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Fossil wood of *Dryobalanops* from Pliocene deposits of Indonesia

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ABSTRACT

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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).

इण्डोनेशिया के प्लायोसीन निक्षेपों से प्राप्त ड्रायोबैलेनॉप्स का अश्मित काष्ठ

रश्मि श्रीवास्तव एवं नोरिको कागेमोरी

सारांश

प्रस्तुत शोध-पत्र में डिप्टेरोकार्पेसी कुल के *ड्रायोबैलेनॉप्स* गार्टेन. एफ. नामक आधुनिक वंश के साथ सादृश्यता प्रदर्शित करने वाली अश्मीभूत काष्ठ के शारीरीय गुणों का विस्तृत विवेचन किया गया है। यह अश्मित काष्ठ इण्डोनेशिया के पश्चिमी जावा में बोगोर के समीपस्थ स्थल के ज्वालामुखीय अवसादों में स्थित एक बड़े वृक्ष स्तम्भ से प्राप्त किया गया है। विद्यमान *ड्रायोबैलेनॉप्स* का वितरण मलेशिया एवं इण्डोनेशिया (सुमात्रा तथा बोर्नियो) के ऊष्णकटिबन्धीय सदाहरित वृष्टिमय जंगलों में सीमित है। यद्यपि प्लायोसीन कल्प से लेकर आज तक यहाँ के जलवायुविक रुझानों में बहुत अधिक परिवर्तन नहीं हुए हैं, तथापि वर्तमान में यह जावा के प्राकृतिक वनों में अनुपस्थित है। प्रायद्वीप में इसकी अनुपस्थिति के कारणों का समुचित विवेचन भी इस शोध-पत्र में किया गया है।

संकेत शब्द—शारीरविज्ञान, अश्मीभूत काष्ठ, *ड्रोयोबैलेनॉप्स*, डिप्टेरोकार्पेसी, प्लायोसीन, जावा (इंडोनेशिया).

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, Ciram 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.

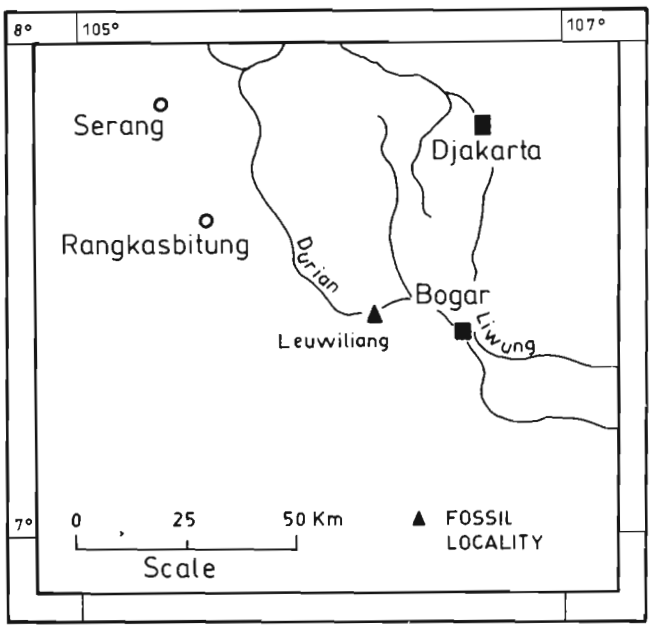

Fig. 1—Map of Bogor. West Java showing fossil locality.

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,

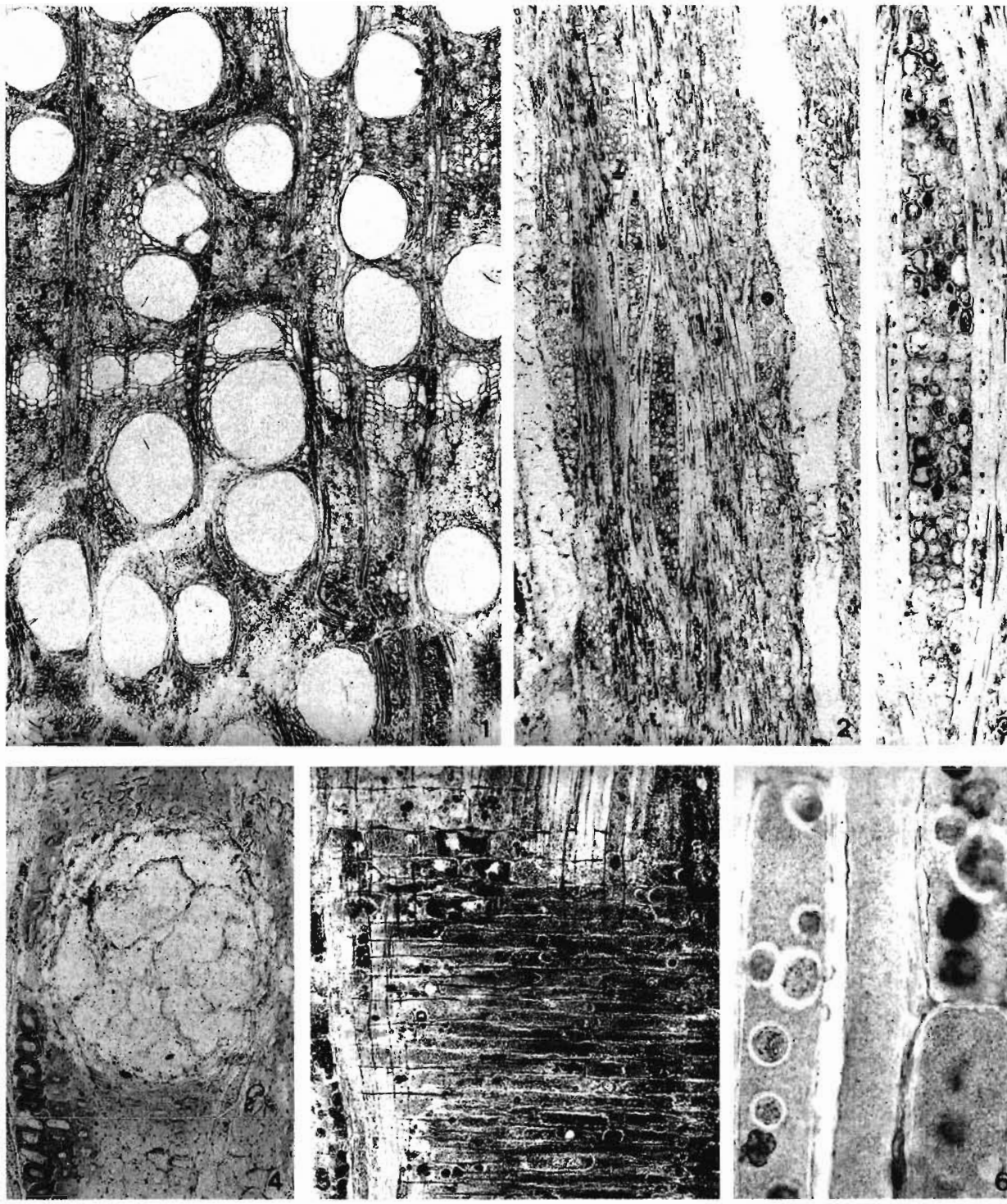

PLATE 1

Dryobalanops bogorense 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 infilteration 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, Dioticarpus, Doona, Dryobalanops, Hopea, Isoptera, Parashorea, Pentacme* and *Shorea* (Metcalfe & Chalk, 1950; Desch, 1957; Chowdhury & Ghosh, 1958; Hayashi *et al*., 1973; Ilic, 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. aromatica* 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. aromatica,* the size of vessels, tyloses and parenchyma pattern matches the fossil wood, however, in a few modern specimens ripple marks are present due to storied nature of rays while in others rays are not storeyed. (Desch, 1957; p.109). Among the examined species, in *D. beccari* (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 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. keralaensis* differs in having less amount of paratracheal vasicentric parenchyma. In *D. klumerinum* 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. tambouense* 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 thickenings 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. tobleri* 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.

Name of Fossil Species	Age	Horizon/Country	References
Dryobalanoxylon bangkoense *Schweitzer*	Quaternary	Central Sumatra, Indonesia; *Southwest Bangkok, Thailand*	Schweitzer 1958
Dryobalanoxylon cf. bangkoense *Schweitzer*	Quaternary	Central Sumatra, Indonesia; *Southwest Bangkok, Thailand*	Schweitzer 1958
D. borneense Schweitzer	Miocene	Borneo, Indonesia	Schweitzer 1958
D. holdeni (Ramanujam) *Awasthi*	Miocene-*Pliocene*	Cuddalore Sandstone, India	Awasthi 1971
D. indicum (Ramanujam) *Awasthi*	Miocene-*Pliocene*	Cuddalore Sandstone, India	Awasthi 1971
D. javanicum (Kräusel) *Den Berger*	Pliocene	West Java, Indonesia	Den Berger 1927; *Schweitzer 1958*
D. keralaensis Awasthi & Ahuja	Miocene	Warkalli Formation, India	Awasthi & Ahuja 1982
D. khmerinum Boureau	----------	Combodia, Indo-China	Boureau 1952; Schweitzer 1958
D. mirabile Schweitzer	Quaternary	Central Sumatra, Indonesia; South Bangkok, Thailand.	Schweitzer 1958
D. musperi Schweitzer	Early-Late Pliocene	West Java, Indonesia	Schweitzer 1958
D. neglectum Schweitzer	Quaternary	Central Sumatra, Indonesia; Southwest Bangkok, Thailand	Schweitzer 1958
D. rotundatum Schweitzer	Quaternary	Central Sumatra, Indonesia; Southwest Bangkok, Thailand	Schweitzer 1958
D. spectabile (Crié) Den *Berger*	Pliocene	West Java; between Batavia and *Rangkas-Bitoeng, Indonesia*	Den Berger 1923; *Schweitzer 1958*
D. sumatrense Schweitzer	Late Pliocene	Central Sumatra, Indonesia	Schweitzer 1958
D. tambouense Vozenin-Serra	Pliocene	South Vietnam	Vozenin-Serra, 1981
D. tobleri (Kräusel) Den *Berger*	Pliocene	West Java; between Batavia and *Rangkas-Bitoeng, Indonesia*	Den Berger, 1923; *Schweitzer, 1958*
D. bogorense sp. nov.	Pliocene	Bogor, West Java, Indonesia	----------

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; Lakhanpal, 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* (Cluciaceae), *Dillenia* (Dilleniaceae), *Ochanostachys* (Olacaceae), *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, Rubroshorea* 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, Cotylelobium, Rubroshorea,* etc. failed to regenerate. Thus they became extinct in the natural forests of Java.

The genus *Dryobalanops* Gaertner f. consists of 7 species restricted in present day tropical evergreen rain forests of Indonesia (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.

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