene of Texas	Ball, 1931
T. indicola Berry	Eocene of Texas	Ball, 1931
T. elegans Heer	-	Schimper, 1874
T. estimina	Middle Eocene of Central Sierra, Nevada, USA	MacGinitie, 1941
T. europea	Tertiary of Germany	Weyland, 1942
T. fenzliana Unger	Tertiary of Czeckoslovakia	Nemejc 1975
T. gypsorum Saporta	-	Schimper, 1874
T. italica	-	Berry, 1919
T. maxima	Tertiary of Brazil	Principi, 1915
T. miocenica	Tertiary of Germany	Weyland, 1942
T. kachchhensis	Tertiary of Kachchh	Lakhanpal and Guleria, 1981
T. lauriana	Tertiary of Brazil	Krasser, 1903
T. lesleyana	Eocene of southestern N. America	Berry, 1916
T. panandhroensis	Tertiary of Kachchh, India, Siwalik of Koilabas, Nepal	Lakhanpal and Guleria, 1981 Prasad, 1994c
T. panonica	Tertiary of South Guistine	Unger, 1867
T. phaeocarpoides	Eocene of South Carolina, USA	Berry, 1914
T. radobojana	Tertiary of Kumi, Euboea	Unger, 1867
T. nottensis	Tertiary of Germany	Weyland, 1942
T. tallyana Ett.	-	Schimper, 1874
T. trinitense Berry	Cenozoic of North America	LaMotte, 1952
T. ungeri Ett.	Tertiary of Czeckoslovakia	Nemejc, 1975
Terminalia sp.	Tertiary of Alaska	Hollick, 1936
Terminalia sp.	Palaeogene of Japan	Matsuo, 1970
Terminalia sp.	Siwalik of Koilasbas, Nepal	Tripathi and Tiwari, 1983
T. koilabasensis	Siwalik of Koilabas, Nepal	Prasad, 1990a
T. siwalica	Siwalik of Koilabas, Nepal	Prasad, 1990a
T. palaeochebula	Siwalik of Suraikhola, Nepal	Awasthi and Prasad, 1990
T. palaeochebula Awasthi and Prasad	Miocene of Neyveli Lignite, South India	Agarwal, 2002
T. chebula	Late Tertiary of Mahuadanr, Jharkhand	Singh and Prasad, 2007
T. tomentosa	Late Tertiary of Mahuadanr, Jharkhand	Bande and Srivastava, 1990
T. paniculata	Miocene of Neyveli Lignite, South India	Agarwal, 2002
T. miobelerica Prasad	Miocene of Neyveli Lignite, South India	Agarwal, 2002
T. neyvelensis	Miocene of Neyveli Lignite, South India	Agarwal, 2002
T. mulleri	Siwalik of Ranibagh, Uttaranchal	Trivedi and Srivastava, 1985
T. balugoloensis	Siwalik of Balugoloa, H. P.	Lakhanpal and Awasthi, 1992
T. miobelerica	Siwalik of Kathgodam, Uttaranchal Siwalik of West Bengal	Prasad, 1994a, Antal and Prasad, 1998
T. obovata	Oligocene of Makum Coalfield, Assam	Awasthi and Mehrotra, 1995
T. palaeocatapa	Oligocene of Makum Coalfield, Assam	Awasthi and Mehrotra, 1995
	Tura Formation, Meghalaya	Mehrotra, 2000a
	Miocene of Neyveli lignite, South India	Agarwal, 2002
	Upper Siwalik of Arunachal Pradesh	Jhoshi *et al.,* 2003
T. precatapa	Oligocene of Mizoram	Tiwari and Mehrotra, 2002
T. himachalensis	Siwalik of Sarkaghat, H. P.	Prasad *et al.,* 2013

(Pl. VIII, figs. 1, 2). Vessel members 75–50µm in length with usually truncate ends, perforation simple, pit pairs bordered, alternate, small, 4-6µm in diameter, circular to oval in shape, with linear apertures (Pl. VIII, figs. 5,6). *Parenchyma* terminal and apotracheal, terminal parenchyma in the form of thin 1–3 seriate tangential lines, apotracheal parenchyma in the form of 1–4 mostly (2–3) seriate wavy, almost continuous bands (Pl. VIII, figs. 2). Parenchyma cells 12–30µm in diameter and 50-180µm in length. *Xylem rays* 1-3 rarely 4 seriate, 15–20 per mm, rays tissues weakly heterogeneous (Pl. VIII, figs. 4, 5),



EXPLANATION OF PLATE V

Fig. 1-3. ***Lagerstroemia pateli*** **Lakhanpal and Guleria** Fossil leaves showing shape, size and venation pattern. BSIP Museum no. 40795, 40796; Fig. 2. ***Lagerstroemia flos-reginae*** **Retz**. Modern leaf showing similarity with the fossil leaf; 4. A part of fossil leaf (Fig.1) magnified to show details of venation pattern; 5. A part of modern leaf magnified to show similar details of venation. (Scale bars equal to 10mm).

rays composed of both procumbent and upright cells, upright cells sometimes present as *extension* or marginal cell at usually multiseriate rays, sometimes ray to ray fusion occur, 14–40µm in width and 5–30 cells or 105–600µm in height (Pl. VIII, fig. 4), procumbent cells 16–20µm in tangential height and 24–50µm in radial length, upright cells 26-50 µm in tangential height and 16–22µm in radial length (Pl. VIII, fig. 6). *Fibres* libriform, polygonal in cross section, non septate, 8–12µm in diameter and 220–580µm in length (Pl. VIII, figs. 3, 4), interfibre pits not seen.

Material: This species is based on a single piece of decorticated carbonized wood, measuring 8cm in length and 12cm in diameter. The anatomical features are satisfactorily preserved. BSIP Museum specimen no. 40798 (Holo type).

Etymology: The specific epithet is after the name of fossil locality.

Affinity: The diagnostic features of the present fossil wood such as small to medium sized vessels with simple perforation plate, terminal and apotracheal bands of parenchyma, 1-4, weakly heterogeneous xylem rays and small sized inter vascular pit pairs indicate its affinity with the family Meliaceae (Pearson and Brown, 1932; Chowdhury and Ghosh, 1946; Metcalfe and Chalk, 1950; Kribs, 1959; Ghosh *et al*. 1963). The wood slides of available species of a number of genus viz. *Aglaia* Lour, *Amoora* Roxb, *Aphanamixis* Blurne, *Cedrela,* P. Browne, *Chisocheton* Blume, *Chuckrasia* A. Juss., *Dysoxylum* Blume, *Entandophragma* C. DC., *Melia* Linn., *Sandoricum* Cav., *Soyamida* A. Juss., *Swietenia* Jacq., *Trichelia* P. Browne and *Walsura* Roxb., have been examined and found that the modern woods of the genus *Walsura* Roxb., show close affinity with the fossil. In order to find out specific affinity a critical examination of wood slides as well as their published photographs including their description has been carried out and concluded that *Walsura piscidia* (syn. *W. trifoleata* (A. Juss.) Harms is only with which present fossil wood resembles in all the anatomical characters. The other species differ mainly in the thickness of the apotracheal parenchyma bands and size of the vesels. *Walsura glauca* Fisher and *W. villosa* Wallich can be differentiated is being the presence of up to 8 cells thick apotracheal parenchyma band. However, in *Walsura robusta* there is absence of terminal parenchyma and also the rays are fine, usually biseriate with pronounced heterogeneity. *Walsura piscidia* Roxb., with which fossil wood resembles closely is a medium sized semi deciduous tree found in the tropical regions of East Asia, South India, and the drier part of Sri Lanka at low elevation (Dassanayake and Fosberg, 1980).

Fossil record and comparision: So far, six fossil woods resembling to the family Meliaceae have been described from the Cenozoic sediments of India. These are *Aglaioxylon mandalense* Trivedi and Srivastava, 1982, *Heyneoxylon tertiarum* Bande and Prakash, 1980, 1983, *Amoroxylon deccanensis* Bande and Prakash, 1984 and *Walsura deccanensis* Mehrotra, 1989 from Mandla District, Madhya Pradesh and *Aglaia nahanensis* (Prakash) Yadav, 1989 from the Siwalik sediments (Lower Miocene) of Himachal Pradesh and *Aglaia vastanensis* Guleria *et al*,. 2008 from Early Eocene of Vastan lignite mines, Gujarat. Of these, the fossil wood, *Aglaioxylon mandalense*, *Aglaia nahanensis* and *Aglaia vastanensis* showing close resemblance with the modern woods of the genus *Aglaia* Lour can be easily differentiated in possessing aliform to short and thick tangential bands of apotracheal parenchyma as compared to

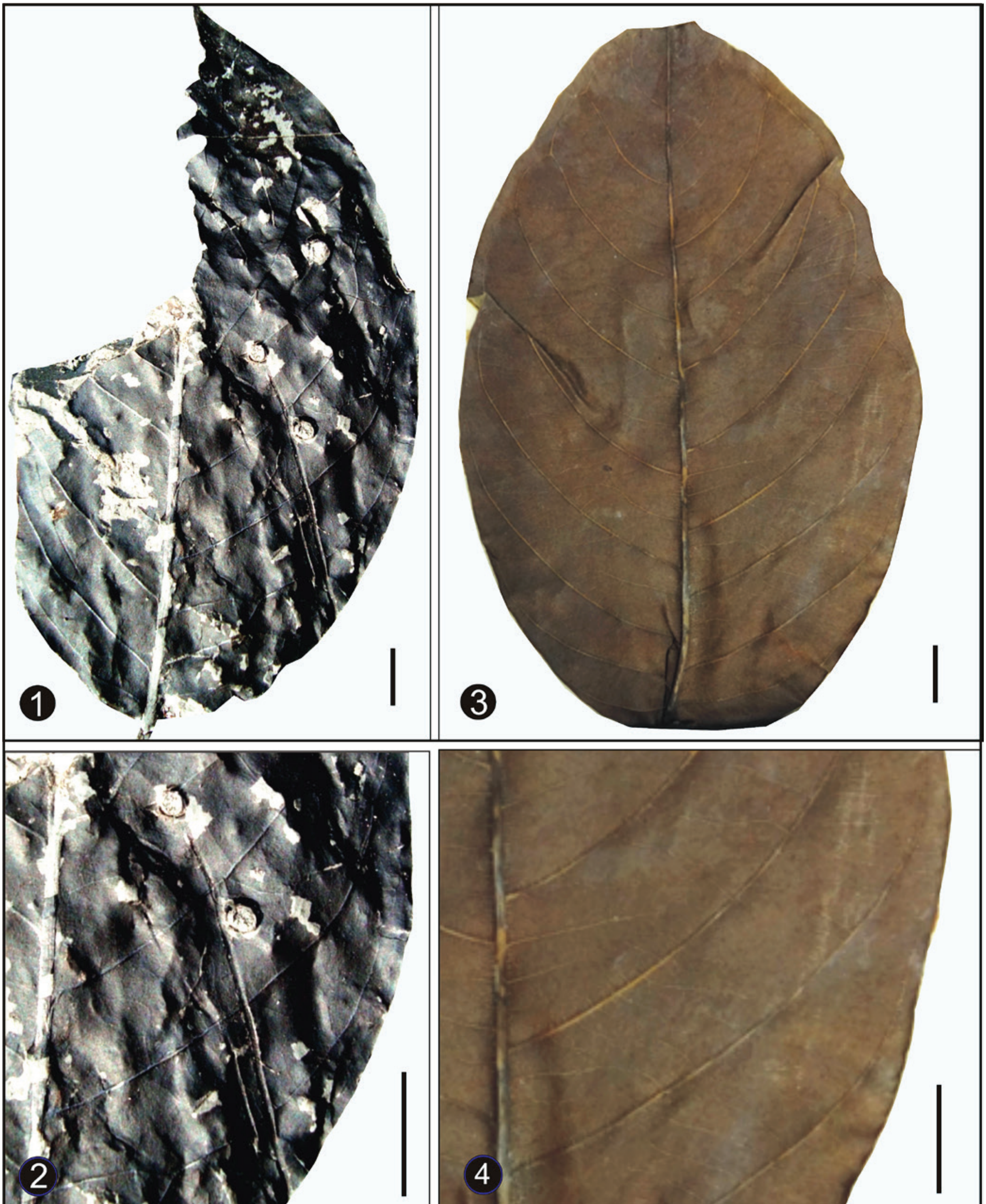
Table 2. Showing differentiate characters of the fossil leaves of known species of the genus *Terminalia* from India and abroad.

S.N.	Name of Taxa	Characteristic features of fossil leaves						
		Shape & size	**apex**	**base**	**Venation pattern**	**Secondary veins**	**Inter Sec.**	**Tertiary veins**
1.	*Terminalia panandhroensis* Lakhanpal and Guleria	Symmetrical, elliptic, 16.0 X 10.5 cm	-	-	Eucamptodromous	10 pairs, angle of divergence, 75˚-90˚,	+	AR-RO, forked, almost straight, oblique in relation to midvein, close
2.	*T. palaeochebula* Awasthi and Prasad, 1990	Symmetrical, elliptic, 12.0 X 6.5 cm	-	Obtuse	Eucamptodromous	8-9 pairs, angle of divergence, 60˚,	-	RR, oblique in relation to midvein, close
3.	*T. koilabasensis* Prasad, 1990a	Symmetrical, narrow elliptic, 7.0 X 6.0 cm	acute	Acute cuneate	Eucamptodromous	11 pairs, 0.6-1cm apart angle of divergence, 65˚-70˚, more acute on one side, unbranched	-	AR-RR, branched straight, oblique in relation to midvein, close
4.	*T. siwalica* Prasad,1990	Asymmetrical, narrow obovate, 8.9 X 4.0 cm	acute	Acute, inequilateral	Eucamptodromous	7-8 pairs, angle of divergence, 50˚, 0.8-1.2 cm apart, unbranched	-	AO, almost straight, nearly right angle in relation to midvein, close
5.	*T. miobelerica* Prasad,1994	Asymmetrical elliptic, 12.0 X 6.5 -7.5cm	-	-	Eucamptodromous	6 pairs, 1.3-3.2 cm apart, angle of divergence 65˚, unbranched	+	RR-AO, straight, branched, oblique in relation to midvein, close
6.	*T. balugoloensis* Lakhanpal and Awasthi, 1992	Symmetrical, narrow elliptic, 18.5 X 5.0 cm	acuminate	Obtuse	Eucamptodromous	16 pairs,0.8-1.4cm apart angle of divergence, 60˚-80˚, unbranched	+	Usually RR, straight to sinuous, branched, oblique to nearly right angle near the margin, close
7.	*Terminaliophyllum keayi* Puri, 1966	Not clear, fragment 6.0 X 4.8 cm	-	-	Eucamptodromous	4-5 pairs, visible, 1.3-2.0 cm apart, angle of divergence, 70˚-85˚	+	RR-AO, branched, oblique in relation to midvein, almost straight, close
8.	*T. faggei* Puri, 1966	Elliptic, 8.0 X 2.03cm 8.0 X 6.0 cm	-	-	Eucamptodromous	5-6 pairs,vissible1-2.0 cm apart angle of divergence, 55˚-60˚	+	Usually RR, straight to sinuous, branched, oblique in relation to midvein, close,
9.	*T. indicola* Berry	Symmetrical, lanceolate, 20.0 X6.0 cm	acute	Cuneate	Camptodromous	12-14 pairs, angle of divergence, 70˚-85˚ upper, 30˚-40˚, unbranched	-	RR, straight to sinuous, branched, oblique to nearly right angle in relation to midvein, close
10.	*T. lesleyana* Berry, 1916	Symmetrical, obovate, 15X 8 cm	Bluntly acute	-	Camptodromous	Nnumerous, closely placed, angle of divergence, 45˚ (60˚-70˚)	-	-
11.	*T. hilgardiana* Berry (Ball,1931)	Symmetrical, oblong-oval upto 25x10 cm	-	Obtuse	Camptodromous	About 20 pairs, angle of divergence 40-70˚	-	-
12.	*T. phaeocarpoides* Berry, 1914 (Ball,1931)	Obovate, 16.0X8.0cm.	acute (pointed)	Cuneate	Camptodromous	8 pairs, angle of divergence 50˚	-	AO, almost straight, right angle in relation to midvein, close
13.	*Terminalia clai-bornensis* Berry (Ball,1931)	Symmetrical, narrow elliptic, 10.5 X 3.0 cm	Seemingly acute	Cuneate	Eucamptodromous	Numerous, closely placed, fine, angle of divergence about 60˚	-	Very fine, usually RR, straight, oblique in relation to midvein, close
14.	*T. mulleri* Trivedi and Srivastava, 1985	Symmetrical, elliptic, 3.0 X 1.6cm.	Obtuse	Obtuse	Camptodromous	About 10 pairs, closely placed, angle of divergence 45˚-65˚ , unbranched	-	RR, -AO, straight to sinuous, oblique in relation to midvein, close

EXPLANATION OF PLATE VI

Fig. 1, ***Lagerstroemia palaeomacrocarpa* n. sp.** Fossil leaf showing shape, size and venation pattern BSIP Museum no. 40794 (Holotype); Fig. 2. A part of fossil leaf (Fig.1) magnified to show details of venation; Fig. 3. ***Lagerstroemia macrocarpa* Wall**. Modern leaf showing similarity with the fossil leaf; Fig. 4. A part of modern leaf magnified to show similar details of venation as fossil leaf (Fig.2). Scale bars equal to 10mm).

Plate VI

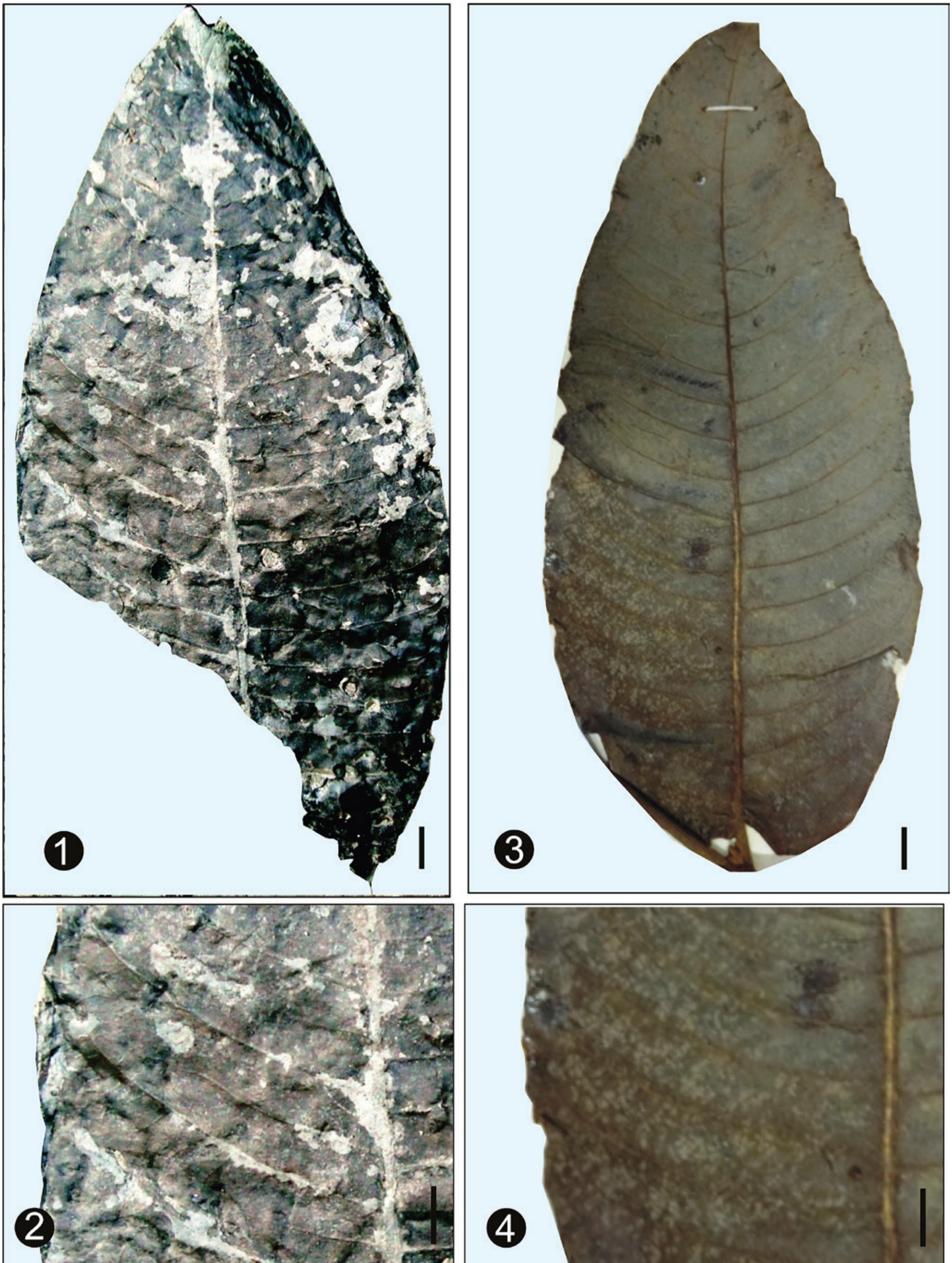


15.	*T. chebula* Retz. Singh and Prasad, 2007	Symmetrical elliptic, 21 X 10.7cm.	Acute	Rounded	Eucamptodromous to brochidodromous	17-18 pairs, angle of divergence about 70˚, unbranched	-	AO, straight to sinuous, branched, oblique in relation to midvein, close
16.	*T. kachchhensis* Lakhanpal and Guleria, 1981	Appearing symmetrical, elliptic-oblong, 8.0 X 6.0 cm	-	Rounded	Eucamptodromous	10 pairs visible, angle of divergence 55˚-80˚, unbranched		RR-RA, branched, oblique in relation to midvein, close
17.	*T. obovata* Awasthi and Mehrotra, 1995	Symmetrical, narrow obovate, 9.5 X 4.5 cm.	Rounded	-	Eucamptodromous	9 pairs, 0.9-1.2cm apart, angle of divergence 45˚-65˚	-	AR, recurved, oblique in relation to midvein,close
18.	*T. palaeocatappa* Awasthi and Mehrotra, 1995	Symmetrical, narrow obovate, 13 X 8.5 cm.	Obtuse to rounded	Obtuse	Eucamptodromous	12pairs visible 0.7-1.7cm apart, angle of divergence 70˚-80˚, bifurcated	-	Percurrent
19.	*Terminalia* sp. Matsuo, 1970	Symmetrical, elliptic- ovate, 6.5 X3.3 cm.	Wide acute	-	Camptodromous	9 pairs, 0.4-0.8cm apart, angle of divergence 35˚-70˚	-	Fine, usually AO, straight, oblique in relation to midvein,close
20.	*T. estimina* MacGinitie, 1941	Symmetrical, ovate- obovate, 11.0 X5.0 cm.	Obtuse-acuminate	Cuneate	Eucamptodromous to brochidodromous	6-9 pairs, 0.4-1.4cm apart, angle of divergence 40˚-50˚, loop formation, branched	-	Fine, straight to sinuous, oblique to nearly right angle in relation to midvein, close
21.	*T. panonica* Unger, 1867	Symmetrical, elliptic- ovate, 9.8 X3.2 cm.	Acuminate	Acute	Eucamptodromous	5 pairs, 0.5-2.5cm apart, angle of divergence about 60˚	+	Usually RR, straight to sinuous, oblique to right angle in relation to midvein, branched, close to nearly distant.
22.	*T. europaea* (Web.) Weyland, 1942	Almost symmetrical, obovate- elliptic, 6.0-9.0 X 2.1-2.8 cm.	Acute	Cuneate	Camptodromous	About 10 pairs, 0.5-1.4cm apart, angle of divergence 50˚-55˚	-	RR, straiaght, oblique to nearly right angle, close
23.	*T. rottensis* Weyland, 1943	Symmetrical, obovate.6.7 X 3.5 cm.	Obtuse	Cuneate	Camptodromous	10 pairs, 0.4-1.2cm, angle of divergence about 60˚	+	RR, straight to sinuous, oblique in relation to midvein
24.	*T. miocenica* (Unger, 1847) Weyland, 1943	Ovate	Cuneate	Obtuse	-	-	-	-
25.	*T. tallyana* Ett. Schimper, 1874	Obovate to lanceolate, 10X3 cm,	-	-	Camptodromous	Angle of divergence 40˚-50˚	-	-
26.	*T. ungeri* Ett. Nemejc, 1975	Oblong- lanceolate	-	-	brochidodromous	-	-	-
27	*T. tomentosa* W. and A. Bande and Srivastava, 1990	4.4 X 4.5 cm, fragment	Acuminate		Camptodromous to eucamptodromous	Only 3-4 pairs visible, sharply curved near the margin, unbranched,	-	AR, retroflexed, oblique to right angle in relation to midvein, close
28	*T. radobojana* Unger, 1867	Symmetrical, ovate, 8.0 X3.9 cm.	Acute	Acute	Eucamptodromous	10 pairs, 0.3 0.9cm aprt, angle of divergence 60˚-70˚, unbranched	-	AO-RR, straight, oblique in relation to midvein, close
29	*Terminaliphyllum rectinervis* Velenovsky, 1889	Almost symmetrical, narrow elliptic, 6.0 X 2.5 cm.	Acute	Acute	Craspedodromous to eucamptodromous	7 pairs, closely placed, 0.4-0.9cm apart	-	-
30	*Terminalia* cf. *T. catapa* Nemejc, 1975	Symmetrical, narrow obovate, 12.0 X 3.3 cm.	Obtuse	Cuneate	Craspedodromous to eucamptodromous	13 pairs, 0.8-1.3cm apart, angle of divergence 60˚-80˚, branched near the margin	-	Usually RR ,almost straight, oblique in relation to midvein, close

EXPLANATION OF PLATE VII

Fig. 1, ***Terminalia sahni* n. sp**. Fossil leaf showing shape, size and venation pattern. BSIP Museum no. 40797; Fig. 2. A part of fossil leaf magnified to show details of venation pattern; Fig. 3, ***Terminalia tomontosa* (Roxb.) Wight & Arn**. Modern leaf showing similarity in shape, size and venation with the fossil leaf (Fig.1); Fig. 4, A part of modern leaf magnified to show similar details of venation as fossil leaf. Scale bars equal to 10mm).

Plate VII



31.	*Terminalia* sp. Tripathi and Tiwari, 1983	Symmetrical, elliptic, 7.4 X 3.5 cm.	-	Acute	Eucamptodromous	6-7 pairs, 0.4-1.2cm apart, unbranched	-	RR, almost straight, oblique in relation to midvein,close
32.	*T. palaeopaniculata* Agarwal, 2002	Symmetrical, narrow elliptic, 6.8 X 5.0 cm.	-	Obtuse	Eucamptodromous	6-9 pairs, 0.3-0.6cm apart, angle of divergence 60˚-75˚, unbranched	-	RR, almost straight, oblique in relation to midvein, close
33.	*T. neyvelensis* Agarwal, 2002	Symmetrical, elliptic, 6.0 X 2.5 cm.	-	Obtuse	Eucamptodromous	5-6 pairs, 0.7-0.8cm apart, angle of divergence 50˚-60˚, branched	-	RR-AR, straight, unbranched, oblique in relation to midvein, close
34.	*T. elegans* Heer Schimper, 1874	Oblong	Obtuse	-	Camptodromous	Sub- opposite, closely placed	-	-
35.	*T. fenzliana* Unger Nemejc, 1975	Unequal, obovate with serrate margin	obtuse	Attenuate (Cuneate)	-	-	-	-
36.	*Terminalia* sp. Hollick, 1936	Only basal portion of the lamina, 6X5.8 cm, wide elliptic	-	Seemingly acute	Eucamptodromous	8-9 pairs visible, 0.5-1.3cm apart, angle of divergence 60˚-70˚	+	AO to rarely RR, straight, oblique in relation to midvein, close to distant
37.	*Terminalia himachalensis* Prasad *et al.,* 2013.	Almost symmetrical, narrow oblong, 12.6x4.5cm,	-	-	Eucamptodromous	11-12 pairs visible, 0.8-1.4cm apart, unbranched, angle of divergence 60˚-70˚	-	RR rarely AO, straight to sinuous, branched, right angle near the margin, close
38.	*T. sahnii* sp. nov.	Symmetrical, narrow ovate, 22.0 x 10.7cm	-	-	Eucamtodromous	16 pairs visible, 0.9-1.3cm apart, alternate to opposite, angle of divergence 85˚-90˚		RR, percurrent, sometimes sinuous, branched, oblique to right angle in relation to midvein

thin continuous and wavy parenchyma bands in the Tarkeshwar fossil wood. *Heyneoxylon tertiarum* differ in possessing broad (1-6) seriate xylem rays and thicker (3-10 cells in thickness) parenchyma band. The other fossil wood *Walsura deccanensis* showing affinity with the same genus also differ in having broader (3-8 cells thick) parenchyma bands instead of mostly 2-3 cell thick, parenchyma bands in the present fossil wood. As the Tarkeshwar fossil wood shows differences from already known fossil woods of Meliaceae, it is being described here as *Walsura tarkeshwarensis* n. sp. The specific epithet indicates the name of locality from where the fossil specimen was recovered.

Family **Sapindaceae** De Jussieu, 1789
Genus ***Schleicheroxylon*** Awasthi *et al*., 1982

Schleicheroxylon bharuchense Singh *et al*., 2011
(Pl. IX, figs. 1-6)

Description: Wood diffuse porous, *Growthring* distinct, demarcated by dense parenchyma near the ring. *Vessels* small to medium t.d. 70–175µm, r.d. 70–200µm, circular to oval, sometimes compressed, solitary or in radial multiples of usually 2–3, evenly distributed, 12–18mm^2, tyloses occasionally present (Pl. IX, figs. 1, 2), vessel members 250–590mm in length with usually truncated ends, perforation simple (Pl. IX, figs. 3,4) inter vessel pits alternate, about 4µm in diameter, bordered (Pl. IX, fig. 6). *Parenchyma* both paratracheal and apotracheal, paratrachaeal parenchyma santy to vasicentric, sometime extending in to aliform, apotracheal parenchyma sparse and diffuse, parenchyma cells round to oval, 16–20µm in diameter (Pl. IX, figs. 1,2). *Xylem rays* 1–3 seriate, usually biseriate, 10–35µm in with and 6–30 cells or 40–600µm in length, 8–12 rays per mm (Pl. IX, figs.4,5). Ray tissues homogeneous to weakly heterogeneous, ray cells thick walled, procumbent cells circular or oval, 12–20µm in tangential height and 45–60µm in radial length, upright cells 14–20 µm in tangential height and 16–25µm in radial length (Pl. IX, figs. 3,5). *Fibers* aligned in radial rows, septate.

Material: Two pieces of carbonized woods measuring 8cmx6cm and 6cmx4cm having secondary xylem only with satisfactory preservation. BSIP Museum specimen no. 40799.

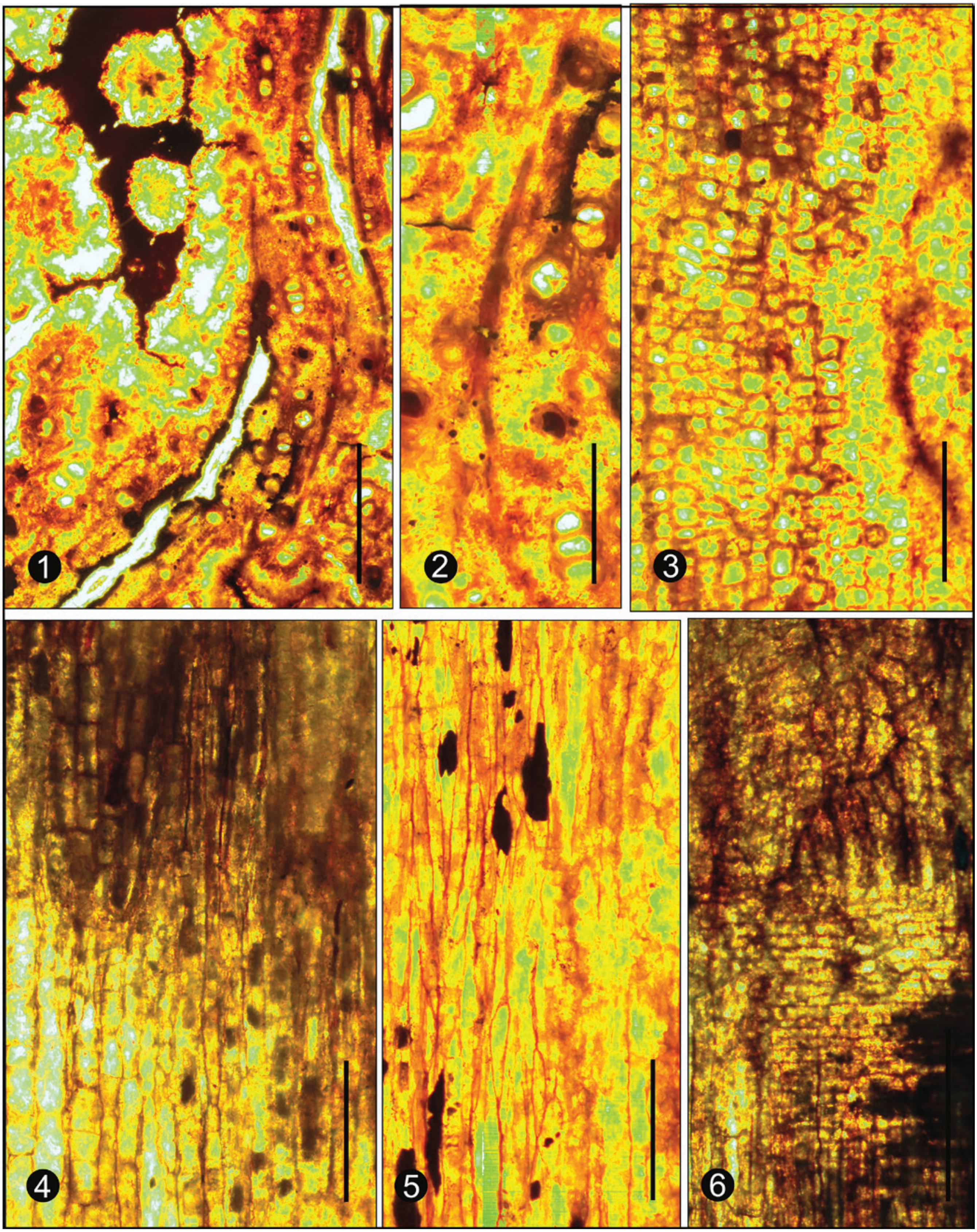
Affinity: Presence of growth ring, small to medium sized, solitary or radial multiple of usually 2-3, vessels, scanty vasicentric to slightly aliform paratracheal parenchyma 1-3 (usually 2) seriate, weakly heterogeneous xylem rays, poorly septate fibres and bordered inter-vessels pits are the diagnostic anatomical features of the present fossil wood. These anatomical features are found common in the modern woods of sapindaceous taxa, like *Arytera* Blume, *Schelichera* Wildnow and *Pometia*

EXPLANATION OF PLATE VIII

Fossil wood of *Walsura tarkeshwarensis* n. sp.

Fig. 1. Cross section under low magnification showing nature and distribution of vessels, parenchyma, fibres and xylem rays. (BSIP 40798/I); Fig. 2. Cross section under high magnification showing nature and distribution of vessels, parenchyma and fibres in details. (BSIP 40798/I); Fig. 3. Tangential longitudinal section under low magnification showing nature and distribution of xylem rays. (BSIP 40798/II); Fig. 4. Tangential longitudinal section under high magnification showing nature of vessel segments and xylem rays in details. (BSIP 40798/II); Fig. 5. Radial longitudinal section under high magnification showing weakly heterogeneous xylem rays. (BSIP 40798 III); Fig. 6. Tangential longitudinal section under high magnification showing the nature of intervessel pits. (BSIP 40798 II). (Scale bars equal to 200µm in (1), 100µm in (2), (3), (4) and (5), 20µm in (6)).

Plate VIII



Forster and Forster (Kanehira, 1921; Pearson and Brown, 1932; Metcafe and Chalk, 1950; Desch, 1954). From a critical examination of wood slides of above sapindaceous taxa, it has been concluded that the present Tarkeshwar foosil wood shows affinity with the woods of the genus *Schleichera* Wildenow. The wood structure of *S. oleosa* (monospecific genus) is quite similar to that of present fossil wood (BSIP slide no. 6132, 465). *S. oleosa* Wild. is a large tree of Indo-Malayan region. It is evergreen to moist deciduous tree and is widely distributed in southern Asia, Malaysian Archipelago and Philippines. It also occurs in Sub-Himalayan tract, east of Sutlej and central and western India mainly all along the streams or in moist places (Mabberley, 1997; Pearson and Brown, 1932).

Fossil record and comparison: Nine fossil woods showing their affinities with sapindaceous taxa have been recorded from the Cenozoic succession of India and abroad. These are *Sapindoxylon jansonii* Kräusel from Sumatra (Kräusel, 1922), *S. stromerii* Kräusel from Egypt (Kräusel, 1924), *S. antioquiense,*Schönfeld from Columbia (Schönfeld, 1947), *S. indicum* Navale from South India (Navale, 1956), *S. schleicheroides* Dayal from Central India (Dayal, 1965), *Schleicheroxylon kachchense* Awasthi *et al*, from Kachchh, western India (Awasthi *et al.,* 1982), *S. bharuchensis* Singh *et al.,* from Vagadkhol area, (Singh *et al.,* 2011) and Vastan Mines, western India (Singh *et al.,* 2015). A comparative study of the anatomical features exhibited by the above mentioned fossil woods suggests that the fossil wood, *Schleicheroxylon bharuchense* Singh *et al.,* 2011 described from the Vagadkhol Formation shows close similarities with the Tarkeshwar wood. The remaining species differ either in having different size and frequency of the vessels or in the nature of xylem rays. *S. jansonii* and *S.antioquiense* differ from present fossil in having large vessels with a lower frequency (2–8mm^2) while *S. stromerii* differs in possessing small vessels with a higher frequency (20–40mm^2) and mostly uniseriate rays as compared to mostly biseriate rays in the Tarkeshwar wood. *S. indicum* also differ in possessing mostly upright cells of uniseriate xylem rays. *S. schleicheroides* differs from present fossil in possessing slightly smaller vessels and mostly 1-2 seriate xylem rays. Lastly, *Schleichoroxylon kachchhensis* can be differentiated by the presence of mostly uniseriate and homogeneous xylem rays as compared to mostly biseriate and weakly heterogeneous xylem rays of the Tarkeshwar fossil wood. Thus, keeping in view the above comparison, the present fossil is being placed under *Schleicheroxylom bharuchense* Singh *et al*.

Family **Ebenaceae** Hiern, 1873
Genus ***Ebenoxylon*** Felix, 1882

Ebenoxylon kalagarhense Prasad, 1989
(Pl. X, figs. 1- 6)

Description: *Wood* diffuse-porous. *Growth rings* indistinct. *Vessels* very small to medium, t. d. 40–85µm, r. d. 60–105µm, solitary as well as in radial multiples of 2–4 (rarely 6), 6–8 per sq. mm, round to oval, sometimes filled with dark content (Pl. X, figs. 1, 2), vessel members 180–300µm in length with truncate to tailed ends, perforation simple, intervessel pits medium sized, about 6µm in diameter, bordered alternate with linear to lenticular apertures (Pl. X, fig. 5). *Parenchyma* apotracheal and paratracheal, apotracheal parenchyma in regular, concentric, 1–2 (mostly 1) seriate lines, 22–28 lines per mm, paratracheal parenchyma scanty, associated with vessels (Pl. X, figs. 2,3), parenchyma cells thick walled, 12–16µm in diameter. *Xylem rays* fine, 1–2 mostly uniseriate, 12–35µm in width, 3–23 cells and 80–760µm in length (Pl. X, figs. 4,5), ray tissues heterogeneous with rays composed of both upright and procumbent cells, ray cells thin walled, procumbent cells 12–22µm in tangential height and 22–70µm in radial length, upright cells 30–70µm in tangential height and 14–32µm in radial length, upright cells sometimes swollen and crystalliferous (Pl. X, fig. 6). *Fibres* aligned in radial rows, semi libriform, moderately thick walled, non septate, 12–18µm in diameter and 600–950µm in length.

Material: There is a small piece of secondary xylem wood measuring about 6cm in length and 18cm in diameter. The anatomical features are poorly preserved. BSIP Museum specimen no. 40800.

Affinity: Closely placed, 1–2 seriate, concentric, tangential apotracheal parenchyma and 1–2 seriate xylem rays are the diagnostic features of present fossil wood. These types of parenchyma and xylem rays are found in the modern woods of family Apocynaceae, Ebenaceae, Rubiaceae and Sapotaceae (Peasrson and Brown, 1932; Metcalfe and Chalk, 1950). Among them, the woods of Sapotaceae differ in having vasicentric tracheides which are absent in the present fossil wood. The woods of family Apocynaceae and Rubiaceae differ in possessing vestured intervessel pits. Thus, the family Ebenaceae comes closest to the present fossil wood. Keeping in view the other anatomical characters of the fossil wood viz., very small to medium, solitary as well as radial multiples vessels, mostly uniseriate, rarely biseriate, hetrocellular xylem rays with some crystalliferous upright cells show closest affinity with the modern woods of the genus *Diospyros* Linn. A critical examination of thin section of woods of all the available species of *Diospyros* Linn viz., *D. ebenum* Koenig, *D. evena* Bakh., *D. guaiacana*, Robin, *D. kurzii* Hiern, *D. macrocarpa* Wall., *D. malabarica* Kostel, *D. melanoxylon* Roxb., *D. pentamera* Woods and F. Muell, *D. pilosula* Wall., *D. paniculata*, Dalz., *D. pyrrhocarpa* Miq., *D. tuberculata* Bakh. and *D. verginiana* Linn. has been carried out in order to find out its specific affinity. Besides the published literature on the anatomy of a number of *Diospyros* species were also consulted (Kanehira, 1924; Pearson and Brown, 1932; Chowdhury, 1945; Metcalfe and Chalk, 1950; Desch, 1957; Kribs, 1959; Normond, 1960; Brazier and Franlin, 1961) and found that the modern woods of *D. pilosula*

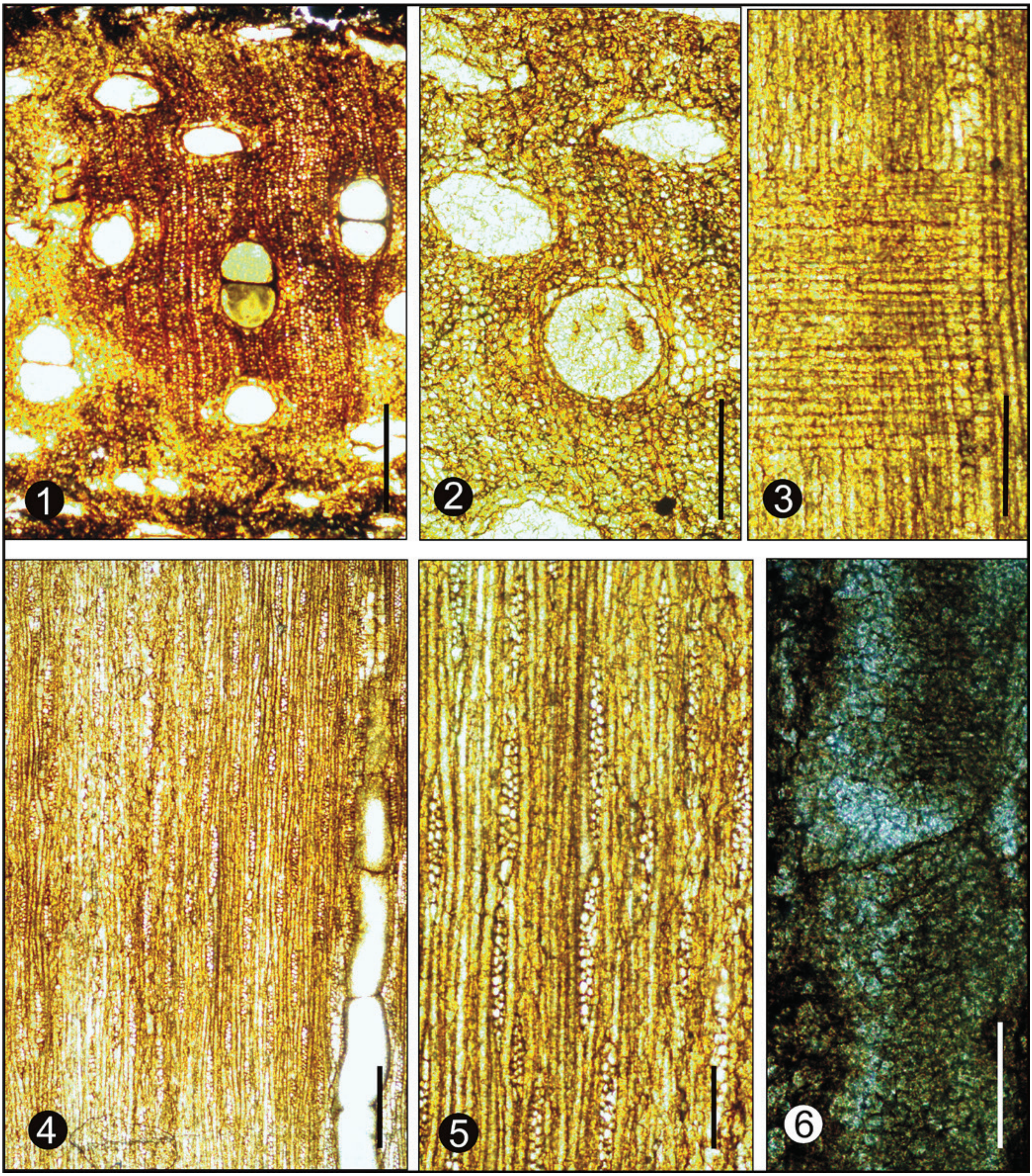
EXPLANATION OF PLATE IX

Fossil wood of *Schleicheroxylon bharuchense* Singh *et al.*

Fig. 1. Cross section under low magnification showing nature and distribution of vessels, parenchyma, fibres and xylem rays. (BSIP 40799 I); Fig. 2. Cross section under high magnification showing nature of vessels and scanty vasicentric to aliform parenchyma. (BSIP 40799 I); Fig. 3. Tangential longitudinal section under low magnification showing nature and distribution of xylem rays and vessel segments. (BSIP 40799 II); Fig. 4. Tangential longitudinal section under high magnification showing nature of xylem rays and fibres in details. (BSIP 40799/ II); Fig. 5. Radial longitudinal section under high magnification showing heterogeneity in the xylem rays. (BSIP 40799/ III); Fig. 6. Tangential longitudinal section showing nature of intervessel pits. (BSIP 40799/II). (Scale bars equal to 200µm in (1), (3), (4), and (5), 100µm in (2), 50µm in (6).

Journal of the Palaeontological Society of India
Volume 64(2), December 31, 2019

Plate IX



Wall. and *D. malabarica* Kostel show close affinity with the Tarkeshwar fossil wood. Of these two, the wood of *D. pilosula* is very close to the fossil wood as it possesses similar nature of vessels, parenchyma and xylem rays. *Diospyros pilosula* Wall. is a large tree presently distributed in the evergreen forests of Khasia Mountains, Peguyoma and Andman Islands in Indian subcontinents (Hooker, 1879).

Fossil record and comparisons: The fossil woods showing affinity with the genus *Diospyros* Linn. (= Maba) have been described under the form genera, *Ebenoxylon* Felix, *Diospyroxylon* Greguss and *Diospyros* Linn. So far, 26 fossil woods have inferred to the family Ebenaceae. They have already been documented in the literature (Singh *et al*, 2015; p. 310, table 1, Prasad, 1989, p.140–141). The Tarkeshwar fossil wood is assigned to an already known species, *Ebenoxylon kalagarhense* recorded from the Middle Miocene sediments of Kalagarh, Uttarakhand, India. This is very similar in the nature and frequency of the vessels and apotracheal parenchyma lines. Moreover, in both of them the xylem rays are mostly uniseriate with some swollen cells and heterogeneous in nature. The remaining species can be differentiated either in possessing larger vessels or broader (1–3 seriate) xylem rays which are most of them homogeneous in nature as compared to mostly uniseriate, heterogeneous xylem rays.

Family **Combretaceae** Brandis, 1893
Genus ***Terminalioxylon*** Schönfeld, 1947

Terminalioxylon felixi Ramanujam, 1956
(Pl. XI, figs. 1-6)

Description: *Wood* diffuse porous. *Growth rings* distinct demarcated by narrow lines of parenchyma, *Vessels* small to large, usually medium sized, t. d. 70–240µm, r. d. 90–280µm, mostly solitary or in radial multiples of 2–3, evenly distributed, 5–8 per mm^2, vessel members 160–540µm in length with usually truncate ends, perforation simple, tyloses present, vessels sometimes filled with dark contents (Pl. XI, figs.1, 2), intervessel pit-pairs small, alternate, oval to elliptic, 4–6µm in diameter, vestured (Pl. XI, fig. 6). *Parenchyma* paratracheal and apotracheal, paratracheal parenchyma vasicentric to aliform and confluent (Pl. XI, figs.1,2), apotracheal parenchyma present in the form of 1–4 cells thick lines of growth ring, parenchyma cells circular to oval, 14–22µm in thin walled, crystalliferous strands poorly seen. Xylem rays fine, 1–2 seriate, mostly uniseriate (Pl. XI, figs. 3, 4), 12–45µm in width, 4–25 cells or 118–580µm in length, ray tissues homo to hetrogeneous composed of both procumbent and upright cells, crystalliferous cells present, procumbent cells 50–75µm in radial length and 20–46µm in tangential height, upright cells 45–60µm in radial length and 45–70µm in tangential height (Pl. XI, fig. 5). Fibres alligned in radial rows in between the two consecutive *xylem rays*, libriform, circular to polygonal in cross section, non septate, 14–22µm in diameter and 340–650µm in length, interfibre pits not seen.

Material: A piece of carbonized wood measuring about 7cmx9cm having secondary xylem only. This wood revealed poor preservation of anatomical characters. BSIP Museum specimen no. 40847.

Affinity: Mostly small to medium sized vessel with vestured pits, vasicentric to aliform and confluent parenchyma, mostly uniseriate heterogeneous xylem rays with crystalliferous cells are the characteristic features of the present fossil wood which suggests its affinity with those of *Terminalia* Linn. and *Anogeissus* (DC.) Wall. of the family Combretaceae. However, it can be differentiated from the wood of *Anogeissus* (DC.)Wall. in having more pronounced heterogeneity in the xylem rays and the presence of crystalliferous parenchyma strands. (Ramesh Rao and Purkayastha, 1972; Pearson and Brown, 1932). With a view to find out the modern equivalent of the present fossil wood, thin section of modern woods of all the available species (30 species) has been studies. Besides published descriptions and illustrations of some more species of this genus were also consulted (Pearson and Brown, 1932; Metcalfe and Chalk, 1950, Desch, 1957; Chaudhury and Ghosh, 1958; Kribs, 1959; Normond, 1960; Miles, 1978). From the detailed study it is seen that the present fossil wood resembles closely the modern woods of extant species *Terminalia tomentosa* (Roxb.) W. and A. (BSIP wood slide no. 2293). *T. tomentosa* (Roxb.) W. and A. is a large tree widely distributed in all the important forests of India. It also occurs in the Sub-Himalayan region from Punjab to eastwards up to Assam (Brandis, 1906).

Fossil record and comparison: More than 40 fossil woods resembling with those of the genus *Terminalia* Linn. have been referred to the organ genus *Terminalioxylon* Schönfeld, 1947 (listed earlier in Prasad, 1989, Table 1). From a detailed comparison with all the known species of *Terminalioxylon* Schönfeld it has been found that the present fossil wood resembles with *Terminalioxylon felixi* Ramanujam described from Cenozoic of south India and hence it is placed under the same form species of *Terminalioxylon felixi* Ramanujam. The fossil woods of *Terminalia* showing close affinity with modern wood of *Terminalia tomentosa* are also known from the Neogene sediments of India (Ghosh and Roy, 1980; Lakhanpal *et al.,* 1981, 1984; Prakash and Dayal, 1966; Prakash, 1966; Ramanujam, 1956).

3. Fruit taxa

Family **Rhamnaceae** Horaninow, 1834
Genus ***Ziziphus*** Miller, 1789

Ziziphus eocenica Singh *et al*., 2010
(Pl. XII, fig. 3)

Description: Fruit carbonized, drupe type, globose, pericarp thin, mesocarp seemingly fleshy, size 3.0 x 3.1cm, dark brown in

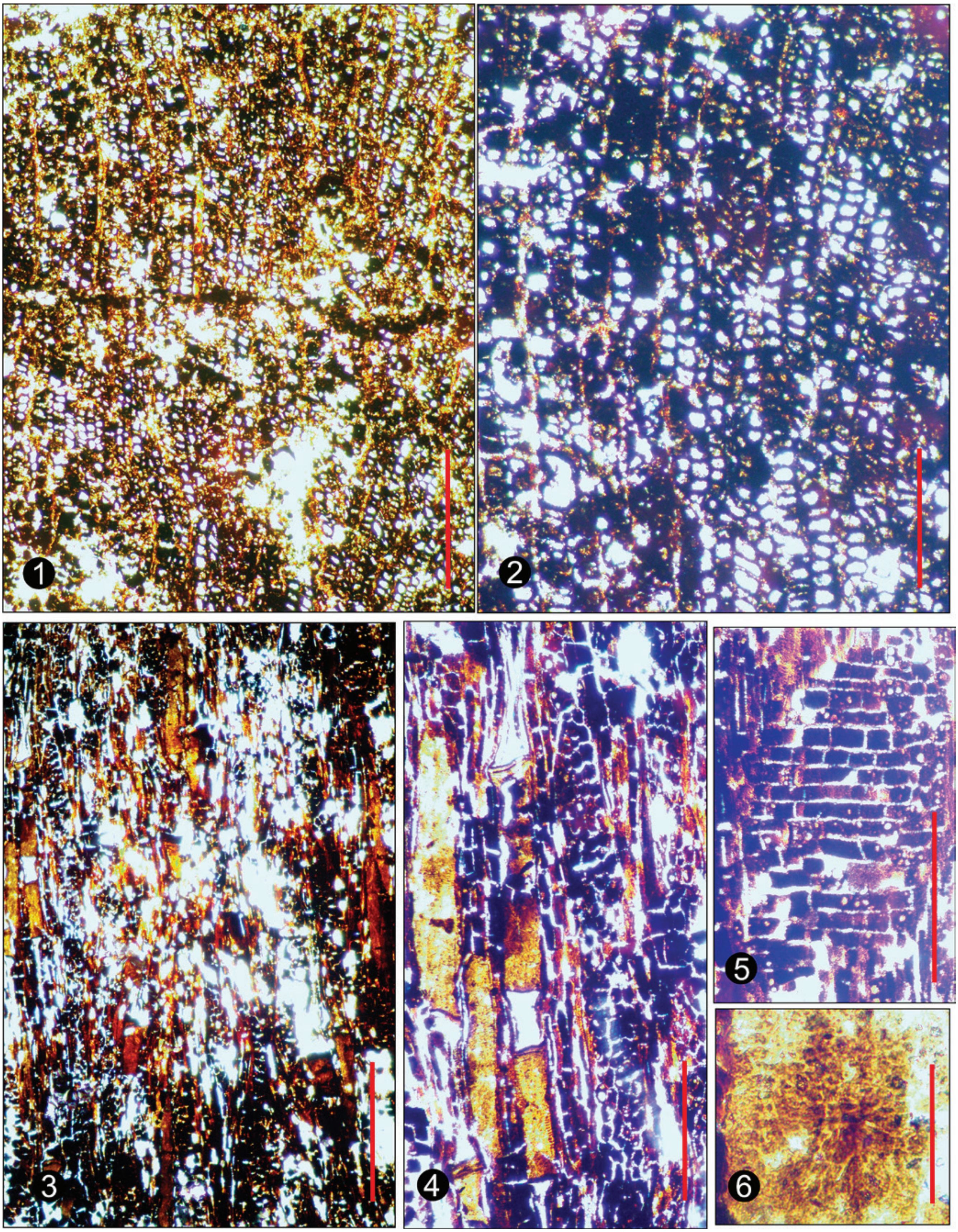
EXPLANATION OF PLATE X

Fossil wood of *Ebenoxylon kalagarhense* Prasad

Fig. 1. Cross section under low magnification showing nature and distribution of vessels, parenchyma, fibres and xylem rays. (BSIP 40800/I); Fig. 2. Cross section under high magnification showing nature of vessels sometimes filled with dark content. (BSIP 40800/I); Fig. 3. Cross section under higher magnification showing nature and distribution of parenchyma lines and fibres. (BSIP 40800/I); Fig. 4. Tangential longitudinal section under low magnification showing nature and distribution of xylem rays. (BSIP 40800/ II); Fig. 5. Tangential longitudinal section under high magnification showing details of xylem rays. (BSIP 40800/ II); Fig. 6. Radial longitudinal section under high magnification showing heterogeneous xylem rays. (BSIP 40800/III). (Scale bars equal 200µm in (1, 2) and 100µm in (3, 6) and 50µm in (4, 5).

Journal of the Palaeontological Society of India
Volume 64(2), December 31, 2019

Plate X



colour, stalk broken, attachment point is distinct on fruit surface.

Material: BSIP Museum specimen no. 40848.

Locality: Tarkeshwar Lignite Mine, District Surat, Gujrat, western India.

Horizon and Age: Cambay shale Formation, Early Eocene.

Affinity: The fruit is highly carbonized and there is distinct mark of attachment with stalk, shape, size and other morphological features of this fruit suggest its close resemblance with the extant taxa *Ziziphus xylopyrus* (Retz). Willd. of the family Rhamnaceae (Singh *et al*., 2010).

Remarks. A fossil fruit resembling the genus *Ziziphus* Miller is recorded from the Eocene sediments of Vastan, western India under the form species *Z. eocenica*. Critical study on this known fossil fruit suggests that it is very similar to the present fossil fruit in almost all the morphological characters. The size of present fossil is slightly greater than the *Z. eocenica* Singh *et al*., 2010. It is observed that the modern fruit of *Ziziphus xylopyrus* (Retz) Willd. has also such variation in size. As the present fossil fruit is similar to the fossil fruits. *Z. eocenica* Singh *et al.,* 2010, it has been described under the same.

Ziziphus xylopyrus (Retz.) Willd is a shrub to small tree found in the dry to moist deciduous forests of Himalayan sub-tract, India and Srilanka. It is very common in the deciduous forests of South India (Kerala, Karnataka, etc.).

Family **Combretaceae** Brandis, 1893
Genus ***Terminalia*** Linn., 1787

Terminalia cambaya Singh *et al*., 2010
(Pl. XII, fig. 1, 5)

Description: Fruit drupe type, oblong to ellipsoidal with obtuse apex and base, flattened, dark brown in colour, size 4.2x 2.8cm and 3.0x2.5cm, ridges present, somewhat indistinct, striation in between the ridges are distinct. In one of the specimen of the fruit (Pl. XII, fig. 5) the apical part is broken showing seed view inside the fruit.

Material: BSIP Museum specimen no.40849, 40850.

Locality: Tarkeshwar Lignite Mine, District Surat, Gujrat, western India.

Horizon and Age: Cambay shale Formation, Early Eocene.

Affinity: Oblong to elliptical shape with longitudinal ridges with striation between them indicates its affinity with the fruit of extant genus *Terminalia chebula* Retz. of the family Combretaceae (Singh *et al*., 2010, fig. 3).

Remarks: The genus *Terminalia* Linn is well represented in the fossil history of Cenozoic sediments of India and abroad by the occurrence of mainly fossil woods and leaves. (Prakash, 1979; Ghosh and Roy, 1980; Prasad, 2008; Agarwal, 1998; Harsh and Sharma, 1995). However, three fossil fruits resembling the genus *Terminalia* Linn. have been known from the Indian Cenozoic sediments. These are *Terminalia precatapa* Tewari and Sharma, 2002 from Brail group of Mizoram. *Terminalia sesawngensis* Agarwal and Mandaokar, 2007 from Bhuban Formation (Lower Miocene) of Mizoram and *Terminalia cambaya* Singh *et al*., 2010 from Eocene sediments of Vastan, western India. Out of these mentioned fossil fruit*, Terminalia cambaya* Singh *et al*. show its modern affinity with the extant fruit of *Terminalia chebula* (Retz.) Willd. like the present fossil and also possesses similar morphological characters. In view of this present fossil fruit has been described under the same species, *Terminalia cambaya* Singh *et al.,* 2010.

The extant species *Terminalia chebula* (Retz.) Willd. is a small to large tree, commonly found in the moist deciduous forest of India and Myanmar and Srilanka. It is also found in Bengal, Assam, Garo Hills (Meghalaya) and Western Ghats (Ramesh Rao and Purkayastha, 1972; Brandis, 1906).

Terminalia eobellerica n. sp.
(Pl. XII, fig. 4)

Diagnosis: Fossil fruit drupe one seeded, ovate to spherical 3.8x3.4cm, basal part rounded, apical part is slightly tapering, surface smooth, seed rounded, about 2.8cm in diameter, mesocarp is distinct.

Description: Fossil fruit drupe type, one seeded, dark brown in colour, ovate to spherical 3.8x3.4cm, basal part rounded, apical part is slightly tapering indicating the points of attachment to the stalk, surface almost smooth, There is no ridges on the fruit surface, one seed appearance is distinct inside. Seed rounded, about 2.8cm in diameter, mesocarp is distinct in between the seed and pericarp (outer layer).

Material: BSIP Museum specimen no.40851 (Holotype).

Locality: Tarkeshwar Lignite Mine, District Surat, Gujrat, western India.

Horizon and Age: Cambay shale Formation, Early Eocene.

Etymology: This species is named after the modern equivalent, *T. bellerica* with which fossil fruit resembles.

Affinity: The diagnostic features of the present fruit such as drupaceous nature, ovate to spherical shape, presence of one large seed and smooth fruit surface indicate its affinity with the modern fruits of *Terminalia bellerica* (Gaertn.) Roxb. of the family Combretaceae.

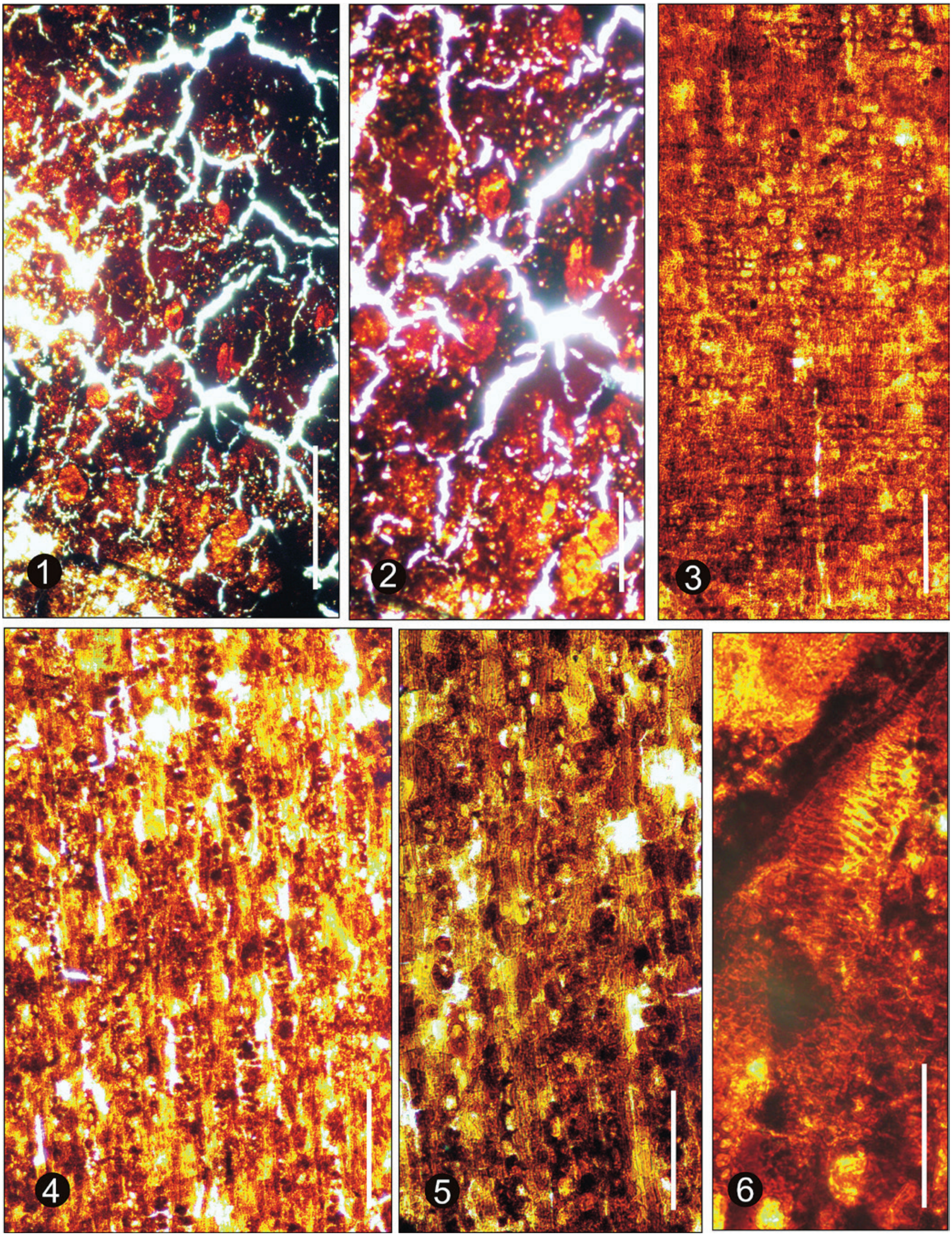
Remarks: So far, four fossil fruits resembling the genus *Terminalia* Linn have been recorded from the Cenozoic sediments of India. These are listed earlier in this text. The comparative study suggests that they are entirely different from the present fossil fruit and it has been described as *Terminalia eobellerca* n. sp. Out of the known species, *Terminalia sesawngensis* Agarwal and Mandoakar, 2007 described from the Lower Miocene of Mizoram has also been compared with the same extant taxa, *Terminalia bellerica* Roxb. as the present fossil but differ in being smaller and ovoid shape with five longitudinal ridges. The remaining species *Terminalia precatapa* and *T. cambaya* are showing their affinity with the extant species, *T. catapa* and *T. chebula* respectively and differ mainly in shape and size and

EXPLANATION OF PLATE XI

Fossil wood of *Terminalioxylon felixii* Ramanujam

Fig. 1. Cross section under low magnification showing nature and distribution of vessels, parenchyma, xylem rays and fibres. (BSIP 40847/I); Fig. 2. Cross section under high magnification showing nature and distribution of vessels and parenchymain details. (BSIP 40847/I); Fig. 3. Tangential longitudinal section under low magnification showing nature and distribution of xylem rays. (BSIP 40847/II); Fig. 4. Tangential longitudinal section under high magnification showing mostly uniseriate rays with some crystalliferous cells. (BSIP 40847/II); Fig. 5. Radial longitudinal section under high magnification showing procumbent and upright cells of xylem rays. (BSIP 40847/ III); Fig. 6. Tangential longitudinal section under high magnification showing nature of intervessel pits. (BSIP 40847/II). (Scale bars equal to 100µm in (1), (6), 200µm in (2), (3), (5), 50µm in (4).

Plate XI



presence of ridges on the surface.

The comparable taxa, *Terminalia bellerica* (Gaertn.) Roxb. is a large deciduous tree growing in the tropical region of south Asia like India, Nepal, Bhutan, Malaya, Indonesia and China. In India it is generally distributed in the forests of low hills and plains of Tamil Nadu, Assam, Orissa and Gujarat (Brandis, 1906).

Genus ***Combretum*** Linn*.,* 1787

Combretum vastanensis Singh *et al*., 2010
(Pl. XII, fig. 2)

Description: Fruit flattened, compressed, thin, dark brown in colour, size 2.7x 2.8 cm, wide, elliptic, wide, acuminate to obtuse, base and apex, thick longitudinal ridge present dividing two flattened halves which extended in the middle, striation on the surface present, fine and faint.

Material : BSIP Museum specimen no. 40452.

Locality: Tarkeshwar Lignite Mine, District Surat, Gujrat, western India.

Horizon and Age: Cambay shale Formation, Early Eocene.

Affinity: Wide elliptic shape with thick prominent longitudinal ridge dividing the fruit surface in to two halves and wide acuminate to obtuse basal and apical ends undoubtedly suggests that the fossil fruit belong to the extant genus *Combretum* Loefl. of the family Combretaceae.

Remarks: A survey of the published literature (Brandis, 1906; Gamble, 1902) consultation of Herbarium sheets at Central National Herbarium Howrah revealed that the fruit of Tarkeshwar resembles closely to the modern fruits of *Combretum decandrum* Roxb. (CNH Herbarium sheet no. 3019, 2946).

The genus *Combretum* Loefl. is well known in the fossil records by the occurrence of its fossil woods, leaves and fruits in the Cenozoic sediments of India and abroad (Lemoigne, 1978; Bera and Banerjee, 2001; Prasad, 2008; Singh *et al.,* 2010, 2015). A fossil fruit resembling the genus *Combretum* Loefl. has been described under the form species *Combretum vastanensis* Singh *et al.* (2010) from the Cambay shale formation, Vastan lignite mine, India. This fossil fruit has also been compared with the same modern species *C. combretum* Roxb. as the present fossil fruit and almost similar in morphological feature except in size which is smaller than the present fossil. Thus, in being similar with *C. vastanensis* Singh *et al.* (2010), it has been described under the same.

Modern comparable species, *C. decandrum* Roxb. is a large climbing shrub described in the mixed forests throughout the India. It is generally found all along the stream in low hilly forests of mainly central south and northern India (Brandis, 1906).

4. Seed taxa

Family **Cyperaceae** Pax, 1887
Genus ***Fimbristylis*** Vahl., 1805

Fimbristylis eocenicus n. sp.
(Pl. XII, figs. 6, 7)

Diagnosis: Fossil seed 1.5x0.7–0.8mm, elliptic, stipe 130–160μm, smooth, slightly oblique, apical part bulges, surface foveate, margin slightly undulated.

Description: Fossil seed 1.5x0.7–0.8mm, bigonous, elliptic with stipe, stipe medium sized, 130–160μm, smooth, slightly oblique, apical part bulges, surface foveate width lesser towards apical and basal part than middle, margin slightly undulated.

Material: BSIP Museum specimen no. 10. (Holotype).

Locality: Tarkeshwar Lignite Mine, District Surat, Gujrat, western India.

Horizon and Age: Cambay shale Formation, Early Eocene.

Etymology: Named after the epoch 'Eocene' to which fossil locality belongs.

Affinity: The seed without stipe and with stipe are characteristic features of the family Eriocaulaceae and Cyperaceae respectively of the order Poales (Abid *et al*., 2014). The seed morphology of more than 40 species of the family Cyperaceae has been examined in order to identify the present seed. The shape and size of studied seed suggest its affinity with the seeds of extant genus *Fimbristylis* Vahl. Only seven species of this genus available for the comparison viz. *F. Cymosa, F. ferrugineca, F. bisumbellata, F. quinquangularis, F. squarrosa, F. turkestanica* and *F. woodrowi.* Of these only *F. quingangularis* shows nearest affinity with the present seed in shape, size, presence of stipe, nature of apex and foveate nature of surface. The remaining species mainly differ in being reticulate or tuberculate or ribbed nature of the seed surface. *F. turkestanica* differs in possessing obovate suborbicular shape as compared to elliptic shape in the present fossil seed. As far as authors are aware there is no previous record of the fossil seed of the genus *Fimbrioslylis* from India in all the sedimentary sequences of Cenozoic age group. Although few fossil seeds resembling the genus *Carex caricoidea, Scleriocarya* and *Cyperus* etc. are known from Oligocene onwards from Eurasia (Smith *et al.,* 2009). A well-preserved fruit and infructescence has been reported under the form taxa of *Volkeria messelense* from the Eocene of Germany. The present fossil seed has been compared with the already known Cyperaceae seed and found that it is entirely different from them. Thus, in being different it has been described under a new species *Finbristylis eocenica*.

Genus ***Cyperus*** Linn., 1737

Cyperus palaeolaevigatus n. sp.
(Pl. XII, fig. 7)

Diagnosis: Seed size 1.7x 0.7mm, elliptic, stipe medium size, bifid, smooth, almost straight, apex acute, surface smooth.

Description: Fossil seed size 1.7x 0.7mm, elliptic, bigonous with stipe, stipe medium size 25mm, broad, 0.3mm, bifid, smooth, almost straight, apex acute, surface smooth, margin entire.

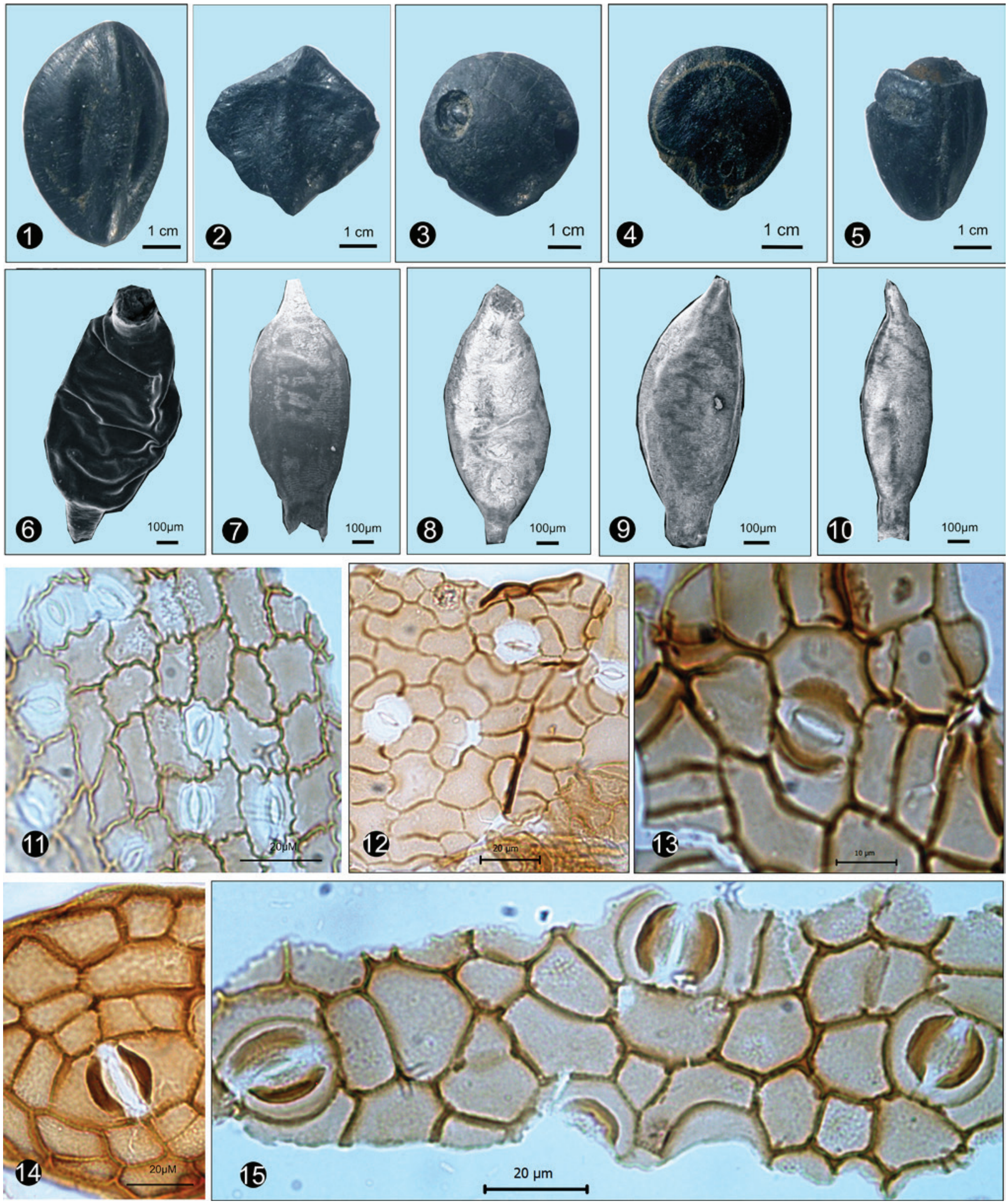
Material: BSIP Museum specimen no. 11. (Holotype).

Locality: Tarkeshwar Lignite Mine, District Surat, Gujrat, western India.

EXPLANATION OF PLATE XII

Figs. 1,5. ***Terminalia cambaya* Singh *et. al*.** BSIP 40849 and 40850; Fig. 2. ***Combretum vastanensis* Singh *et. al*.** BSIP 40852; Fig. 3. ***Ziziphus eocenica* Singh *et. al*.** BSIP 40848; Fig. 4. ***Terminalia eobellerica* n. sp.** BSIP 40851 (Holotype); Figs. 6, 8. ***Fimbristylis eocenica* n. sp**. BSIP Slide no.15484; Fig. 7. ***Cyperus palaeolaevigatus* n. sp**. BSIP Slide no.115484; Fig. 9. ***Cyperus sahnii* n. sp**. BSIP Slide no.15483; Fig. 10. *Dulichium tertiarum* n. sp. BSIP Slide no.15484; Fig. 11. ***Lusaticutis tarkeshwarensis* n. sp**. BSIP Slide no.15479; Fig. 12. ***Lusaticutis cambayensis* n. sp**. BSIP Slide no. 15480; Figs. 13, 15. ***Lusaticutis sahnii* n. sp.** BSIP Slide no.15480; Fig. 14. ***Lusaticutis eocenica* n. sp.** BSIP Slide no. 15479.

Plate XII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20 µm
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10 µm
14
20µM
15
20 µm

Horizon and Age: Cambay shale Formation, Early Eocene.

Etymology: By adding prefix 'palaeo' to to the modern comparable species, *Cyperus laevigata.*

Affinity: Medium size, elliptic shape and presence of the stipe are the characteristic features of the seeds of the family Cyperaceae. The seed of this family show great variation in morphology of seed surface, which are important characters in identifying the different genera (Abid *et al*., 2007, Table 1, 3). Taking into consideration the shape, size and smooth nature of surface the present fossil seed shows close resemblance with the extant seeds of the genus *Cyperus* Linn. In being the presence of bifid stipe in the seed its specific affinity goes to the extant species *Cyperus laevigatus* Linn. This fossil seed also shows superficial resemblance with the extant taxa, *Leptochloa fascicularis* of the same family in being the presence of bifid stipe only. As there is no any fossil record of fossil seeds resembling the genus *Cyperus* Linn. from Cenozoic sediments from the Indian subcontinent, *Cyperus palaeolavigatus* n. sp. proves to be the first record of this genus from the Cambay basin, Gujarat, western India.

Cyperus sahnii n. sp.
(Pl. XII, fig. 9)

Diagnosis: Seed size 1.7x 0.7mm, elliptic with short, blunt stipe, slightly curved, apex bluntly obtuse, slightly oblong, surface reticulate.

Description: Fossil seed size 1.7x 0.7mm, elliptic, bigonous with short, blunt stipe, stipe 300µm wide and 200µm long, curvature on one side pronounced, slightly curved, apex bluntly obtuse, slightly oblong, surface reticulate, reticulation faint, margin entire.

Material: BSIP Museum specimen no. 11. (Holotype).

Locality: Tarkeshwar Lignite Mine, District Surat, Gujrat, western India.

Horizon and Age: Cambay shale Formation, Early Eocene.

Etymology: This species is named after Prof. Ashok Sahni, an eminent palaeontologist.

Affinity: The characteristic features of the present fossil seed are medium size, elliptic shape, blunt stipe and reticulate venation. These features are found common in extant taxa of the taxa *Glyceria striata, Carex abscondita, C. mops, Cyperus odoratus* and *Cyperus fuscus* of the family Cyperaceae. After critical examination of their morphological features of the studied seeds of described extant taxa has been observed that *Glyceria striata* differs in possessing slight striation on the surface. The seeds of *Carex obscondita* and *C. mops* can be easily differentiated in possessing narrow stipe, which is sometimes bifid as *Carex mop, Cyperus fuscus* also differs in being presence of mucronate apex as compared to bluntly obtuse apex. Thus *Cyperus odoratus* is only with which fossil seed shows nearest affinity in shape, size and other morphological features. The fossil seed, *Cyperus palaeolaevigatus* described earlier in this text differs from present fossil seed in being presence of bifid stipe. In view of this it has been described as a new species *Cyperus sahnii.*

*Genu*s ***Dulichium*** Pers., 1805

Dulichium tertiarum n. sp.
(Pl. XII, fig. 10)

Diagnosis: Seed size 1.6mm x0.5mm, narrow elliptic, with long stipe, stipe blunt, apex acute, surface smooth.

Description: Fossil seed size 1.6mmx0.5mm, narrow elliptic, bigonous, with long stipe, stipe 200µm long, 160µm wide, blunt, apex acute, curved, surface smooth, margin entire.

Material : BSIP Museum specimen no. 11. (Holotype).

Locality: Tarkeshwar Lignite Mine, District Surat, Gujrat, western India.

Horizon and Age: Cambay shale Formation, Early Eocene.

Etymology: The specific epithet is after the 'Tertiary' to which fossil locality belongs.

Affinity: Presence of stipe in this seed is the characteristic feature of the family Cyperaceae. Narrow elliptic shape with broad stipe, smooth surface and acute apex determined the identity of this seed with the extant taxa *Dulichium aurandinaceum* (L.) Britton of Cyperaceae. The comparative study of all the described seed in this text has been done and observed that these are different either in their surface morphological characters or nature of stipe. The width of the present fossil seed is lesser than the earlier known seed. Therefore it has been described as *Dulichium tertiarum* n. sp.

5. Cuticle taxa

Genus ***Lusaticutis*** Roselt and Schneider, 1969

Lusaticutis tarkeshwarensis n. sp.
(Pl. XII, fig. 11)

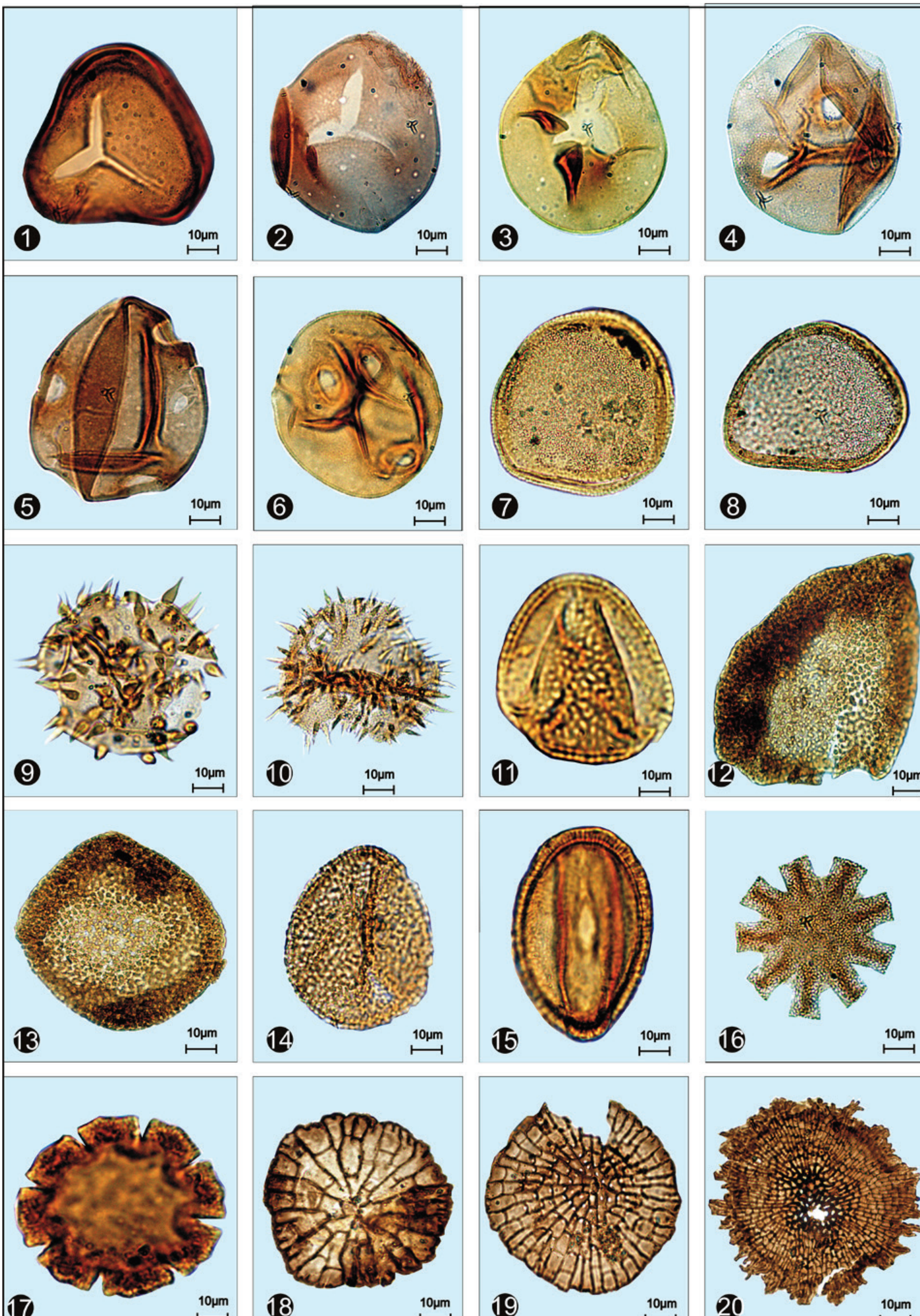
Diagnosis: Cuticular cells elongate, walls transverse, sometimes oblique, wall surface crenulated, stomata anomocytic, 12-14µm x 7-10µm, guard cells thin, reniform, stomata 70-80/mm^2, subsidiary cells resemble with other epidermal cells but comparatively smaller, stomatal index 15-18.

Description: Cuticular cells elongate, angular, arranged almost parallel to each other, walls transverse, sometimes oblique, 15-22x7-14µm, wall surface crenulated, rectangular to polygonal, 260-280µm, stomata anomocytic, small, 12-14µm x 7-10µm, aperture open, guard cells thin, up to 6µm wide, reniform, stomata 70-80/mm^2, surrounded by 5-6 subsidiary cells which resemble with other epidermal cells but sometimes comparatively smaller, stomatal index 15-18.

EXPLANATION OF PLATE XIII

Fig. 1. ***Cyathidites minor* Couper**, BSIP Slide no. 14474; Fig. 2. ***Todiosporites kutchensis* Sah & Kar,** BSIP Slide no. 15474; Fig. 3. ***Dandotispora telonata* Sah *et al.*,** BSIP Slide no. 15474; Fig. 4. ***Lakiapollis ovatus* Venkatachala & Kar**, BSIP Slide no. 15474; Figs. 5-6. ***Lakiapollis ovatus* Venkatachala & Kar**, BSIP Slide no. 15474; Fig. 7. **Proxapertites microreticulatus Jain *et al.*,** BSIP Slide no. 15477; Fig. 8. **Proxapertites cursus Van Hoeken-Klinkenberg**, BSIP Slide no. 15478; Fig. 9. ***Acanthotricolpites bulbospinosus* Kar** BSIP Slide no. 15479; Fig. 10. ***Spinizonocolpites prominatus* Stover & Evans**, BSIP Slide no.15480; Fig. 11. ***Longapertites* sp**. BSIP Slide no.15474; Figs. 12-13. ***Matanomadhiasulcites maximus* (Saxena) Kar**, BSIP Slide no.15481; Fig. 14. ***Tricolporopollis matanomadhensis* (Venkatachala & Kar, 1969) Tripathi & Singh**, BSIP Slide no. 15480; Fig. 15. ***Barringtoniapollenites retipilatus* Kar & Sharma**, BSIP slide no.15474; Fig. 16. ***Ctenolophonidites retipilatus* sp.1 BSIP Slide no.** 15474; Fig. 17. ***Ctenolophonidites costatus* (Von Hoeken-Klinkenberg, 1964) Von Hoeken-Klinkenberg,** BSIP Slide no. 15474; Fig. 18. ***Callimothallus assamicus* Kar *et al.*,** BSIP Slide no.15475; Fig. 19. ***Callimothallus* sp**. 1 BSIP Slide no. 15475; Fig. 20. ***Phragmothyrites eocenica* Kar and Saxena**, BSIP Slide no. 15476.

Plate XIII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20
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Material : BSIP Museum slide no. 4. (Holotype).

Locality: Tarkeshwar Lignite Mine, District Surat, Gujrat, western India.

Horizon and Age: Cambay shale Formation, Early Eocene.

Etymology: This species is named after the fossil locality Tarkeshwer.

Remarks: In overall features the present fossil leaf cuticles shows affinity with the dicotyledonous families. In order to identify up to genus/ species level the published literature pertaining to the angiosperm leaf cuticle were consulted. The shape, size and crenulate nature of cuticular cells and anomocytic stomata indicate its resemblance with the modern taxa, C*upania jackiana* (Sapindaceae) *Ligustrum vulgare* L. (Oleaceae), *Myristca agusanenensis* Elmer and *Virola* sp. (Myristicaceae), *Acaphila magnifolia* Elmer and *Edenophaedra megatophylla* Muell. Arg. The critical examination of the leaf cuticles of different genera and families it has been observed that the present fossil leaf cuticle belong to the family Sapindaceae. The present leaf cuticle C. *tarkeshwarensis* is not comparable to any known cuticles from the Cenozoic of Indian subcontinent (Dalvi and Kulkarni, 1982; Agarwal *et al.,* 2002; Upchurch, 1984; Prasad and Khare, 2004; Tewari *et al.,* 2002). Thus, it has been described as *Lusaticutis tarkeshwarensis* n. sp.

Lusaticutis cambayensis n. sp.
(Pl. XII, fig.12)

Diagnosis: Cells polygonal, cell wall sinuate, thin walled, 280-300 cells per mm^2, anomocytic, 12- 20 x 15-20µm, guard cells reniform, stomata apple shaped, 5-6 subsidiary cells of irregular shape, size surrounded the stomata, aperture, about 10 x 5µm and elliptic in shape. Stomatal density 30-40 per mm^2. Stomatal index 12-14.

Description: Cuticular cells medium sized, polygonal, cell wall sinuate, 10-22µm x 10-18µm, irregular, thin walled, 280-300 cells per mm^2, stomata distinct, anomocytic, 12- 20 x 15-20µm, guard cells wide, reniform, about 10µm thick, stoma open, stomata apple shaped, notched at both the end, 10-12µm wide, 5-6 subsidiary cells of irregular shape, size surrounded the stomata, subsidiary cells are almost similar to cuticular cells, inner wall of guard cell thin, aperture, about 10 x 5µm and elliptic in shape. Stomatal density 30-40 per mm^2. Stomatal index 12-14.

Material: BSIP Museum slide no. 4. (Holotype).

Locality: Tarkeshwar Lignite Mine, District Surat, Gujrat, western India.

Horizon and Age: Cambay shale Formation, Early Eocene.

Etymology: Named after the Cambay Shale Formation to which fossil locality belongs.

Remarks: The diagnostic features such as cell wall irregular, polygonal shape with anomocytic stomata are found common in the modern cuticles of the extant taxa, *Trichelia cuneata* Radlk. (Meliaceae), *Sideroxylon languginosum* Michx. (Sapotaceae), *Diospyros verginianum* L., *Alyxia sinensis* Champ. ex Benth. (Apocynaceae), *Cissus brevipes* C.V. Morton and Standl., *C. cucurbita* Standl., *C. sicyoides* L. (Vitaceae), *Myrica carolinensis* Mill. (Myricaceae), *Comptonia peregrina* (L.) J. M. Conlt., *Aiouea impressa* (Lauraceae), *Artocarpus intergrifolius* L. f. (Moraceae) *Antedisma bunius* (L.) Spreng. and *Terminalia bucaras* Wright (Combretaceae). After a critical examination of the cuticles of the above species it has been observed that the modern cuticles of *Artocarpus integrifolius* L. f. and *Terminalia buceras* Wright show close resemblance with the present fossil leaf cuticle (Cuticular data base, Barclay *et al.,* 2007). The present fossil cuticle, *L. cambayensis* differ from already known cuticles from Cenozoic sediments. It also differs from *L. tarkeshwarensis* described in this text mainly in the size and nature of cuticular cells which are crenulate as compared to sinuate nature in the present fossil cuticle.

Lusaticutis eocenica n. sp.
(Pl. XII, fig. 14)

*Diagnosis***:** Cells squire to rectangular and rarely polygonal, 8-15µm x 8-35µm, smooth, slightly thick walled, 250-270 cells per mm2, stomata anomocytic, stomata surrounded by a ring of subsidiary cells, 20-30µm in size, guard cells wide, inner wall of guard cell is swollen. Stomatal density 20-30/mm2 and stomata index is about 10.

*Description***:** Cuticular cells squire to rectangular and rarely polygonal, small to large, 8-15µm x 8-35µm, smooth, irregular, slightly thick walled, 250-270 cells per mm^2, stomata distinct, anomocytic, stomata surrounded by a ring of subsidiary cells similar to cuticular cells which give the appearance of cyclocytic type of stomata, 20-30µm in size, guard cells wide, 22µm in width, inner wall of guard cell is swollen or thick, stomatal aperture wide, open, about 10µm in width. Stomatal density 20-30/mm^2 and stomata index is about 10.

Material: BSIP Museum slide no. 5. (Holotype).

Locality: Tarkeshwar Lignite Mine, District Surat, Gujrat, western India.

Horizon and Age: Cambay Shale Formation, Early Eocene.

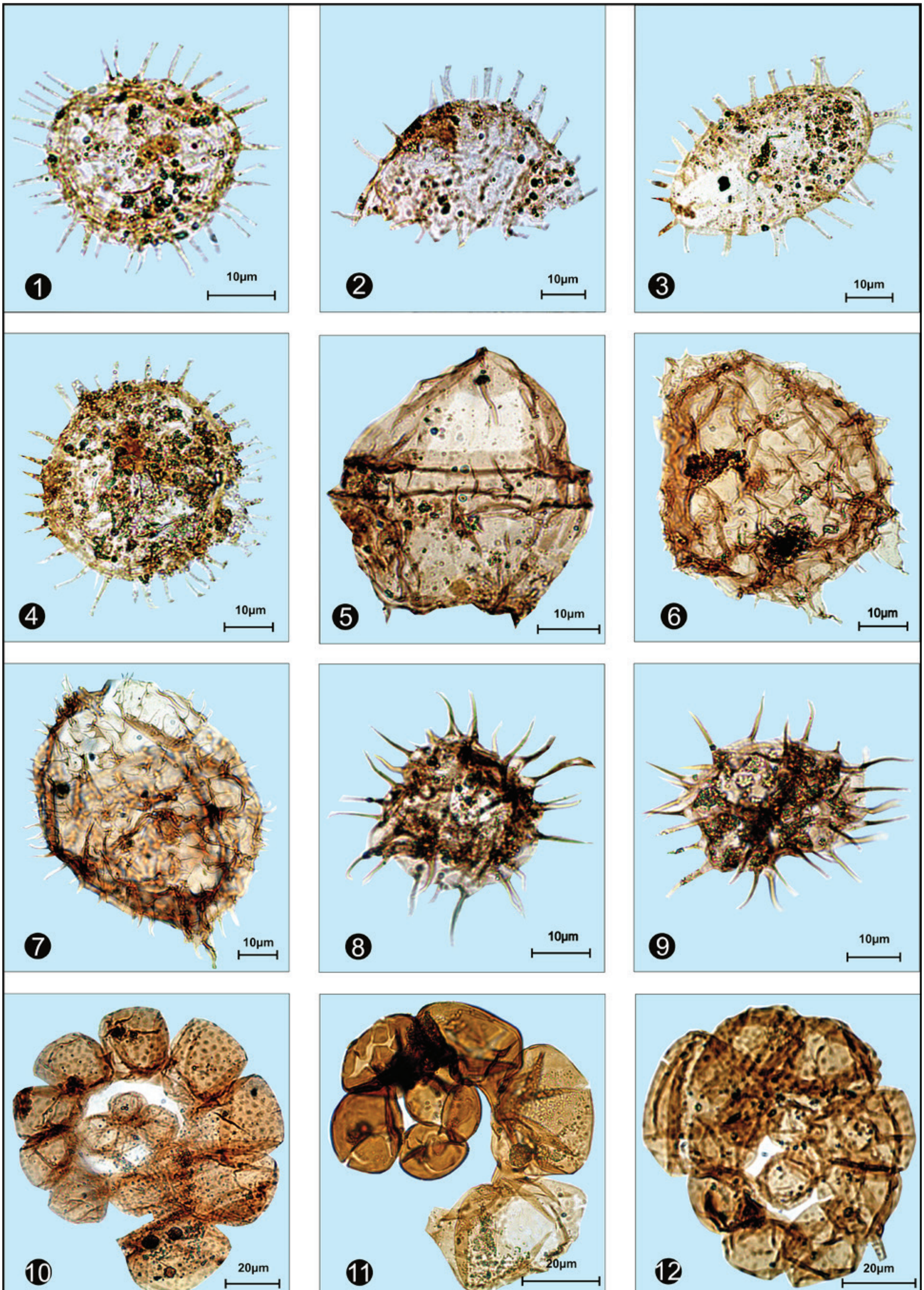
Etymology: Named after the epoch 'Eocene' to which fossil locality belongs.

Remarks: The characteristic features of the present fossil leaf cuticle are squire to rectangular cuticular cells with thick and smooth cell wall, anomocytic stomata surrounded by small rectangular cells, wide guard cell with thick inner walls. These features are found common in the modern cuticles of *Pterospermum acrifolium* Willd. (Malvaceae) *Mitragyne stipulosa* (DC.) Kutz. (Rubiaceae) *Cupania fulcat* A. Gray (Sapindaceae) *Chrysophyllum roxburghii* (Sapotaceae). *Guarea bijuga* C. DC, *Cedrella odorata* L. (Meliaceae), *Amosonia hirtella* (Apocynaceae), *Ambnoa potamophila* Croizat (Euphorbiaceae), *Ficus clusiodes* Miq. and F. *benjamina* L. (Moraceae). Of these, the modern cuticles of *Pterospermum acerifolium* Willd. and *Ficus benjamina* L. show the closest resemblance with the present fossil leaf cuticle. The fossil leaf cuticle (L. *eocenica*) has been compared with earlier known cuticles and found that it does not match any of them. The fossil cuticle L. *tarkeshwarensis* and L. *cambayensis* differ in nature of cuticular cells and subsidiary cell which are smaller in size and surrounding the stomatal complex. Thus, in being these differences it is described as *Lusatcutis eocenica* n. sp.

EXPLANATION OF PLATE XIV

Figs. 1-2. ***Polyspharedium subtile*** BSIP Slide no.15480, 15479; Figs. 3, 4. **cf. *Polyspharedium*** BSIP Slide no. 15480; Fig. 5. ***Lejeunecysta* sp**. BSIP Slide no. 15479; Fig. 6. ***Apectodinium* sp**. BSIP Slide no. 15482; Fig. 7. ***Apectodinium* sp**. BSIP Slide no.15481; Figs. 8-9. ***Selenopemphix armata* Bujak *et al.*** BSIP Slide no. 15479,15480; Figs. 10-12. **Foraminiferal linings** BSIP Slide no.15480.

Plate XIV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Lusaticutis sahnii n. sp.
(Pl. XIII, figs. 13,15)

Diagnosis: Cells rectangular to polygonal in shape, 10-15µm, x 12 x 25µm, cell wall smooth and thick, 80-100 cells per mm^2, stomata anomocytic, surrounded by usually 5 subsidiary cells, guard cells reniform, inner wall very thick, stoma almost circular, stomata index 12-15.

Description: Cuticular cells rectangular to polygonal in shape, medium to large size, 10-15µm, x 12 x 25µm, cell wall smooth and thick, irregular, 80-100 cells per mm^2, stomata anomocytic, medium size 12 x 18µm, surrounded by usually 5 subsidiary cells which are almost similar to the cuticular cells, guard cells reniform, guard cells about 17µm, inner wall very thick, 8µm, wide. Stoma almost circular, 15-20 per mm^2 and stomatal index 12-15.

Material: BSIP Museum specimen no. 5. (Holotype).

Locality: Tarkeshwar Lignite Mine, District Surat, Gujrat, western India.

Horizon and Age: Cambay Shale Formation, Early Eocene.

Etymology: This species is named after Prof. Ashok Sahni, an eminent palaeotologist.

Remarks: The most important features of the present fossil leaf cuticle are rectangular to polygonal, thick and smooth walled cuticular cells, anomocytic type of almost circular stomata, surrounded by 5-6 subsidiary cells similar to cuticular cells, reniform guard cells with very thick inner walls. A critical survey of the published literature on cuticular study (Cuticular data base, Barclay *et al*. *(*2007), Upchurch (1945), Payne (1979), Metcalf and Chalk (1950), Bandulska (1926) shows that the above features are formed common in the modern cuticles of *Guarea bijuga* C. D., *Cedrella odorata* L. (Meliaceae), *Zizyphus* sp. (Rhamaceae), *Amosonia hirtella, Alstonia scholaris, Alyxia floribunda* Mark (Apocynaceae) and *Bilschmiedia costaricensis* (Mez. and Pitter) C.K. Allon. The further observation on the cuticles of the above species suggests that *Alstonia scholaris* is only with which the present fossil leaf cuticle shows closest affinity.

On comparison of present fossil cuticle with already known fossils cuticles from Cenozoic sediments it has been found that none of them comparable to it. The fossil cuticle, *Lusaticutis tarkeshwarensis* differ in possessing crenulated cuticle cells with high density of stomata. *L.cambayensis* can be differentiated in being presence of sinuate cuticular cells as compared to smooth cells and the stomata are also unlikely looking like a apple in present fossil cuticles. Similarly *L. eocenica* possesses squire to rectangular cuticular cells as compared to mainly polygonal cells in the present fossil species. Further the subsidiary cell in *L. eocenica* arranged in a ring around the stomata. In view of this the present fossil cuticle has been described as *L. sahnii* n. sp.

6. Palynomorph taxa

Cyathidites minor Couper, 1953
(Pl. XIII, fig. 1)

Description: Spores triangular, 51-55µm, trilete mark distinct, Y-rays distinct, raised, trilete mark longer extending almost up to the equator, apices bluntly rounded lips thick, medium, ends sub rounded. Exine ±1.5µm –2µm thick, laevigate, equatorial folding present.

Remarks: *Cyathidites minor* (Couper 1953) has similar size range than the specimens investigated here. Besides, they have also concave-straight interapical margin. In Palaeogene age, it is also quite common in India. This species is also well-known in Jurassic and Cretaceous age group of sediments in the world.

Todiosporites kutchensis Sah and Kar, 1969
(Pl. XIII, fig. 2)

Description: Spores circular to sub circular in polar view, size range 60-67µm, trilete mark visible, trilete rays distinct extending up to two-thirds of radius. Exine 1.2-1.8µm thick, laevigate and folded.

Remarks: Spores assignable to *Todisporites kutchensis* Sah and Kar (1969) are subcircular in shape and have a larger size range viz. 75-101µm, than those first reported by Sah and Kar 1969 from the Lower Eocene localities of the Naredi Formation, Kutch. Trilete rays are distinct–indistinct and they do not extend more than two-thirds of the radius.

Dandotiaspora telonata Sah *et al*., 1971
(Pl. XIII, fig. 3)

Description: Spores triangular-subtriangular in polar view, 60-69µm. Trilete, rays extending up to three-fourths of radius. Exine 2-2.8µm thick, sometimes more thickened at apices, laevigate, sometimes intrapunctate at inter-radial areas, exine distally thickened opposite to trilete rays throughout, sometimes bifurcating or producing globular heads at ray ends.

Remarks: *Dandotiaspora telonata* (Sah *et al*., 1971) has similar size range than the specimen investigated from present study area. This species is more common in Meghalaya and Assam than in Kutch.

Lakiapollis ovatus Venkatachala and Kar, 1969
(Pl. XIII, fig. 4)

Description: Pollen grains spheroidal to subspheroidal, size range 51-70µm. Tribrevicolporate, colpi small 10-15µm. Spindle shaped, elongate, coarse, exine up to 2.5µm thick and smooth, but sometime verrucose, sexine thicker (2µm) than nexine. Aperture subiequatorial in position pores well developed oval elliptical outer margin thickened, pores situated sub-equatorially.

Lakiapollis ovatus Venkatachala and Kar, 1969
(Pl. XIII, fig. 5, 6)

Description: Pollen grains mostly sub-equatorial in polar view. Colpi not more than 9µm long, ± oval or funnel shaped, generally ill developed and not traceable in most of the specimens. Pores well recognizable oval-elliptical in outline, outer margin of the pores appreciably thickened sometimes more thickened at lateral ends of the pore. Exine 1.5-2.5µm thick, generally irregularly folded, sexine thicker then nexine, psilate without any discernible intrastructure.

Remarks for both above grains: The present species is closely comparable with *Lakiapollis ovatus* Venkatachala and Kar from Kachahh (Venkatachala and Kar, 1969). It also resembles *L. assamicus* Tripathi and Singh from Meghalaya (Tripathi and and Singh, 1985) except for a slight variation in the size of the grain and larger aperture in the present specimen.

Proxapertites microreticulatus Jain *et al*., 1973
(Pl. XIII, fig. 7)

*Description***:** Pollen grains bilaterally symmetrical, anisopolar, distally arched to provide a long colpus, covering more than two thirds of greater circumference. Pollen grain size range 50-55µm, exine about 2.1µm thick, intramicroreticulate, sexine thicker than nexine, retipilate. amb circular to sub circular or oval splitting in to saucer-shaped halves.

Remarks: This species is quite common in the present study material. The overall shape of the specimen is mostly sub circular with a pronounce suture at the margin; completely detached specimens are however rare. The microreticulation is mostly well-developed and the exine is sometimes irregularly folded.

Proxapertites cursus Van Hoeken-Klinkenberg, 1966
(Pl. XIII, fig. 8)

Description: Pollen grain subcircular, pollen grain size range 50-60µm, sometime split equatorially into two halves, reticulate, meshes may be bigger in size in equatorial and smaller in middle region. Exine 2µm thick.

Remarks: These species are also common in present study material. The shape of the pollen grain is subcircular and elliptical in equatorial view beside to polar view. Microreticulation is visible and well developed and exine sometime folded.

Acanthotricolpites bulbospinosus Kar, 1985
(Pl. XIII, fig. 9)

Description: Pollen grain sub-triangular in shape, size 56µm (including the spines), triporate, pores distinct, with medium thickened margins. Exine 1.5µm thick, spinose, spines 11-15µm long with tapering ends, sexine as thick as nexine spines with bulbous base and pointed tip, inter-spinal area psilate and covered with grana and bacula. Pollen grains almost always found in polar view, 36-53x37-54µm. Colpi broad, position of colpi easily distinguishable at margin but length can not be properly ascertained due to sculptural elements.

Remark: The present specimen is similar in all the morphological characters viz. number and size of apertures and ornamentation to *A. Bulbospinosus* Kar (1985).

Spinizonocolpites prominatus Stover and Evans, 1973
(Pl. XIII, fig. 10)

Description: Pollen grains subcircular to oval. Size range 46-53µm. Zonisulcate. Exine 1-1.5µm thick, spinose, spines 5-7.5µm long with pointed tips, interspinal area laevigate or microreticulate.

Remarks: Present specimen is closely similar in all the morphological character (shape, size) of all the described species. The exine, nexine and spinose with their microreticulate characters are also similar as described pollen grain.

Longapertites sp.
(Pl. XIII, fig. 11)

*Description***:** Pollen grain subcircular in polar view, elongately oval in shape, size range 60-65µm, monocolpate. Colpi generally indistinct, broad, exine 1-2µm finely reticulate, sexine is thick as nexine and clearly visible than sexine. These pollen morphotype are extensively recorded in Palaeocene-Eocene successions of India.

Remarks: Present form differs from the other species of the genus in possessing extraordinary long and stout spines. The interspinal exine is scabrate.

Matanomadhiasulcites maximus Kar, 1985
(Pl. XIII, figs. 12,13)

Description: Pollen grains broadly oval, large in size, 68-80µm. Monosulcate, sulcus indistinct, sometimes very broad, tapering at ends, exine 1µm thick, microreticulate, baculate, bacula small, 1µm, luminae about 2µm, pila 2-6µm long, 1-2.5µm broad, sometimes interspersed with bacula, pila closely placed, 1.0-2.5µm apart, forming negative reticulum in surface view.

Remarks: Kar, 1985 described *Matanomadhiasulcites maximus* which differs from *Liliacidites maximus* Saxena in having a uniform reticulum in the exine with smaller luminae generally 1µm in size. Pollen grain oval-elliptical in shape.

Tricolporopollis matanomadhensis (Venkatachala and Kar, 1969) Tripathi and Singh, 1985
(Pl. XIII, fig. 14)

Description: Pollen grain subcircular, medium in size, 50-61µm, tribrevicolporate, Aperture generally in subequatorial view, sometimes not discernible due to heavy ornamentation, colpi generally 6-10µm long, poorly developed, elliptical in shape, often appear as slits. Pore easily recognizable due to their thickened margin. Exine 2-4µm thick, sexine usually as thick as nexine, exine pilate and baculate, together forming reticulate pattern, meshes of different sizes and shapes.

Remarks: The present species is closely comparable in shape; size and morphological character of the pollen with the grain *Tricolporopollis matanomadhensis* Tripathi and Singh, 1985.

Barringtoniapollenites retipilatus (Kar and Sharma, 2001)
(Pl. XIII, fig. 15)

Description: Pollen grains oval-subcircular in shape, size range 41-62µm, exine thick, sexine and nexine well developed, retipilate, pila 2-3µm long, with swollen tip and narrow base, pila closely placed to form pseudoreticulation, trisyncolpate, colpi extending almost from one end to the other in equatorial view.

Remarks: Present species is bigger in size *Barringtoniapollenites retipilatus* Kar and Sharma, 2001. Otherwise all the morphological characters are similar as described Kar and Sharma, 2001. Pollen grain oval-subcircular, exine retipilate, trisyncolpate, colpi extending from end to end.

Ctenolophonodites retipilatus sp. 1
(Pl. XIII, fig. 16)

Description: Pollen grain spheroidal in polar and equatorial view, 55-55µm, nonacolpate (nine), colpi long and distinct. Ectexine thickened to form long, sinuous ridges on both sides, ridge overlap in polar and then extend towards mesocolpial region. Exine less than 2µm thick, ± laevigate.

Remarks: Spherical to subspherical pollen grain. Radially symmetrical. Nine colpate with the colpi fusing together at centre of the grain.

Ctenolophonodites costatus (Rao, 1990)
(Pl. XIII, fig. 17)

Description: Pollen grain subcircular in polar view, size range 51-60µm, octaacolpate, colpi medium and distinct, narrow, appearing as slit in polar view. Ectexine thickened to form long, sinuous ridges on both sides, ridge overlap in polar and then extend towards mesocolpial region. Exine less than 2µm, thick, ± laevigate weakly intrastructured.

Remarks: pollen grain circular to subcircular in shape. Radially symmetrical. Nine colpate with the colpi fusing together at centre of the grain.

Callimothallus assamicus (Kar *et al.,* 1972)
(Pl. XIII, fig. 18)

Description: Ascomata circular to subcircular in shape, size range 50-54µm, eccentric, radial and transverse hyphae, rectangular cells, cells porate, pores small, thick margined, cells towards the centre are smaller in size than those towards the periphery, cells distinguished along the margin of periphery. Pore 1-2µm in diameter in upper surface, usually at extreme proximal end of the cell slightly elevated, randomly spaced.

Remarks: Stroma round, often somewhat lobed, astromate, multiporous, entire to crenate margins, lack free hyphae, stroma 30-250µm in diameter, consist of radiating rows of cells which increase in number as the diameter of the stroma increases. Centre of the stroma consists of irregularly angled, often isodiametric cells 3-5µm in diameter. Central cells often much darker than the rest of the stroma, Radiating rows of cells extend outword from central cells. Individual cells in radiating rows, long, rectangular, often slightly wedge-shaped.

Callimothallus sp. 1
(Pl. XIII, fig. 19)

Description: Ascomata semidiscoidal, size range 60-67µm, slightly ecentric, nonostiolate, radial and transverse hyphae form almost rectangular cells, individual cell porate, pores small, thick margined, cells towards center are slightly smaller than those towards periphery distinctly marked constrictions along the peripheral margin.

Remarks: Stroma rounded, astomate, multipores. Cells exist radiating rows. The recovered specimen resembles close to the reported from the Cenozoic lignite sediments of Bhavnagar (Samant, 2000). Except larger size all the morphological characters are similar.

Phragmothyrites eocenica (Kar and Saxena, 1976)
(Pl. XIII, fig. 20)

Description: Ascomata circular to subcircular in shape with crenate to almost entire margin. Nonostiolate. Size range 66-74µm in diameter. Hyphae radially arranged and interconnected with each other to form mostly one-celled thick pseudoparenchymatous cells. Generally cells in the middle region less elongated than the marginal ones, marginal cells being darker and setose. In some specimens, cells of the central region bear a single pore in each cell, pore 1 to 2.5µm in diameter.

Remarks: The documented specimen resembles close to the specimen described by Singh, Saxena and Rao, 1986. All the morphological characters are similar.

Floral analysis and phytogeographical implication

A rich floral assemblage of the fossils comprising well preserved leaf impressions, semi carbonized woods, carbononized fruits, seeds, cuticles, pollen and spore and marine assemblage of the Dinoflagellate cysts and foraminiferal linings has been reported for the first time from Early Eocene (Cambay Shale Formation) of Tarkeshwar Lignite mine exposed in between the Village Tarkeshwar and Mandavi, Surat District Gujarat, western India. The fossil flora suggests significant change in the terrestrial ecosystem which is responssible for a rapid diversification and dispersal of plants after the establishment of Indian plants in the Tethys region. This change in climate is useful for their luxuriant gowth and development of deciduous forest in the tropical and subtropical regions of the world. The modern equivalents of these fossil biota are supposed to be a good proxy for phytogeographic reconstruction. Most of the fossil taxa identified with their modern equivalent are also significant for phytogeographic and palaeoclimatic point of view (Table 3).

In the present macrofloral assemblage all the leaf impressions have been allied to their modern analogs belonging to the dicotyledonous taxa, *Saurauia napaulensis* DC. (Actinidiaceae), *Calophyllum inophyllum* Linn. (Clusiaceae), *Drimycarpus racemosus* Hook. f. (Anacardiaceae), *Lagerstroemia macrocarpa* Wall. *Lagerstroemia flosreginae* Retz. (Lythraceae) and *Terminalia tomentosa* (Roxb.) Wight and Arn. (Combretaceae). The monocots are totally absent. These taxa growing presently either in evergreen or deciduous forests of north east and south India or south east Asian region (Myanmar, Sri Lanka, Malaya, Philippines, etc.) but they do not occur in the study area today, most probably due to unfavourable climate prevailed after the Eocene. In a small collection of fossil wood only four have been identified on the basis of their anatomical characters with the extant taxa *Walsura piscidia* Roxb. (Meliaceae), *Schleichera oleosa* Wild. (Sapindiaceae), *Diospyros pilosula* Wall. (Ebenaceae) and *Terminalia tomentosa* (Roxb.) Wight and Arn. (Combretaceae). The present day distribution of the comparable taxa indicates that they are distributed in the evergreen to moist deciduous forests of North east India and south-east Asian regions. *Walsura piscidia* Roxb. and *Diospyrus pilosula* Wall. also found to grow in South Indian region. None of them found presently in and around the fossil locality or even the western Indian regions.

The fossil fruits comparable to four extant taxa namely *Ziziphus xylopyros* Willd. (Rhamnaceae) *Combretum decandrum* Roxb., *Terminalia chebula* Retz. and *T. bellerica* (Gaertn.) Roxb. (Combretaceae) are described from the subsurface sedimentary sequences of Cambay Shale Formation exposed in Surat district, Gujarat, western India. The fossilized fruits are of great significance to provide data about the existence of the forest as they have limited potential for transportation and are responsible for the formation of lignite. One fruit has been referred to a new form species *Terminalia eobellerica*. The remaining three species are belonging to the fruits reported from the Vastan Lignite Mines, western India (Singh *et al.,* 2010). The habitat and present day distribution of extant taxa of these fruits suggests that a tropical decideous forest was in existence in the Tarkeshwar area during Early Eocene period.

The macro fossil flora is represented by a variety of taxa mainly trees and shrub belonging to 13 tropical to subtropical families namely Cyperaceae, Actinidiaceae, Malvaceae, Calophyllaceae, Meliaceae, Rhamnaceae, Sapindaceae, Anacardiaceae, Apocynaceae, Combretaceae, Lythraceae, Ebenaceae and Artocarpaceae. They are distributed in the evergreen to moist deciduous forest of different geographical regions and most of them are phytogeographically important.

The family, Actinidiaceae representing genus *Saurauia* Willd. is reported first time in Cenozoic sediments of Indian subcontinent. It is a small family of about 300 species. *Saurauia* Wild is a largest and important genus of this family comprising more than 250 species distributed in the tropical and subtropical regions of Asia and South and Central America. The modern comparable species, *S. napaulensis* D C. is a small evergreen tree presently found in the low altitude hills in Mizoram and Assam. It is totally extinct from the Tarkeshwar area of western India. The fossil record indicates the narrow distribution of this family in the past, Keller *et al*., 1996 reported some flowers and fruits of Actinidiaceae affinity from the Late Cretaceous of Georgia, America, The occurrence of fossil leaf *Saurauia eocenica* in the Early Eocene of Tarkeshwar lignite mine and fossil flowers and fruits of *Parasaurauia*, an extinct genus belonging to Actinidiaceae are suggestive of its Gondwanan origin.

Meliaceae includes only one fossil taxa *Walsura piscidia* Roxb. based on a fossil wood. At present this family is represented by about 51 genera and 565 species distributed in the tropical and subtropical region of world over. In the past, this family was also widely distributed in India and abroad (Bande and Prakash, 1984; Mehrotra, 1987; Prasad, 2008; Monteillet and Lappartient, 1981). Data mainly based on fossil woods and leaf impressions are known from late Cretaceous onwards. The following genera (*Swietenia, Trichilia, Toona, Chukrassia*, *Dysoxylum, Chloroxylon, Aglaia, Chisocheton, Aphnanamixis, Beddomia, Amoora, Heynea, Melia, Turraeanthus* and *Walsura)* are recorded from Cenozoic sediments of Indian subcontinent (Lakhanpal *et al.*, 1976; Prasad, 2008). The fossil records indicate that the origin of family Meliaceae in India goes back to Late Maastrichtian (Bande and Prakash, 1984; Mehrotra, 1989) and it has continued to present till now.

Malvaceae is represented by the genus *Pterospermum* Schreber based on the fossil leaf cuticles. It is an important family of Malvales including about 70 genera distributed in the tropical regions of both the hemispheres. *Pterospermum* Screber is a genus of wide distribution in the present and past. Both fossil leaves and petrified woods resembling the genus *Pterospermum* Schreber are reported from the Mio- Pliocene sediments of India. The fossil leaves, *P. palaeoheyneanum* Antal and Awasthi, 1993, *P. siwalicum* Antal and Prasad, 1996 and *P. mioacerifolium* are reported from Miocene (Siwalik) sediments of Darjeeling District, West Bengal. However the fossil wood, *Pterospermoxylon kutchensis* Awasthi et *al.,* 1980 reported from Pliocene of Kutch, Gujarat, western India and *Pterospermoxylon bengalensis* Roy and Mukhopadhyay, 2005 from Miocene (Tippam series) of west Bengal. Moreover, the occurrence of *Pterospermoxylon sahnii* Singh *et al.*, 2015 and *Pterospermoxylon kutchensis* Awasthi *et al*., 1980 from the Cambay Shale Formation (Early Eocene) of Vastan lignite mine and now Tarkeshwar lignite mine further suggests wider distribution of the genus *Pterospurmum* Schreber in the past. The record of one of the genus *Sterculia* Linn (*Sterculioxylon shahpurensis* Bande and Prakash, 1980) of this family from Late Cretaceous suggests the existence of family Malvaveae in India from Late Cretaceous onwards.

The family Calophyllaceae (previousely Clusiaceae) in the order Malpighiales was recognized by Angiosperm phylogeny group III, 2009 which is here represented by the presence of well preserved fossil leaf, *Calophyllum inophyllum* Linn. This genus comprises about 187 species distributed mostly in the tropics of Indo-Malayan regions. There is an abundant fossil record of this genus in the Cenozoic period specially recorded from Miocene of Himalayan fore land basin (Prasad, 2008). The other members like, *Kayea* Wall. and *Mesua* Linn. are also found along with this genus. The record of a fossil wood, *Calophyllum dharmendrae* from Deccan intertrappean bed of India (Bande and Prakash, 1980) represent its oldest record from the Indian subcontinents. The modern comparable species, *Calophyllum inophyllum* Linn. of the fossil leaf is a tall tree growing now a days in the evergreen forest of western and eastern peninsula, Malaya, Archipelago, Australia and Polynesia (Hooker, 1875) but do not found to grow in the locality areas where it was in existence during Early Eocene period. It was shifted to south wards due to prevalence of drier conditions after Early Eocene.

In the present assemblage the family Rhamnaceae is represented by a fossil fruit *Ziziphus eocenica*, Singh *et al.,* 2010 (also described from Eocene of Vastan Lignite) showing closest resemblance with a small, deciduous tree taxa, *Z. xylopyrus* which is native of India, Nepal and Sri Lanka. The family Rhamnaceae is widely distributed in tropical regions favoring towards drier climate. The genus *Ziziphus* is widespread in tropical to subtropical regions of Asia, Africa, North America, Oceania and Europe showing its abundance occurrence in the Asian regions. The oldest fossils of Rhamnaceous affinity are known from the Late Cretaceous rocks of Mexico (Calvilo-Canadell *et al*., 2007) and Maastrichtian sediments of Colombia (Correa *et al*., 2010). The record of some Rhamanaceous form species, *Rhamnus* sp. Udhoje and Verma, 1990, *Ziziphus ambabagholiense* Gaykward and Patil, 1993, *Rhamnoxylon intertrappea* Chitaley and Kate, 1972 and *Ziziphoxylon mandlaensis* Trivedi and Srivastava, 1982 from the Deccan trappean beds (Maastrichtian) show the earliest record in India. The recovery of fossil leaves of *Ziziphus* from throughout the Himalayan foreland basin (Miocene-Pliocene) of India and Nepal (Prasad, 2008) undoubtedly suggests that this genus is highly diversified during Miocene after its origin before late Cretaceous times.

Sapindaceae, a family of tropical to sub-tropical distribution is represented by the presence of a fossil wood, *Schleicheroxylon bharuchense* Singh *et al*. and a leaf cuticles *Lusaticutis tarkeshwarensis*. The family Sapindaceae comprises more than 137 genus and 1450 species distributed with their main centre of diversity in the south- east Asian region. The fossil record also shows its wide spread distribution during the past from late Cretaceous to Mio-Pliocene. Some sapindiaceous taxa like, *Sapindus, Cupania*, *Arytera, Harpulia*, *Euphoria, Lepisanthes, Nephelium* and *Paranephelium* are also recorded from the Miocene sediments of Himalayan foreland basin of India and Nepal. Moreover, two fossil leaves, *Sapindus billinicus* and *Sapindus falcifolius* are also reported from Eocene sediments of Barmer district, Rajasthan (Deshmukh and Sharma, 1978). The oldest record of the family Sapindaceae (*Sapindoxylon schleicheroides* Dayal, 1965 and *Euphorioxylon deccanensis* Mehrotra, 1987 are from Deccan intertrappean beds (Maastrichtian) of India. The modern equivalent taxa *Schleichera oleosa* (L.) Oken confined to fossil woods recoverd from the Tarkeshwar lignite mine was commonly found during the Early Eocene period in the fossil locality areas (Awasthi *et al.,* 1980; Singh *et al.,* 2015). However, it is today absent from these area and found to grow nowa days throughout southern Asia, Malaysian Archipelago and Philippines (Gamble, 1902), which suggests its migration towards south and south east wards due to existence of unfavourable condition after sedimentation.

The fossil leaf *Drimycarpus tarkeshwarensis* n. sp. is only taxa which represents the family Anacardiaceae. This leaf shows affinity with extant taxa, *D. racemosus* Hook f. having distribution in the evergreen forest of North east India, Bangladesh and Bhutan (Brandis, 1906). The family Anacardiaceae has pantropical distribution, grows mainly in the tropical regions of both the hemispheres. The fossil record representing woods, leaf, fruit and pollen is well documented from Cenozoic rocks of different geographical regions of India and abroad (Mehrotra *et al.*, 1998; Prasad, 2008; Srivastava *et al.,* 1992). The palaeobotanical data (pollen data) suggests that this family has originated in Cretaceous (Raven and Axelrod, 1974; Marting-Cabrera and Cevallos-Ferriz, 2004). Further, the abundant occurrence of Anacardiaceous fossil remains in the Oligocene sediments of Mexico and Oregon in South America suggests that this family is diversified during Oligocene from the centre (Mexico and some area in S. America) as demonstrated by high level of diversity and endemism (Ramifrez and Cevallos - Ferriz, 2002). Several important Anacardiaceous taxa like, *Mangifera indica* Linn. *Holarrhena antidysentrica* Wall. *Swintonia schwenkii* Teysn*, S. floribunda* Griff., *Bouea burmanica* Grif, *B. macrophylla* Griff, *Tapiria hirsuta* Hook.f., *Dracantomelum sylvestris* Blume, *Drimycarpus racemosus* (L.) Oken are also recorded from Miocene sediments of India and Nepal. It shows high level of diversification during Miocene in Indian sub continent. *Eomangiferophyllum damalgiriense* (Mehrotra *et al.*, 1998) from Palaeocene of Northeast India, *Melanorroeophyllum suratum* (Singh *et al.,* 2015) from Early Eocene of Vastan lignite mines and *Drimycarpus tarkeshwarensis* in the present assemblage are suggestive of the earliest record of the family Anacardiaceae in India.

The family Combretaceae is one of the important constituent in this floral assemblage comprising fossil wood, (*Terminalioxyon felixii,* Ramanujam), fossil leaf (*Terminalia Sahnii* n. sp. and fossil fruits (*Terminalia cambaya* Singh *et al.,* 2010 and *Terminalia eobellerica* n. sp.) showing affinity with extant taxa *Terminalia tomentosa* (Roxb) W. and A, *T. Chebula* (Retz.) Willd. and *T. bellerica* (Gaertn.) Roxb. Combretaceae is cosmopolitan in distribution throughout the tropics with limited extensions into warm temperate zone of South America, Africa, Australia and China. It consists of about 20 genera and 500 species of mainly tree or shrubs found to grow from sea level to 300m above sea level (Stace, 2007). *Terminalia* Linn. is a largest genus of this family comprises 150 species and has a cosmopolitan distribution mainly in south east Asian regions. There are global reports of fossils of wood, leaves, fruits and palynomorphs from Cretaceous onwards (Velenovsky, 1883, 1889; Geyler, 1887; Nemejc, 1975; Ball, 1931; Schimper, 1874; Berry, 1916, 1919; Principi, 1914; Weyland, 1942; Krausel, 1903; Unger, 1867; Hollick, 1936; LaMotte, 1952). In India, it is also well documented from the Cenozoic sedimentary sequences of different formations (Prasad, 2008; Puri, 1966; Lakhanpal and Guleria, 1981; Agarwal, 2002; Mehrotra, 2000; Prasad *et al.*, 2013). The oldest fossils of *Terminalia* are known from the Upper Cretaceous of Bohemia (Velenovsky, 1883); Purtgal (Friis *et al.*, 1992) and *Terminalia panandhroensis* Lakhanpal and Guleria, 1981 from Lower Eocene of Kutch district, Gujarat, and from Palaeocene of Cherrapunji, Meghalaya N.E. India, *Terminalia cambaya* Singh *et al.*, 2010 from Eocene of Vastan lignite mine western India and two petrified fossil wood showing their affinity with extant taxa, *Terminalia tomentosa* W. and A. also reported from the Eocene sediments of western India (Mahabale and Deshpande, 1965, Prakash and Dayal, 1966. Thus fossil record of the genus *Terminalia* Linn (also see Table 2, 3) it is evident that *Terminalia* Linn. has continued from the Late Cretaceous to the present and it was widely diversified during the Cenozoic period in India. The genus *Combretum* is another member representing the family Combretaceae and widely spread throughout India from Miocene to Late Cretaceous (Prasad, 2008; Prakash and Dayal, 1966; Mehrotra, 2000; Singh, *et al.,* 2010, 2011, 2015). Stace, 2007 also cataloged the fossil remains of the genus *Combretum* from Late Cretaceous of Purtgal.

The family Lythraceae comprises about 31 genera and 600 species distributed in the tropical and subtropical regions of throughout the world. In the Tarkeshwar flora Lythraceae is represented by *Lagerstromia premacrocarpa* n. sp. and *L. Patelii* Lakhanpal and Guleria, 1987. They occur primarily in the moist and wet habitats including stream site, mangroves and marshes. Family has its extensive fossil record from India and abroad viz. from Middle Eocene of British Columbia (Cevallus - Ferriz and Stockey, 1988), Middle Eocene of Oregon (Manchester, 1994), Miocene of Bohemia (Kvacek and Sakala, 1999) from Oligocene of Chivon and Salcedo (Principi, 1914), Pliocene of Saromaziana (Principi, 1914, from Cenozoic sediments of Mexico, Russia, England, Germany the Czech Republic and North America (Tiffney, 1981), from Middle Miocene of India and Nepal (Prasad, 2008, Khan *et al*., 2011), Lower Miocene of Kasauli (Arya and Awasthi, 1995), from Early Eocene of Vastan lignite mine (Singh *et al.,* 2010, 2015) and from Late Cretaceous of Deccan (Trivedi, 1956). Thus it is obvious that the family Lythraceae was also widely spread during the Cenozoic period. The fossil record and present day distribution of this family suggests that it is originated during the Late Cretaceous and diversified during the Eocene.

Ebenaceae, a family of bony is represented by a fossil wood, *Ebenoxylon kalagarhense* showing affinity with *Diospyros pilosula* Wall. *Diospyros* Linn. Is the well known genus of the family Ebenaceae comprises about 470 species and distributed in tropical and subtropical region of the world with greater diversity in the Indo-Malayan regions. The genus is also widely distributed during the past. Based on fossil wood about 25 form species have been reported from Pliocene to late Cretaceous of throughout the world (Kaiser, 1890; Platen, 1908; Prakash andBarghoom, 1961; Slijper, 1932; Prakash and Tripathi, 1970; Awasthi, 1970; Chitaley and Patil, 1972; Prakash, 1978, 1981; Trivedi and Srivastava, 1982; Prasad, 1989, 1993; Navale, 1968). *Ebenoxylon ebenoides* described from Late Cretaceous of Libyan Desert is the oldest record (Kaiser, 1890). In India the oldest record of this family is also goes back to Late Cretaceous from where two fossil woods *Ebenoxylon mohagaoense* Chitaley and Patil, 1972 and *E. deccanensis* Trivedi and Srivastava are reported. Similarly, based on fossil leaves, more than 75 form species are reported from all over the world (India, Japan, Panama, Africa, Bohemia, Canada, Europe, England, Greek, Greenland, etc). Out of these about 12 form species are described from the Indian subcontinent (Prasad *et al*., 2015). The earliest record of fossil leaf, *Diospyrophyllum provectum* Linn. cf *Diospyros* goes back to Upper Cretaceous of Bohemia (Velenovsky, 1883). Thus, from the past and present distribution of *Diospyros* Linn. it is evident that this genus has a cosmopolitan distribution in the geological past.

The microfloral assemblage recovered from Tarkeshwar lignite mine, Gujarat, western India is quite diverse and highly rich comprising spore, pollen, algal remains and fungal bodies. Angiosperms are dominated over the pterodophytic and fungal remains. These palynofossils previously not reported particularly from the sedimentary sequences of Tarkeshwar lignite mine of the Cambay shale formation except from amber (Singh *et al*., 2014). The Pteridophytes are represented by *Cyathidites minor*, *Todiosporites kutchensis, Dandotispora telonata*. The fungal spores are *Callimothallus assamicus, Callimothallus* sp. and *Phragmothyrites eocenicus* of the family Microthyricaceae. The angiospermous pollen grains are identified to 11 taxa namely, *Lakiapollis ovatus, Proxapertites microreticulatus, Proxapertites* *cursus, Acanthotricolpites bulbospinosus, Spinizonocolpites prominatus, Longapertites* sp., *Matanomadhiasulcites maximus, Tricolporopollis matanomadhensis*, *Barringtoniapollenites retipilatus, Ctenolophonidites retipilatus, Ctenolophonidites costatus.* Pteridophytic taxa in Tarkeshwar assemblage show their affinity with the family Cythiaceae, Osmundaceae and a fern family Matoniaceae. These are cosmopolitan in nature and widely distributed in tropical to sub tropical environmental conditions. The microthyricaceous thallus is indicative of tropical humid and moist climatic conditions.

The angiosperm palynotaxa, *Matanomadhiasulcites maximus* is widely reported from the Cenozoic sediments of India. It supposed to be a marker pollen grain of the Palaeocene-Eocene age (Saxena, 1991; Upadhay *et al.*, 2004). Previousely, these pollen taxa was allied with the family Liliaceae (Saxena and Ranhotra, 2009) and later on it was attributed to the family Annonaceae (Tripathi and Srivastava, 2012). The Arecaceous palynotaxa like *Proxapertites, Acanthotricolpites, Spinizonocolpites* and *Longapertites* represent monocot group of plant and are indicative of humid and warmer conditions, as this family is pan- tropical confined to equatorial zone. The coastal environmental is reflected by the *Nypa* pollen (*Spinizonocolpites)* which is a mangrove element. Such mangroves are mainly found all along the equatorial and mostly in tropical climate with high precipitation regions (Dercourt *et al.,* 1993). Some palynotaxa referable to *Lakiapollis ovatus* (Bombaceae), *Ctenolophonodites reticulates* and *Ctenolophonodites* sp. (Ctenolophonaceae), *Tricolporopollis matanomadhensis* (Euphorbiaceae) indicate the presence of fresh water swamps.

Palaeoclimatic implications

The palaeoclimatic interpretation of fossil plants study of any geological formation is one of the important aspects of the palaeobotanical study in any particular area. The Cenozoic fossils are supposed to be the best indicator of past climates specially those fossils that are accurately identified with extant taxa. It is possible only for those fossils whose modern equivalent taxa still exist in the forests of different phytogeographical regions. As the fossils herein are recorded from the early Eocene of Tarkeshwar Lignite Mine Gujarat, and most of them have been identified with their corresponding extant taxa, it has therefore become easier to interpret the palaeoclimate of the Tarkeshwar area in western India. It follows the nearest living relatives phytogeography and is based on the assumption that the climate requirements of a fossil taxon are similar to its modern equivalents. The physiognomic characters of the fossil plants (wood and leaves) are supposed to be a parameter for interpreting the palaeoclimate. The floral assemblage recovered from the Tarkeshwar lignite mines (early Eocene) near Tarkeshwar, Surat, western India comprises 19 fossil taxa and were identified with their extant taxa (Table 3). The present habit and habitat of these taxa indicate that they usually occur in the tropical evergreen to moist deciduous forest of northeastern regions of south India, Myanmar and south-east Asia. Some of them are common in the Indo-Malayan region. Thus it may be inferred that a tropical warm humid climate prevailed in Tarkeshwar and nearby areas of western India. The dominance of evergreen elements in the assemblage, suggests the existence of a tropical climate with plenty of rainfall. Most of the comparable taxa of the macrofossils (wood and leaves) do not occur in the vicinity of the fossil locality, Tarkeshwar or even the western India. Thus this indicates that the change in climatic conditions must have taken after the deposition of the Tarkeshwar Lignite deposits.

The physiognomic features of the fossil leaves have been used for determining palaeoclimate, however, the number of taxa is far low for such an approach. The leaf margin, leaf size, venation density, texture and leaf tip have a good relationship with climate. Bailey and Sinnot (1916) opined that the woody plants of tropical lowlands possess entire margins, while in temperate regions they possess non-entire margins. The Tarkeshwar leaf assemblage comprises six fossil taxa and all of them possess entire margin. Thus it may suggest that there was low land tropical forest locality. The other physiognomic feature, leaf size is also considered as a indicator for climate. The leaf size of any forest type is correlated with available moisture and it has been observed that the bigger leaves occur in the understory evergreen forests and size decreases with low temperate or precipitation (Raunkiear, 1934). The leaf sizes of all the fossil taxa in the present assemblage are of mesophyll and macrophyll type and thus further indicate the prevalence of high temperature and precipitation during deposition. Similarly, the venation density and leaf texture of these fossil taxa also suggests the same climate during their growth.

The physiognomic (xylotomical) features of the fossil wood, like vessel size and vessel density, nature of xylem rays, simple and scalriform perforation plates and amount of parenchyma, play an important role in deciphering the palaeoclimate (Wheeler and Baas, 1993; Marting – Cabvera and Cevallos Ferriz, 2004; Wheeler and Baas, 1933) observed that the diameter and density of vessels may be used to differentiate tropical or temperate conditions. The diffuse porous woods (uniform size of the vessels) are characteristic of a little seasonality and the ring porous woods are of a marked seasonal climate. As all the fossil woods in the present assemblage are diffuse porous in nature, it may be suggested that there was a prevalence of tropical climate with a little seasonality. Similarly, the presence of medium to large vessels with a simple perforation plate, presence of high amount of parenchyma and the absence of vasicentric trachids in the fossil woods of present collection further suggest the prevelance of tropical climate with higher precipitation (Wolfe and Upchurch, 1987).

The investigation on a large number of microfossils collected from Eocene of Cambay Shale Formation revealed the occurrence of only four morphotype of seeds. These seeds show their resemblance with the extant genera, *Fimbristylis* Vahl., *Cyperus* Linn. and *Dulichium* (L.) Birtton of the family Cyperaceae. The morphological study of these seeds has great importance for drawing the evolutionary trend and phylogenetic similarity in the different taxa. Based on seed morphology Simpson *et. al.* (2003, 2007) clarify that the distinctive sub-family Mapainioideae is sister to the rest of Cyperaceae in the order Poales. Chandler (1963) for the first time reported some Cyperaceous taxa from Middle Palaeocene (Lower Cenozoic) of England. Some of the entire fruits and endocarps are also documented from the Palaeocene – Eocene of Eurasia (Chandler, 1978; Mai, 2000). According to Smith *et al.* (2009), these micro fossil seeds have the potential to clarify our understanding of evolutionary trend in the family Cyperaceae. He further opined that cyperaceae (sedge family) is an ecologically important monocot family dating back- at least to the Palaeocene. In overall, the existence of Cyperaceous taxa in the Eocene of western India and Europe (Smith *et al.,* 2009) and Palaeocene of England (Chandler, 1963) might be suggested its origin during the Gondwana period.

Table 3. Affinity, Climate, and ecology of macro and micro fossils recovered from Tarkeshwar Lignite Mines, Gujrat, India.

Affinities	Fossil taxa	Climate	Ecological group
Cyathiaceae	*Cyathidites minor*	Tropical-subtropical	Moist and wet condition
Osmundaceae	*Todiosporites kutchensis*	Tropical-subtropical	Low land
Matoniaceae	*Dandotispora telonata*	Tropical-subtropical?	Swamp/water edge
Microthyricacea	*Callimothallus* sp.	Tropical-subtropical	Humid tropical
Microthyricacea	*Phragmothyrites eocanica*	Tropical-subtropical	Humid tropical
Microthyricacea	*Notothyrites setiferus*	Tropical-subtropical	Humid tropical
Arecaceae	*Proxapertites microreticulatus*	Tropical-subtropical	Near shore environment
Arecaceae	*Proxapertites cursus*	Tropical-subtropical	Mangrove swamp/ Sandy Beach element
Arecaceae	*Acanthotricolpites bulbospinosus.*	Tropical-subtropical	Sand dune/ Beach element
Arecaceae	*Spinizonocolpites prominatus*	Tropical-subtropical	Mangrove swamp/sandy beach element
Arecaceae	*Longapertites sp.*	Tropical-subtropical	Sand dune/Beach element
Cyperaceae	*Fimbristylis eocenica* n, sp.	Tropical to subtropical	Wet ground
Cyperaceae	*Cyperus palaeolaevigata* n, sp.	Tropical	Coastal, wetland
Cyperaceae	*Cyperus sahnii* n, sp.	Tropical to Warm temperate	Wet muddy
Cyperaceae	*Dulichium tertiarum* n, sp.	Tropical	Fresh water, Wetand
Annonaceae	*Matanomadhiasulcites maximus*	Tropical-subtropical	Evergreen forest
Calophyllaceae	*Calophyllum eocenicum* n. sp.	Tropical	Coastal conditions
Actinidiaceae	*Saurauia eocenica* n. sp.	Tropical	Fresh water, Lowhll tracct
Bombacaceae	*Lakiapollis ovatus*	Tropical-subtropical	Low land
Meliaceae	*Walsura tarkeshwerensis* n. sp.	Tropical	Low land diciduous forest
Rhamnaceae	*Ziziphus eocenica*	Tropical	Fresh water, Low land
Anacardiaceae	*Drimycarpus tarkeshwarensis* n. sp.	Tropical	Fresh water, Evergreen forest, Low land
Lythraceae	*Lagerstroemia palaeomacrocarpa* n. sp.	Tropical	Fresh water, Low land
	L. patelii	Tropical	Moist places, Evergreen forest
Combretaceae	*Terminalia sahnii* n. sp.	Tropical	Fresh water, Low land
Combretaceae	*Terminalia cambaya*	Tropical	Fresh water, Low land
Combretaceae	*Terminalia eobellerica*	Tropical	Fresh water, Low hil tract, Evergreen to moist deciduous
	Terminalioxylon felixii	Tropical	
Combretaceae	*Combretum vastaensis*	Tropical	Low height land
Ctenolophonaceae	*Ctenolophonidites retipilatus*	Tropical-subtropical	Fresh water swamp/water edge
Ctenolophonaceae	*Ctenolophonidites* sp.	Tropical-subtropical	Fresh water swamp/water edge
Lecythidaceae	*Barringtoniapollenites retipilatus*	Tropical-temperate?	Beach and swamps
Euphorbiaceae	*Tricolporopollis matanomadhensis*	Tropical-subtropical	Low land
Sapindaceae	*Schleicheroxylon bharuchense*	Tropical to Subtropical	Moist deciduous, Low hill tract
	Lusaticutis tarkeshwarensis n. sp.	Tropical	Low land
Artocarpaceae	*Lusaticutis cambayensis* n. sp.	Tropical	Low land
			Evergreen forest
Malvaceae	*Lusaticutis eocenica* n. sp.	Tropical	Coastal Wetland
Apocynaceae	*Lusaticutis sahnii* n. sp.	Tropical	Foreste, stream sites
Ebenaceae	*Ebenoxylon kalagharense*	Tropcal	Low hill tract, Evergreen forest

The family Cyperaceae is one of the largest families of monocotyledon and comprises more than 5500 species belonging to about 90 genera. These species are widely distributed in both tropical and temperate regions. The ecological diversity of this family is cosmopolitan occurring in almost all the habitats except extreme desert and marine and deep water. The Cyperacian species are the major components of stable wetland communities and is played major role in wetland ecosystems. These genera like *Cyperus, Eleocharis*, *Fimbristylis* and *Schoenoplectus* are the first colonizers on the bare soils of newly wetland.

The fossil cuticles are also one of the important palaeobotanical tool used to focus on both taxonomic identification of species and on the assessment of palaeoclimatic condition (Dilcher and Zenk, 1968; Kowach and Dilcher, 1984; Lee *et al.,* 1990; Rowelt *et al.,* 1994; Royer and Sparrow, 1994; Salisbury, 1928). The cuticular data available so far from the Indian subcontinent are not so sufficient so that we faced difficulty to identify the fossil cuticles up to specific/generic level. Upchurch and Dilcher (1990) and Upchurch (1995) also opined that the available cuticular data/characters are only sufficient to suggest affinity to the family and orders. Taking into the consideration the above fact the authors are able to identify only four morphotype out of a large (about 50) disperse cuticle. These morphotypes have been described under a form genus *Lusaticutis* instituted by Roselt and Schneider (1969) for those cuticles having cellular structure with anomocytic stomata. Based on diagnostic features of cuticles such as cellular structures, cell density, nature of subsidiary cells and stomata density and nature of guard cells. These cuticles have been identified with the modern cuticles of different taxa of dicotyledonous families. The fossil cuticles having distinct anatomy are useful for inferring the palaeoecology and palaeoclimate. Arens (1997) suggest that the sun leaves have different morphological characteristic than shady leaves. The degree of crenuation on cell wall as present in *Lusaticutis tarkeshwarensis* and *L. cambayensis* can be used to differentiate between sun and sunshade leaves in both fossil and modern plants. The number of stomata per squire mm (stomatal density) is also useful for determining the plant habit. The stomatal density tends to be lower for shade-adapted leaves. The stomatal density and stomatal index are higher in the two species, *Lusaticutis tarkeshwarensis* and *L. cambayensis* recorded from Eocene sediments of western India, which is suggestive of the cuticles of sun leaves. Further both of them the cuticular cells are not smooth but they crenuate and sinuate which also indicate the cuticles are from a sun leaf. The overall features preserved in the present cuticles such as hypostomatic nature of cuticles, smooth surface wall (*Lusaticutis eocenica* and *L. sahnii*) superfacial stomata and the nature of subsidiary cells are indicative of a mesophytic type of forest under heavy precipitation and humidity.

The presence of rich Microthyriaceous fungal remains along with pteridophytic spores (*Cyathidites minor* and *Dandotispora telonata*) in the sedimentary succession also supports a tropical to sub tropical climate with heavy rainfall. A considerable number of fossil taxa especially palynotaxa, *Proxapertites microreticulatus*, *P. cursus, Acanthotricolpites bulbospinosus, Spinizonocolpites prominatus, Longapertites* sp.*, Cyperus tarkeshwarensis, Calophyllum eocenicum, Baringtoniapollenites retipilatus* and *Lusaticutis eocenicus* are indicative of coastal or near-shore environment of deposition of the Cambay Shale Formation of the Cambay basin and Dinoflagellate cysts completely support marine environment it means the area was clearly close to coastal region. However most of the macrofossil taxa along with some palynotaxa show fresh water conditions, thus these are indicative of the confluence of a river with the sea. The overall flora interestingly indicates that this area was covered by dense ever green rain forest in a tropical-subtropical environment in a humid moist climate near the shore line, where fresh water rivers connected with the sea and these forest plants contributed to the formation of huge lignit deposits.

Plant–Insect Herbivore Diversity

The angiosperms of the early Eocene Cambay Shale Formation had been attacked by herbivorous insects. However, considering the incidence of insect damage on individual host species, the diversity of damage type is not high. Interestingly, insect damage at the (Pl. III, fig. 1, 2) and galling (Pl, VI, fig. 1, 2) whereas external foliage feeding seems to be rare (Pl, V, fig. 2, 3). In the early and middle Eocene leaf floras from North America, Patagonia and Europe show a marked increase in the amount and diversity of insect damage and specialized associations (Wilf *et al*., 2005; Currano *et al*., 2008, 2010; Wappler *et al*., 2012). This increase in diversity appears to be highly correlated with rising temperature CO_2 levels as well as plant diversity. Thus, the Eocene Cambay Shale flora probably records high herbivore pressure as is seen in modern Neotropical rainforests (Coley and Aide, 1991), couple with characteristic elevated insect-feeding diversity and host-specialized feeding associations (Dyer *et al*., 2007).

CONCLUSIONS

A palaeobotanical investigation has been carried out on the early Eocene Lignite and Shale sedimentary sequences of the Cambay Shale Formation, Surat District, Gujarat. The fossil-bearing Lignite and associated Shale bed contains a dominance of angiosperrmous taxa followed by pteridophytic spores and fungal remains. The recovered assemblage of macro- and microfossils clearly indicates a dense and varied forest environment of early Eocene age in the Cambay Basin, Gujarat, during the period of sedimentation.

Biostratigraphically significant macro and microfloral assemblage were extracted for the first time from the sedimentary succession of the Tarkeshwar locality.

The dominance of angiospermous pollen (especially from palm) *Proxapertites microreticulatus, Proxapertites cursus, Acanthotricolpites bulbospinosus, Spinizonocolpites prominatus, Spinizonocolpites echinatus* and *Longapertites* sp. followed by pteridophytic spores, fungal remains, dinoflagellate cysts and foraminiferal linings. The assemblage of macro and microfossils clearly indicate a dense evergreen rain forest during early Early Eocene age in the Cambay Basin, Gujarat. The flora also indicates mangrove-rich forest near the shoreline which served as the source material for the formation of lignite.

Well preserved fossil woods, leaves, fruits, seeds and leaf cuticles occur in some of the sedimentary sequences and spores/ pollen were found in most of these sedimentary successions. They revealed autumnal season in a storm environment. The rich palynoflora indicates a flowering season, as angiosperm pollen is abundant and dominate in most of the succession. Some of the amberised fossil flowers also fully support flowering season. The large carbonized fossil timber also indicating storm conditions and flood plain environment near the shoreline during sedimentary deposition.

The recovered palynofloral assemblages are closely similar to the other Eocene localities of India. These taxa (*Dandotiaspora telonata, Proxapertites reticulates, Proxapertites curcus, Longapertites* sp. and *Matanomadhiasulcites maximus*) are similar to the floral assemblage of other localities in the Cambay Formation, Vagadkhol Formation, Matanomadh Formation, Panandhro (Gujarat) and Akli formation, Kapurdi Formation, Palana Formation and Marh formation (Rajasthan). Micro palynofloral taxa are indicative of mixed forest under a tropical-sub tropical palaeoclimate with high rainfall and humidity.

All the recorded plant families in the floral assemblage are existed in India since the Late Cretaceous and have a worldwide distribution at present.

A variety of mega plant fossils (e.g., woods, leaves, fruits, seeds and leaf cuticles) showing close resemblance with 19 extent taxa belonging to 13 angiospermous families and are reported for the first time from the Tarkeshwar Lignite Mine. The present day distribution of all the extant taxa indicates that a tropical humid climate prevailed in the study area during Paleocene-Eocene times. The habit and habitat of most of the taxa indicate fresh water condition in low land depositional setting of the sediments. The extant taxon, *Calophyllum inophyllum* along with some palynotaxa mainly belonging to families Arecaceae, Lythraceae and Dipterocarpaceae indicate evergreen rain forest.

Arecaceous pollen assemblages suggest coastal humid tropical environmental condition during deposition. The diversified vegetational complex indicates a dense, mixed vegetational forest ecosystem.

The occurrence of dinoflagellate cysts and foraminiferal linings (Pl. XIV, Figs. 1-9) in certain levels clearly indicates marine environment, whereas large quantity of arecaceous pollen fully supports a near-shore environment exhibiting mixing of marine and terrestrial elements. The relative abundance of the various species of the genus *Apectodinium* (Bankole *et al*.,

2007) indicates deposition of the formation during the global Palaeocene-Eocene thermal maximum.

Palaeobotanical study shows that the sediments were deposited under a tropical to sub-tropical climatic conditions near to a coastal site in proximity to the palaeo-shoreline.

The whole floral assemblage shows an aquatic to swampy and marshy to brackish and cosmopolitan mangrove rich mixed vegetational ecosystem.

The presence of good amount of fungal remains within the palynofloral assemblage indicates a warm and humid climate with high precipitation.

The recorded terrestrial and marine evidences indicate a confluence of riparian and marine environments at Tarkeshwar in the Early Eocene during the deposition of sediments.

ACKNOWLEDGEMENTS

The authors are grateful to the Director, BSIP for providing the infrastructure facilities and permission (Permission letter No. BSIP/RDCC/Publication no. 98/2016-17) to publish the paper. Authors thanked to Dr. R.K. Saxena (Former Tertiary Division Head), BSIP for his constructive suggestions on palynoflora. We are also grateful to Dr. T. Danial University of Lasi, Romania and Dr. Vartika Singh BSIP for their valuable suggestions on Dinoflagellate cysts. We are also thankful to authorties of GMDC, Tarkeshwar, lignite mine for permission and support to collect the fossil materials from his mine sites. Thanks are also due to the authority of Central National Herbarium, Sibpur, Howrah for giving permission to consult the Herbarium during the identification of leaves and fruit fossils. Hukam Singh express sincere gratitude to the the Science and Engineering Research Board (SERB), New Delhi for providing the DST sponcered project for financial support (Project No. EEQ/2016/000112).

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Manuscript received : May 2018

Manuscript accepted : October 2019