Fossil wood of *Dryobalanops* from Pliocene deposits of Indonesia

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(Received 24 August 2000; revised version accepted 06 August 2001)

ABSTRACT


The present paper gives a detailed account of anatomical features of petrified wood showing affinities with the modern genus *Dryobalanops* Gaertn.f. of the family Dipterocarpaceae. The fossil wood was found as a big tree trunk in volcanic sediments near Bogor, West Java (Indonesia). The distribution of extant *Dryobalanops* is restricted to tropical evergreen rain forests of Malaysia and Indonesia (Sumatra & Borneo). Today it is absent in the natural forests of Java, although the broad climatic setting has not changed much since Pliocene times. Reasons for its absence in the island are discussed.

Key-words—Anatomy, petrified wood, *Dryobalanops*, Dipterocarpaceae, Pliocene, Java (Indonesia).

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INTRODUCTION

Southeast Asia is of special interest for botanists dealing with antiquity and evolution of angiosperm floras. Plant megafossils are reported from the Cenozoic sediments of Southeast Asian countries like Myanmar (Prakash, 1973; Prakash & Bande, 1980), Thailand (Endo, 1963; Prakash, 1979; Vozenin-Serra & Privé-Gill, 1989; Vozenin-Serra et al., 1989), Cambodia (Boureau, 1950, 1950a, 1952); Malaysia (Warburg, 1897) and Vietnam (Boureau, 1950, 1950a, 1952; Vozenin-Serra, 1981). From Indonesia (Java, Sumatra, Borneo, Ceram and other islands) a large number of fossil leaves and wood were reported by many workers, namely, Göppert (1854); Heer (1876); Gayler (1875, 1887); Crie (1888); Den Berger (1923, 1927); Tobler (1923); Kräusel (1926); Edwards (1931); Schweitzer (1958); Kramer (1974a, b); Sukiman (1977); Vozenin-Serra (1980).

In a comprehensive review of the Tertiary flora of Southeast Asia, Bande and Prakash (1986) gave an almost complete list of fossil records with remarks on phytogeography, migration and palaeoenvironment of the Indo-Malaysian region. In the present paper, present status of diperocarps in Indonesia and probable reasons for disappearance of Dryobalanops along with few other members from the natural forests of Java are being discussed.

MATERIAL AND METHODS

Indonesia is an archipelago in the Indian and Pacific oceans across the equator off the coast of Southeast Asian mainland. The fossil wood reported here was collected from Pliocene volcanic sediments of Leuwiliang, about 20 km westward from Bogor, in Western Java, Indonesia. (Fig. 1). The fossil is a piece of a tree trunk measured 60 cm long and 66 x 43 cm in diameter. The preservation is good showing all the xylotomical characters.

Sections of the fossil wood in transverse, tangential-longitudinal and radial-longitudinal planes were cut and ground to obtain thin sections. A few peel sections were also prepared by etching the surface of the fossil wood with Hydrofloric Acid and then after thorough washing cellulose acetate film was placed on it. The fossil wood and microscopic slides are deposited in the Xylarium of the Wood Research Institute, Kyoto University, Uji, Kyoto, Japan. For identification of the fossil wood, slides of extant species of Dryobalanops present in the Xylaria of Birbal Sahni Institute of Palaeobotany, Lucknow, India and Forest Research Institute, Dehradun, India were examined carefully.

SYSTEMATICS

DICOTYLEDONS

Family—DIPTEROCARPACEAE

Genus—DRYOBALANOXYLON Den Berger, 1923

DRYOBALANOXYLON BOGORENSE sp. nov. (Pl. 1.1-6)

Description—Wood diffuse porous (Pl. 1.1). Growth rings absent (Pl. 1.1). Vessels evenly distributed, 3-4 per sq mm; almost exclusively solitary, rarely in radial or oblique pairs, round to oval in cross-section (Pl. 1.1); medium to large, tangential diameter 120-286 (average 203) mm, radial diameter 165-336 (average 250) mm; tyloses commonly present (Pl. 1.4); vessel elements 308-572 (average 500) mm long; end walls transverse to oblique (Pl. 1.2); perforation plates simple; intervessel pits not observed. Parenchyma both paratracheal and apotracheal; paratracheal vasicentric to aliform forming 2-3 cells thick sheath which extends laterally joining 2-3 vessels (Pl. 1.1); apotracheal associated with vertical gum canals forming 2-4 cells thick sheath or bands encircling gum canals (Pl. 1.1); each cell 32-36 mm in diameter and 90-164 mm long; silica-like particles present in parenchyma cells (Pl. 1.6). Vasicentric tracheids present, intermingled with vasicentric parenchyma, bordered pits present in double rows in tangential and radial walls. Fibre tracheids constitute ground mass of the wood, polygonal or rectangular in cross-section, 30-40 mm in diameter, walls 7-8 mm thick; nonseptate, single row of small bordered pits present (Pl. 1.2, 3). Gum canals vertical; normal; smaller than the vessels; forming tangential rows; embedded or encircled in 2-3 cells thick apotracheal parenchyma bands (Pl. 1.1); 33-100 mm in tangential diameter and 55-130 mm in radial diameter. Rays 1-6 seriate,

Fig. 1—Map of Bogor, West Java showing fossil locality.
PLATE 1

Dryobalanops bogorensis sp. nov.

1. Cross-section of fossil wood showing distribution of vessels, parenchyma and vertical gum canals. x 51
2. Tangential longitudinal section showing distribution of rays and fibre tracheids. x 51
3. Same section magnified showing multiseriate ray and pits on fibre tracheid. x 125.
4. Cross-section magnified showing tylosed vessels. x 125.
5. Radial longitudinal section showing heterocellular rays and vessel-ray pits. x 125.
6. Tangential longitudinal section showing silica-like particles in parenchyma cells. x 515
heterocellular composed of both upright and procumbent cells (Pl. 1.5); uniseriate rare, composed of upright cells only; multiseriate made up of procumbent cells in the centre with 1-4 marginal row of upright cells at one or both the ends; 11-36 cells or 500-1200 mm tall; upright cells 38-54 mm in both tangential height and radial length; procumbent cells 16-38 mm in tangential height and 83-115 mm in radial length; vessel ray pits simple, many per cell; ? gummy infiltration or some deposit present in ray cells (Pl. 1.2, 3, 5).

Holotype—Specimen no. KYO F2, Wood Research Institute, Kyoto University, Kyoto, Japan.

Locality—Leuwiliang, about 20 km from Bogor, West Java, Indonesia.

Age—Pliocene.

Etymology—Specific name is after Bogor, a place in west Java where fossil locality is situated.

Number of specimen examined—One large piece of petrified wood.

Affinities—The presence of normal vertical gum canals in tangential rows; medium to large, almost exclusively solitary vessels occluded with tylosis; heterocellular rays; vasicentric tracheids and fibre tracheids clearly indicate affinity of the present fossil with the woods of Dipterocarpaceae, particularly with the genera Balanocarpus, Dioicticarpus, Doona, Dryobalanops, Hopea, Isoperta, Parashorea, Pentacme and Shorea (Metcalfe & Chalk, 1950; Desch, 1957; Chowdhury & Ghosh, 1958; Hayashi et al., 1973; Ibc, 1991). However, the presence of exclusively solitary vessels or nearly so and thick-walled fibre tracheids with distinctly bordered pits shows close similarity with the genus Dryobalanops and differentiate it from rest of the genera. In order to find out nearest modern counterpart of the fossil, a detailed comparison with thin sections as well as published descriptions and photographs of modern woods of Dryobalanops, namely, D. arotictica Gaertn. f., D. beccarii Dyer PS, D. lanceolata Burck, D. keithii Symington, D. oblongifolia Dyer, D. rappa Becc. was made. The fossil wood shows gross resemblance with all these species. In D. arotictica, the size of vessels, tyloses and parenchyma pattern matches the fossil wood, however, in a few modern specimens ripple marks are present due to stored nature of rays while in others rays are not stored (Desch, 1957; p 109). Among the examined species, in D. beccarii (BSIP W 2112) the vessels and rays are slightly smaller than the present fossil wood while in D. lanceolata (BSIP W 1497) the vessels are larger and tyloses are more frequent. In D. keithii (BSIP W 2420) the rays are taller than the fossil while in other specimens of the same species (BSIP W 2105) the vessels are larger, apotracheal diffuse parenchyma in greater amount and rays are taller than the wood under consideration. In D. oblongifolia the vessels are larger, tyloses less developed and rays are broader. D. rappa (BSIP W 2356) differs in having less developed tyloses and vessels in pairs are frequent with some solitary ones.

Comparison with fossil species—Den Berger (1923) instituted the genus Dryobalanoxylon for the fossil woods showing resemblance with modern Dryobalanops Gaertn.f. So far these three species have been reported from the Neogene of India and 13 species are reported from Neogene and Quaternary deposits of Southeast Asia (Fig. 2). Dryobalanoxylon bangkoense differs from the present fossil wood in having large amount of apotracheal parenchyma and homocellular, 1-5 (mostly 3) seriate rays ranging from 4-70 cells in height, while in Dryobalanoxylon cf. bangkoense parenchyma is less abundant and rays are up to 10 seriate. D. holdenii has 1-4 seriate rays with occasional occurrence of sheath cells. Vessel size and parenchyma pattern matches with the present fossil wood. In D. indicum the rays are taller (up to 90 cells or 1900 mm) and have uniseriate extensions of 1-15 upright cells at both the ends. In D. javanicum the vessels are slightly smaller (t.d. 125-225 mm, r.d. 125-275 mm) and rays are 2-9 (mostly 3-5) seriate. D. keralensis differs in having less amount of paratracheal vasicentric parenchyma. In D. klimernerum vessels are smaller (t.d. 100-200 mm) and rays are broader and shorter (1-8 seriate; up to 700 mm long). D. mirabile differs in having smaller vessels (t.d. 75-175 mm, r.d. 100-275 mm), homocellular rays and large gum canals (t.d. 60-200 mm). In D. musperi also the vessels are smaller (t.d. 60-200 mm, r.d. 60-150 mm) and xylem rays are 1-4 (mostly 2-3) seriate. In D. neglectum both the apotracheal and paratracheal parenchyma is scanty, rays are homocellular and very broad (4-18 seriate). D. rotundatum differs from the present fossil in having abundant parenchyma and rays are 1-4 (mostly 1-3) seriate and homocellular. In D. spectabile the vessels are smaller (t.d. 95-200 mm, r.d. 125-275 mm), paratracheal parenchyma very scanty and apotracheal only associated with gum canals, while rays are 1-4 (mostly 3) seriate. D. sumatrense differs in having smaller vessels (t.d. 75-200 mm) and taller rays (up to 90 cells). In D. tanibouense also vessels are smaller (t.d. 125-234 mm), mostly solitary but groups of 2-4 also present (13%) gum canals are very small (t.d. 23.4-33.8 mm) and spiral thickening on the tracheids are found. Vessel multiples up to 4, spiral thickenings and intervessel pits are not observed in modern Dryobalanops. The general look also does not match Dryobalanops. In D. toleri vessels are 150-200 mm in tangential diameter, paratracheal parenchyma sparse and apotracheal parenchyma associated with gum canals, rays are 1-5 (mostly 3-4) seriate.

The fossil wood under consideration either differs in vessel size or in ray character from all the known species, hence it is described as Dryobalanoxylon bogorense sp. nov. The specific epithet indicating its occurrence in Bogor in West Java.
<table>
<thead>
<tr>
<th>Name of Fossil Species</th>
<th>Age</th>
<th>Horizon/Country</th>
<th>References</th>
</tr>
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<tbody>
<tr>
<td>Dryobalanoxylon</td>
<td>Quaternary</td>
<td>Central Sumatra, Indonesia; Southwest Bangkok, Thailand</td>
<td>Schweitzer 1958</td>
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<tr>
<td>bangkoense Schweitzer</td>
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<tr>
<td>Dryobalanoxylon cf.</td>
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<td>Central Sumatra, Indonesia; Southwest Bangkok, Thailand</td>
<td>Schweitzer 1958</td>
</tr>
<tr>
<td>bangkoense Schweitzer</td>
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<tr>
<td>D. borneense Schweitzer</td>
<td>Miocene</td>
<td>Borneo, Indonesia</td>
<td>Schweitzer 1958</td>
</tr>
<tr>
<td>D. holzii (Ramanujam)</td>
<td>Miocene-Pliocene</td>
<td>Cuddalore Sandstone, India</td>
<td>Awasthi 1971</td>
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<td>Awasthi</td>
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<tr>
<td>D. indicum (Ramanujam)</td>
<td>Miocene-Pliocene</td>
<td>Cuddalore Sandstone, India</td>
<td>Awasthi 1971</td>
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<td>Awasthi</td>
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<tr>
<td>D. javanicum (Kräusel)</td>
<td>Pliocene</td>
<td>West Java, Indonesia</td>
<td>Den Berger 1927; Schieit 1958</td>
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<td>Den Berger</td>
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<tr>
<td>D. keraeensis (Awasthi &amp; Ahuja)</td>
<td>Miocene</td>
<td>Warkalli Formation, India</td>
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<td>D. khimerinum (Boureau)</td>
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<td>D. mirabile (Schweitzer)</td>
<td>Quaternary</td>
<td>Central Sumatra, Indonesia; Southwest Bangkok, Thailand</td>
<td>Schweitzer 1958</td>
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<td>D. musperi (Schweitzer)</td>
<td>Early-Late Pliocene</td>
<td>West Java, Indonesia</td>
<td>Schweitzer 1958</td>
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<td>D. neglectum (Schweitzer)</td>
<td>Quaternary</td>
<td>Central Sumatra, Indonesia; Southwest Bangkok, Thailand</td>
<td>Schweitzer 1958</td>
</tr>
<tr>
<td>D. rotundatum (Schweitzer)</td>
<td>Quaternary</td>
<td>Central Sumatra, Indonesia; Southwest Bangkok, Thailand</td>
<td>Schweitzer 1958</td>
</tr>
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<td>D. spectabile (Criè) Den Berger</td>
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<td>West Java; between Batavia and Rangkas-Bitoeng, Indonesia</td>
<td>Den Berger 1923; Schweitzer 1958</td>
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<td>D. sumatrense (Schweitzer)</td>
<td>Late Pliocene</td>
<td>Central Sumatra, Indonesia</td>
<td>Schweitzer 1958</td>
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<td>D. tambouense (Vozenin-Serra)</td>
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<td>D. tohleri (Kräusel) Den Berger</td>
<td>Pliocene</td>
<td>West Java; between Batavia and Rangkas-Bitoeng, Indonesia</td>
<td>Den Berger, 1923; Schweitzer, 1958</td>
</tr>
<tr>
<td>D. bogorense sp. nov.</td>
<td>Pliocene</td>
<td>Bogor, West Java, Indonesia</td>
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</table>

Fig 2—Fossil species of Dryobalanoxylon.

**DISCUSSION**

Dipterocarpaceae is the most important family in the present day flora of Southeast Asia as most of the genera are confined to this area (Awasthi, 1996). In view of its earliest authentic record from the Oligocene of north-west Borneo (Muller, 1970, 1981), and its abundance in modern flora of Malaysian region, it is believed that the family had originated in western Malaysia during the Early Tertiary (Merrill, 1923; Bancroft, 1933; Ashton, 1969; Lakanpal, 1974). Fossil records of Dipterocarpus and Hopea leaves are reported from younger horizons (probably Eocene) of Sumatra and Borneo (Heer, 1876; Geyler, 1875, 1887), but their age and affinities need confirmation. Brandis (1895) and Bancroft (1933) have already suggested that Geyler’s records should not be taken into account in the geological history of the family.

To evaluate the diversity of fossil floras in West Java, a preliminary survey of three fossil localities, namely, Ciampea, Leuwiliang and Jasinga was carried out by Mandang and Martono (1996). Among the wood examined (199), 81.4% (162) belong to the family Dipterocarpaceae. With in the dipterocarps, 19.4% belong to Dryobalanops while the rest (18.6%) belong to Alstonia (Apocynaceae), Calophyllum (Clucaceae), Dillenia (Dilleniaceae), Ochanostachys (Olaraceae), Terminalia (Combretaceae) and some legums. Dipterocarps are less abundant (both in generic diversity and number) in the present day natural forests of Java (Prawira, 1976) and are represented by Anisoptera, Dipterocarpus, Hopea, Shorea and Vatica while in the fossil assemblage Dryobalanops, Rubrosoreia and Cotylelobium are also present in addition to these genera. The fossil assemblage in western Java is similar to present day flora of Sumatra and Kalimantan.
where dipterocarps are in abundance (Directorate of Forestry Planning, 1981).

The deterioration of dipterocarps (both in generic diversity and number) can be explained by Molengraf Theory (Van Bammelen, 1949). According to that theory until Early Pleistocene, Sunda Flatten (Java, Sumatra Kalimantan & intervening smaller islands) was united with the mainland of Asia. But after the last ice age, during the Late Pleistocene, melting of polar ice along with volcanic activity due to tectonic disturbances, resulted separation of Java, Kalimantan and Sumatra. Due to volcanic activity, natural forests were buried under lava and some of the genera viz., Dryobalanops, Ceylonelobium, Rubroshorea, etc. failed to regenerate. Thus they became extinct in the natural forests of Java.

The genus Dryobalanops Gaertn. f. consists of 7 species restricted in present day tropical evergreen rain forests of India (Sumatra and Borneo) and Malaysia (Merrill, 1923; Foxworthy, 1946; Mabberley, 1997). However, it was more widely distributed in the geological past (Fig. 2) as its fossil records are known from India and other Southeast Asian countries like Cambodia and Vietnam and it has also been reported from Java in Indonesia.

Acknowledgements—Rashmi Srivastava is thankful to Indian National Science Academy, New Delhi for her participation in INSA-JSPS International Scientific Exchange Programme. She is also grateful to Prof. Anshu K Sinha, Director, Birbal Sahni Institute of Palaeobotany, Lucknow, India for his help and cooperation. One of the authors (NK) is thankful to Prof. Hisao Kumai, Osaka City University, Japan for ascertaining the age of wood bearing bed as Pliocene in her personal discussion. We are extremely grateful to Prof. Shuch Kawai of Wood Research Institute, Kyoto University for his pains taking efforts in transporting the big fossil wood log from Bogor, Indonesia to Japan. The authors are also thankful to Prof. M Suzuki of Tohoku University, Japan, Prof. David L. Dilcher of Florida University, U.S.A. and Dr JS Gartler of Birbal Sahni Institute of Palaeobotany, India for their valuable suggestions.

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