Review of Palaeobotany and Palynology 238 (2017) 34–42

Contents lists available at ScienceDirect

Review of Palaeobotany and Palynology

journal homepage: www.elsevier.com/locate/revpalbo

The Cairo Petrified Forest revisited

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ARTICLE INFO

Article history:
Received 8 May 2016
Received in revised form 30 November 2016
Accepted 1 December 2016
Available online 9 December 2016

Keywords:
Cairo Petrified Forest
Oligocene
Africa
Egypt
Fossil wood
Palaeoclimate

ABSTRACT

The study of the wood flora of the Oligocene Cairo Petrified Forest (CPF) protected area is resumed here after five years. The study added seven Fabaceae species *Afzelioxylon welkitii*, *Copaiferoxylon matanzensis** -Caesalpinoideae, *Andiroxylon aegyptiacum** sp. nov.-Faboideae, *Dichrostachyoxylon palaeonyassanum**, *D. royaderum**, *D. zirkelii** and *Mimosoxylon tenax* -Mimosoideae as new records to the area and five (asterisked) as new records to Egypt; one of which is new to science. Descriptions and illustrations are given for these five asterisked species. Descriptions of the other reported species were given in earlier publications mentioned in the text. Affinities and comparisons are given for the studied species. Climatic interpretations based on the anatomical features of all the CPF fossil taxa are presented. Moreover, the relationships and comparisons with the nearest living relatives are discussed.

1. Introduction

The Cairo Petrified Forest (CPF) protected area is about 7 km^2 and exists in the Eastern Desert of Egypt between latitudes 29° 58′ 30″ and 29° 59′ 40″ N and longitudes 31° 27′ 30″ and 31° 28′ 30″ E (El-Saadawi et al., 2011) (Fig. 1). A large number of massive silicified tree trunks, a small number of palm trunks and innumerable loose wood fragments of varying sizes lie horizontally on the surface or are buried partly or completely by sand inside the protected area while sometimes by basalt outside this area. Fossil trunks are denser in the protected area than in its outside extended tributaries and, therefore known as Gebel El-Khashab or "wood hill". The CPF extends for tens of kilometers outside the protected area, towards Suez to the east. The trunks inside and outside the protected area are of early Oligocene age and occur in Gebel Ahmer Formation (El-Saadawi et al., 2013; Ziada, 2014).

In a visit (on 21.6.2012) to the CPF protected area 41 fossil wood specimens were collected; one of these specimens proved to be *Terminalioxylon edwardsii* (Combretaceae) raising the number of fossil dicot woods known from the CPF to 20 species (El-Saadawi et al., 2013). Palaeobotanical data resulting from the examination of the remaining 40 specimens, palaeoclimatic inferences based on them and comments on the families Fabaceae and Combretaceae are the aim of this paper.

2. Materials and methods

The 40 specimens studied here were collected from inside the protected area by Ziada. The specimens range in size between 5 and 20 cm in length. Some of them were chopped off in the field from large logs ranging in length from 1 to 25 m and in diameter from 0.2 to 1.6 m and some were already loose fragments.

Ground thin-sections (cross, tangential and radial) were prepared from the 40 specimens for detailed anatomical investigation following the procedure described by Andrews (1961) and Kamal El-Din (1996). The 40 specimens and the prepared slides were numbered and housed in the palaeobotanical collection of the Department of Botany, Faculty of Science, Ain Shams University. The identification is based on the microscopic anatomy of the studied specimens. The descriptions of the identified woods in this paper have mostly been made according to the format of the IAWA list of features suitable for hardwood identification (IAWA Committee, 1989). Affinities of the identified woods were determined by consulting the literature (e.g. Metcalfe and Chalk, 1950; Müller-Stoll and Mädel, 1967) and searches in the online wood database (Inside wood, 2004-onwards). Relevant fossil wood genera were discussed in the light of the comprehensive survey of fossil woods (Gregory et al., 2009). Systematic assignment follows the APG (2009) classification. Other consulted reference descriptions will be mentioned where appropriate. The Vulnerability Index (V) and mesomorphy ratio

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http://dx.doi.org/10.1016/j.revpalbo.2016.12.001
0034-6667/

(M) were calculated using the equations developed by Carlquist (1977), in addition to that for Conductive capability (C) which was developed by Wolfe and Upchurch (1987). A diverse set of anatomical characteristics of wood were also analyzed in terms of their associated palaeoclimatological requirements.

3. Results

Careful investigation of anatomical features of the 40 fossil specimens proved that their preservation is satisfactory to good and that they are all dicots. However, it was difficult to assign 3 samples (20 NZ, 26 NZ and 38 NZ; where NZ refers to Nermeen Ziada) to any family due to their poor preservation. Anatomical features of the 37 relatively well preserved specimens proved that 36 of them belonged to 9 species of Fabaceae namely: *Afzelioxylon welkitii* (old record to Egypt but new to the study area, one specimen), *Copaiferoxylon matanzensis* (new to Africa, one specimen), *Cynometroxylon tunesense* (old to the study area, two specimens), *Detarioxylon aegyptiacum* (old to the study area, 24 specimens), *Andiroxylon aegyptiacum* (new to science, one specimen), *Dichrostachyoxylon palaeonyassanum* (new to Egypt, two specimens), *D. royaderum* (new to Africa, one specimen), *D. zirkelii* (new to Africa, two specimens) and *Mimosoxylon tenax* (old to Egypt but new to the study area, two specimens) and one specimen to a species of Malvaceae sensu *lato*; *Bombacoxylon owenii* (old to the study area) (Kräusel, 1939; Kamal El-Din, 1996, 2002; Kamal El-Din and El-Saadawi, 2004; El-Saadawi et al., 2011, 2014; Kamal El-Din et al., 2015).

This paper describes only the five species that are recorded here for the first time from Egypt i.e. *C. matanzensis*, *A. aegyptiacum* sp. nov., *D. palaeonyassanum*, *D. royaderum* and *D. zirkelii*. Descriptions of the other five, old to Egypt, records (*A. welkitii*, *C. tunesense*, *D. aegyptiacum*, *M. tenax* and *B. owenii*) are to be found in Kräusel (1939), Kamal El-Din (1996), Kamal El-Din and Refaat (2001), Kamal El-Din and El-Saadawi (2004), El-Saadawi et al. (2011, 2014) and Kamal El-Din et al. (2015).

4. Descriptions, affinities and comparisons

Family: Fabaceae Lindley, 1836.

Subfamily: Caesalpinioideae Candolle, 1825.

Genus: *Copaiferoxylon* Müller-Stoll and Mädel, 1967.

1- Species: *Copaiferoxylon matanzensis* Cevallos-Ferriz and Barajas-Morales, 1994. (Plate I, 1-5)

Specimen examined: Specimen no. 16NZ (location 29° 58′ 43″ N and 31° 27′ 58″ E, a small fragment); the description and illustrations are based on this well-preserved piece of silicified wood.

Growth rings distinct, marked by the presence of normal axial canals arranged in transverse lines, enclosed within tangential bands of parenchyma. Wood diffuse- porous. Vessels mainly solitary (about 80%) and in radial multiples of 2-3 (about 20%) (Plate I, 1); mean tangential diameter of 105 μm (range 90–120 μm), mean radial diameter of 130 μm (range 100–150 μm); average vessel frequencies of 8 (5–11/mm^2). Perforation plates simple. Intervessel pits alternate. Mean vessel element length 300 μm (range 200–360 μm); short in length. Fibres non-septate and thin-walled. Axial parenchyma lozenge-aliform, confluent; in addition to the tangential parenchyma bands usually enclosing normal axial canals (Plate I, 3). Diffuse parenchyma cells are also noticed (Plate I, 2). Rays heterocellular (Plate I, 5), composed of procumbent cells with 1-3 rows of marginal square cells; 1-3 seriate (Plate I, 4); non-storied and the mean height of multiseriate rays is 485 μm (range 300–825 μm).

V = 13.1, M = 3930, C = 61

4.1. Affinities and comparisons

The main anatomical characters of the fossil wood, i.e. the presence of growth rings marked by the presence of normal axial canals arranged in tangential bands, simple perforation plates, abundant paratracheal parenchyma (lozenge-aliform and confluent) and 1-3 seriate heterocellular rays; attribute the specimen under study to woods of family Fabaceae.

The presence of axial canals in family Fabaceae is a rare character restricted mainly to subfamily Caesalpinioideae (Evans et al., 2006). These canals can be normal canals arranged in tangential bands or scattered or they may be traumatic canals in tangential bands (Cevallos-Ferriz and Barajas-Morales, 1994). Extant caesalpinioid genera characterized by having normal axial canals arranged in transverse lines and 1-4 seriate rays include *Copaifera*, *Epeura*, *Prioria*, *Pseudosindora* and *Sindoropsis* (Brea et al., 2012). The presence of diffuse-in-aggregate parenchyma in *Epeura*; vessel element length of ≥800 μm and storied structure in *Prioria*; vasicentric parenchyma in only *Pseudosindora* and vessel tangential diameter of ≥200 μm in *Sindoropsis*; relate the studied fossil specimen to the genus *Copaifera*. Fossil woods with tangential bands of secretory canals resembling *Copaifera* are assigned to the genus *Copaiferoxylon* (see Müller-Stoll and Mädel, 1967). The identification is confirmed by utilizing Müller-Stoll and Mädel's (1967) key, where the following steps apply: Diffuse porous wood; fibres with narrow lumen; rays disposed in vague storeys; parenchyma vasicentric, slightly aliform, sporadically confluent, partially diffuse, apotracheal tangential bands with secretory canals; to end with *Copaiferoxylon*.

Eight species of *Copaiferoxylon* have been reported worldwide: *C. assamicum* from Myanmar, *C. camerounense* from Cameroon, *C. copaiferoides* from Tunisia, *C. detarioides* from Chad (or Cameroon?), *C. eosiamensis* from Myanmar, *C. matanzensis* from Mexico, *C. migiurtinum* from Egypt and Somalia and *C. sindoroides* from Southeast Asia (Dupéron-Laudoueneix and Dupéron, 1995; Gregory et al., 2009; El-Saadawi et al., 2011). Descriptions of two of these eight species (namely *C. camerounense* and *C. detarioides*) are not available to us being reported in an unpublished thesis by Dupéron-Laudoueneix (1991) (cf. Gregory et al., 2009). The qualitative and quantitative anatomical similarities and differences between the six remaining species support the designation of the studied specimen to *Copaiferoxylon matanzensis*, which was previously recorded from the Oligocene/Miocene of Mexico (Cevallos-Ferriz and Barajas-Morales, 1994). This is the first report of this species from Africa and therefore from Egypt and of course the study area.

Subfamily: Faboideae Rudd, 1972.

Genus: *Andiroxylon* Müller-Stoll and Mädel, 1967.

2- Species: *Andiroxylon aegyptiacum* sp. nov.

Etymology: The specific epithet *aegyptiacum*, indicates its occurrence in Egypt.

Holotype: Specimen no. 37NZ (location 29° 58′ 41″ N and 31° 28′ 02″ E a small piece selected from scattered fragments).

Repository: Housed in the palaeobotanical collection of the Palaeobotany Unit, Botany Department, Faculty of Science, Ain Shams University, Cairo, Egypt.

Stratigraphic horizon: Oligocene.

Locality: CPF, Egypt.

Author: Nermeen Ziada.

4.2. Species diagnosis

Wood diffuse-porous, indistinct growth rings; vessels solitary and in radial multiples of 2-3, occasionally of 4-5; perforation plates simple; axial parenchyma forming irregular bands, parenchyma strands 4-8 cells high; rays heterocellular, irregularly storied and 1-4 seriate. Diffuse axial canals are present.

Growth rings indistinct or absent. Wood diffuse-porous. Vessels partly solitary (54%) and in radial multiples of 2-3 (43%), occasionally four or five (3%); mean tangential diameter of 85 μm (range 55–95 μm), mean radial diameter of 100 μm (range 75–115 μm); average vessel frequencies of 20 (14–24/mm^2). Perforation plates simple with oblique to transverse end-walls. Intervessel pits alternate. Mean vessel element length 340 μm (range 170–470 μm); short to medium in length. Fibres non-septate and thick-walled, forming bands narrower