Fossil wood diversity record from Merangin region, Jambi, Indonesia

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Abstract. Merangin is a region in Jambi province, Indonesia, which well-known for its geodiversity. As part of geodiversity, fossil woods play an important role in reconstructing the ancient trees during geological history. Since the study on fossil wood origin Merangin Regency, Jambi, is still limited, this study was conducted to determine fossil wood identity through anatomical features observation and estimate the age of fossil wood samples through geological analysis. The anatomical characteristics were observed using a light microscope to identify the botanical identity of the discovered fossil wood samples. The description of anatomical features refered to the IAWA list of microscopic features for hardwood identification. The result showed that all fossil woods had similarities with the modern wood from the Dipterocarpaceae family, namely Dryobalanoxylon sp. (Kamper), Hopenum sp. (Merawan/Hopea), Shoreoxylon sp. (Meranti), and Cotylelobioxylon sp. (Giam/Resak). These fossil woods were found in different estimated geological age namely Late Permian/Perem age (254-252 million years old), Late Miocene age (7.24-5.33 million years old); Late Pliocene to Early Pleistocene age (3.60-2.58 million years old); and Holocene age (11,700 years old - present). Another approach by using Global Mapper 11 resulted that all the fossil woods were estimated grown in Permian age (290 - 250 million years).

1. Introduction

Indonesia is well-known as one of the mega biodiversity countries in the world. The presence of fossil wood in many regions of Indonesia has shown biodiversity during pre-history time. One of Indonesia’s regions, known as a source of diversity of plants known to the world as geodiversity, is Merangin Regency in Jambi Province. The geodiversity area has been designated and certified by UNESCO as Global Geopark, namely Geopark Merangin, with a total area of 20,360 km² [1]. In the Merangin area, the most striking outcrop is the Permian Mengkarang formation, which has fossil fossils. Mengkarang formation is the oldest uncovered formation in Jambi, has a special tectonic mechanism visible in the surface with an inverted “U” curve shape [2]. Merangin area is located in the Kerinci Seblat National Park (TNKS). It was informed that the flora and fauna fossils in the area along the Batang Merangin and Batang Mengkarang (Bangko) rivers contain flora and fauna fossils aged 250 to 290 million years (Upper Permian/late-early Jurassic era). Based on the Geological Agency research results in
collaboration with experts from the Netherlands (Geological Research Institute-Naturalis Leiden, Netherlands) along this river flow, there are fossils of Araucarioxylon tree trunks [3].

Biodiversity of tree species that grew in the past was recorded in the finds of wood fossils in Indonesia through a series of studies initiated by scientists more than a century ago. Krausel [4] reported that the discovery of fossil wood in Indonesia began in 1854 by Goppert, who discovered fossil wood on Java island. The finding of fossil wood of *Naucleoxylon spectabile* (Rubiaceae) by Crie [5] originating from Mount Kendeng (Java) was revised by Krausel [6] to *Dipterocarpxylon spectabile*. *Dipterocarpxylon* sp. fossil wood also was found in South Sumatra Province, and *Dipterocarpxylon javanense* in Bolang, Rangkasbitung area [7-8]. But then, the findings of the two fossils were revised to *Dryobalanoxylon spectabilis* and *Dryobalanoxylon javanense* by Den Berger [9-10]. *Shoreoxylon pulchrum* and *Vaticoxylon plocaenicum* from Jambi, *Dryobalanoxylon tobleri* from Banten, and *Dipterocarpxylon javanicum* from Indramayu were described by Schweitzer [11]. Sukiman also reported another fossil wood from Pacitan (East Java) as *Shoreoxylon pachitanensis* [12].

Current investigation on fossil wood exploration shows that most fossil woods were identified to the Dipterocarpaceae family. Mandang and Martono [13] discovered fossil wood of Cotyleloboxylon, Dryobalanoxylon, Dipterocarpxylon, Parashoreoxylon, Anisopteroxylon, Shoreoxylon, and Hopeoxylon at the commercial fossil wood collection site in Ciampea, Leuwiliang (Bogor) and Jasinga (Banten). Then in 2001, Srivastava and Kagemori [14] identified *Dryobalanoxylon bogorensis* fossil wood collected from the same location in Leuwiliang. The fossil wood of *Dryobalanoxylon lunaris* from Maja-Lebak (Banten) was also found by Mandang and Kagemori [15]. Another species, namely *Gluta wallichii* fossil wood from Central Java, was reported by Andianto *et al.* [16]. A recent study reported fossil wood from Gorontalo as *Shoreoxylon* sp. and *Hopenium* sp. [17]. A comprehensive study on fossil wood in Indonesia has not been fully revealed, and many regions have not been fully explored. This paper presents the exploration research on fossil wood from Merangin Regency, Jambi, to complete the database of fossil wood distribution in Indonesia. The comprehensive database of fossil wood distribution in Indonesia is important to reconstruct the past vegetation of tree species. The database can be used as reference for tree species selection in reforestation program, so that the sustainable management of forest and natural resource subsequently can be achieved.

### 2. Materials and Methods

#### 2.1. Study area

The area of this study was located in Merangin Regency, Jambi Province, Sumatra. Survey and sample collection were carried out in West Bangko and Nalo Tantan districts and the Tantan River, Merangin Regency. The information on the targeted location was gathered from the local community. Fossil woods were found in lowland areas which are covered by oil palm and rubber plantations. The coordinate point of each location of fossil wood was recorded. The geographical site of fossil woods is presented in Table 1.

| No. | Site                  | Coordinate          | Altitude | Code of specimen |
|-----|-----------------------|---------------------|----------|------------------|
| 1.  | Bukit Beringin (West Bangko) | (S) 02°13'990" (E) 102°16'503" | 177      | A                |
| 2.  | Bukit Beringin (West Bangko) | (S) 02°14'008" (E) 102°16'505" | 178      | B                |
| 3.  | Bukit Beringin (West Bangko) | (S) 02°14'096" (E) 102°16'531" | 185      | C                |
| 4.  | Danau (Nalo tantan)    | (S) 02°00'453" (E) 102°10'648" | 85       | D                |
| 5.  | Danau (Nalo tantan)    | (S) 01°59'333" (E) 102°11'055" | 105      | E                |
| 6.  | Telun                 | (S) 02°01'329" (E) 102°10'047" | 94       | F                |
| 7.  | Telun                 | (S) 02°01'639" (E) 102°10'133" | 111      | G                |
2.2. Materials
The fossil woods were excavated in West Bangko and Nalo Tantan, Merangin Regency, Jambi Province (Figure 1). These fossil wood samples were further observed in the laboratory to investigate their botanical identity.

![Figure 1. Discovered fossil woods in Merangin, Jambi.](image)

2.3. Methods
A thin section of cross, radial and tangential fossil wood samples was prepared by cutting a piece of fossil wood measuring 3 cm x 3 cm x 6 cm for each section. The targeted sections were thinned using a rock scrubbing machine that has been sprinkled with 100 mesh carborundum powder. Then each slice of fossil wood was washed with water and rubbed again with 5 mm thickness glass with adding 320 mesh of carborundum powder, continuously to get the thinnest slice using smoother carborundum powder (600 mesh). Following that, each slide of fossil wood along with the object-glass was heated in a hot plate to a temperature of 70-80°C, then mounted using canada balsam. Each section then observed for anatomical characteristics under the light microscope (Carl Zeiss-Axio Imager A1m).

The descriptions of anatomical features refer to IAWA Committee [18]. The anatomical characteristics of fossil wood samples were compared to the present wood species which have similar anatomical characteristics. The fossil wood samples were matched with the authentic wood collection in Xylarium Bogoriense to confirm the similarities. The determination of the estimated age of wood fossils was plotted according to geological maps of Sarolangun and Muarabungo, Sumatra, which provide information on rock stratigraphy with estimated age information. Another approach was by using Global Mapper 11 software.

3. Results and Discussion
3.1. Anatomical features
The fossil wood specimens show anatomical resemblances with the Dipterocarpaceae family. We identified the fossil wood specimens were similar to genus Dryobalanops (3 specimens), Hopea (1 specimen), Shorea (2 specimens), and Cotylelobium (1 specimen). The diagnostic characteristics of the Dipterocarpaceae family which found in all the specimens are diffuse-porous (5), simple perforation plate (13), alternate inter vessel pit (22), the presence of axial intercellular canals in long tangential lines (127), vasicentric parenchyma (79), and prismatic crystals (136). The anatomical features of seven fossil kinds of wood specimens are presented in Table 2. It can be seen that different species have differences in some anatomical characteristics. Scanty paratracheal parenchyma (78) shows the diagnostic feature that differentiates Shoreoxylon spp. with other species, but all of them have vasicentric parenchyma (79). While for the confluent type of parenchyma (83) was identified in Hopenium sp. (specimen B) and Shoreoxylon spp. (specimen C and D).
Table 2. Anatomical features of fossil woods from Merangin, Jambi.

| Anatomical features                      | Specimen A | Specimen B | Specimen C | Specimen D | Specimen E | Specimen F | Specimen G |
|-----------------------------------------|------------|------------|------------|------------|------------|------------|------------|
| A. Vessels                              |            |            |            |            |            |            |            |
| 1. Porosity                             | (5)        | (5)        | (5)        | (5)        | (5)        | (5)        | (5)        |
| 2. Vessel grouping                      | (9)        | -          | -          | -          | (9)        | (9)        | (9)        |
| 3. Perforation plates                   | (13)       | (13)       | (13)       | (13)       | (13)       | (13)       | (13)       |
| 4. Intervessel pit arrangement          | (22)       | (22)       | (22)       | (22)       | (22)       | (22)       | (22)       |
| B. Fibre wall thickness                |            |            |            |            |            |            |            |
| C. Parenchyma                           |            |            |            |            |            |            |            |
| 1. Paratracheal                         | (79)       | (79), (83) | (78), (83) | (78), (83) | (79)       | (79)       | (79)       |
| 2. Apotracheal                          | (76), (77) | (77)       | (76), (77) | (76), (77) | (76), (77) | (76), (77) | (76), (77) |
| 3. Banded                               | -          | -          | -          | -          | -          | -          | -          |
| 4. Cell type/strand length              | (92)       | -          | -          | -          | (92)       | (92)       | (92)       |
| D. Ray                                  |            |            |            |            |            |            |            |
| 1. Width (seriate)                     | (97), (98) | (97), (98) | (97), (98) | (97), (98) | (97), (98) | (97), (98) | (97), (98) |
| 2. Composition                          | (106), (107)|(106), (107)|(106), (107)|(106), (107)|(106), (107)|(106), (107)|(106), (107)|
| E. Intercellular canals                 | (127)      | (127)      | (127)      | (127)      | (127)      | (127)      | (127)      |
| F. Mineral inclusion                    |            |            |            |            |            |            |            |
| 1. Prismatic crystals                   | (136), (142)|(136), (137)|(136), (137)|(136), (137)|(136), (142)|(136), (142)|(136), (137)|
| 2. Silica                               | (159), (160), (161) | - | - | - | (159), (160), (161) | (159), (160), (161) |

| Species                                  | Dryobalanoxylon | Hopenium sp. | Shoreoxylon sp. | Shoreoxylon sp. | Dryobalanoxylon | Dryobalanoxylon | Cotylelobiisylon |
|------------------------------------------|-----------------|--------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Dryobalanoxylon sp.                      | (136), (142)    |              |                 |                 |                 |                 |                 |
| Hopenium sp.                             |                 |              |                 |                 |                 |                 |                 |
| Shoreoxylon sp.                          |                 |              |                 |                 |                 |                 |                 |
| Shoreoxylon sp.                          |                 |              |                 |                 |                 |                 |                 |
| Dryobalanoxylon sp.                      |                 |              |                 |                 |                 |                 |                 |
| Dryobalanoxylon sp.                      |                 |              |                 |                 |                 |                 |                 |
| Cotylelobiisylon sp.                     |                 |              |                 |                 |                 |                 |                 |

Note: the number in parentheses present the code of anatomical characteristics according to IAWA committee [18]

The microscopic features of specimens A to G are presented in Figures 2 to 8.

Figure 2. Microscopic features of Dryobalanoxylon sp. (Specimen A): a. transverse section, b. tangential section, c. radial section.

The anatomical features of specimen A are similar to those of the genus Dryobalanops (camphor/kamper/kapur) (Figure 2). Therefore, based on such characteristics, the fossil wood of specimen A was categorized as Dryobalanoxylon sp. (Dipterocarpaceae). Meanwhile, the anatomical characteristics of specimen B are close to those of Hopea sp. (Merawan), a member of the Dipterocarpaceae family. Therefore, due to the similarity with the modern wood of Hopea, specimen B can be named Hopenium sp. (Dipterocarpaceae) (Figure 3). Some fossil woods of Hopea has been defined as Hopenium like for example, which found in various Tertiary sediments of India [19].
Figure 3. Microscopic features of Hopenium sp. (Specimen B): a. transverse section, b. tangential section, c. radial section.

For specimen C, fossil wood characteristics were similar to those of the genus Shorea sp. (Meranti) from the Dipterocarpaceae family, so based on such characteristics, this fossil is described as Shoreoxylon sp. (Meranti) (Figure 4). Similarly, the anatomical features of specimen D were also similar to modern wood of Shorea sp. (Meranti). Due to the similarity of such characteristics, the fossil wood of specimen D can also be considered meranti wood species (Shoreoxylon sp.) (Figure 5).

Figure 4. Microscopic features of Shoreoxylon sp. (Specimen C): a. transverse section, b. tangential section, c. radial section.

Figure 5. Microscopic features of Shoreoxylon sp. (Specimen D): a. transverse section, b. tangential section, c. radial section.

The anatomical characteristics of specimen E fossil wood are close to Dryobalanops sp. (camphor/kamper/kapur) from the Dipterocarpaceae family. Hence, based on such characteristics, specimen E can be named Dryobalanoxylon sp. (Figure 6). Similar characteristics were also identified for specimen F, which resemble genus Dryobalanops (camphor/kamper/kapur), a member of the Dipterocarpaceae family, so based on such characteristics, this fossil is also can be identified as Dryobalanoxylon sp. (Figure 7).
Figure 6. Microscopic features of *Dryobalanoxylon* sp. (Specimen E): a. transverse section, b. tangential section, c. radial section.

Figure 7. Microscopic features of *Dryobalanoxylon* sp. (Specimen F): a. transverse section, b. tangential section, c. radial section.

Lastly, the anatomical characteristics of specimen G showed the affinity with the characteristics of *Cotylelobium* sp. (resak/giam) from the Dipterocarpaceae family. Therefore, this fossil wood can be identified as *Cotylelobioxylon* sp.

Figure 8. Microscopic features of *Cotylelobioxylon* sp. (Specimen G): a. transverse section, b. tangential section, c. radial section.

The identified fossil wood samples in this study showed that all fossil woods belong to the Dipterocarpaceae family. Previous studies reported that mostly fossil woods in Indonesia have identified as members of the Dipterocarpaceae family. The studies have proven that the Dipterocarpaceae family can survive the environmental conditions of its lifetime.

3.2. Estimated age of fossil wood

According to a graphical map of the estimated age of fossils [20], it is known that the geological time scale is divided into two time periods, namely the Precambrian / Cryptozoic (4.6 billion - 540 million years ago) and Panerozoicum (540 million - when this). The Precambrian is divided into the Archaeozoic
(Archean) and Proterozoic Eras, while the Panerzoicum is divided into the Paleozoic, Mesozoic, and lastly, the Cenozoic Era. The Archaeozoic lasted about 4 to 2.5 billion years ago. The Proterozoic Era lasted between 2.5 billion and 542 million years ago. The Paleozoic Era lasted from 542 to 251 million years ago. The Mesozoic Era lasted about 251 to 65 million years ago and the Cenozoic era lasted from 65.5 million years ago to the present.

The discovered fossil woods were found in four formations (based on the geological map data of the Sarolangun sheet, Sumatra), namely:

1. The Palepat Formation
   This formation is included in volcanic rock consisting of andesite, dacite and diaphragma, tuff inserts, shale volcanic breccia, siltstone, sandstone, slab, local conglomerates, and limestone. The identified fossil wood species found in this formation were meranti (Shoreoxylon sp.), camphor/kapur (Dryobalanoxylon sp.), and giam/or serak (Cotylelobioxylon sp.) with specimen codes D, F and G located at coordinates (S) 02°00'453''-(E) 102°10'648'', (S) 02°01'329''-(E) 102°10'047'' and (S) 02°01'639''-(E) 102°10'133''. Based on the analysis of this geological map, it was found that the ages of these three fossils were between 254 and 252 million years ago (late Permian). Permian period (290-250 million years) belong to the Paleozoic era, when it was growing coniferous plants and primitive Ginko.

   Specifically for specimen code D, this fossil was found on the surface of the Tantan river. Even though these fossil finds were on the surface of the river, after being traced on the Geological map of the Sarolangun sheet, this river flow was still included in the Palepat formation. So that the estimated age of this fossil is also included in the Permian era.

2. Air Benakat Formation
   This formation is included in sedimentary and malihan rock which consists of alternating slab and sandstone; insert conglomerate of limestone, silt, marl and coal. The fossil wood found in this area is camphor/kapur (Dryobalanoxylon sp.) with specimen code E (coordinates (S) 01°59'333''-(E) 102°11'055''). Based on the analysis on geological maps, the estimated age of these fossils is between 7.24 to 5.33 million years ago (during the late Miocene) which belongs to the Cenozoicum era.

3. Kasai Formation
   This formation is also included in the sedimentary and malihan rocks consisting of tuff, pumice tuff, and tuff, tuff clay; local conglomerates; wood scraped off. The fossil wood found in this area is camphor/kapur (Dryobalanoxylon sp.) with the specimen code A. This wood fossil was found at the coordinates (S) 02°13'990''-(E) 102°16'503''. The estimated age of fossils through geological map analysis is 3.60 to 2.58 million years ago (late Pliocene to early Plistocene) which belonged to the Cenozoicum era.

4. Volcanic-tuff Breccia formation
   This formation is included in volcanic rock consisting of tuff, lava, volcanic breccia, tuff breccia, and lava. The fossil wood in this area were identified as merawan/hopooa (Hopenium sp.) and meranti (Shoreoxylon sp.) with specimen codes B and C. Each is located at coordinates (S) 02°14'008''-(E) 102°16'505'' and (S) 02°14'096''-(E) 102°16'531''. Based on the analysis, the estimated age of these two fossils is 11,700 years ago to the present (during the Holocene) which is also included in the Cenozoicum era.

Fossils of meranti wood (Shoreoxylon sp.), camphor (Dryobalanoxylon sp.) and giam/resak (Cotylelobioxylon sp.) found in the Palepat formation are thought to have the oldest age, living in the Permian period (290-250 million years ago). In addition, there were other camphor wood fossils in the Air Benakat formation between 7.24 and 5.33 million years ago (during the late Miocene) which belong to the younger era, namely the Tertiary era. The findings of wood fossils 290-250 million years ago are almost the same as those informed by Abdurahman [3], in the form of ancient wood fossil findings in sediments of the age of Perem, approximately 300-250 million years ago.

Camphor wood fossil (Dryobalanoxylon sp.) was also found in the Kasai formation with an estimated age of between 3.60 and 2.58 million years ago (during the late Pliocene to early Plistocene). This period is an era when there were large carnivorous animals and early human life emerged [21]. In addition, in the Breccia Gunung Api-Tuf formation, fossils of hopea (Hopenium sp.) and meranti (Shoreoxylon sp.)
wood were found which are estimated to be 11,700 years ago until its below period (during the Holocene). The Holocene era was the end of glaciation and the rise of human civilization [21].

![Geological map of Sarolangun sheet](image)

**Figure 9.** Geological map of Sarolangun sheet [20].

The second approach by plotting the coordinate point of the discovered fossil woods in the Global Mapper 11, it can be identified that the coordinate points of specimens A, B, C, D, F, and G were included in the geological map of the Sarolangun sheet (Figure 9). In contrast, point E was included in the geological map of the Muarabungo sheet. Based on the geological map, specimen A, B, C, D, E, and F belong to the Mengkarang formation. In contrast, point G belongs to the Palepat formation with the estimated geological age for all wood fossil specimens in the Permian age. Previous studies have identified some fossil woods from the Early Permian Mengkarang formation in Sumatra, such as Araucarioxylon, Dadoxylon, and Dammaroxylon [22]. The Permian-aged Mengkarang formation is located in the central part of Sumatra [23].

However, the geological age of the Mengkarang formation and the Jambi paleo flora based on stratigraphical observation has been debatable amongst geologists. Hutchison (2007) stated that the palaeoflora of Jambi, well-known as "Permo-Carboniferous", in age. Waveren et al. [24] reviewed many studies from various aspects of the Mengkarang formation from previously published literature. Based on the taxonomy of paleo flora from Jambi, Mengkarang formation was suggested to be a Late Carboniferous age [25], but Meyer [26] determined the late Permian base on brachiopods collected from limestone layers of the Mengkarang formation at Telok Gedang, previously known as the early Permian (Dyas) [27]. Ozawa [28] estimated the fusulinid foraminifera from Telok Gedang to be Carboniferous, but Thompson [29] scrutinized the Tobler collection and suggested an early Permian age. A new collection of macrofossils and microfossils from Telok Gedang studied by Fontaine [30] recommended a late Asselian (Early Permian) age for the Karangean Formation. Crippa [31] investigated fusulin from Telok Gedang and analyzed the Asselian era.

A previous study by Waveren et al. [24] observed eight stratigraphical points along Merangin; from these results known that wood fossils were found in several sequences. In Point II, in situ tree trunk was found in the tuff layer. Point III on the tuff and tuffaceous sandstone layers contained 'transported' wood. In point IV, at the tuffaceous sandstone layer, and tuff was found 'transported' wood. In point VI, in situ logwood was found in the tuff layer, while in the tuffaceous sandstone layer, 'transported' wood was found. Point VIII in the tuff and claystone layers contains 'transported' wood, while in the tuffaceous sandstone layer, there was in situ logwood. In this study, further study on the lithology of wood fossils is necessary to investigate the similarities with the stratigraphic points from the aforementioned study.
4. Conclusion
Several wood fossils obtained from the Merangin Regency (West Bangko Barat and Nalo Tantan Districts) have been successfully taken directly from their existence to observe anatomical features and analyze their estimated age. The results showed that the wood fossils were identified as *Shoreoxylon* sp. (Meranti), *Dryobalanoxylon* sp. (Kapur), *Cotylenobioxylon* sp. (Giam/Resak), and *Hopeanum* sp. (Merawan/Hopea). These fossil woods were found in different estimated geological age namely Late Permian, Late Miocene, Late Pliocene to Early Pleistocene age; and Holocene age. Another approach by using Global Mapper 11 resulted that all the fossil woods were estimated grown in Permian age. Further study on the lithological and stratigraphical is required to investigate more comprehensive geological analysis. The information on botanical identity of wood fossils can be used as reference to determine tree species for reforestation program. Thus, comprehensive study on past vegetative composition together with the geological aspects would be important to support forest and natural resource management sustainably.

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