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A New Species of Dryobalanoxylon Den Berger from the Neyveli Lignite Formation, Tamil Nadu, India

KUMARASAMY, D. ELAYARAJA, M.
Botany Wing-DDE, Annamalai University, Annamalai Nagar-608 002, Tamil Nadu, India

Abstract
Neyveli lignite formation is one of the largest tertiary brown coal filed lignite formation found in the Neyveli, Cuddalore district of Tamil Nadu, India. So far many mega fossils and micro fossils reported from this formation. The present study is about a charcoalified wood found in this formation. The fossil wood is identified as *Dryobalanoxylon* as a new species *D. neyveliensis* sp.nov. This is a first report of *Dryobalanoxylon* from the Neyveli formation.
Keywords: *Dryobalanoxylon neyveliensis* sp.nov., Neyveli formation, Tertiary.

1. Introduction

The Neyveli lignite field is one of the single largest brown coal deposits in India. It occurs near Neyveli town (latitude 11° 15′ to 11° 40′ and longitude 79°25′ to 79°40) found in Cuddalore district of Tamil Nadu. The major lignite seam found 45-150 m below ground and it comes under the Neyveli formation (over 300 m thick) consists of semiconsolidated sandstone and clay beds with the lignite deposits and it lies below the Cuddalore sandstone formation (made up of ferruginous, arkosic, semiconsolidated sandstone exhibiting some herringbone type cross laminations) and the lignite is of Tertiary (Miocene) age (Singh *et al*., 1992). There are about 3300 million tons of lignite spread beneath an area of 300 sq. kms in seams having an average thickness of 23 m. (Navale,1973). So far, many plant mega fossils (include many compressed leaves and petrified woods of angiosperms) and microfossils (include pollen grains of gymnosperms and angiosperms) were reported from this formation. (Verma *et al.,* 1989). The present study is about the identification of charcoalified angiosperm wood collected from the Neyveli lignite formation.

2. Material and Methods

The material was collected from the Mine-II of the Neyveli lignite field and it is a small part of a long charcoalified wood (about 16 m long and 95 cm in diameter). Hand sections (TS, TLS, & RLS) were prepared from the wood fragment and the sections were mounted in DPX. The sections were observed in light microscopes and the microphotographs were taken using Olympus CCD camera attached with Olympus Trinocular Microscope.

A small part of Charcoalified wood

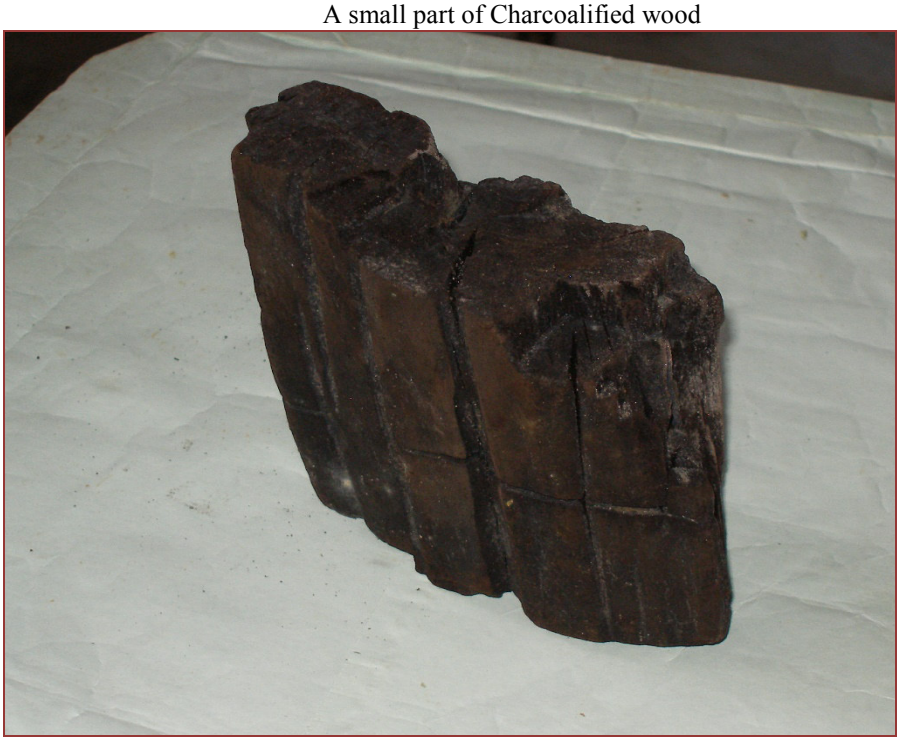

Plate - 1

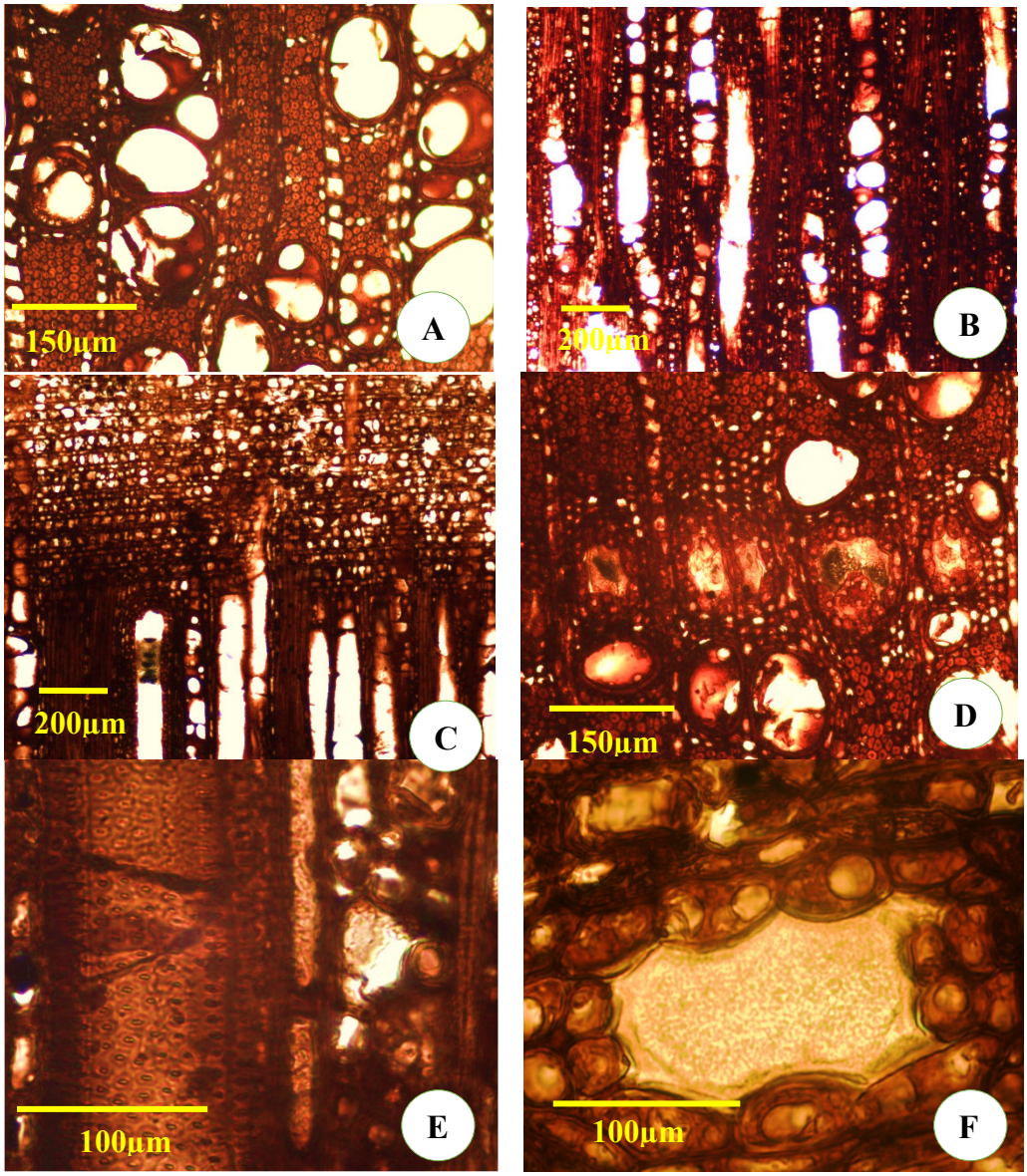

Figure:

A. *Dryobalanoxylon neyveliensis* sp. nov. TS
B. *Dryobalanoxylon neyveliensis* sp. nov. TLS
C. *Dryobalanoxylon neyveliensis* sp. nov. RLS
D. *Dryobalanoxylon neyveliensis* sp. nov. TS showing gum canals in concentric tangential rows
E. *Dryobalanoxylon neyveliensis* sp. nov. TS showing inter vessel pits.
F. *Dryobalanoxylon neyveliensis sp*. nov. TS a single gum canal enlarged.

Table-1
Table showing the *Dryobalanoxylon* species reported from the South East Asia.

S. No	Species	Country	Age	Reference
1	*D.bangkoense* Schweitzer	Indonesia &Thailand	Quaternary	Schweitzer,1958
2	*D.bogorensis*	Indonesia	Pliocene	Srivastava & kagemori,2001
3	*D.borneense* Schweitzer	Indonesia	Miocene	Schweitzer,1958
4	*D.holdeni*(Rmanujam)Awasthi	India	Miocene Pliocene	Awasthi,1971
5	*D.indicum*(Rmanujam)Awasthi	India	Miocene Pliocene	Awasthi,1971
6	*D.javanense*	Indonesia	Pliocene Pliocene	Krausel,1922 DenBerger,1923
7	*D.keralensis* Awasthi & Ahuja	India	Miocene	Awasthi & Ahuja, 1982
8	*D.lunaris*	Indonesia	Pliocene	Mandang & kagemori, 2004
9	*D.mirabile* Schweitzer	Indonesia &Thailand	Quaternary	Schweitzer,1958
10	*D.musperi* Schweitzer	Indonesia	Pliocene	Schweitzer,1958
11	*D.neglectum* Schweitzer	Indonesia &Thailand	Quaternary	Schweitzer,1958
12	*D.rotundatum* Schweitzer	Indonesia &Thailand	Quaternary	Schweitzer,1958
13	*D.spectabile* (crie)DenBerger	Indonesia	Pliocene Pliocene	DenBerger, 1923 Schweitzer,1958
14	*D.sumatrense* Schweitzer	Indonesia	Pliocene	Schweitzer,1958
15	*D.tambouense* Vozenin-Serra	Vietnam	Pliocene	Vozenin-Serra, 1989
16	*D.tobleri* (Krausel) DenBerger	Indonesia	Tertiary Pliocene	DenBerger, 1923 Schweitzer,1958

3. Description of wood (Plat: 1. Fig-A, B, C, D, E and F)
Wood diffuse porous. Growth rings absent. Vessels exclusively solitary, rarely in radial groups of two to three; round to oval in cross section; small to medium, tangential diameter 60- 170 (average 107) µm, radial diameter180-201(average 196) µm; 7-9 per sq mm; tyloses not observed in the wood; vessel elements 212-320 (average 302) µm long; end walls oblique; inter vessel pits abundant, bordered, alternate, 8-10 µm in diameter; rounded or slightly flattened with elliptical apertures. Parenchyma both apotracheal and paratracheal; apotracheal parenchyma associated with vertical gum canals forming 2-4 cells thick sheath around the gum canals, apart from this, apotracheal parenchyma also distributed as isolated cells in between the vasicenric tracheids; paratracheal parenchyma vasicentric, forming 2-3 cells thick sheath around the vessels. Vasicenric tracheids are interspersed between the vasicentric parenchyma cells; pits found on radial wall of the tracheids are bordered, oval to circular with rounded to elliptical aperture. Fibre tracheids constituted bulk of the wood, polygonal in cross section, 15-27 (average 8.0) µm in diameter, thick walled, non-septate, small bordered pits in a single row was found on the radial walls of fibre-tracheids. Rays 2-3 seriate, homogeneous, mostly 3 seriate, rarely bi seriate, 21-66 cells high, 10-12 per sq mm, hetercellular, composed of both upright and procumbent cells and they are found in haphazard arrangement. Gum-gum canals vertical, normal, forming tangential rows, embedded in 2-3 cells thick apotracheal parenchyma bands; almost circular in outline, 60-110 (average 82)µm in diameter; epithelium consists of single layer of cells which are oval to rounded and bulged or arched towards the side facing the interior of the cavity.

4. Comparison with fossil species
The presence of vertical gum canals in tangential rows, exclusively solitary vessels, vasicentric trchaeids, heterocellular rays and the presence of thick walled fibre trachaeids clearly indicate affinity of the present fossil wood with woods of Dipterocarpaceae, particularly, genera like *Balanocarpus*, *Dipterocarpus*, *Doona*, *Dryobalanops*, *Hopea*, *Isoptera*, *Parashorea*, *Pantacme* and *Shorea* (Metcalf & Chalk, 1950; Desch, 1957; Chowdhury, *et al*. 1958; Hayashi *et al*, 1973; Ilic, 1991). Among these genera, the present fossil wood is more closely related to *Dryobalanops* in the presence of solitary vessels or nearly so and the thick walled fibre trachaeids. Fossil woods resembling *Dryobalanops* are placed in the form genus *Dryobalanoxylon* Den Berger. So for sixteen species of *Dryobalanoxylon* reported from the Neogene and quarternary deposits of south East Asia. Among these species, three species viz. *Dryobalanoxylon indicum* , *D. holdeni* (from the Cuddalore sandstone formation)and *D. keralensis*, reported from Miocene-Pliocene sediments of India and the remaining species are from the Neogene and quarternary deposits of Java, Sumatra, Borneo, Cambodia, and Viet-Nam(See

table-1).

The present fossil wood differs from *D. mirabile, D.neglectum* and *D. bangkoense* in the presence of heterocellular rays. In the latter species the rays are homocellular. The present wood also compares well with *D. javanense, D.spectabile* and *D. borneense* but it differ from the latter species in the absence of sheath cells in the rays. But this sheath cells are distinct in the latter species. The present wood also compare well with *D. rotundatum* but it differ from the latter in having non-storied rays,

The present wood also compares well with *D.musperi*, but it differs from latter in the complete absence uniseriate rays. The present wood also compare well with *D. bogorensis* and *D. holdeni* but it differ from the latter species in the presence of long rays (21-66 cells) where as in the latter the rays are less than 40 cells high. So the present specimen identified as a new species of *Dryobalanoxylon.* as *Dryobalanoxylon neyveliensis* sp.nov.

4.1. *Dryobalanoxylon neyveliensis* sp. nov.

Holotype–Specimen. NY.1. Deposited in Neyveli lignite corporation museum, Neyveli,
Tamil Nadu, India
Locality–Neyveli Lignite Corporation Mine-II A.
Age–Miocene
Etymology–Specific name after the Neyveli formation.

Class: Dicotyledons
Family: Dipterocarpaceae
Genus: *Dryobalanoxylon* Den Berger,
Species: *Dryobalanoxylon neyveliensis* sp.nov.

4.2. Specific diagnosis

Wood diffuse porous, vessel almost exclusively solitary, vasicentric tracheid present; parenchyma paratracheal and apotracheal; paratracheal parenchyma vasicentric; apotracheal parenchyma associated with concentric rings of axial gum canals and also found in diffused state; rays 2-3-seriate, 10-12 per sq mm, ray tissue homogeneous, heterocellular up to 66 cells high; fibre trachids non-septate, thick walled; gum canals vertical, arranged in tangential rows, seemingly circular, 60-110 µm in diameter.

5. Discussion

The Miocene flora in the peninsular part of India is mostly preserved in the from of woods and is known mainly from Kachchh, Bhavnagar, and Bharuch (Gujarat), Varkala (Kerala), Neyveli and Tiruvakkarai (Tami Nadu), Birbhun (West Bengal), and Kalaicharpar hills (Meghalaya), Teliamura (Tripura), Zawlnuam (Mizoaram), Diphu Hailakandi, Nahorkatiya and Nailalung (Assam), Naginimora (Nagaland) and Jairampura (Arunachal pradesh) (Mehrotra *et al*., 2014). So far fossil woods related to *Cryptostegia*, *Melodinus* and *Nerium* of (Apocynaceae) *Bouea*, *Gluta*, and *Swintonia* (Anacardiacaeae), *Cordia* (Boraginaceae) *Canarium* (Burseraceae), *Calophyllum, Kayea*, and *Mesua* (Calophyllaceae), *Parinari* (Chrysobalanaceae), *Garcinia* (Clusiaceae), *Terminalia* (Combretaceae), *Dipterocarpus* and *Hopea* (Dipterocarpaceae), *Diospyros* (Ebenaceae), *Excoecaria* and *Hevea* (Euphorbiaceae), *Bauhinia*, *Cassia*, *Dialium*, and *Millettia* (Fabaceae), *Altingia* (Hamamelidaceae), *Machilus* (Lauraceae), *Careya* (Lecythidaceae), *Lagerstoemia* and *Sonneratia* (Lythraceae), *Grewia* (Malvaceae), *Ficus* (Moraceae), *Syzygium* (Myrtaceae), *Bischofia* and *Phyllanthus* (Phyllanthaceae), *Carallia* (Rhizoporaceae), *Anthocephalus*, *Ceriscoides* and *Randia* (Rubiaceae), *Geijera* (Rutaceae), *Euphorbia*, *Filicium*, *Harpullia* and *Otophora* (Sapindaceae) and *Mimusops* (Sapindaceae) reported from Neyveli lignite (Saxena, 1992). This is the first report of wood related to *Dryobalanops* in this formation. But it is already reported from Cuddalore sandstone formation found in the upper part of Neyveli lignite formation.

The genus *Dryobalanops Gaertn.f* consists of 7 species restricted in present day tropical evergreen forest of Indonesia (Sumatra and Borneo) and Malaysia (Merrill, 1923; Foxworthy, 1946; Mabberley, 1997). However it was more widely distributed in the geological past as its fossil records are known from India and other South East Asian countries like, Cambodia, Vietnam and it was also been reported from Java and Indonesia. Because of land connections between Malaysia, India, Arabia and Eastern Africa and the prevalent moist climate in this region during the Neogene times, it is envisaged that there were large scale migrations and inter mingling of floras in this vest region during that period.

Occurrence of Dipterocarpaceae and other Malayan elements in the Cuddalore sandstone and Neyveli formation indicates that from Eastern India they also took a South-Western route to establish themselves in South India in the Upper Tertiary. At that time Ceylon was connected with South India where by the Dipterocarps also entered this island. Its subsequent separation resulted in the development of many endemic species of the Dipterocarpaceae in Ceylon.

The comparison between the Neogene and modern distribution of Dipterocarpaceae leads to an

important palaeoecological conclusion. While most equable climate must have prevailed in Mio-Pliocene times from India to Eastern Africa to enable the growth of the Dipterocarpaceae, aridity must have set in towards the close of the Neogene, resulting in the complete eradication of Dipterocarps from North Eastern Africa to Northern India today. Due to arid conditions in the Middle East, African Dipterocarps were cut off from the main stock and evolved endemically in to an aberrant group called Monotoideae with aridity spreading from Western Asia towards India, the family receded in to North Eastern and South Western India. This aridity must have been one of the results of growing continentality caused by the rise of the mountains and severance of connections with sea (Lakhanpal, 1970).

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