

## On the Fossil Wood Flora of Wadi Ankebieh, Egypt, with Two New Records

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**T**WO FOSSIL dicot wood species (*Dichrostachyoxylon royaderum*-Fabaceae and *Ficoxylon cretaceum*-Moraceae) are reported and described for the first time from the Oligocene of Wadi Ankebieh in Egypt. Comments are made on the distribution of the fossil wood flora of Wadi Ankebieh in Egypt, other African countries, the world and on the palaeoclimate under which the trees had lived.

**Keywords:** *Dichrostachyoxylon*, Egypt, Fabaceae, *Ficoxylon*, Moraceae, Oligocene, Wadi Ankebieh.

Wadi Ankebieh (or Anqabiya) is one of the Oligocene fossil wood sites in Egypt (Kräusel, 1939 and Issawi *et al.*, 1999). It belongs to the Gebel Ahmar Formation (Fourtau, 1894; Barron, 1907 and Shukri, 1954). There is only one earlier report (Kräusel, 1939) on fossil woods [*Bombacoxylon owenii* (Carruthers) Gottwald (Malvaceae-Bombacoideae), *Detarioxylon aegyptiacum* (Unger) Louvet (Fabaceae-Caesalpinioideae) and *Terminalioxylon primigenium* (Schenk) Mädler-Angeliewa and Müller-Stoll (Combretaceae)] from this site, which lies in the northern part of the Eastern Desert, about 34 km to the east of Cairo on the southern side of the Cairo-Suez Desert Road (Fig. 1) (Abd Allah, 1988). Only trunks were found; no roots, leaves or other organs. The lithostratigraphic section exposed in the Gebel Ahmar Formation appears as: vividly coloured sands and gravels with cylindrical pipes etc. Limits are: underlies the basalt flows and intrusions of the marine Miocene and overlies unconformably the Upper Eocene (Shukri 1954 and Said 1971).

The aim of this paper is the furtherance of our knowledge about the fossil woods of Wadi Ankebieh.

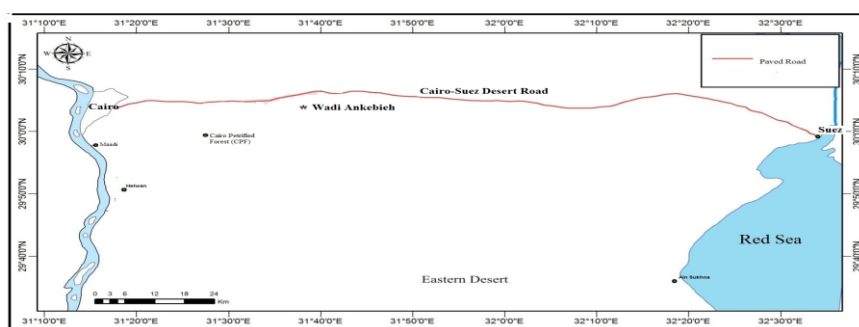
### Materials and Methods

Four wood specimens were collected, about ten years ago, from the site. They range between 10-30 cm in length and 5-10 cm in diameter. Ground thin sections of cross, tangential and radial surfaces were prepared according to the

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method described by Andrews (1961) and Kamal El-Din (1996). The specimens and the prepared slides are numbered from 1WA to 4WA (WA refers to Wadi Ankebieh; the study area) and deposited in the palaeobotanical collection of the Department of Botany, Ain Shams University.

The descriptions followed the International Association of Wood Anatomists Committee recommendations (IAWA Committee 1989). Affinities were determined by consulting reference works which will be mentioned where appropriate. The Vulnerability Index (V) was calculated using the Carlquist (1977) equation. Relevant fossil wood genera were discussed in light of the comprehensive survey of fossil woods (Gregory *et al.*, 2009). Systematic assignment follows the APG III (2009).



**Fig. 1.** Map showing location of the study area (Wadi Ankebieh) and some relevant landmarks.

### Results and Description

Microscopic examination showed that specimens no. 2WA & 4WA belonged to *Dichrostachyoxylon royaderum* (Fabaceae-Mimosoideae), specimen no. 3WA to *Ficoxylon cretaceum* (Moraceae), while the fourth specimen (no. 1WA) could not be identified being badly preserved, however it belongs to the dicots. *Dichrostachyoxylon royaderum* and *Ficoxylon cretaceum* are new records to the site which is now known to contain five species in four families. The two new records are described, illustrated and discussed in this paper.

Order: Fabales

Family: Fabaceae

Subfamily: Mimosoideae

Genus: *Dichrostachyoxylon* Müller-Stoll and Mädler 1967

Species: *Dichrostachyoxylon royaderum* Privé 1969

Growth rings distinct, marked by marginal parenchyma. Wood diffuse-porous. Vessels solitary and in radial multiples of 2-3. Vessels round to oval in cross section; tangential diameter 110–170  $\mu\text{m}$  (mean 140  $\mu\text{m}$ ), radial diameter 140–220  $\mu\text{m}$  (mean 180  $\mu\text{m}$ ). Vessels 3–8 per sq. mm. Perforation plates simple

with oblique end walls, intervessel pits alternate. Mean vessel element length 330 µm; short to medium in length. Fibres non-septate and thin- to thick-walled. Axial parenchyma vasicentric, weakly aliform, marginal parenchyma bands and diffuse parenchyma cells. Rays 1-5 seriate; homocellular, composed of procumbent cells.

Order: Rosales

Family: Moraceae

Genus: *Ficoxylon* Kaiser 1880

Species: *Ficoxylon cretaceum* Schenk 1883

Growth rings indistinct. Wood diffuse-porous. Vessels solitary and in radial multiples of 2–3 (4). Vessels round to oval in cross section; tangential diameter 100–150 µm (mean 120 µm), radial diameter 220–275 µm (mean 240 µm). Vessels 3–9 per sq. mm. Perforation plates simple with horizontal to oblique end walls, intervessel pits alternate. Mean vessel element length 350 µm. Fibres in bands alternating with parenchyma bands (are more or less of the same thickness); libriform non-septate with simple to minutely bordered pits. Axial parenchyma in regular bands more than six cells wide; 4-8 cells per strand and crystalliferous strands present. Rays mostly 2-3 cells wide (a few uniseriate), 10–20 cells in height, homocellular composed of procumbent cells.

### Distribution, Comparisons and Discussion

The family Fabaceae has about 100 fossil wood genera worldwide (Gregory *et al.*, 2009). And fossil legume wood genera and species described in the literature outnumber those of any other dicot family (Wheeler and Manchester, 2002; Kamal El-Din and El-Saadawi, 2004; El-Saadawi *et al.*, 2011 and Kamal El-Din *et al.*, 2015). The genus *Dichrostachyoxyton* was established by Müller-Stoll and Mädler in the year 1967 and fifteen species have since been described worldwide (Gregory *et al.*, 2009 and Ziada, 2014). Species of *Dichrostachyoxyton* were spread in the Palaeogene (Palaeocene, Eocene and Oligocene) and Neogene (Miocene and Pliocene) of four continents (Africa, Asia, Europe and North America) (Gregory *et al.*, 2009). In Egypt, genus *Dichrostachyoxyton* was recorded, for the first time, from the Oligocene of Gebel Qatrani by Bkhat (2012) but he mentioned no species. Two years later Ziada (2014) reported on *D. palaeonyassanum*, *D. royaderum* and *D. zirkelii* from the Oligocene of the Cairo Petrified Forest (CPF). Outside Egypt the species *D. royaderum* is only known from the Oligocene of France (Privé, 1969).

There are slight anatomical differences between the samples of *D. royaderum* described from Wadi Ankebieh (this work), the CPF in Egypt (Ziada, 2014) and France (Privé, 1969) (Table 1).

**TABLE 1.** Xylotomical comparison of specimens of *D. royaderum* from Wadi Ankebieh (this paper), the Cairo Petrified Forest (CPF) (Ziada, 2014) and France (Privé, 1969).

| Features                        | Egypt   |   | France  |
|---------------------------------|---|---|---|
|                                 | Wadi Ankebieh                                       | CPF   |   |
| Growth rings                    | Distinct  | Distinct  | Distinct  |
| Vessels                         | Solitary & in radial multiples of 2-3               | Solitary & in radial multiples of 2-3               | Solitary & in radial multiples of 2-3               |
| Vessel mean tangential diameter | 110-170 $\mu\text{m}$<br>(av. 140 $\mu\text{m}$ )   | 125-190 $\mu\text{m}$<br>(av. 155 $\mu\text{m}$ )   | 60-145 $\mu\text{m}$<br>(av. 105 $\mu\text{m}$ )    |
| Vessel frequency                | 3-8/ $\text{mm}^2$                                  | 2-7/ $\text{mm}^2$                                  | 10-20/ $\text{mm}^2$                                |
| Axial parenchyma                | Diffuse, vascentric, weakly aliform, marginal bands | Diffuse, vascentric, weakly aliform, marginal bands | Diffuse, vascentric, weakly aliform, marginal bands |
| Ray width                       | 1-5   | 1-5   | 1-5   |
| Ray composition                 | Homocellular  | Homocellular  | Homocellular  |

It is clear from Table 1 that specimens of *D. royaderum* from the two Egyptian sites are almost identical and those from France differ only in vessel frequency (being higher in France) and vessel mean tangential diameter (being narrower in France), indicating a cooler palaeoclimate for the French specimens.

Fabaceae includes about 700 extant genera and 20,000 extant species worldwide (Wojciechowski, 2003). It is the third largest family of the flowering plants and its members are found in tropical rain forests to desert and alpine tundra (Wojciechowski, 2003). *Dichrostachys*; the “nearest living relative” of *Dichrostachyoxylon* has 9 species spread in tropical areas of three continents: Africa, America and Asia (Mabberley, 1987). *i.e.*, similar in its distribution to its ancestor (*Dichrostachyoxylon*) except that the latter occurred also in Europe (Gregory *et al.*, 2009).

The family Moraceae has ten fossil wood genera worldwide (Dupéron-Laudoueneix and Dupéron, 1995 and Gregory *et al.*, 2009; Bernabei *et al.*, 2010 and Franco, 2010 and Boonchai *et al.*, 2015). The ages of these genera range from the Upper Cretaceous to the Pliocene (Collinson, 1989; Gregory *et al.*, 2009), with most occurrences reported from the Oligocene to Pliocene (Gregory *et al.*, 2009). Only two of these 10 genera, *i.e.*, *Ficoxylon* and *Myrianthoxylon* were reported from Africa (Dupéron-Laudoueneix and Dupéron, 1995; Kamal El-Din, 2003 and

Gregory *et al.*, 2009). Genus *Ficoxylon* has over 15 species worldwide (Africa, Asia, Europe, North America and South America) (Gregory *et al.*, 2009 and Jolly-Saad *et al.*, 2010) ranging in age from Cretaceous to Miocene/Pliocene. The species *F. cretaceum* (recorded here from Wadi Ankebieh) is already known from Africa (Egypt, Ethiopia and Tunisia) and South America (Colombia) (Dupéron-Laudoueneix and Dupéron, 1995; Gregory *et al.*, 2009).

There are slight anatomical differences between the samples of *F. cretaceum* described here from Wadi Ankebieh and those described from different sites in Egypt (Kräusel, 1939), Farafra Oasis in Egypt (Kamal El-Din, 2003), Ethiopia (Lemoigne *et al.*, 1974) and Tunisia (Fessler-Vrolant, 1979) (Table 2). It has to be mentioned that the description of the samples from Colombia is not available to the present authors, therefore not included in Table 2.

**TABLE 2.** Xylotomical comparison of specimens of *F. cretaceum* from Wadi Ankebieh (this paper), different sites in Egypt (Kräusel, 1939), Farafra Oasis (Kamal El-Din, 2003), Ethiopia (Lemoigne *et al.*, 1974) and Tunisia (Fessler-Vrolant, 1979).

| Features                        | Egypt   |                      |  | Ethiopia             | Tunisia              |
|---------------------------------|---|----------------------|--|----------------------|----------------------|
|                                 | Wadi Ankebieh                                     | Different sites      | Farafra Oasis                                    |                      |                      |
| Vessel mean tangential diameter | 100-150 $\mu\text{m}$<br>(av. 120 $\mu\text{m}$ ) | 80-260 $\mu\text{m}$ | 65-165 $\mu\text{m}$<br>(av. 140 $\mu\text{m}$ ) | 90-350 $\mu\text{m}$ | 70-136 $\mu\text{m}$ |
| Vessel frequency                | 3-9/mm <sup>2</sup>                               | 6-12/mm <sup>2</sup> | 4-8/mm <sup>2</sup>                              |                      | 4-9/mm <sup>2</sup>  |
| Mean vessel element length      | 350 $\mu\text{m}$                                 | 400 $\mu\text{m}$    | 385 $\mu\text{m}$                                | -                    | 300 $\mu\text{m}$    |

The extant genera of the family Moraceae are found mainly in subtropical to tropical regions with a few in temperate regions (Boonchai *et al.*, 2015). The family includes 53 extant genera and 1.500 extant species (Elpel, 2013). *Ficus*; the “nearest living relative” of *Ficoxylon* is the largest genus of the Moraceae with more than 900 species in Africa, America and Australasia (Koek-Noorman *et al.*, 1984). However, it is more restricted in distribution than its ancestor (*Ficoxylon*) which was spread in five continents (Africa, Asia, Europe, North America and South America). The distribution of the five species of Wadi Ankebieh in Egypt is given in Table 3.

As shown in Table 3 there are 38 Egyptian sites from which, at least, one of the five species was reported. Table 3 shows also that the 5 species occur together in only two out of the 38 sites, *i.e.* Wadi Ankebieh and the CPF (which lies at a distance of about 20 Km from Wadi Ankebieh, (Fig. 1). Four of the five species of Wadi Ankebieh are known from two other sites: Wadi Faregh and West of Giza

Pyramids. Other sites include only one to three of the five species. Table 3 shows also that the wood species reported from Wadi Ankebieh except *D. royaderum* are wide spread in Egypt being reported in 27 (*B. owenii*), 18 (*D. aegyptiacum*), 17 (*T. primigenium*) and 11 (*F. cretaceum*) sites ranging in age from Cretaceous to Quaternary (Kräusel, 1939; Kamal El-Din, 2002, 2003; El-Saadawi *et al.*, 2011, 2014 and Ziada, 2014; Kamal El-Din *et al.*, 2015). Most of these sites are in the Western and Eastern Deserts while a few are in Nile Delta, Nile Valley and Sinai.

*Bombacoxylon owenii* is not only the most widespread species in Egypt but also in Africa (7 countries) and in other continents (Asia and Europe) (Table 4) ranging in age from Cretaceous to Quaternary (Dupéron-Laudoueneix and Dupéron, 1995; Kamal El-Din, 2002; Gregory *et al.*, 2009 and El-Saadawi *et al.*, 2014). *D. aegyptiacum* is recorded from only Africa (6 countries) (Table 4) ranging in age from Eocene to Quaternary (Dupéron-Laudoueneix and Dupéron, 1995; Kamal El-Din and Refaat, 2001; El-Saadawi *et al.*, 2011 and Kamal El-Din *et al.*, 2015). *D. royaderum* is reported from the Oligocene of two continents (Table 4) (Africa, one country) (Ziada, 2014) and Europe, one country (Gregory *et al.*, 2009). *F. cretaceum* is recorded from four countries in Africa and from one country in South America (Table 4) ranging in age from Cretaceous to Pliocene (Dupéron-Laudoueneix and Dupéron, 1995; Kamal El-Din, 2003 and Gregory *et al.*, 2009). *T. primigenium* is reported from only Africa (3 countries) (Table 4) ranging in age from Oligocene to Miocene (Dupéron-Laudoueneix and Dupéron, 1995; El-Saadawi and Kamal El-Din, 2004 and El-Saadawi *et al.*, 2014).

The V values (mean tangential diameter/mean number of vessels per square mm) for *D. royaderum* and *F. cretaceum* (described here) are 25 and 20 respectively. The V values of the three other species reported earlier from Wadi Ankebieh were not mentioned in the original publication (Kräusel, 1939) but are calculated here for specimens of *B. owenii* and *D. aegyptiacum* as described from the CPF by Ziada (2014) and for specimens of *T. primigenium* as described from Widan El-Faras by El-Saadawi and Kamal El-Din (2004). The V values of the 3 species are 42.5, 40 and 25 respectively. These high V values of the 5 species suggest that these woods likely grew in an area of low water stress (Carlquist, 1977). These wood species show features that are more common in the tropics than in temperate floras such as: abundant axial parenchyma (banded, vasicentric and diffuse), diffuse-porous wood, medium to slightly large sized vessels and low number of vessels per sq. mm (Wheeler and Baas, 1991; Wheeler, 2001; Alves and Angyalossy-Alfonso, 2002). The Oligocene palaeoclimate of Wadi Ankebieh or the site of growth in case these woods had been transported is suggested to be tropical or subtropical which confirms earlier (El-Saadawi *et al.*, 2011, 2014 and Ziada, 2014) assumptions regarding the palaeoclimate of the growth site of these trees.

**TABLE 3 . The distribution the fossil wood flora of Wadi Ankebieh in other Egyptian sites. (based on: Kräusel, 1939; Youssef, 1993; Kamal El-Din and Refaat, 2001; Kamal El-Din, 2002; Kamal El-Din, 2003; El-Saadawi and Kamal El-Din, 2004; El-Saadawi *et al.*, 2011, 2014; Ziada, 2014; Kamal El-Din *et al.*, 2015).**

| Fossil wood taxa<br>Sites             | <i>B. owenii</i> | <i>D. aegyptiacum</i> | <i>D. royaderum</i> | <i>F. cretaceum</i> | <i>T. primigenium</i> | total no. of species/site |
|---------------------------------------|------------------|-----------------------|---------------------|---------------------|-----------------------|---------------------------|
| Wadi Ankebieh                         | +                | +                     | +                   | +                   | +                     | 5                         |
| Abou Roasch                           |                  |                       |                     | +                   |                       | 1                         |
| Bahariya                              | +                | +                     |                     |                     |                       | 2                         |
| Bir El-Fahme                          | +                | +                     |                     |                     |                       | 2                         |
| Bir Lebuk                             | +                |                       |                     | +                   | +                     | 3                         |
| Birket Qerun                          | +                | +                     |                     |                     | +                     | 3                         |
| Cairo-Bahariya Oasis Desert Road      | +                |                       |                     |                     |                       | 1                         |
| CPF                                   | +                | +                     | +                   | +                   | +                     | 5                         |
| Der Baramus                           | +                |                       |                     |                     | +                     | 2                         |
| Farafra Oasis                         |                  |                       |                     | +                   |                       | 1                         |
| Fayum                                 | +                | +                     |                     |                     | +                     | 3                         |
| Garet Aujan                           | +                |                       |                     |                     |                       | 1                         |
| Gebel Ahmer                           | +                | +                     |                     |                     | +                     | 3                         |
| Gebel Amuna                           |                  | +                     |                     |                     | +                     | 2                         |
| Gebel Dera in Suez                    | +                |                       |                     |                     |                       | 1                         |
| Gebel El-Khashab (NPF)                | +                |                       |                     | +                   |                       | 2                         |
| Gebel El-Khashab (SPF)                | +                | +                     |                     |                     | +                     | 3                         |
| Gebel Garra west Aswan                |                  |                       |                     | +                   |                       | 1                         |
| Gebel Geneffe                         | +                |                       |                     |                     |                       | 1                         |
| Gebel Giaffara                        |                  |                       |                     | +                   | +                     | 2                         |
| Gebel Hadahid in Sinai                |                  | +                     |                     |                     |                       | 1                         |
| Gebel Qatrani                         | +                | +                     |                     |                     | +                     | 3                         |
| Gebel Ruzza                           | +                |                       |                     |                     | +                     | 2                         |
| Gebel Shabraweet                      | +                |                       |                     |                     |                       | 1                         |
| Helwan                                |                  | +                     |                     |                     |                       | 1                         |
| Moghara                               | +                | +                     |                     |                     |                       | 2                         |
| Mokattam                              | +                | +                     |                     |                     | +                     | 3                         |
| Siwa Oasis                            | +                |                       |                     |                     |                       | 1                         |
| Tanta                                 |                  | +                     |                     |                     |                       | 1                         |
| Turra                                 | +                |                       |                     |                     | +                     | 2                         |
| Wadi Dugla                            |                  | +                     |                     |                     |                       | 2                         |
| Wadi Faregh                           | +                | +                     |                     | +                   | +                     | 4                         |
| Wadi Natrun                           | +                |                       |                     |                     |                       | 1                         |
| Wadi Schait                           | +                |                       |                     |                     |                       | 1                         |
| Wadi Sanur                            | +                |                       |                     |                     |                       | 1                         |
| West of Giza Pyramids (Giza Pyramids) | +                | +                     |                     | +                   | +                     | 4                         |
| Widan El-Faras                        |                  |                       |                     |                     | +                     | 1                         |
| Zone between Cairo and Suez           |                  |                       |                     | +                   |                       | 1                         |
| total no. of sites for each species   | 27               | 18                    | 2                   | 11                  | 17                    |                           |

**TABLE 4. The distribution the fossil wood flora of Wadi Ankebieh in different continents of the world.**

| <b>Continents</b><br><b>Fossil wood taxa</b> | <b>Africa</b>  | <b>Asia</b>                             | <b>Europe</b>                    | <b>South America</b> |
|--|--|---|----------------------------------|----------------------|
| <i>B. owenii</i>                             | Egypt, Libya, Tunisia, Algeria, Rio de Oro, Ethiopia and Somalia | Jordan or Israel, Pakistan and Thailand | France, Germany, Sardinia and UK |                      |
| <i>D. aegyptiacum</i>                        | Egypt, Libya, Tunisia, Algeria, Rio de Oro and Somalia           |   |                                  |                      |
| <i>D. royaderum</i>                          | Egypt  |   | France                           |                      |
| <i>F. cretaceum</i>                          | Egypt, Tunisia, Ethiopia and Mali                                |   |                                  | Colombia             |
| <i>T. primigenium</i>                        | Egypt, Libya and Somalia   |   |                                  |                      |

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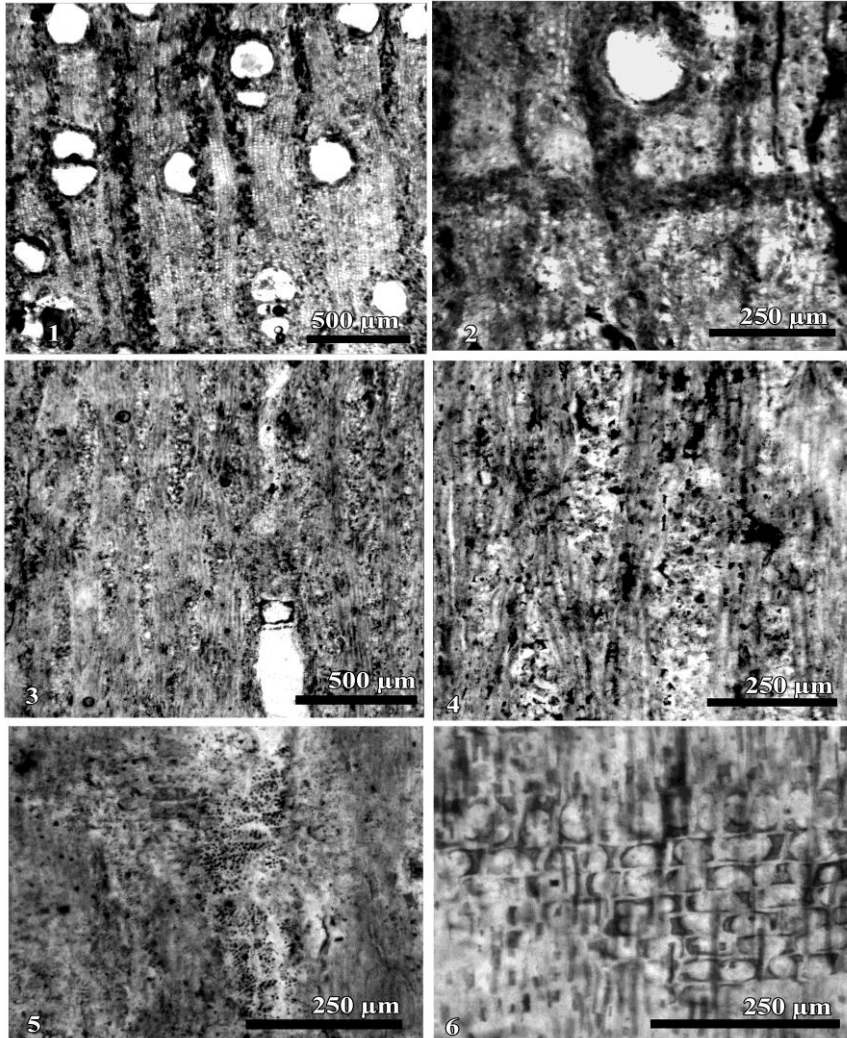
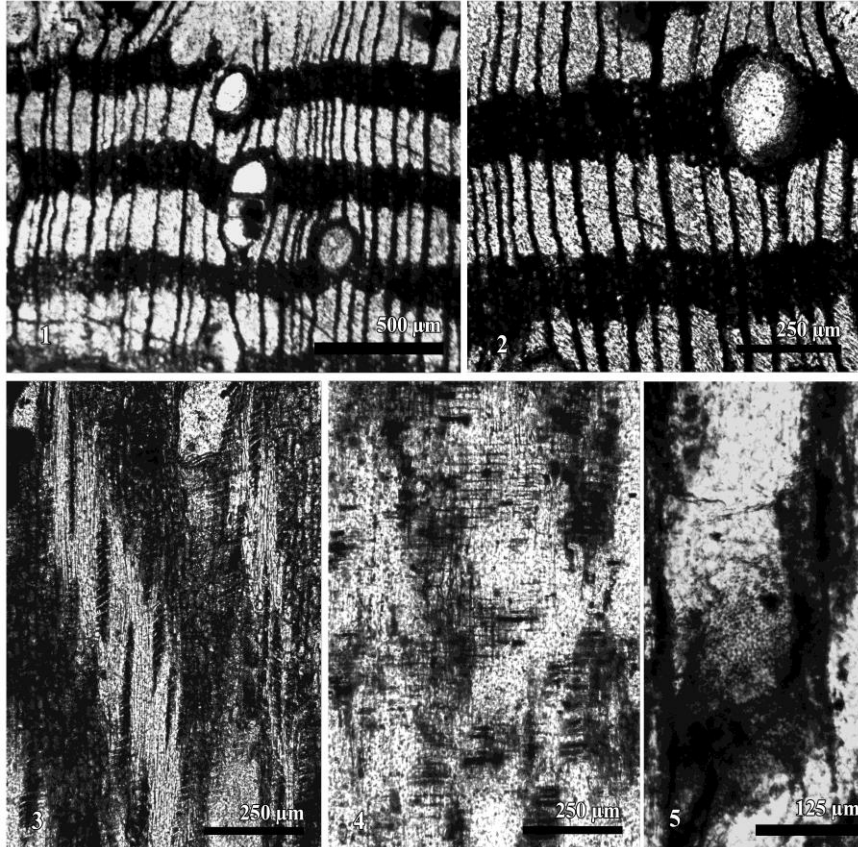


Plate I. *Dichrostachyoxylon royaderum* 1: Cross section showing diffuse-porous wood, solitary vessels and 2-3 multiples of vessels; 2: Cross section magnified to show one growth ring and diffuse parenchyma cells; 3 & 4: Tangential longitudinal section showing rays; 5: Longitudinal section showing alternate intervessel pits; 6: Radial longitudinal section showing homocellular rays.



**Plate II.** *Ficoxylon cretaceum* 1: Cross section showing diffuse-porous wood and regular bands of parenchyma; 2: Cross section magnified to show fibres bands alternating with parenchyma bands; 3: Tangential longitudinal section showing rays; 4: Radial longitudinal section showing homocellular rays; 5: Longitudinal section showing alternate intervessel pits.

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## عن فلورة الخشب الحفري بوادي عنجبية بمصر، مع تسجيل نوعين جديدين علي الوادي

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تم جمع ووصف خشب حفري من عصر الاوليغوسين ينتمي لنوع  
*Ficoxylon cretaceum* و *Dichrostachyoxylon royaderum*  
من الفصيلة القرنية والفصيلة التوتية علي التوالي ، وذلك لأول مرة من وادي  
العنجبية بمصر، وتم التعليق علي توزيع أنواع فلورة الخشب الحفري المسجلة  
حتى اليوم من وادي العنجبية في مختلف انحاء مصر وغيرها من دول افريقيا  
وكذلك في العالم اجمع مع الاستدلال علي المناخ الذي كان سائدا في الموقع  
الاصلي لنمو هذه الانواع من الاشجار.