

Some new fossil woods from the Cuddalore Sandstone of south India

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ABSTRACT

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Five petrified woods showing affinities with *Hopea* of the family Dipterocarpaceae, *Berrya* of Malvaceae, *Eucalyptus* of Myrtaceae and *Diospyros* of Ebenaceae are systematically described from the Cuddalore Sandstone Formation exposed near Puducherry, Tamil Nadu. Among them, four are new species, namely *Hopenium tertiarum* sp. nov., *Berryoxylon cuddalorensis* gen. et sp. nov., *Eucalyptoxylon cuddalorensis* sp. nov. and *Ebenoxylon cuddalorensis* sp. nov. Their modern counterparts indicate the existence of wet evergreen forests in the region during the depositional period. However, most of the modern comparable forms of the fossils are absent from the region today and found in the Western Ghats and northeast India having equable climate thereby indicating a change in the climatic conditions in the eastern coast of south India since the late Cenozoic.

Key-words—Fossil wood, Late Miocene–early Pliocene, Palaeoclimate, Phytogeography.

दक्षिण भारत के कुड्डालूर बलुआपत्थर से प्राप्त कुछ नूतन जीवाश्म काष्ठें

एन. अवस्थी, आर.सी. मेहरोत्रा एवं अनुमेहा शुक्ला

सारांश

पुडुचैरी, तमिलनाडु के निकट अनावरित कुड्डालूर बलुआपत्थर शैलसमूह से प्राप्त डिप्टेरोकार्पेसी कुटुंब के *होपिया*, माल्वेसी के *बेरीया*, मायरटेसी के *इयुकेलिप्टस* तथा इबेनेसी के *डिओस्पीरोज* से सदृशता रखती हुई पांच अशमीभूत काष्ठें वर्गीकरणतः वर्णित की गई हैं। इनमें से नामतः *होपेनियम टर्टिएरम* जाति नवम, *बेरीऑक्सीलान कुड्डालोरेन्सिस* वंश प्रकाशन नवम, *इयुकेलिप्टॉक्सीलॉन कुड्डालोरेन्सिस* जाति नवम एवं *इबेनॉक्सीलॉन कुड्डालोरेन्सिस* जाति नवम चार अभिनव जाति हैं। अंचल में निक्षेपणीय अवधि के दरम्यान उनके प्रतिस्थानी आर्द्र सदाहरित वनों की विद्यमानता प्रकट करते हैं। तथापि, जीवाश्मों के ज़्यादातर आधुनिक तुलनीय प्ररूप अंचल में आज नदारद हैं तथा पश्चिमी घाटों एवं उत्तर पूर्व भारत में मिलते हैं, एक-सी जलवायु होने से विलंबित नूतनजीव से दक्षिण भारत के पश्चिमी तट में जलवायवी स्थितियों में परिवर्तन द्योतित कर रहे हैं।

सूचक शब्द—जीवाश्म काष्ठ, विलंबित मध्यनूतन—प्रारंभिक अतिनूतन, पुराजलवायवी, पादप भूगोल।

INTRODUCTION

Cuddalore Sandstone Formation named after the Cuddalore Town of Tamil Nadu is exposed along the east coast of south India and considered as late Miocene to early Pliocene in age (Wadia, 1966). The formation consists of lateritised and ferruginous sandstones which are light pink and dirty white in colour, medium to coarse grained

in texture (Krishnan, 1968; Kumarasamy, 2012). Though a lot of fossil woods are known from the Mio–Pliocene sediments of India, the Cuddalore Sandstone Formation exposed near Puducherry (11°54'49.8954" N; 79°48'52.0986" E) in the Villupuram District of Tamil Nadu is the richest in permineralised woods. So far, a number of fossil woods were described by many workers from Murattandichavadi, Ayyankuttipalayam, Kasipalayam and Tiruchitambalam

localities of this district. Guleria (1992) has enlisted these woods and since then only a few have been added to this list (Jeyasingh & Devadoss, 1996; Kumarasamy, 2012). In the present communication, we describe five new fossil woods collected from Murattandichavadi and Ayyankuttipalayam localities which are situated 4–10 km NW of Puducherry, in the Villupuram District of Tamil Nadu (Fig. 1). The woods are silicified and satisfactorily preserved to reveal the structural details.

The woods were cut into thin sections, viz. transverse, tangential longitudinal and radial longitudinal and their slides were prepared by the standard method of cutting, grinding and polishing (Lacey, 1963). The thin sections were examined under the high power microscope and photographed. Their identification was made by examining thin sections of modern woods and consulting published literature. The anatomical terms used in describing these woods are those adopted by Wheeler *et al.* (1986), International Association

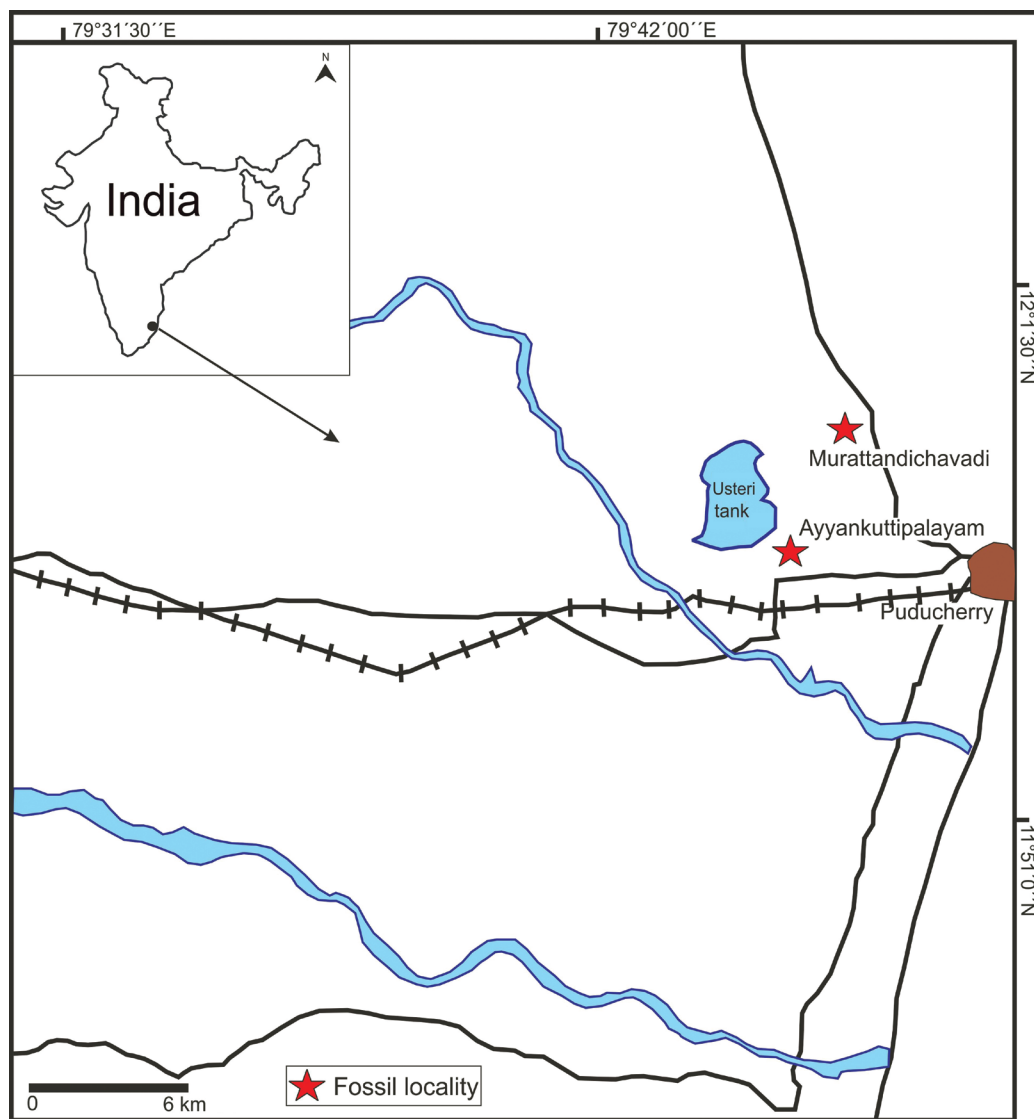


Fig. 1—Location of fossil localities near Puducherry.

PLATE 1

Hopenium tertiarum Awasthi *et al.*, sp. nov.



1. Cross section (CS) showing a tangential row of gum canals and distribution of vessels.
2. CS magnified to show vasicentric axial parenchyma intermingled with vasicentric tracheids (marked by arrows).
3. Tangential longitudinal section (TLS) showing ray pattern.
4. TLS magnified to show upright cells interspersed among procumbent cells (marked by arrows).
5. Vested intervessel pits.

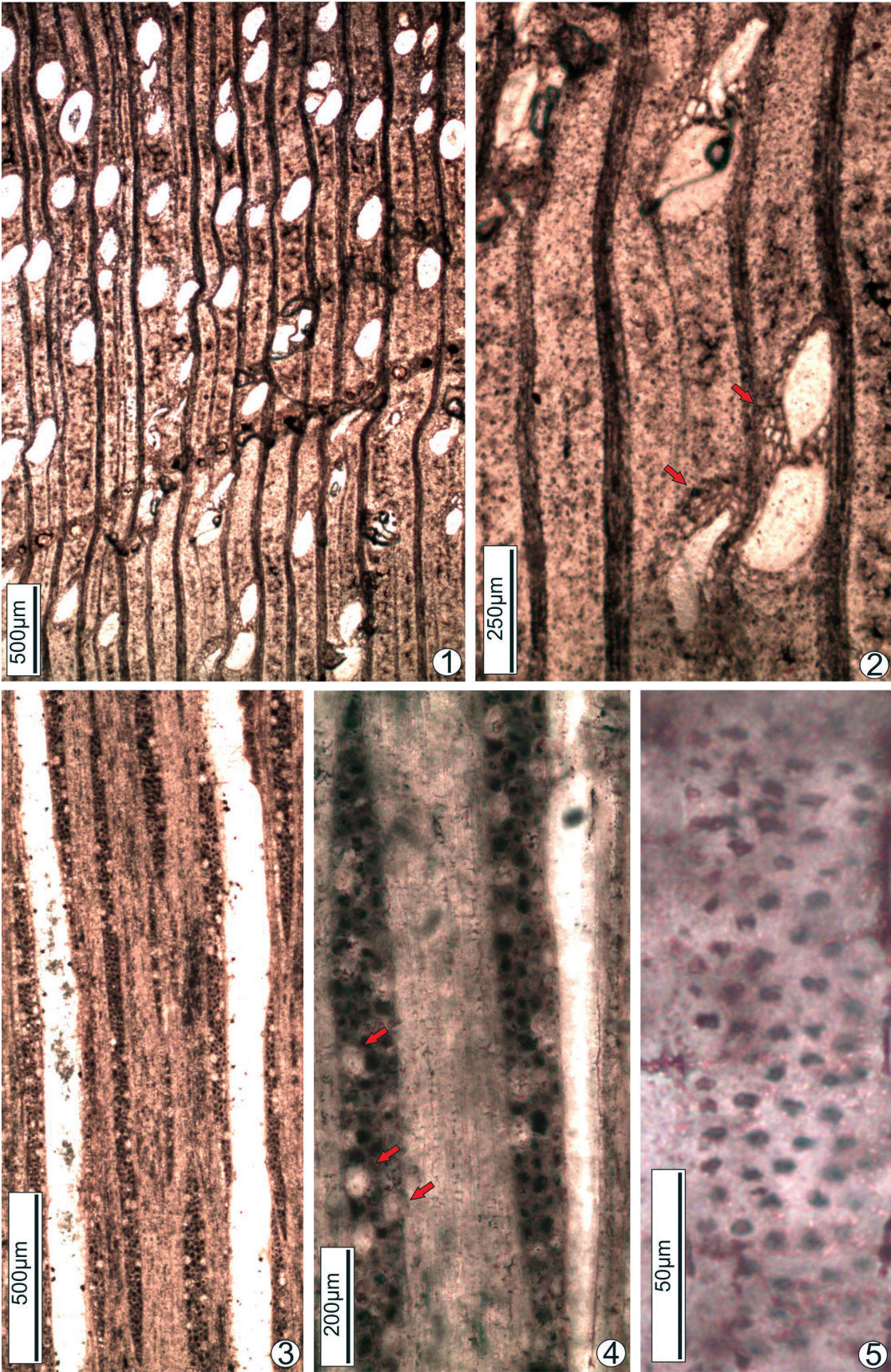


PLATE 1

of Wood Anatomists (1989) and insidewood database (<http://insidewood.lib.ncsu.edu>). The type slides are deposited in the Museum of the Birbal Sahni Institute of Palaeosciences, Lucknow (India).

SYSTEMATICS

Family—DIPTEROCAPACEAE

Genus—HOPENIUM Awasthi (1980)

Hopenium tertiarum Awasthi *et al.*, sp. nov.

(Pl. 1.1–5; Pl. 2.1–5)

Diagnosis—Wood diffuse-porous. Growth rings absent. Vessels small to medium, tangential diameter range 90–160 μm , mean 130 μm , mostly solitary, rarely in radial pairs, mostly oval in shape, sometimes compressed to various shapes, evenly distributed, occasionally tylosed; vessel elements range 440–580 μm , mean 513 μm , with oblique to horizontal ends, storied at places; perforations simple; intervessel pits poorly preserved, bordered, alternate, seemingly vested. Vasicentric tracheids present. Axial parenchyma paratracheal and apotracheal, paratracheal parenchyma intermingled with vasicentric tracheids, forming 1–4 celled sheath around the vessels; apotracheal parenchyma diffuse and in the form of tangential bands enclosing gum canals; parenchyma strands storied; cells thin walled. Rays 1–4 (mostly 3–4) seriate, uniseriate rare, multiseriate up to 100 cells or > 2 mm high and 51–72 μm wide, heterocellular, crystalliferous upright cells interspersed among the procumbent cells all along the rays; tangential height of procumbent and upright or square cells 16–29 μm and 31–86 μm respectively. Fibres thick-walled and non-septate. Gum canals normal, vertical, mostly aligned in tangential rows and enclosed in parenchyma bands, sometimes solitary also, circular to oval, small to very small, 38–85 μm in diameter.

Holotype—Specimen No. BSIP 41588.

Horizon—Cuddalore Sandstone Formation.

Locality—Murattandichavadi near Puducherry, Villupuram District, Tamil Nadu.

Age—Late Miocene–early Pliocene.

Affinities—The anatomical features of the fossil such as diffuse porous wood, mostly solitary vessels plugged with tyloses, vasicentric tracheids, rows of vertical gum canals enclosed in parenchyma bands, simple perforation plates,

cystalliferous upright cells interspersed among the procumbent cells, heterocellular rays and non-septate fibres indicate its affinity with the extant taxa of the family Dipterocarpaceae (Pearson & Brown, 1932; Metcalfe & Chalk, 1950; Kribs, 1959; Miles, 1978; Ilic, 1991). On the basis of arrangement of gum canals, the extant genera of the family have been divided into two groups (Ghosh, 1958): (i) gum canals always in concentric rings (e.g., *Shorea* Roxb., *Doona* Thwaites, *Hopea* Roxb., *Parashorea* Kurz., *Pantacme* A. DC., *Balanocarpus* Bedd. and *Dryobalanops* C.F. Gaertn.) and (ii) gum canals diffuse, solitary and in short tangential rows (e.g., *Anisoptera* Korth., *Dipterocarpus* C.F. Gaertn., *Vatica* L., *Vateria* L. and *Cotylelobium* Pierre). As the present fossil possesses gum canals in concentric rings, it was compared with *Shorea*, *Doona*, *Hopea*, *Parashorea*, *Pantacme*, *Balanocarpus* and *Dryobalanops* and showed close resemblance with the modern genus *Hopea*. The other genera can easily be differentiated in not having upright cells interspersed among the procumbent cells. The fossil wood was further compared with the extant species of *Hopea* and found very similar to *Hopea helferi* (Dyer) Brandis.

Fossil woods showing resemblance with *Hopea* are described under the organ genus *Hopenium* (Awasthi, 1980) and a number of fossil woods systematically described under this genus are: *Hopenium pondicherriense* Awasthi (1980) from the Cuddalore Sandstone of south India, Siwalik of Kalagarh (Prasad, 1993) and Neogene sediments of Bhavnagar, Gujarat (Shukla *et al.*, 2013), *H. neyveliense* Awasthi (1984) from the Neyveli Lignite Mine, *H. kalagarhensis* Prasad & Prakash (1988) and *H. prenutasoides* from the Siwalik of Kalagarh Prasad & Prakash (1988), *H. payangadiensis* Awasthi & Srivastava (1990) from the Neogene sediments of Payangadi, Cannanore District, Kerala and *Hopenium* sp. cf. *Hopea odorata* (Prakash *et al.*, 1994) from the Tipam Sandstone of northeast India. The present fossil was compared with the known fossil species of *Hopea* but found them anatomically different. *Hopenium pondicherriense*, *H. neyveliense*, *H. prenutasoides* and *Hopenium* sp. are different from the present fossil in having more parenchyma, while *H. kalagarhensis* and *H. payangadiensis* can be separated out in having smaller rays. As the present fossil wood is different from the known fossil woods of *Hopea*, it is described with a new specific name, *Hopenium tertiarum* Awasthi *et al.*, sp. nov.

Hopea helferi is a large tree found in the semi-evergreen to evergreen forests of Cambodia, India (Andaman), Malaysia, Myanmar and Thailand.

PLATE 2

Hopenium tertiarum Awasthi *et al.*, sp. nov.



1. TLS showing storied vessel elements (marked by arrows).
2. TLS showing storied parenchyma strands (marked by arrows).
3. Showing vasicentric tracheids (marked by arrows).
4. Radial longitudinal section (RLS) showing heterogeneous ray tissue.
5. RLS showing vessel–ray pits.

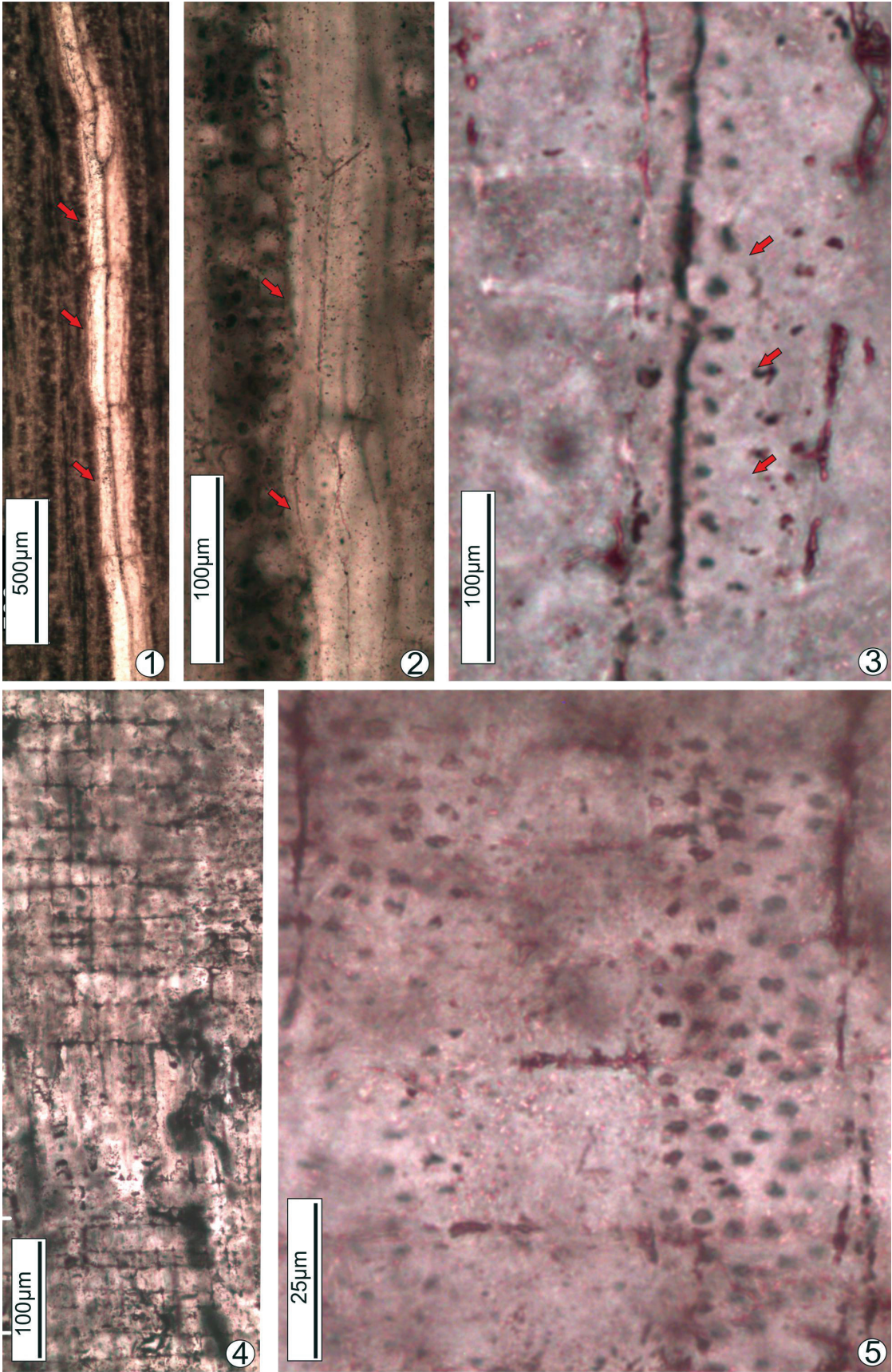


PLATE 2

Family—MALVACEAE**Genus—BERRYXYLON** Awasthi *et al.*, gen. nov.***Berryoxylon cuddalorensis*** Awasthi *et al.*, gen. et sp. nov.

(Pl. 3.1–6)

Diagnosis—Wood diffuse-porous. Growth rings present marked by marginal parenchyma bands. Vessels small to medium, mostly medium in size, tangential diameter range 87–166 µm, mean 133 µm, solitary and in radial multiples of 2–5, evenly distributed, 8–10 per sq mm, usually round to oval, tylosed; vessel members range 180–362 µm, mean 271 µm, with transverse to oblique ends, occasionally storied; perforations simple; intervessel pits bordered, alternate, 6–8 µm, with lenticular apertures. Axial parenchyma both paratracheal and apotracheal, paratracheal vasicentric to aliform-confluent, apotracheal diffuse. Rays 7 to 8 per mm, 1–4 (mostly 2 to 3) seriate, storied, uniseriate rays about 25 µm in width and up to 280 µm in height, multiseriate rays 27–61 µm in width and 9–23 cells or 185–482 µm in height, ray to ray fusion present, homo to heterocellular, usually made up of procumbent cells, with 1 row of upright or square cells; ray tissue weakly heterogeneous. Fibres thick-walled and non-septate.

Holotype—Specimen No. BSIP 41589.

Horizon—Cuddalore Sandstone Formation.

Locality—Murattandichavadi near Puducherry, Villupuram District, Tamil Nadu.

Age—Late Miocene–Pliocene.

Affinities—The main characteristic features of the fossil wood are: diffuse-porous wood, growth rings marked by marginal parenchyma bands, simple perforations plates, bordered intervessel pits with lenticular apertures, vasicentric to aliform-confluent and diffuse axial parenchyma, storied vessel elements and parenchyma strands, 1–4 (mostly 2 to 3) seriate, storied, homo to heterocellular rays and non-septate fibres. They show its affinity with the extant woods of *Berrya* (family Malvaceae), especially with *B. cordifolia* (Willd.) Burret (Pearson & Brown, 1932; Metcalfe & Chalk, 1950; Kribs, 1959; Miles, 1978; Ilic, 1991).

Berrya is a genus of evergreen trees found in Southeast Asia and the Pacific Region. As there is no fossil wood, known so far, showing similarities with the genus *Berrya*,

we are describing it under a new genus *Berryoxylon* Awasthi *et al.*, gen. nov.

Generic diagnosis—Wood diffuse porous. Growth rings present marked by marginal parenchyma bands. Vessels small to medium, evenly distributed, tylosed; vessel members with transverse to oblique ends, weakly storied; perforations simple; intervessel pits bordered, alternate, with lenticular apertures. Axial parenchyma both paratracheal and apotracheal, paratracheal vasicentric to aliform-confluent, apotracheal diffuse. Rays 1–4 seriate, storied, ray to ray fusion present, homo to heterocellular; ray tissue weakly heterogeneous. Fibres non-septate.

Genotype—*Berryoxylon* Awasthi *et al.*, gen. nov.

Family—MYRTACEAE**Genus—EUCALYPTOXYLON** Shukla *et al.* (2014)***Eucalyptoxylon vagadkholensis*** Shukla *et al.* (2014)

(Pl. 4.1–4)

Description—Wood diffuse-porous. Growth rings indistinct. Vessels small to medium (mostly medium), tylosed, mostly solitary, rarely in pairs, arranged in oblique pattern of 4–6 vessels, round to oval in shape, 14–18 per sq mm, tangential diameter range 76–159 µm, mean tangential diameter 127 µm; vessel elements range 80–400 µm with transverse to oblique ends, mean 188 µm. Perforations simple; intervessel pits not visible; vasicentric tracheids present, appearing as a thin sheath around the vessels. Axial parenchyma both apotracheal and paratracheal, apotracheal parenchyma diffuse, scattered among fibres and paratracheal parenchyma scanty, a few cells associated with the vessels; cells thin walled, 27–33 µm long and 18–20 µm wide. Rays fine, 15–18 per mm, almost exclusively uniseriate, homo to heterocellular, made up of mostly procumbent cells, 7–14 in width and 4–8 cells or 64–153 µm high; tangential height of procumbent and upright or square cells 13–16 µm and 17–21 µm respectively. Fibres thick-walled and non-septate.

Figured specimen—Specimen No. BSIP 41590.

Horizon—Cuddalore Sandstone Formation.

Locality—Ayyankuttipalayam near Puducherry, Villupuram District, Tamil Nadu.

PLATE 3*Berryoxylon cuddalorensis* Awasthi *et al.*, gen. et sp. nov.

1. CS showing shape, size and distribution of vessels and marginal parenchyma.
2. TLS showing structure of rays.
3. Showing storied vessel elements.
4. Intervessel pits showing lenticular apertures.
5. CS magnified to show vasicentric to aliform-confluent parenchyma.
6. RLS showing weakly heterogeneous ray tissue.

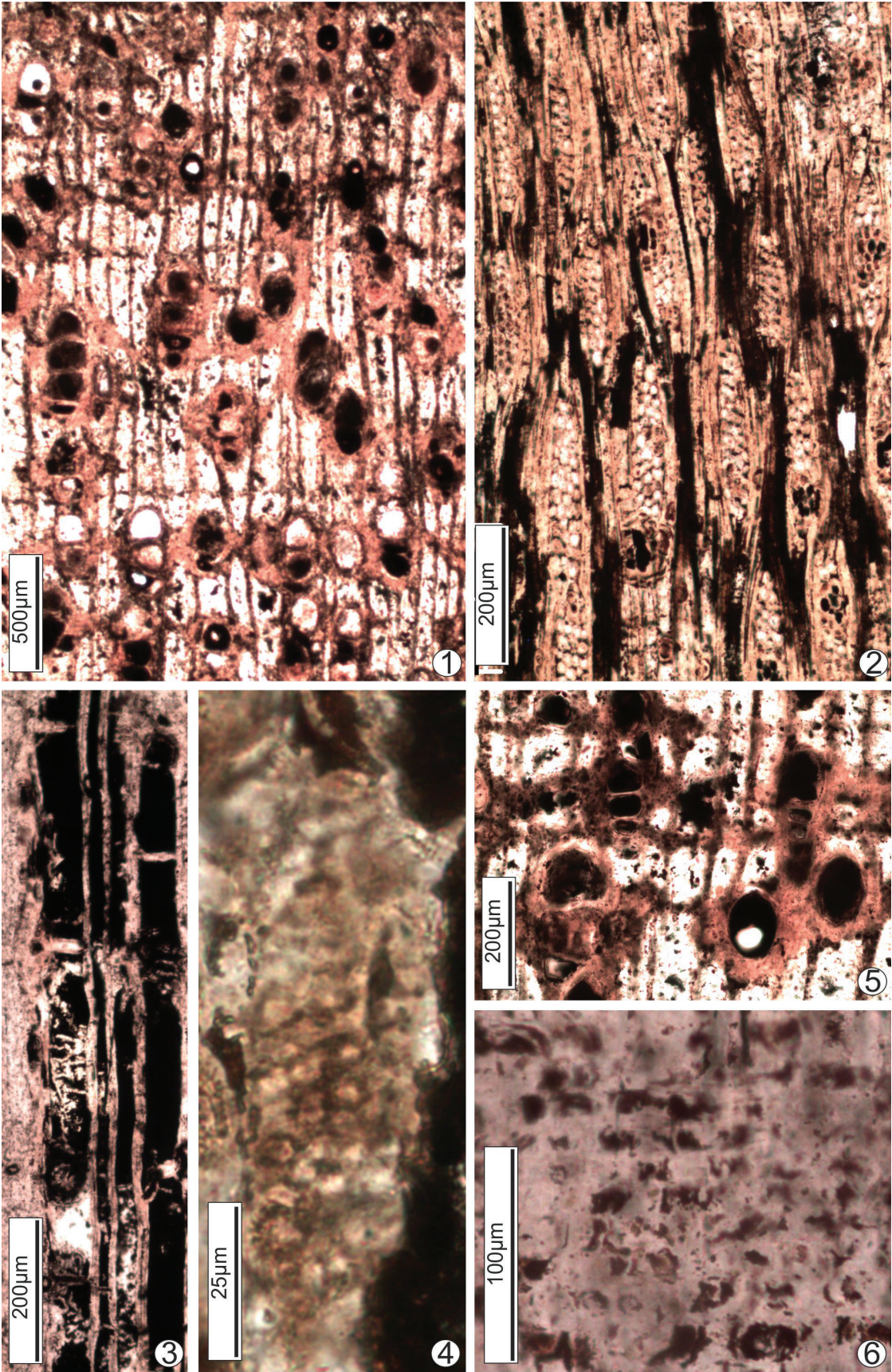


PLATE 3

Age—Late Miocene–Pliocene.

Affinities—The anatomical features of the fossil wood such as diffuse–porous wood, mostly medium sized solitary and tylosed vessels arranged in oblique pattern of 4–6 and plugged with tyloses, vasicentric tracheids, apotracheal diffuse parenchyma scattered among fibres and scanty paratracheal parenchyma, simple perforation plates, exclusively uniseriate rays and non–septate fibres indicate its affinity with the extant woods of Myrtaceae (Metcalfe & Chalk, 1950; Kribs, 1959; Miles, 1978; Purkayastha *et al.*, 1982; Ilic, 1991). Among the genera of this family *Eucalyptus* L' H'ér., *Melaleuca* L. Nom. Cons. and *Xanthostemon* F. Muell. share many similarities with the present fossil. However, extant woods of *Melaleuca* can be separated in having aliform to confluent parenchyma in comparison to diffuse parenchyma in the fossil, while *Xanthostemon* has heterocellular rays in contrast to homocellular rays in the fossil. The fossil wood shows maximum similarities with that of *Eucalyptus*.

The fossil woods of *Eucalyptus* have been described under the organ genus *Eucalyptoxylon* Shukla *et al.* (2014) and till date two fossil woods have been described under this genus, i.e. *E. vagadkholensis* Shukla *et al.* (2014) from the Palaeocene–early Eocene of Bharuch, Gujarat and *E. eocenicus* Shukla *et al.* (2014) from the Eocene of Bikaner, Rajasthan. Further, two more fossil woods resembling *Eucalyptus* have been placed under the modern genus and described as *Eucalyptus dharmendrae* Bande *et al.* (1986) and *E. ghughuensis* Shukla *et al.* (2012) from the Deccan Intertrappean beds of Madhya Pradesh. The present fossil wood was compared with them and found close to *Eucalyptoxylon vagadkholensis* Shukla *et al.* (2014). However, a slight variation was observed in the rays which in the previously described fossil are longer than that of the present fossil. *Eucalyptoxylon eocenicus* differs from the present fossil in having broader (1–3 seriate) rays, *Eucalyptus dharmendrae* can be distinguished due to septate fibres, while *Eucalyptus ghughuensis* is a semi–ring porous wood and thus is different from the present fossil. As the present fossil wood is more or less similar to *Eucalyptoxylon vagadkholensis* Shukla *et al.* (2014), it has been described under the same specific epithet.

A few years back Kumarasamy (2012) also described a fossil wood of *Eucalyptus dharmendrae* from the Cuddalore Sandstone of south India. After going through its description and photographs it has been found that it does not resemble *Eucalyptus*. It lacks the diagnostic features of the modern genus such as echelon arrangement of vessels, vested pits

and absence of tyloses. Though the author has mentioned vasicentric tracheids in the description, yet no photograph of the same was furnished. Hence, its affinity with *Eucalyptus* remains doubtful.

***Eucalyptoxylon cuddalorensis* Awasthi *et al.*, sp. nov.**

(Pl. 5.1–5)

Diagnosis—Wood diffuse–porous. Growth rings absent. Vessels mostly small to sometimes very small in size, tangential diameter range 35–77 μm , mean 58 μm , almost exclusively solitary, rarely in radial pairs, evenly distributed, 25–35 per sq mm, usually round to oval, tylosed; vessel members range 65–270 μm , mean 158 μm , with transverse to oblique ends; perforations simple; vasicentric tracheids present forming a thin sheath around most of the vessels, tracheidal pits in 1 or 2 rows and 3 to 4 μm in size. Axial parenchyma both paratracheal and apotracheal, paratracheal scanty and intermingled with tracheids, apotracheal diffuse to diffuse–in–aggregate; parenchyma cells thin–walled, 39–107 μm in length and 11–19 μm in width; crystals present in parenchyma cells. Rays closely spaced, 16–22 per mm, 1–2 seriate, heterocellular, made up of procumbent cells in the middle portion with 1–2 rows of upright cells at the end of the rays; ray cells 11–14 μm in tangential height. Fibres thick–walled and non–septate.

Holotype—Specimen No. BSIP 41591.

Horizon—Cuddalore Sandstone Formation.

Locality—Murattandichavadi near Puducherry, Villupuram District, Tamil Nadu.

Age—Late Miocene–Pliocene.

Affinities—The diagnostic features of the fossil are: diffuse–porous wood, mostly small–sized, almost exclusively solitary vessels plugged with tyloses, simple perforation plates, vasicentric tracheids, axial parenchyma both paratracheal and apotracheal, scanty paratracheal parenchyma intermingled with tracheids, apotracheal diffuse to diffuse–in–aggregate, crystals in parenchyma cells, 1 to 2 seriate, heterocellular rays and non–septate fibres. They indicate similarity of the fossil with the family Myrtaceae (Metcalfe & Chalk, 1950; Kribs, 1959; Miles, 1978; Purkayastha *et al.*, 1982; Ilic, 1991). The extant taxa of this family, viz. *Eucalyptus*, *Melaleuca* and *Lophostemon* show close affinities with the fossil wood. However, *Melaleuca* can be separated out on the basis of more paratracheal parenchyma, while *Lophostemon* can be distinguished due to the absence of crystals in parenchyma.

PLATE 4

Eucalyptoxylon vagadkholensis Shukla *et al.*



1. CS showing echelon arrangement of vessels plugged with tyloses.
2. TLS showing vasicentric tracheids (marked by arrows).
3. TLS showing exclusively uniseriate rays.
4. RLS showing heterogeneous ray tissue.

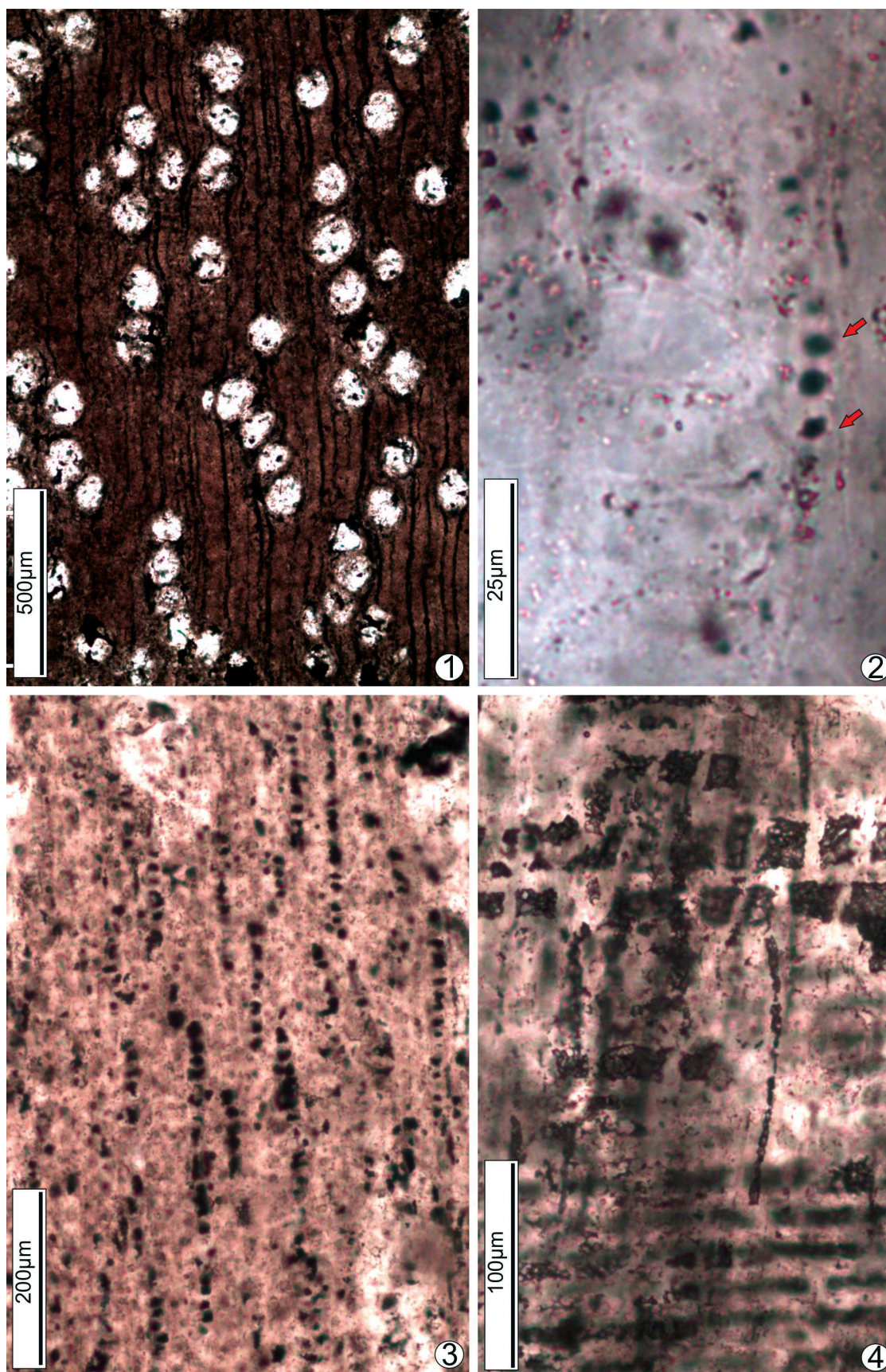


PLATE 4

The fossil wood shows maximum similarities with the modern woods of *Eucalyptus*.

The present fossil wood was compared with the known fossil woods (mentioned in the previous pages) resembling *Eucalyptus* but found different from them in having crystals in parenchyma cells and absence of well developed echelon arrangement of vessels, therefore, it is described under a new specific name, *Eucalyptoxylon cuddalorensis* Awasthi *et al.*, sp. nov.

Family—EBENACEAE

Genus—EBENOXYLON Felix (1882)

Ebenoxylon cuddalorensis Awasthi *et al.*, sp. nov.

(Pl. 6.1–5)

Diagnosis—Wood diffuse-porous. Growth rings absent. Vessels small to medium, tangential diameter range 70–184 µm, mean 126 µm, solitary as well as in radial multiples of 2–5, sometimes in tangential pairs, irregularly distributed, 5–7 per sq mm, round to oval, tylosed; vessel-members range 90–270 µm, with oblique to horizontal ends, mean 170 µm; perforations simple; intervessel pits bordered, alternate, oval, small, about 4 to 5 µm in diameter with linear-lenticular apertures. Axial parenchyma apotracheal, diffuse to diffuse-in-aggregate in the form of predominantly uniseriate, irregular, tangential lines; cells 40–50 µm in length and 15–25 µm in width. Rays 1 to 2 seriate, predominantly uniseriate, biseriate rays made up of procumbent cells in the middle portion with upright or square cells at the ends, 6–11 per mm, 14–18 µm in width and 3–10 cells or 81–259 µm in height; crystals observed in ray cells. Fibres thick-walled and non-septate having bordered pits of 2–4 µm.

Holotype—Specimen No. BSIP 41592.

Horizon—Cuddalore Sandstone Formation.

Locality—Murattandichavadi near Puducherry, Villupuram District, Tamil Nadu.

Age—Late Miocene–Pliocene.

Affinities—The fossil wood possessing anatomical features like diffuse-porous wood, simple perforation plates, bordered pits in fibres, diffuse to diffuse-in-aggregate axial parenchyma, 1 to 2 seriate, heterocellular rays indicates its close affinity with the modern woods of *Diospyros* L. of the family Ebenaceae (Pearson & Brown, 1932; Metcalfe & Chalk, 1950; Kribs, 1959; Ilic, 1991). The fossil wood was compared

with thin sections of the modern woods of *Diospyros* available at the Birbal Sahni Institute of Palaeosciences, Lucknow, besides its published descriptions and photographs (Pearson & Brown, 1932; Metcalfe & Chalk, 1950; Kribs, 1959; Ilic, 1991; Kazmi, 1982). The fossil shows best resemblance with *Diospyros malabarica* (Desr.) Kostel.

Felix (1882) instituted the genus *Ebenoxylon* for the fossil woods resembling *Diospyros*. To date the following 15 species of it are known from various parts of the world: *Ebenoxylon aegypticum* Kräusel (1939) and *E. ebenoides* Kräusel (1939) from the Tertiary of Libya, *E. indicum* Ghosh & Kazmi (1958) from the late Miocene–Pliocene of Arunachal Pradesh, *E. arcotense* Awasthi (1970, 1984) from the late Miocene–Pliocene of Puducherry, *E. kartikcherraense* Prakash & Tripathi (1970) from the Tipam Sandstone (late Miocene) of Assam, *E. mohgaoense* Chitale & Patil (1972) and *E. deccanensis* Trivedi & Srivastava (1982) from the Deccan Intertrappean beds of central India, *E. bavaricum* Selmeier (1976) from the Miocene of Bavaria, *E. miocenicum* Prakash (1978), *E. siwalicus* Prakash (1981), *E. kalagarhensis* Prasad (1989) and *E. palaeocalendula* Prasad (1993) from the Siwalik of Uttarakhand, *E. obliquiporosum* Awasthi & Ahuja (1982) from the late Miocene–Pliocene of Kerala, *E. burmense* Du (1988) from the Pliocene of Myanmar and *E. neyveliense* Mukherjee & Prasad (2013) from the late Miocene–Pliocene Neyveli lignite deposits of Tamil Nadu. Many of these are based on minor characters (possibly due to intraspecific variations) and difficult to be differentiated. However, the present fossil is distinct from all of them in having bordered pits in fibres. Therefore, it has been described as *Ebenoxylon cuddalorensis* Awasthi *et al.*, sp. nov., the specific name is after the Cuddalore Sandstone.

Diospyros is a genus of over 700 species of evergreen and deciduous trees and shrubs mostly distributed in tropical regions, with a few species in temperate regions. *Diospyros malabarica*, the modern counterpart of the fossil, is a medium-sized evergreen tree native to the Indian subcontinent and Southeast Asia.

DISCUSSION

A large number of dicot woods are known from the Cuddalore Sandstone of south India (Guleria, 1992). They belong to *Alangium* of the Alangiaceae, *Gluta* and *Mangifera* of the Anacardiaceae, *Calophyllum* and *Mesua* of the Calophyllaceae, *Parinari* of the Chrysobalanaceae, *Anogeissus* and *Terminalia* of the Combretaceae, *Anisoptera*,

PLATE 5

Eucalyptoxylon cuddalorensis Awasthi *et al.*, sp. nov.



1. CS showing exclusively solitary vessels plugged with tyloses.
2. Crystals in parenchyma cells (marked by arrows).
3. RLS showing weakly heterogeneous ray tissue.
4. TLS showing distribution of rays.
5. Showing vasicentric tracheids (marked by arrows).

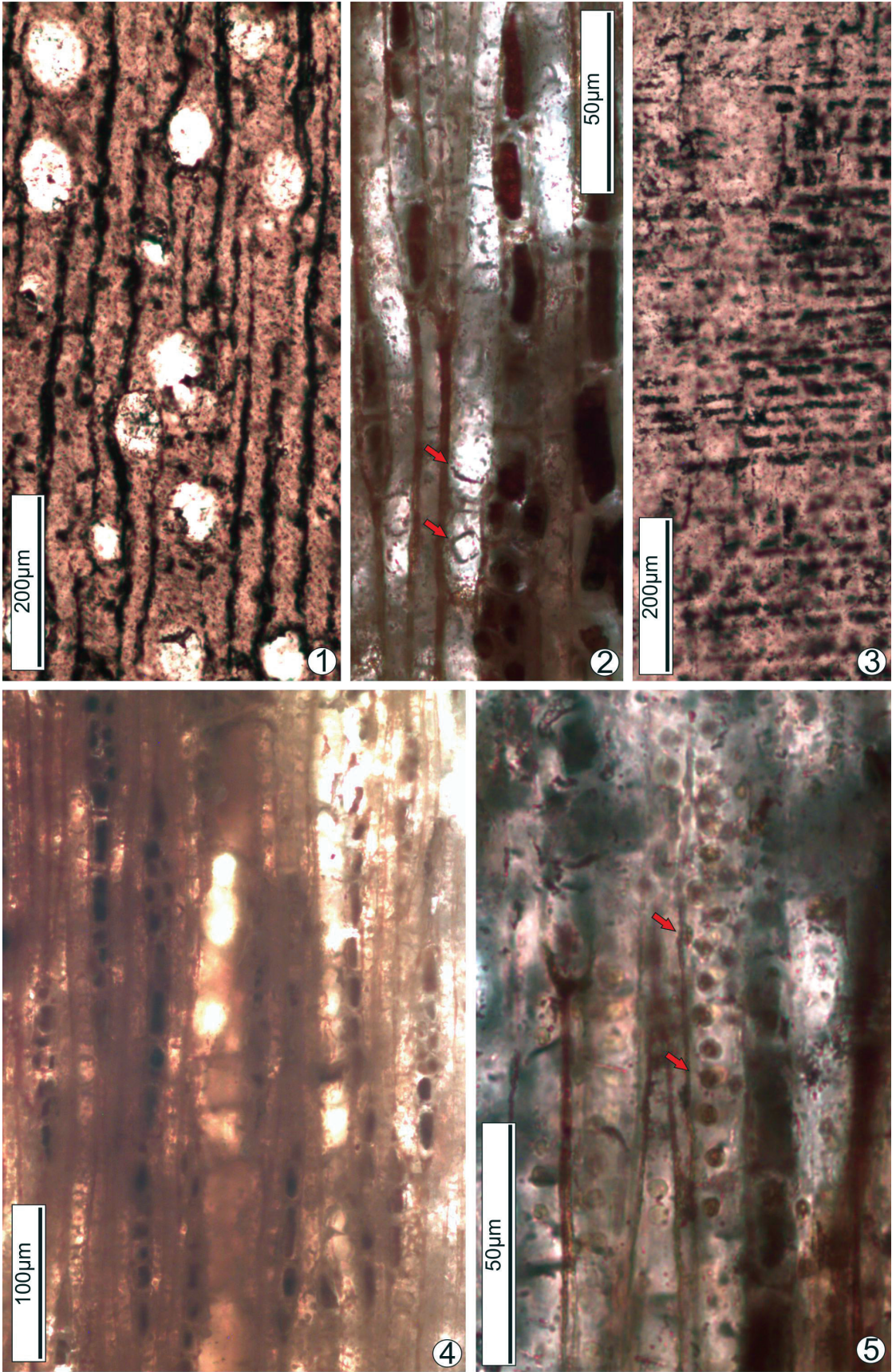


PLATE 5

Dipterocarpus, *Dryobalanops*, *Hopea* and *Shorea* of the Dipterocarpaceae, *Diospyros* of the Ebenaceae, *Putranjiva* of the Euphorbiaceae, *Acacia*, *Azelia*, *Albizia*, *Bauhinia*, *Cassia*, *Cynometra*, *Millettia*, *Peltophorum*, *Pericopsis* and *Sindora* of the Fabaceae, *Barringtonia* and *Careya* of the Lecythidaceae, *Duabanga*, *Lagerstroemia* and *Sonneratia* of the Lythraceae, *Firmiana*–*Sterculia* of the Malvaceae, *Xanthophyllum* of the Polygalaceae, *Euphoria* of the Sapindaceae, *Chrysophyllum* of the Sapotaceae, and *Holoptelea* of the Ulmaceae. Many of them such as *Alangium*, *Calophyllum*, *Cynometra*, *Dipterocarpus*, *Dryobalanops*, *Duabanga*, *Gluta*, *Hopea* and *Mesua* are typical tropical evergreen elements indicating the existence of wet evergreen forests near Puducherry during the depositional period. The present findings of *Hopea*, *Berrya* and *Diospyros* further support the above view as these trees are tropical evergreen elements. In addition, the presence of *Azelia*, *Barringtonia* and *Sonneratia* suggests littoral and swamp forests there during the late Miocene–Pliocene. Most of the modern comparable forms of the fossils are absent from the fossil locality today and found in the Western Ghats and northeast India indicating a change in the climatic conditions in the region since the late Cenozoic. The area has become drier now and the evergreen taxa have shifted to the regions having equable climate.

The presence of *Eucalyptus* in the flora is phytogeographically significant as the genus has become extinct not only from the fossil locality, but from the Indian subcontinent also. It grows in some parts of the Indian subcontinent where it is cultivated. At present, the genus comprising more than 700 species is confined mainly to Australia, with a few species in the adjacent regions of New Guinea, Indonesia and Philippine archipelago (Mabberley, 1997). Based on its fossil records from India, Australia, New Zealand and South America, Shukla *et al.* (2014) concluded that an ancient lineage of *Eucalyptus* was present in the Gondwanaland continents prior to their separation. As the family of *Eucalyptus* (Myrtaceae) has a southern gondwanic origin (Ladiges *et al.*, 2003), this provides further strength to the above view. The present day dominance of *Eucalyptus* in Australia may be an artefact of human influence.

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PLATE 6

Ebenoxylon cuddalorensis Awasthi *et al.*, sp. nov.



1. CS showing radial multiples of vessels and parenchyma pattern.
2. CS magnified to show diffuse to diffuse-in-aggregate parenchyma.
3. TLS showing predominantly uniseriate rays.
4. Showing bordered pits in fibres (marked by arrows).
5. RLS showing heterogeneous ray tissue.

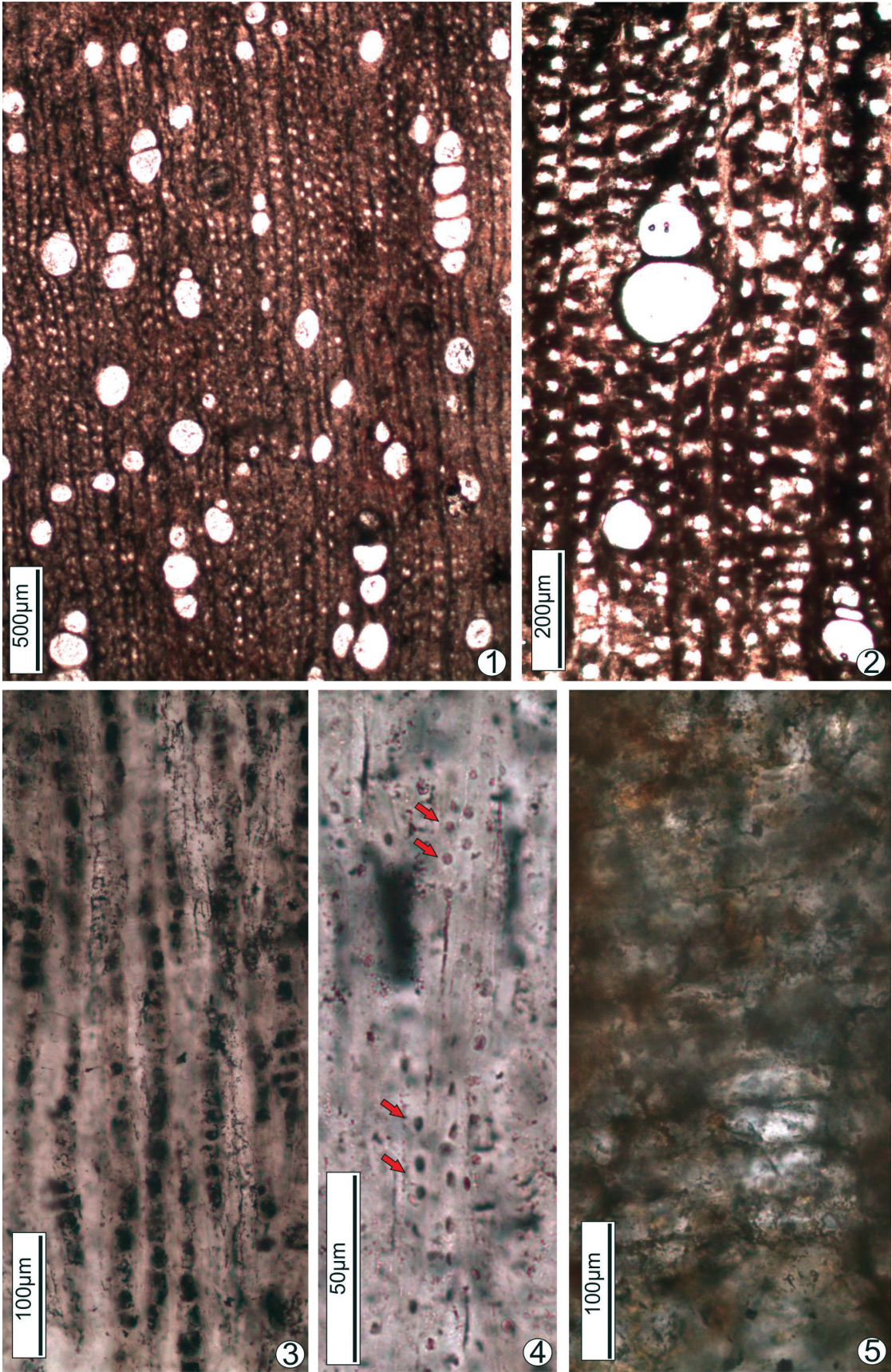


PLATE 6

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