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# On the occurrence of carbonised woods resembling *Terminalia* and *Sonneratia* in Palaeogene deposits of Gujarat, western India

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The carbonised woods resembling modern woods of the genus *Terminalia* Linn. and *Sonneratia* Linn. belonging to family Combretaceae and Sonneratiaceae, respectively are described from the Rajpardi lignite mine situated in Bharuch District of South Gujarat. The fossils indicate the existence of tropical palaeoclimate and presence of sea in the vicinity of Rajpardi during Eocene. These form the first record of carbonised woods from Gujarat and from the Palaeogene sediments of India too.

**Key-words**—Carbonised woods, *Terminalia*, *Sonneratia*, Palaeoenvironment, Palaeogene (India).

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## सारांश

पश्चिमी भारत में गुजरात के पुरानूतन निक्षेपों में टर्मिनलिया एवं सोनरेरेशिया से मिलती-जुलती कार्बनी काष्ठों की उपस्थिति

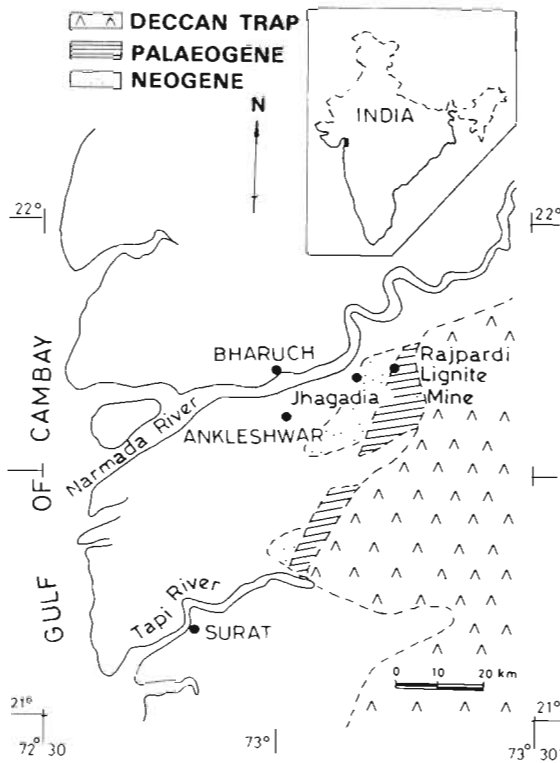
जसवन्तसिंह गुलेरिया

दक्षिण गुजरात के भड़ोच जनपद में राजपाड़ी लगुड़ांगार खान से कॉम्ब्रीटेसी एवं सोनरेरेशियाई कुलों की क्रमशः टर्मिनलिया एवं सोनरेरेशिया नामक वर्तमान प्रजातियों से तुलनीय कार्बनी काष्ठों का वर्णन किया गया है। उपलब्ध पादपाश्र्वों से आदिनूतन कल्प में राजपाड़ी के आस-पास समुद्र की उपस्थिति तथा उष्णकटिबन्धीय पुराजलवायु का होना इंगित होता है। गुजरात से ही नहीं, अपितु भारत के पुरानूतन अवसार्दों से भी कार्बनी काष्ठों का यह पहला अभिलेख है।

THE carbonised woods have been reported from the Lower Karewa of Kashmir (Awasthi & Guleria, 1982; Lone *et al.*, 1985), the Neogene sediments of Neyveli in Tamil Nadu (Ambwani, 1982; Awasthi 1984; Awasthi & Agarwal, 1987; Agarwal, 1989) and from Varkala in Kerala (Awasthi & Ahuja, 1982; Awasthi & Panjwani, 1984; Awasthi & Srivastava, 1990a,b). It is evident from the above records that all the carbonised woods have so far been recorded only from the Upper Tertiary sediments of India. In the present paper carbonised woods are being described for the first time from the Palaeogene sediments of India.

The Rajpardi lignite mine from where the present fossils are described belongs to Palaeogene. There has been difference of opinion about the precise age of the Rajpardi lignite. Kathiara (1969) proposed Oligocene to Upper Eocene age, whereas

Gadekar (1980) opined it to be Oligocene. Sudhakar and Basu (1973), based on outcrops and subsurface geology, established the Palaeogene stratigraphy of the southern Cambay Basin and inferred Middle Eocene to Upper Eocene age for the Rajpardi lignite. Recently, palynological investigations of the lignite have been carried out by Bhattacharya (1987) and Kar and Bhattacharya (in Press), and they have assigned Lower Eocene age to the lignite. Phadtare and Thakur (1990) on the other hand consider the age of Rajpardi lignite as Early to Middle Eocene. The lignite mine is situated about 35 km north-east of Bharuch on Ankleshwar-Rajpipla road (at about 21° 43' 35" Lat. : 73° 13' 30" Long. : Map 1). The area in general is characterised by undulating and flat topography with a number of small rivers and water channels which ultimately join river Narmada in the north. The carbonised woods were recovered



Map 1

from lignite bands and lenses alternating with carbonaceous clay from block number 13 of the mine in the form of big and small logs. Preservation apparently seems good but on closer microscopic examination most of the samples were found completely oxidised. Due to compression and overcharring, it is difficult to make out the anatomical details satisfactorily, thus making the task of identification difficult. A large number of samples were sectioned and studied and two of them with workable preservation are being described in the present paper.

It is important to mention here that Panandhro lignite mine in district Kutch is the only other lignite mine in Gujarat. Lignite of this mine has also been

dated as Lower Eocene (Kar, 1978). In contrast to Rajpardi lignite, the Panandhro lignite is almost devoid of carbonised woods although a number of leaf-impressions have been reported from this mine (Lakhanpal & Guleria, 1981; Guleria & Lakhanpal, 1984).

## SYSTEMATIC DESCRIPTION

### Family—Combretaceae

#### Genus—*Terminalioxylon* Schönfeld 1947

*Terminalioxylon palaeocalamansanai* sp. nov.

Pl. 1, figs 1-3, 5, 9

The present species is based on a small piece of carbonised wood measuring about 20 cm long and 6 cm in diameter.

*Description*—Wood diffuse porous (Pl. 1, figs 1, 2). *Growth rings* inconspicuous, delimited by smaller vessels and broader bands of fibrous tissue in the outer portion of the ring and narrow closer concentric bands of zonate parenchyma. *Vessels* small to large (mostly medium), solitary or in multiples of 2-4, rarely more or in double row, round to oval, almost evenly distributed, 3-8 per sq mm; t.d. 62-210  $\mu$ m, r.d. 62-160  $\mu$ m; vessel members 270-620  $\mu$ m long with truncated or tailed ends; perforations simple nearly horizontal or oblique, tyloses not seen, gummy infiltration present (Pl. 1, figs 1, 2), intervessel pits bordered, alternate, oval, elliptic to angular, sometimes coalescent, 4-6  $\mu$ m in diameter, vested. *Parenchyma* abundant, paratracheal forming narrow sheath around the vessels, rarely aliform with short lateral extensions; zonate parenchyma forming sometimes broken mostly concentric wavy bands partially or completely enclosing the vessels, 1-6 cells wide (Pl. 1, figs 1, 2), parenchyma bands separated by somewhat wider bands of fibrous tissues; apotracheal parenchyma sparse, scattered in fibrous tissue; parenchyma cells round, oval to slightly elliptic in cross section, up to 28  $\mu$ m in diameter, thin-walled, sometimes filled

## PLATE 1

*Terminalioxylon palaeocalamansanai* sp. nov.

*Sonneratioxylon preapetalum* Awasthi

1. Cross section showing nature and distribution of vessels and parenchyma.  $\times 60$ ; Slide no. BSIP 36563-I.
2. Cross section magnified to show details of vessels and parenchyma.  $\times 100$ ; Slide no. BSIP 36563-I.
3. Intervascular pitting,  $\times 550$ ; Slide no. BSIP 36563-II.
5. Tangential longitudinal section showing xylem rays,  $\times 100$ ; Slide no. BSIP 36563-II.
9. Radial longitudinal section showing xylem rays,  $\times 200$ ; Slide no. BSIP 36563-III.

4. Cross section showing nature and distribution of vessels and xylem rays,  $\times 90$ ; Slide no. BSIP 36554-II.
6. Tangential longitudinal section showing uniseriate xylem rays,  $\times 120$ ; Slide no. BSIP 36564-III.
7. Cross section showing growth rings,  $\times 90$ ; Slide no. BSIP 36564-I.
8. Radial longitudinal section showing xylem rays,  $\times 180$ ; Slide no. BSIP 36564-IV.

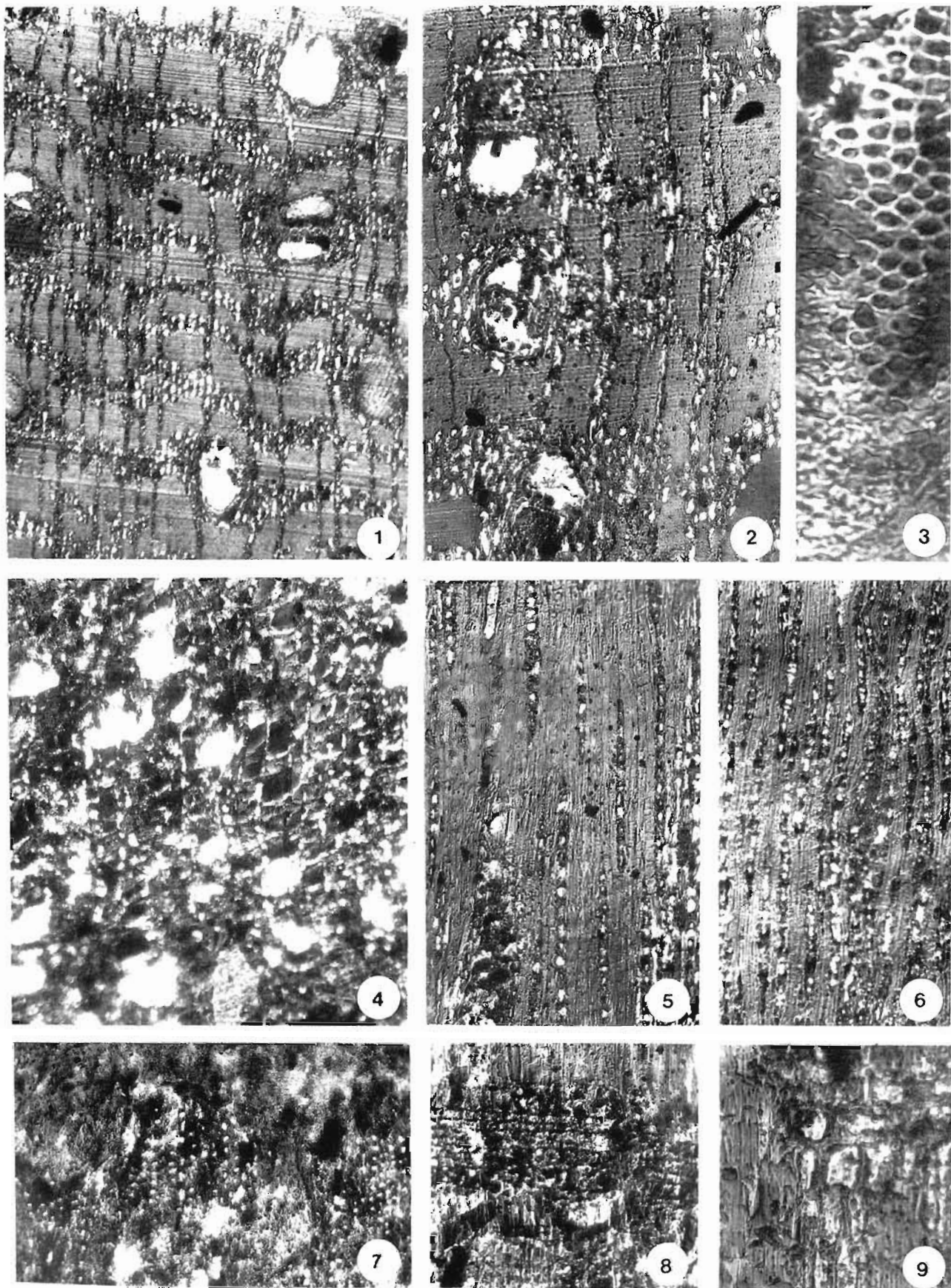


PLATE 1

with gummy deposit or granular infiltration, crystals present. *Xylem rays* fine, closely spaced, uniseriate or rarely biseriate due to pairing of cells (Pl. 1, fig. 5); 6-24  $\mu\text{m}$  wide, 3-29 cells or 44-775  $\mu\text{m}$  high, 13-20 rays per mm; homocellular to weakly heterocellular, consisting of wholly procumbent cells or with single marginal rows of upright or squarish cell at one or both ends (Pl. 1, figs 5, 9), gummy infiltration abundant in ray cells, crystals not seen. *Fibres* more or less aligned in radial rows, forming concentric and somewhat wavy bands alternating with narrower bands of parenchyma, angular to polygonal in cross section, 8-20  $\mu\text{m}$  in diameter, 3-6  $\mu\text{m}$  thick, occasionally septate, interfibre pits rarely seen, very small, simple.

The above mentioned characters collectively indicate affinity of the fossil wood to the genus *Terminalia* Linn. Among a large number of the Indian species of *Terminalia*, woods of only three species, namely *T. bellerica* Roxberg, *T. bialata* Steud and *T. calamansanai* (Blanco) Rolfe (syn. *T. pyrifolia* Kurz) possess banded parenchyma (Pearson & Brown, 1932; Ramesh Rao & Purkayastha, 1972) and are thus comparable with the present fossil. However, *T. bialata* can easily be differentiated from the present fossil in the absence of typical concentric bands. The common pattern of parenchyma in this species is usually aliform to confluent (Pearson & Brown, 1932, p. 534; Ramesh Rao & Purkayastha, 1972, p. 184; Purkayastha *et al.*, 1976, p. 36) though sometimes forming bands. *Terminalia bellerica* like *T. calamansanai* shows very close similarity with fossil in the nature of parenchyma. However, absence of septate fibres in *T. bellerica* differentiates it from *T. calamansanai* as well as from the present fossil. Thus the fossil shows closest resemblance with the wood of *Terminalia calamansanai*.

The genus *Terminalioxylon* was established by Schönfeld (1947) for the fossil wood of *Terminalia*. Mädél-Angeliewa and Müller-Stoll (1973) emended the diagnosis of the genus *Terminalioxylon* Schönfeld and merged *Anogeissusoxylon* Navale 1964 and *Anogeissuxylon* Louvet 1964 in it. However, Prakash (1979, p. 54) disagreed with the contention of Mädél-Angeliewa and Müller-Stoll and again separated the genus *Anogeissusoxylon* Navale 1964 for the fossil woods of *Anogeissus* and *Terminalioxylon* Schönfeld for the fossil woods of all species of *Terminalia*. The genus *Terminalioxylon* is used here in its original sense as proposed by Schönfeld.

A large number of fossil woods have been described under the genus *Terminalioxylon* from India and many other countries. The author is aware

of 37 species of the genus. A list of 25 species has been given by Mädél-Angeliewa and Müller-Stoll (1973) out of which *T. geinitzii* (Schenk) Mädél-Angeliewa & Müller-Stoll has been merged with *Lumnitzeroxylon* by Kramer (1974b, pp. 20, 22). However, Prakash (1979, p. 55) while re-establishing the genus *Anogeissusoxylon* Navale 1964 has opined that both *T. geinitzii* and *T. intermedium* (Kräusel) Mädél-Angeliewa & Müller-Stoll belong to *Anogeissus*. The remaining species are listed below:

Name	Locality	Age
<i>Terminalioxylon kratiense</i> Serra 1966	Cambodia	Tertiary or Quaternary
<i>T. tunesense</i> Fessler Vrolant & Duperson-Laudoueneix 1986; Duperson-Laudoueneix 1973; Delteil-Desneux, 1981	Tunisia	Oligocene & Miocene
Syn. <i>T. cheidense</i> Fessler-Vrolant 1980		
<i>T. densiporosum</i> Kramer, 1974b	Sumatra	Mio-Pliocene
<i>Terminalioxylon</i> sp. Kramer, 1974b	Java and Sumatra	Mio-Pliocene
<i>Terminalioxylon</i> sp. Lemoigne <i>et al.</i> , 1974	Ethiopia	Probably Miocene
<i>T. pachitanensis</i> Sukieman 1977	Java	Miocene
<i>T. doubingeri</i> Lemoigne 1978	Ethiopia	Miocene
<i>Terminalioxylon</i> sp. Lemoigne 1978	Ethiopia	Plio Pleistocene
<i>T. palaeomanii</i> Prakash 1981	India	Mid-Miocene
<i>T. varkalaensis</i> Awasthi & Ahuja 1982	India	Neogene
<i>T. ghoshii</i> Satyanarayan & Mahabale 1984	India	Oligo-Miocene
<i>T. siwalicus</i> Prasad 1989	India	Mid-Miocene

*Terminalioxylon welkitti* Lemoigne & Beauchamp 1972 listed by Awasthi and Ahuja (1982) and Prasad (1989) has already been merged under *Brachystegioxylon* Laxhanpal & Prakash 1970 by Lemoigne (1978).

In addition, Bande *et al.* (1987) described a fossil wood of *Terminalia* as *Terminalia preglaucescens* from the Tertiary of Zaire. Among all the known fossil species, *Terminalioxylon coriaceum* (Prakash & Awasthi, 1971; Vozenin-Serra & Prive-Gill, 1989) shows some resemblance with the present fossil in possessing infrequent parenchyma bands alongwith aliform parenchyma. However, none of the fossil species possess regular

parenchyma bands, hence the present fossil differs from all of them. Since the present fossil shows close similarity with the wood of *Terminalia calamansanai* and is different from all the known species of *Terminalioxylon*, a new specific name *Terminalioxylon palaeocalamansanai* is assigned to it.

The genus *Terminalia* consists of about 250 species of large trees, widely distributed in the tropical region of both the hemispheres (Willis, 1973, p. 1136). *Terminalia calamansanai*, with which the present fossil shows the closest affinities, is a large tree measuring up to 30 m and found in the plain forests of Lower Myanmar, common in Prome, Pyinmana, Meiktila districts and extends to neighbouring countries in South-East Asia. It is also found as a small tree about 1 to 1.5 m in girth in Tavoy, near the sea-coasts (Pearson & Brown, 1932; Ramesh Rao & Purkayastha, 1972).

### Specific Diagnosis

*Terminalioxylon palaeocalamansanai* sp. nov.

*Wood* diffuse porous. *Growth rings* inconspicuous, marked by smaller vessels and broader bands of fibrous tissue in the outer portion of the ring and narrow closer concentric bands of zonate parenchyma. *Vessels* small to large, mostly medium, t.d. 62-210  $\mu\text{m}$ , r.d. 62-160  $\mu\text{m}$ ; solitary or in multiples of 2-4 or more, 3-8 per sq mm; vessel-members 270-620  $\mu\text{m}$  long with truncated or tailed ends; perforations simple; intervessel pits alternate, bordered, vestured, 4-6  $\mu\text{m}$  in diameter. *Parenchyma* abundant paratracheal forming narrow sheath around the vessels, rarely aliform, mostly forming concentric wavy bands, 1-6 cells wide, parenchyma bands separated by somewhat wider bands of fibrous tissue; apotracheal parenchyma sparse, scattered in fibrous tissue. *Xylem rays* fine, closely spaced, uniseriate or rarely biseriate due to pairing of cells, 6-24  $\mu\text{m}$  wide, 3-29 cells or 44 to 775  $\mu\text{m}$  high, 13-20 per mm, homocellular to weakly heterocellular. *Fibres* forming concentric and somewhat wavy bands alternating with the narrower bands of parenchyma, cells 8-20  $\mu\text{m}$  in diameter, wall 3-6  $\mu\text{m}$  thick, occasionally septate, interfibre pits rarely seen, simple.

*Holotype*—Specimen no. BSIP 36563.

*Locality*—Rajpardi lignite mine, block no. 13.

### Family—Sonneratiaceae

*Genus*—*Sonneratioxylon* Hofmann 1952

*Sonneratioxylon preapetalum* Awasthi 1969

Pl. 1, figs 4, 6-8

The description is based on a single specimen of wood measuring 15 cm in length and 4 cm in diameter. The specimen is slightly compressed due to which tissues are flattened.

*Description*—*Wood* diffuse porous. *Growth rings* present, delimited by somewhat denser fibrous tissue (Pl. 1, figs 4, 7) in the outer portion of the ring. *Vessels* very small to small, usually solitary or in multiples of 2-3 or more; almost evenly distributed, 16-30 per sq mm, round to oval, stretched and flattened due to compression, open and sometimes plugged with gummy contents or tyloses, t.d. 32-96  $\mu\text{m}$  (mostly 49-80  $\mu\text{m}$ ), r.d. 36-104  $\mu\text{m}$ , vessel members 240-640  $\mu\text{m}$  in length with truncate or slightly oblique ends, perforations simple, intervessel pits rarely seen, probably due to crushing of the vessels as a result of compression, alternate, bordered, vestured, 3-6  $\mu\text{m}$  in diameter. *Parenchyma* absent. *Xylem rays* fine, mostly uniseriate (Pl. 1, fig. 6), occasionally biseriate due to pairing of cells; rarely biseriate 8-16  $\mu\text{m}$  wide, 3-26 cells or 64-400  $\mu\text{m}$  in height; closely spaced, 18-30 per mm; ray tissue heterogeneous, rays homocellular to heterocellular, consisting of procumbent cells with upright or squarish cells (Pl. 1, fig. 8), upright cells 28-44  $\mu\text{m}$  in tangential height, procumbent cells 12-24  $\mu\text{m}$  in tangential height; cells usually filled with gummy material, solitary crystals occasionally seen in the upright cells. *Fibres* aligned in radial rows, more or less oval, angular, polygonal to flattened in shape, 8-24  $\mu\text{m}$  in diameter, lumen 4-12  $\mu\text{m}$ , wall 3-6  $\mu\text{m}$  thick, non-libriform, septate, septa rarely seen, interfibre pits could not be seen.

*Specimen*—Specimen no. BSIP 36564.

*Locality*—Rajpardi lignite mine, Block no. 13.

It is clear from the above mentioned characters that the fossil shows close similarity with the modern woods of *Sonneratia* Linn. (Metcalf & Chalk, 1950; Pearson & Brown, 1932; Purkayastha, 1982) of Sonneratiaceae. It has been found to show the closest similarities with the woods of three species of *Sonneratia*, viz., *S. apetala* Buch-Ham., *S. caseolaris* (Linn.) Engler (syn. *S. acida* Linn.) and *S. alba* Smith which are xylotomically very similar (Purkayastha, 1982, p. 41).

In 1952, Hofmann instituted the genus *Sonneratioxylon* to accommodate the fossil woods of *Sonneratia*. Until recently, eight species of *Sonneratioxylon* were known, viz., *S. prambachense* Hofmann 1952 from the Oligocene of Austria; *S. dakshinense* Ramanujam 1957 from the Tertiary of south India; *S. dudukureense* Krishna Rao & Ramanujam 1966 from the Deccan Intertrappean Series, Andhra Pradesh; *S. preapetalum* Awasthi 1969 from the Cuddalore Series of south India; *S.*

*aubrevillei* Louvet 1970 from the Eocene of Libya; *S. intertrappeum* Biradar & Mahabale 1975; *S. caseolarioides* Shete & Kulkarni 1982 and *S. nawargaoensis* Bande & Prakash 1984; the last three species are from the Deccan Intertrappean sediments of Madhya Pradesh and Maharashtra. In addition fossil woods referable to *Sonneratia* have also been reported by Verma (1950) and Shallom (1963). The affinities of some of these woods with *Sonneratia* have been considered to be doubtful by Awasthi (1969, p. 255). Biradar and Mahabale (1975, p. 217) merged the woods described by Verma (1950) and Shallom (1963) into *Sonneratioxylon intertrappeum*. Further, Chitale (1969) described the fossil roots comparable to *Sonneratia apetala* as *Sonneratorhizos raoi*. Out of all the known species of *Sonneratioxylon*, the present fossil shows closest resemblance with *S. preapetalum* reported from south India, Kachchh and South-East Asia (Awasthi, 1969; Lakhanpal *et al.*, 1984; Kramer, 1974a; Vozenin-Serra *et al.*, 1989). Recently Mehrotra (1989) while describing the above species from the Intertrappean sediments of Mandla District of Madhya Pradesh merged *Sonneratioxylon intertrappeum*, *S. caseolarioides* and *S. nawargaoensis* into *S. preapetalum* Awasthi 1969, on the basis that all these species are anatomically very similar but differ only in minor and variable characters and thus accordingly revised the diagnosis of *S. preapetalum*. In his revised diagnosis of *S. preapetalum*, Mehrotra (1989, p. 132) has stated "Growth rings absent" though they have already been mentioned to be present in *S. preapetalum* and *S. intertrappeum* (Biradar & Mahabale, 1975, pp. 211, 215, 216; Lakhanpal *et al.*, 1984, p. 259; Vozenin-Serra *et al.*, 1989, p. 347) and same is the case in modern woods of comparable species of *S. preapetalum* (Pearson & Brown, 1932; Purkayastha, 19p2, p. 41) though at time the growth rings may be inconspicuous and may not be visible.

The genus *Sonneratia* consists of five species (Willis, 1973, p. 1078) growing in the mangrove swamps along the sea coasts of East Africa, North Madagascar, Seychelles, South-East Asia and warmer regions of Australia. The three comparable species, viz., *S. alba*, *S. apetala* and *S. caseolaris* are found in tidal creek and littoral forests of Sundarbans, coastal forests of Orissa, Andhra Pradesh, Karnataka, Maharashtra and Andamans extending westwards to the Indus delta.

Occurrence of fossils of *Sonneratia* and *Terminalia calamansanai* (syn. *T. pyrifolia*) suggests the existence of tropical conditions and the presence of sea in the vicinity of Rajpardi during

Eocene. Evidently the sea has receded since then from the area. It seems that *Sonneratia* must have been growing near the site of deposition and *Terminalia* either near the site of deposition or further inland.

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