# NEW OLIGOCENE FOSSIL WOODS FROM RHODOPES, BULGARIA

**Stănilă Iamandei[1*], Eugenia Iamandei[1], Vladimir Bozukov[2] & Boris Tsenov[2]**

Received: 2 June 2016 / Accepted: 21 December 2016 / Published online: 23 December 2016

**Abstract** A new collection of petrified woods coming from the Nanovitsa Depression, eastern Rhodopes Mts., Bulgaria, was submitted to palaeoxylotomical study. There, a Petrified Forest (Vkamenenata Gora) with numerous dispersed petrified wood fragments and *in-situ* petrified stumps was identified, extended along both sides of a deep gorge (Gabaz gulch) which covers an area of 7.5 hectares. The gorge is more than 120 m long, being cut into Oligocene volcano-sedimentary deposits. Recently, five samples coming from large tree trunks from that area were identified as belonging to a fossil evergreen oak wood type: *Quercoxylon intermedium* Petrescu & Velitzelos. Nine dispersed fossil wood fragments now allows the identification of the following taxa: *Sequoioxylon gypsaceum* (Goeppert) Greguss, *Taxodioxylon taxodii* Gothan, *Magnolioxylon* aff. *transilvanicum* Nagy & Mârza, *Quercoxylon intermedium* Petrescu & Velitzelos, and *Rhysocaryoxylon madsenii* Sakala & Gryc.

**Keywords**: Rhodopes, Nanovitsa Depression, Oligocene Petrified Forest, paratropical paleoclimate**.**

## INTRODUCTION

Numerous petrified wood samples were collected from the Nanovitsa Depression, eastern Rhodopes Mts., Bulgaria (Fig. 1), and of these, 9 samples were studied recently. In the study area a Petrified Forest (local name: Vkamenenata Gora) was identified, extending over an area of about 7.5 hectares, in a deep gorge - locally named Gabaz gulch; it is situated close to Raven, Tatul, Nanovitsa, and Bivoljane localities (Fig. 2), in the Kardzhali region.

Stumps of petrified trunks and dispersed fragments of petrified wood appear there, on both sides of the gorge, distributed over a distance of more than 120 m. The entire site was declared a protected area (landmark category) since 1970, as part of the Borovets Natural Reserve established for Turkish pine and oak (Harkovska, 1992; Georgiev and Marchev, 2005). In that area, known as the Nanovitsa Depression (Fig. 2), a volcano-sedimentary unit preserves a series of pyroclastic rocks derived from acidic Oligocene eruptions overlying the Zvezdel, Dambalak and Sveti Ilia intermediate lava flows, as well as the pyroclastic rocks of the Borovitsa volcanic area, having an age of around 31.8 Ma (Georgiev & Marchev, 2005). The pyroclastic sequence consists of two ignimbrite units (the Raven-type, respectively the Sapdere-type ignimbrites) and of one mixed unit comprising air-fall tuffs and epiclastic rocks (the Tatul rhyolitic tuffs). The air-fall deposits buried a forest with large *in situ* trees, as well as with a large number of wood fragments preserved mainly through petrifaction, but also as charcoal.

The central and northwestern parts of the Nanovitsa Depression are occupied by several bodies of organogenic reef limestone, with numerous mollusk shells of Oligocene age. The presence of reef limestones overlying the rhyolitic tuffs suggests a shallow marine basin with normal salinity, developed under a warm climate (Boyanov and Goranov, 2001).

The Petrified Forest (Vkamenenata Gora) situated in the upper levels of the rhyolitic tuffs, northwest from the village of Tatul, was first reported in a scientific paper by Harkovska et al. (1992). A recently published first palaeoxylotomical study (Iamandei et al., 2014) focused on five samples taken from petrified stumps or large trunk fragments, found together in the same area, and allowed the identification of the fossil evergreen oak *Quercoxylon intermedium* Petrescu & Velitzelos, 1981.

In this new contribution we present the results of our study of nine samples of dispersed silicified wood fragments collected from the same area of Vkamenenata Gora as the previously studied 5 specimens. The methodology followed the basic principles of palaeoxylotomy, employing an adequate preparation method of standard oriented thin sections (cross, tangential and radial), followed by their microscopic study aiming at a synthetic description and concluded by a comparative study using the previously published scientific literature as well as the different IAWA publications (1989, 2004), for the taxonomic identification of the studied material. The palaeoxylotomical study of the nine samples mentioned above allowed the identification of five taxa: *Sequoioxylon gypsaceum* (Goeppert) Greguss, 1967, *Taxodioxylon taxodii* Gothan, 1906, *Magnolioxylon* aff. *transilvanicum* Nagy & Mârza 1967, *Quercoxylon intermedium* Petrescu & Velitzelos, 1981, and *Rhysocaryoxylon madsenii* Sakala & Gryc, 2011.

## SYSTEMATICS

Phylum ***Pinophyta*** Cronquist, Takhtajan & Zimmerman, ex Reveal, 1996
Family **Cupressaceae** Rich. ex Bartling, 1830
Subfamily **Sequoioideae** (Luerss.) Quinn, 1989
Genus ***Sequoioxylon*** Torrey, 1923
*Sequoioxylon gypsaceum* (Goepp.) Greguss, 1967
Fig. 3: a - i; Fig. 4: a - i.

[1]Geological Institute of Romania - 1[st], Caransebeş Street, Ro-012271, Bucharest, Romania. [*] Corresponding author: iamandei@gmail.com.
[2]Institute of Biodiversity and Ecosystem Research- Bulgarian Academy of Sciences, Acad. G. Bonchev Street, Bl. 23, BG-1113, Sofia, Bulgaria, vladimir_bozukov@yahoo.com, fox_boby@yahoo.com.

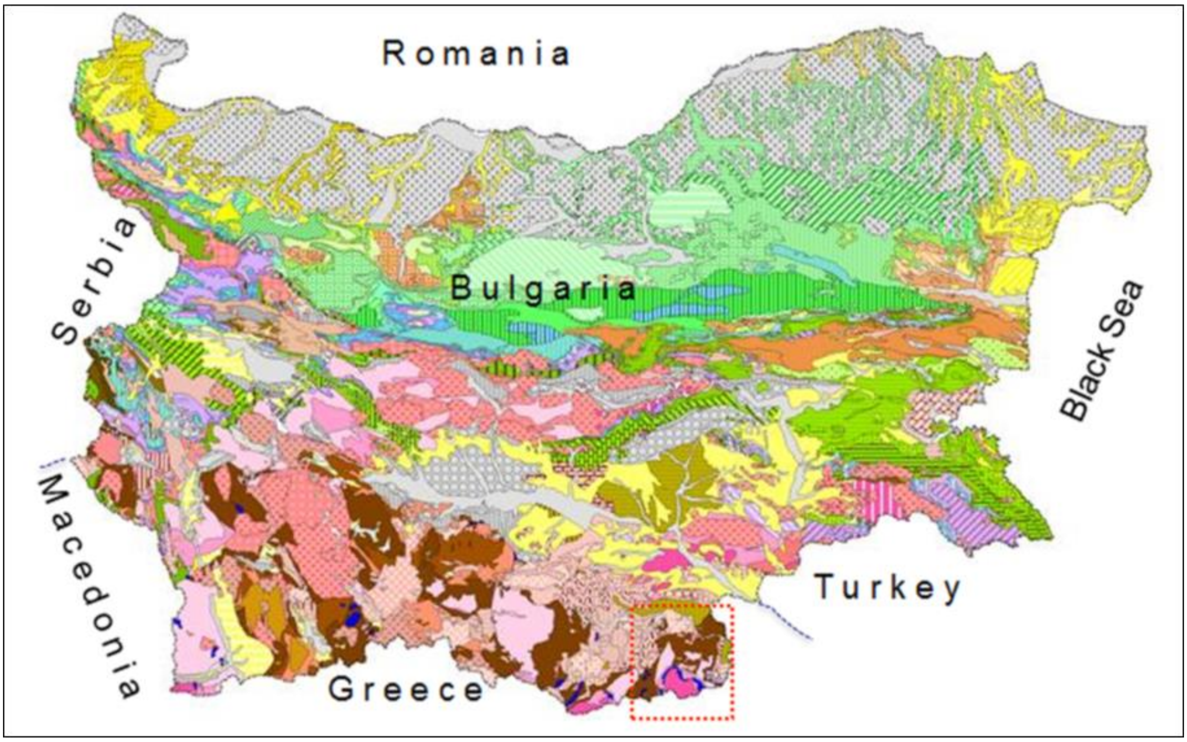


**Fig. 1** Geological map of Bulgaria; boxed area in the Rhodopes Mts. marks the study area (BAS - 2016).

## MATERIAL

The referred material is represented by four silicified wood fragments collected from the area of the Gabaz gorge (Gabaz gulch), Nanovitsa Depression, eastern Rhodopes Mts. The three small samples of silicified wood had the following dimensions: 9/3/1.5 cm, 9/3/1.5 cm, and 7/5/2.5 cm, respectively. Macroscopically the samples have beige to light brown color, a regular fibrous texture, thin rays and obvious annual rings, suggesting a coniferous wood. The fragments resulting after the preparation of the oriented thin slides are registered and kept in the collections of the National Geological Museum (NGM Coll.) in Bucharest, under the registration numbers 27609, 27610, 27611 and 27612.

## MICROSCOPIC DESCRIPTION

*The growth rings* are distinct in cross-section. The earlywood has larger- and thinner-walled cells, gradually passing to thicker-walled cells of the late wood. The ring boundary has 3-5 rows of smaller cells. Normal axial resin canals are absent, but irregular traumatic short canals inside the rings are sometimes visible in cross-sections.

*The tracheids* have polygonal cross-section, are large and radially elongate in the early wood, with radial/tangential (r/tg) diameters of 25-60/15-30 μm, and thin-walled, of 2-4 μm double-wall. In the late-wood the tracheids are smaller, tangentially flattened (r/tg diameters of 12-20/20-30 μm), and thicker-walled, of 6-8 μm double-wall. Usually there are 2-9 regular radial rows of tracheids between two successive rays, and their frequency is of 792-952 tracheids per sq.mm. Tangential pitting is usually absent, although rarely spaced uniseriate small pits could appear. Radially the pitting is of abietineous type; the 12 to 19 μm diameter pits have small borders and round apertures of 4-5 μm, are arranged in 1-3 vertical rows, without visible *crassulae*, most probably due to bad preservation.

*The axial parenchyma* appears in cross-section as a few diffuse cells, of similar size with the tracheids, sometimes with resin content. Between the tracheids, longitudinally arranged short tangential uniseriate rows of rectangular cells also appear, especially in the early or transitional wood, sometimes with dark content. Their end (= horizontal) walls are thin and smooth.

*The rays* are uniseriate, have a height of 1 to 30 cells (occasionally even more), and are homogeneous, sometimes with biseriate stories. Radially, the rays are homocellular and consist of procumbent, 15-20 μm high cells; the marginal cells are slightly higher, and have thin and smooth walls. The cross-fields show 1 to 3 taxodioid pits of 6-8 μm in diameter, with lenticular inclined apertures. The marginal fields are similar, and have more numerous pits arranged in two superposed rows, not well visible due to bad preservation. No indentures have been observed.

## AFFINITIES AND DISCUSSION

According to the xylotomic study of these specimens, the aspect and the distribution of the tracheids and the parenchyma in cross-section, the thin and smooth end walls of the parenchyma cells in vertical section, the radial pitting and the cross-field pitting up to three seriate, all these features are quite similar to the so-called taxodiaceous structures, and are typical for the modern *Sequoia*-type wood structure (see Greguss, 1955, 1967; Kukachka, 1960; Basinger, 1981; Fairon-Demaret et al., 2003).

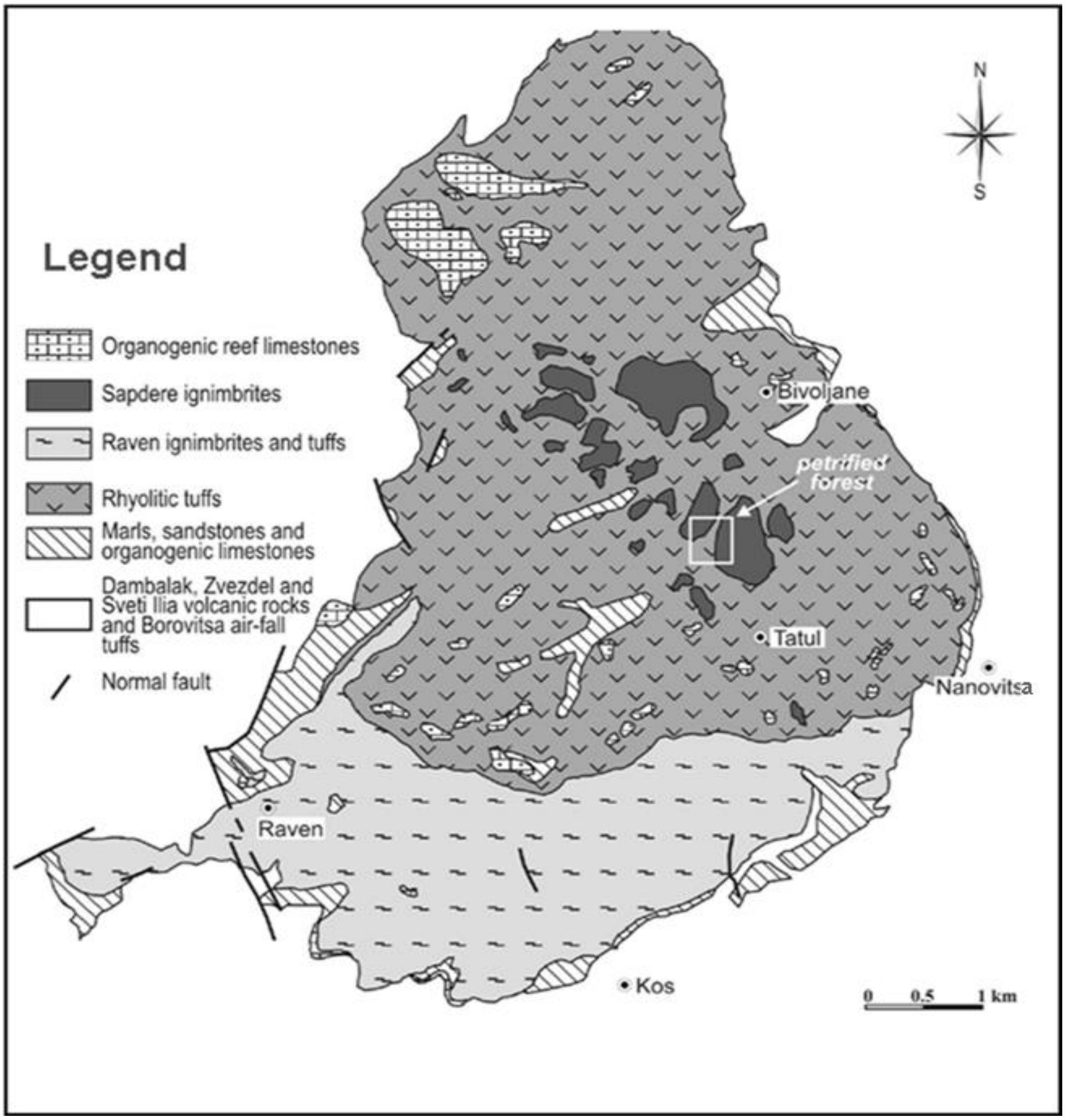


**Fig. 2** Simplified geological map of the Nanovitsa Depression, showing the location of the Petrified Forest (Georgiev & Marchev, 2005; Iamandei et al., 2014).

Advanced taxonomic studies based on genetic and morphologic analysis of a large number of extant species belonging to all genera of the Cupressaceae have led to a new taxonomical synthesis of this family which now includes seven subfamilies (see Gadek et al., 2000; Farjon, 2005; Mao et al., 2012). Thus, the two main genera of the former “Taxodiaceae family”, *Taxodium* and *Sequoia*, are now distributed in two different subfamilies: Taxodioideae, and Sequoioideae, respectively; only *Sciadopitys* was separated in its own family, Sciadopityaceae.

Subfamily Taxodioideae includes only three natural genera: *Taxodium* Rich. (Bald cypress), endemic to the southern US, Mexico and Guatemala, living in riparian and wetland habitats; and two endemic Eastern Asiatic genera, *Glyptostrobus* Tenore (Chinese swamp cypress) and *Cryptomeria* D.Don (sugi, Japanese cedar or Japanese red-cedar) (Farjon, 2005).

Subfamily Sequoioideae includes *Sequoia* Endl., with a single species, *Sequoia sempervirens* (D.Don) Endlicher, the redwood, a taxon living in a longitudinally stretching band in the western part of North America, more precisely, in SW Oregon and NW California, confined to coastal areas, within 60 km of the sea, experiencing a a large amount of fog, and growing at elevations ranging, generally, from lowland to over 900 m altitude (Earle, 2015); *Sequoiadendron giganteum* (Lindl.) J.Buchholz, the giant *Sequoia* or coast redwood, living on the western slopes of the Sierra Nevada Mountains of California; and *Metasequoia*, the dawn redwood, a fast-growing endangered coniferous tree, with a sole living endemic species in Hubei province, China (see Gadek et al., 2000; Farjon, 2005; Schulz & Stützel 2007).

During the Tertiary (and maybe even before), the distribution of these genera was different from that of today; they were also present in Europe and Asia as documented by the quantity of fossilized wood remains and other

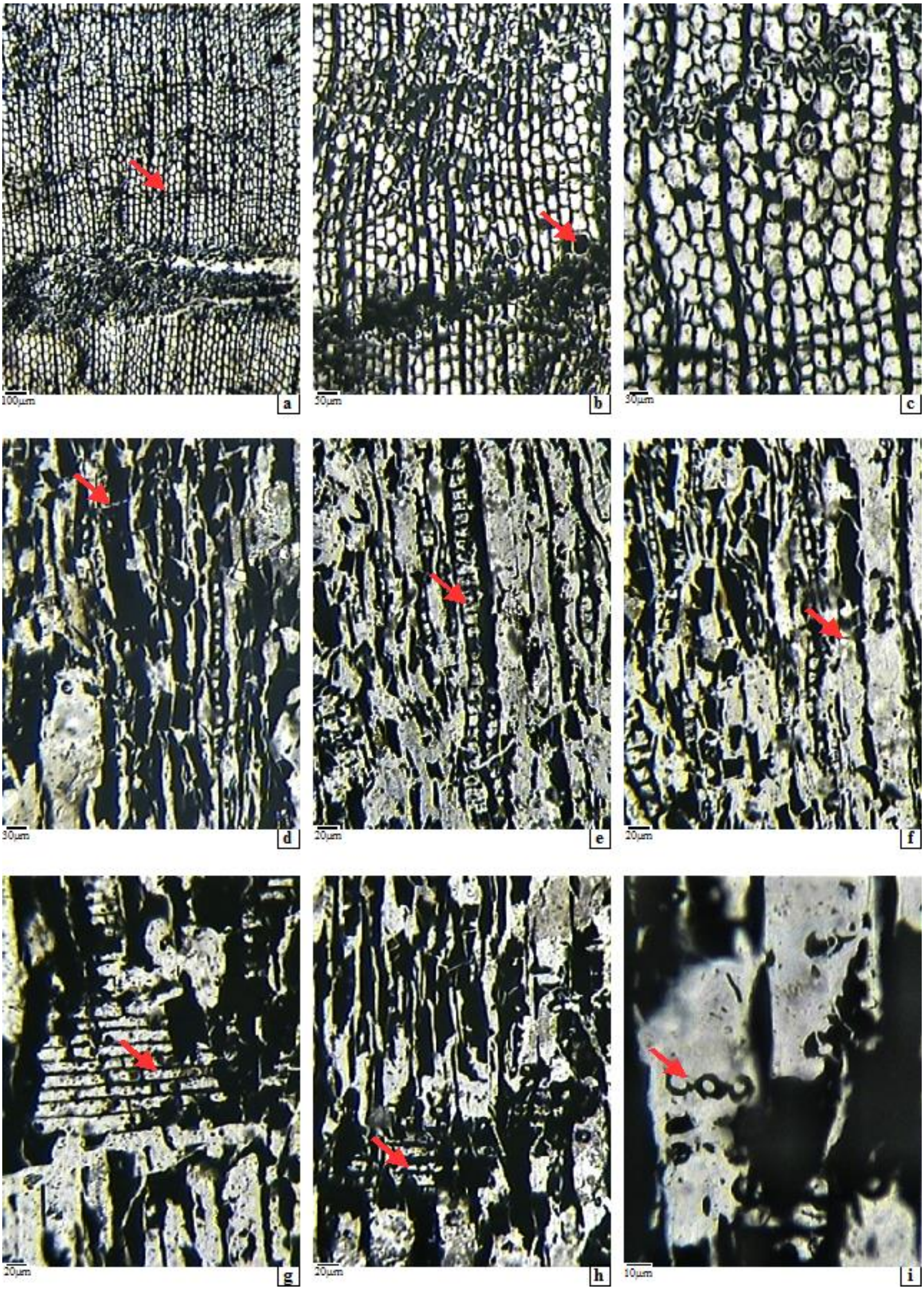


**Fig. 3** *Sequoioxylon gypsaceum* (Goepp.) Greguss, 1967, sample 27611, Nanovitsa Depression, Bulgaria. **a - c** Cross section – Distinct growth rings, traumatic canals, diffuse parenchyma. **d - f** Tangential section – Uniseriate rays with biseriate storeys, resinous parenchyma with smooth end walls (f). **g - i** Radial section – Triseriate radial pitting on large tracheids (i), wide cross-fields, in a badly preserved structure (g, h).

vegetative parts found and described from there. These genera – or at least the fossil forms of *Taxodium* and *Glyptostrobus* – were very often strongly implied in coal-genesis as well, due to their typical habitat preference for wet environments, even swamps or peat-bogs, is still seen today (Greguss, 1955; Earle, 2015).

For the "taxodiaceous" fossil wood structures, Hartig (1848) created the comprehensive genus *Taxodioxylon* (signifying 'taxodiaceous wood'), with *Taxodioxylon goeppertii* type species. The genus was emended by Gothan (1905, 1906) and, later, established by Kräusel (1949) as representing the wood of all members of the "Taxodiaceae". *Taxodioxylon taxodii* Gothan, 1906 has a wood structure similar to the extant *Taxodium mucronatum* Ten. and *T. distichum* Rich. *Taxodioxylon cryptomerioides* Schönfeld 1953 was admitted as a fossil equivalent of *Cryptomeria japonica* D. Don. or else of another extinct form (see Dolezych & Van der Burgh, 2004, p. 408), since *Cryptomerioxylon* Greguss, 1967 is a not validly published genus (ING Database, accessed 01.10.2016).

However, more recently, several fossil genera equivalent to the natural "taxodiaceous" genera have been described, even if not all of these are valid. These include *Metasequoioxylon* Greguss, 1967, a genus that was not validly published (ING Database, accessed 01.10.2016; see also Dolezych, 2011; Dolezych & Estrada, 2012); *Sciadopityoxylon* Schmalhausen 1879, with a *non designatus* type species (ING Database, accessed 01.10.2016) and hence quite disputed (see Philippe & Thévenard, 1996; Philippe et al., 2006); and *Sequoioxylon* Torrey, 1923 (non Greguss 1955), validly published with the type species *S. montanense* Torrey, 1923 (see Andrews, 1955). Finally, *Glyptostroboxylon* (Conwentz, 1885) emend. Dolezych and Van der Burgh, 2004, was typified by the same authors as a valid genus (ING Database, accessed 01.10.2016) of *non designatus* type, explaining that Kräusel in 1949 placed *G. goeppertii* in his new genus *Circoporoxylon* (see Andrews, 1955), and mechanical typification on *C. goeppertii* may be superseded.

The morphospecies *Taxodioxylon gypsaceum*, identified with the extant *Sequoia sempervirens*, was accepted by Kräusel (1949) as equivalent for fossil wood of *Sequoia*-type (an important extant "taxodiaceous" genus in that time), even if the genus *Sequoioxylon* was already created by Torrey (1923), with some already described species (Torrey, 1923; Andrews, 1936). The original diagnosis of *Sequoioxylon* Torrey, 1923, is as follows: 'Annual rings strongly developed; contrast between spring and summer wood very marked. Resin canals are wholly traumatic and in one or both directions. Wood rays with a few oculipores or oopores on the lateral tracheid-field; other walls either smooth or sparingly pitted. Resinous wood parenchyma present, diffuse, sometimes confined to the summer wood. Tracheids with one to several rows of bordered pits separated by bars of Sanio, and when in more than one row, opposite' (see also Philippe & Bamford, 2008). However, this genus was not accepted by some paleoxylologists who considered that "to establish new domains of competence for two genera (*Taxodioxylon* and *Sequoioxylon*) will complicate the identification" (Privé-Gill, 1977). Philippe (1993) considers that Hartig (1848) erected *Taxodioxylon goeppertii* as a valid type-species, perfect equivalent to the extant *Sequoia sempervirens*, and Gothan (1905, 1906) has also admitted this fact. Consequently, numerous fossil woods of *Sequoia* type were described untill now as different species of *Taxodioxylon*.

For example, Van der Burgh & Meijer (1996) identified a *Taxodioxylon gypsaceum* as xylotomically identical with *Sequoia sempervirens* (D.Don) Endl. Furthermore, Dolezych & Van der Burgh (2004, p. 408, 416-418) identifies *Taxodioxylon gypsaceum* (Goepp.) Kräusel, 1949 and *T. germanicum* (Greguss) Van der Burgh, 1973 with the extant *Sequoia sempervirens* (Lamb.) Endl., even if the latter taxon (*T. germanicum*) is considered an extinct form. More recently Teodoridis & Sakala (2008), respectively Koutecky & Sakala (2015) identified two *Taxodioxylon gypsaceum* in the Czech Republic, and Süss & Velitzelos (1997) identified a *Taxodioxylon gypsaceum* in Lesbos, Greece, also as fossil equivalents of the extant *Sequoia sempervirens*.

Yet there have been and still are scientists who preferred the genus *Sequoioxylon* Torrey 1923 and they have described numerous European specimens under this genus name, partially also quoted by van Amerom (2002, p. 619-621), Brown (1962, p. 94), Greguss (1967); *Sequoioxylon* had been reported by Petrescu & Dragastan (1971); Petrescu & Popa (1971); Petrescu (1978); Striegler & Süss (1984); Iamandei (2002); Iamandei & Iamandei (2000); Iamandei et al. (2008a, b; 2012; 2013); Akkemik et al. (2005); and Tiemei et al. (2013). Species of *Sequoioxylon* were reported even from North America or the Asian Far East by Roy & Stewart (1971); Basinger, (1981); Blokhina (1986, 1997, 2004a); Blokhina et al. (2000, 2004 2010); and Afonin (2013).

Taking into account the new taxonomic distribution within the Cupressaceae, based on advanced studies (Schulz and Stützel, 2007; Mao et al., 2012), according to which the subfamily Sequoioideae includes the genera *Sequoia, Sequoiadendron* and *Metasequoia,* and is separated from the subfamily Taxodioideae which includes the genera *Taxodium, Glyptostrobus* and *Cryptomeria*, we propose to reconsider the correspondent fossil genera and to recognize both *Taxodioxylon* Hartig and *Sequoioxylon* Torrey as valid fossil genera, corresponding to the extant taxa which belong to the two different subfamilies within the Cupressaceae, to revise these fossil general, and to establish new diagnoses for each of them.

This also means that all the forms described under the names *Taxodioxylon gypsaceum* (Goepp.) Kräusel, 1949, *Taxodioxylon germanicum* (Greguss) Van der Burgh, 1973 or even only as *Taxodioxylon* sp., but with structure of *Sequoia* type (with smooth end walls of parenchyma, typical cross fields and radial pitting on tracheids up to triseriate), xylotomically different from the *Taxodioxylon* wood type (which has nodular end walls of parenchyma, with 8 knots, typical taxodioid cross fields and radial pitting on tracheids up to biseriate), should be revised as *Sequoioxylon gypsaceum* (Goepp.) Greguss, 1967, *Sequoioxylon germanicum* (Greguss), 1967 and, respectively, *Sequoioxylon* sp.

Consequently, since the features of this taxon (*Sequoioxylon*) are very specific, and our studied material, although relatively badly preserved and showing traumatic canals within some growth rings, certainly of an ecologic significance, also presents the typical features regarding the

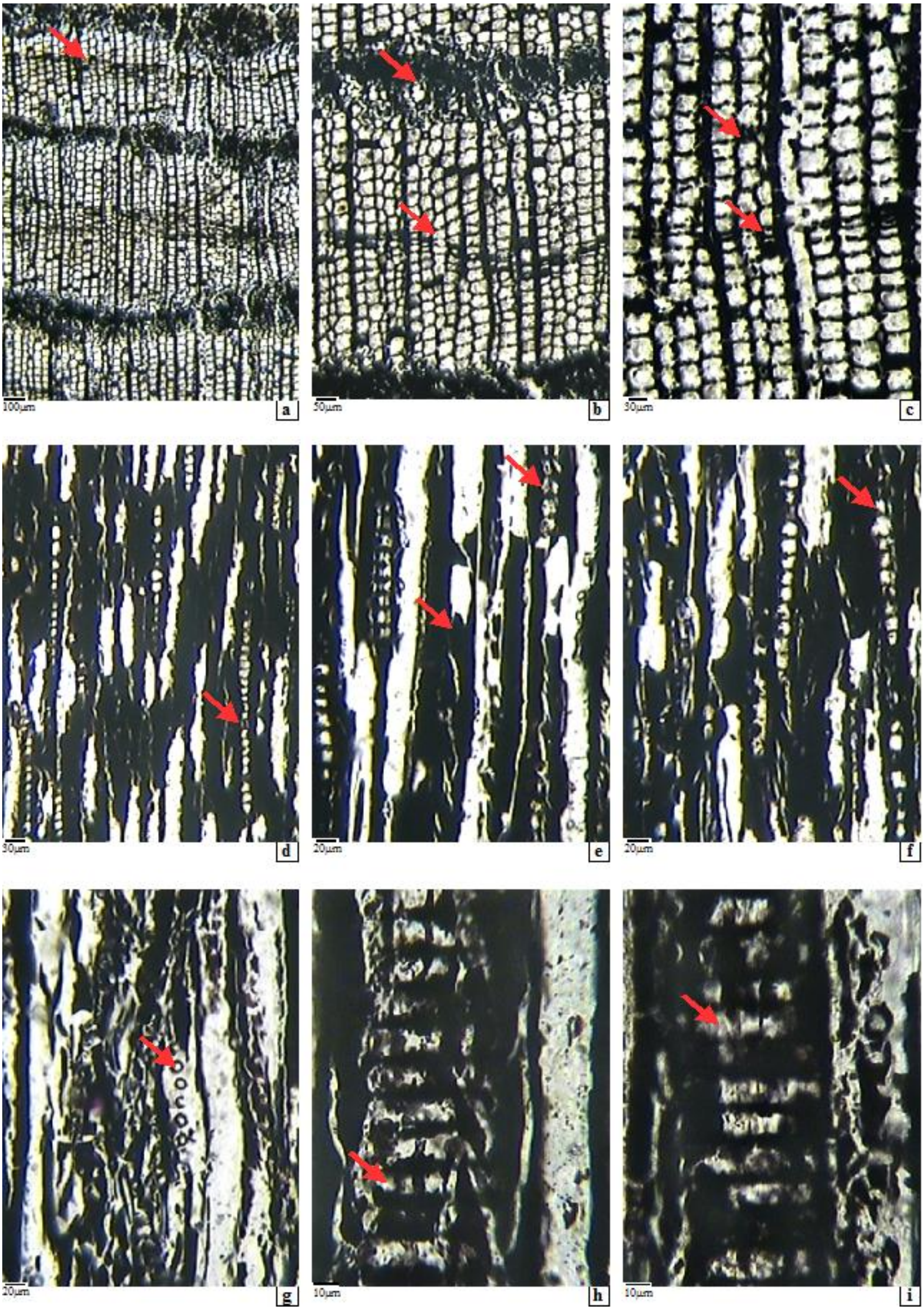


**Fig. 4** *Sequoioxylon gypsaceum* (Goepp.) Greguss, 1967, sample 27612, Nanovitsa Depression, Bulgaria. **a - c** Cross section – Distinct growth rings, traumatic canals, diffuse parenchyma. **d - f** Tangential section – Uniseriate rays with biseriate storeys, resinous parenchyma. **g - i** Radial section – Badly preserved cross field pitting, three pits in line (h-i).

tracheids, the axial parenchyma with smooth end walls and the uniseriate rays and their typical cross field pitting with up to three, marginally more numerous, pits, it can be attributed to the species *Sequoioxylon gypsaceum* (Goepp.) Greguss, 1967.

Phylum **Magnoliophyta** Cronquist, Takhtajan and Zimmermann, ex Reveal, 1996
Family **Magnoliaceae** Juss., 1789
Genus ***Magnolioxylon*** Hofmann, 1952
*Magnolioxylon* aff. *transilvanicum* Nagy & Mârza, 1967
Fig. 5: a-i; Fig. 6: a-i.

## MATERIAL

Two silicified wood fragments collected from the area of the gorge of Gabaz (Gabaz gulch), Nanovitsa Depression, eastern Rhodopes Mts. were studied. The size of the two samples was 9/3/1.5 cm and 7/5/2.5 cm, respectively. Macroscopically the samples show dark-grey color, and a regular fibrous texture with vessels, suggesting a dicotyledonous wood. The material left after the preparation of the standard oriented thin slides are registered and kept in the collections of the National Geological Museum (NGM Coll.) in Bucharest, under the speicmen numbers 27613 and 27614.

## MICROSCOPIC DESCRIPTION

*The growth rings* have not very distinct boundaries; when visible, they are marked by 3-8 tangential rows of smaller cells of parenchyma and fibers. The wood structure is semi-ring-porous to diffuse-porous and with occasional crystalliferous idioblasts scattered in the groundmass.
*The vessels* appear usually solitary in cross-section, but also in radial multiples of 2-4(6), sometimes in clusters, accompanied by some fibro-tracheids. The solitary pores have rounded, irregularly star-like or slightly polygonal cross-section, and are thick-walled, of 4.5-8 μm. Their radial/tangential diameters are small, of 40-52(90)/25-40(60) μm. The total vessel density is 25-56 pores per mm$^2$, sometimes more. Inclined or horizontal simple perforation plates are present, and very rarely short scalariform ones as well, with less than 10 bars. Often they are arranged in stories. The intervascular pits are numerous, opposite to slightly alternate, bordered-elliptic, of 8-12 μm in diameter. Short vascular elements, often difficult to measure, have 350-480 μm in length, and no content or tyloses.
*Fibro-tracheids* appear in cross-section radially arranged before and after solitary pores or grouped vessels, with a wider lumina than the fibers; these are longitudinally pitted with large horizontal lens-like or oval bordered pits (of 12-16/4-6 μm), of buttonhole type, arranged in one or two (opposite) vertical rows.
*The axial parenchyma* appears of paratracheal vasicentric type in cross-section, with 1-3 rows of cells around the vessel as well as dispersed usually as solitary empty cells between fibers, having relatively thin walls, of 2-3.5 μm the double wall. Occasionally they appear as rounded, hypertrophied, bright white secretory idioblastic cells, of 25-50 μm in diameter with brown content or bearing solitary angular crystals, difficult to observe. Marginal parenchyma cells could also appear at the ring boundary, intermingled with fibers in some tangential rows. Longitudinally the parenchyma appears in strands of 8-12 rectangular vertical cells with small simple pitting, hardly discernible on their thin walls.
*The fibers* constitute the major part of the ground tissue and, in cross-section, are arranged in 2-12 radial rows, fairly regularly arranged between two successive rays, usually showing small intercellular spaces. The cells have polygonal section, slightly rounded, thick walls of 5-8(12) μm the double-wall, and wide lumina. Sometimes, small rounded fibers with point-like lumina can appear, representing probably the cross-section of the tapered endings. Quadrangular fibers with slit-like lumina are present in the terminal wood, intermingled with some parenchyma cells,. Longitudinally, the fibers have bordered pits in a slightly irregular vertical row and are not septate.
*The medullary rays* show rectangular radial elongate cells in cross-section, sometimes visibly hypertrophied and filled with yellow to brown content or with dark gums. The rays have a linear trajectory, sometimes touching vessels, and present a slight dilation at the growth-ring boundaries. The rays are 1-3(4)-seriate, usually heterogeneous and their frequency is of 7-11 rays per horizontal tangential millimeter. They have 5-29(40) cells in height, i.e. 115-600(787) μm, but the uniseriate ones are short. The ordinary ray cells show fairly thick walls (4-5 μm the double-wall), have polygonal to rounded shape, are alternately arranged and are very unequal in size: 8-16 μm horizontally and 10-22 μm vertically. The uniseriate endings have 1 to 5 cells, 1-3 of them being secretory idioblastic cells, hypertrophied, thick-walled (5-8 μm the double wall), polygonal or vesicular, terminal or subterminal. When the secretory cells appear in the ray-body, they are pitted. When they are terminally arranged, they are elongated, 25-42(72) μm in width and 28-60(80) μm in height, and have dark content. Radially the rays are heterocellular. The ray-body cells are usually procumbent, of 10-16(22) μm height. The marginal cells can be square, (16)25-30 μm high, and the intermingled idioblastic secretory cells are higher or upright, of up to 95 μm, bearing bright-white, orange-colored or brown content and dark gum remains. Similar content of fine granular dark gum remains may appear within procumbent hypertrophied body ray cells too. In the cross-fields of rays with vessels, small-oval vertical bordered pits of 3.5-7 μm are visible, slightly irregular or arranged in 1-3 horizontal rows. On the higher marginal cells, (4)7-10 superposed pits may be present.

## AFFINITIES AND DISCUSSIONS

The microscopic details observed in the standard oriented thin sections, such as the presence of simple perforated plates and rare low scalariform ones, besides the presence of some hypertrophied secretory cells in rays and also in the axial parenchyma, suggest a magnoliaceous wood structure (Metcalfe & Chalk, 1950; Greguss, 1959). Certain details were initially also suggestive of a lauraceous wood structure, and led our attention to "*Laurinoxylon" intermedium*, described by Huard (1967) from some

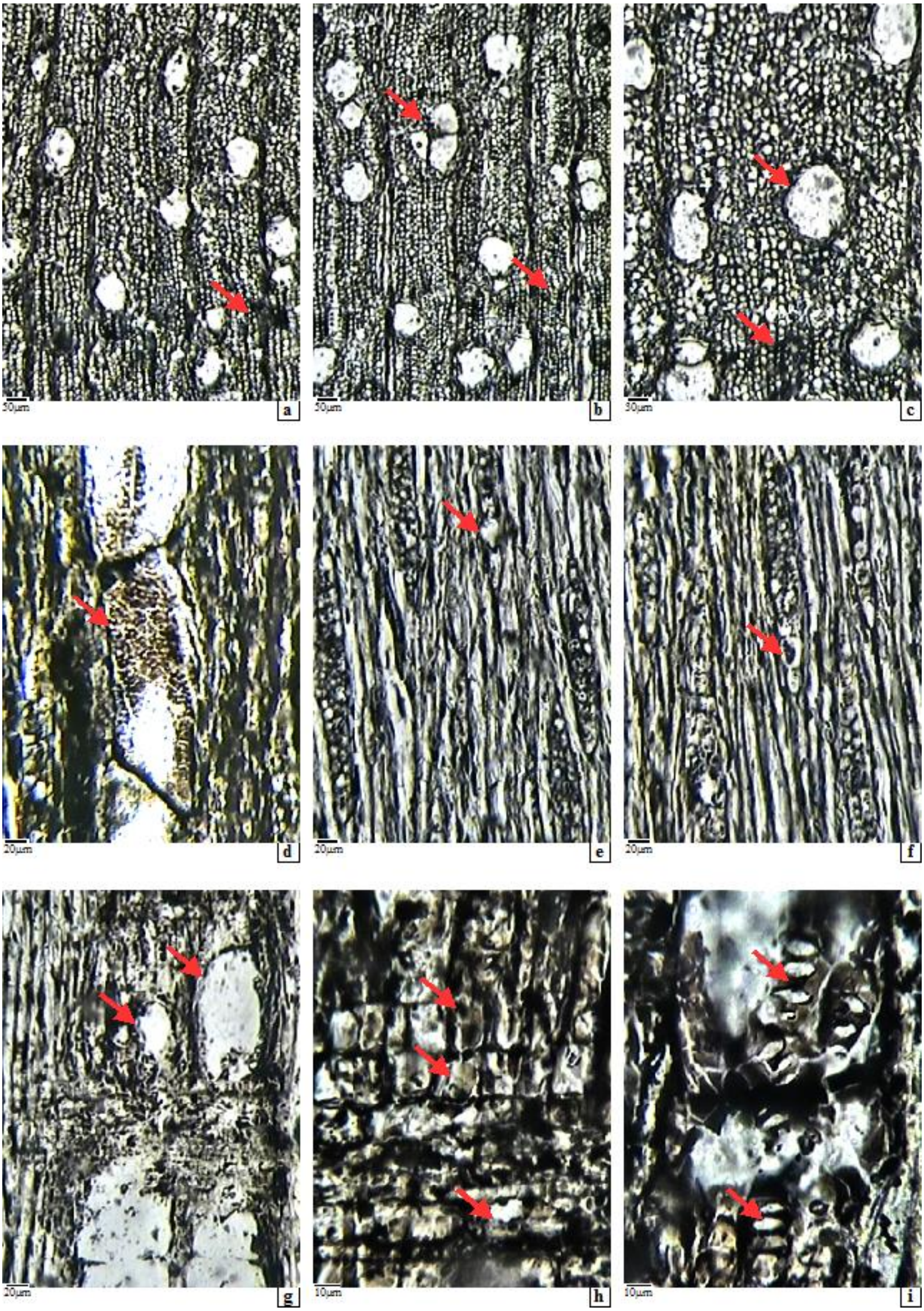


**Fig. 5** *Magnolioxylon* aff. *transilvanicum* Nagy & Mârza, sample 27613, Nanovitsa Depression, Bulgaria. **a - c** Cross section – Indistinct ring boundary, solitary vessels and grouped, ground tissue. **d - f** Tangential section – Alternate vascular pitting, bi- or triseriate rays with terminal oil cells or in the ray endings. **g - i** Radial section – Simple perforation plates, square and tall marginal ray cells, cross-fields, fibro-tracheids with buttonhole-type pitting.

Miocene lignites of Arjuzanx (Landes, France), later revised as *Cinnamomoxylon intermedium* (Huard) Gottwald, 1997, and considered by Mantzouka et al. (2016) as a magnoliaceous wood.

**Magnoliaceae** is a family with 5 genera and 247 species (The Plant List, 2013). They are widespread in temperate to tropical areas from Eastern Asia and North America, and not all of the species show arboreal habit (Watson & Dalwitz, 1992).

However, only three fossil genera were validly described until now:

- *Liriodendroxylon* Prakash, Březinová & Bůžek, 1971, corresponding to the extant genus *Liriodendron* known as tulip tree, whose wood structure is diagnosed by diffuse-porous wood, small to medium-sized vessels, solitary or as multiples of 2 or more scalariform perforated plate with few (6-13) bars, angular to elliptic opposite intervascullar pitting, arranged in horizontal pairs or rows, terminal parenchyma, 1-5-seriate rays or broader, slightly heterogeneous, fibers with polygonal cross-field, thin to thick walled, non-septate.
- *Magnolioxylon* Hofmann, 1952, corresponding to extant genera of magnolias such as *Magnolia*, *Michelia*, and *Talauma*, with the following diagnosis: diffuse-porous wood with low growth rings, small solitary vessels or as multiples of 2-3...5(7), simple perforated (and scalariform) plates, small to large vascular pitting tending to scalariform, paratracheal uniseriate parenchyma, 1-4(5)-seriate rays, rarely broader, slightly sinuous trajectory, high to 22 cells, heterogeneous, procumbent body cells, marginals upright, thick walled fibers. Although Wheeler et al. (1977) proposed to invalidate this name and proposed another replacement genus name for fossil wood of Magnoliaceae, the name *Magnolioxylon* remains valid.
- *Magnoliaceoxylon* Wheeler, Scott et Barghoorn, 1977, established for fossil woods with anatomical similarity to extant genera of Magnoliaceae, having wide vessels (75 mm in mean tangential diameter), numerous bars in the perforation plates (up to 26), opposite and scalariform intervessel pitting, and higher rays (see also in Srivastava and Suzuki, 2001).

Schönfeld (1958) cited some older identifications of magnoliaceous fossil woods (made by Unger, Caspary, Lignier, Edwards, and Kruse), mostly inaccessible for comparison. We also consulted Inside Wood (2004-onwards), and we compared the structure of our specimens with the following published forms:

- *Magnolioxylon scandens* Schönfeld, 1958, described from the Upper Oligocene of Niederrheinischen Bucht, showing diffuse-porous wood with thick growth rings, vessels solitary and in small radial multiples, sometimes diagonal to tangential, simple to scalariform perforated plates (up to 33 bars), scalariform intervascular pitting; tracheids thick-walled, round to scalariform pitted, thick-walled pitted libriform, 1-4-seriate heterocellular high rays, with 1-3(5) rows of marginal, thick walled, upright cells (77-92 mm high). Schönfeld shows that these details suggest similarities with extant species like *Magnolia* and *Talauma*, but also with some lianas like *Schisandra* or *Kadsura*. The same species was found and described by us from Middle Miocene deposits of Prăvăleni, South Apuseni area (Iamandei et al., 2004).
- *Magnolioxylon michelioides* Hofmann, 1952, the type species, with radial multiples of 3-5-7 vessels, paratracheal and marginal parenchyma, numerous rays of two sizes - 3-5 cells broad and respectively uniseriate , characters which make it reminiscent of the extant species *Michelia baviens L*.
- *Magnolioxylon transilvanicum* Nagy & Mârza, 1967, first described from Prăvăleni, South Apuseni area. The wood structure presents bi- and triseriate rays, platanoid dilations at the boundary of the growth-rings, simple and scalariform perforations, elongated to scalariform bordered pits on the vessels, simple and bordered with slit-like apertures to the ray cells, tracheids with spiral thickenings and scalariform pitting. The species described by Nagy & Mârza (1967), and subsequently identified by us in the same area (Iamandei & Iamandei, 1997), also has 2(3)-seriate rays, with secretory cells, simple and scalariform perforations, bordered elliptic to scalariform pitting, similar or of "buttonhole-type" on tracheids or on the fibers.
- *Magnolioxylon sp*., described by Petrescu (1970) from Prăvăleni as well, has badly preserved anatomical details - vessels solitary or in 2-3 radial multiples and 1-4-seriate rays. All of these are typical generic details, but are not sufficient for specific identification.
- *Magnolioxylon kräuselii* (Greguss) Van der Burgh, 1973, initially described by Greguss (1969) as *Liquidambaroxylon*, besides the generic details shows simple and scalariform perforations with (3)10-12 spaced thick bars, sometimes forked, pitted and crystalliferous parenchyma, 1-2-seriate, 10-16 cells high heterocellular rays, thick to very thick fibers, pitted fibro-tracheids.
- *Magnolioxylon parenchymatosum* Van der Burgh, 1973 described from the Upper Oligocene of Niederrheinischen Braunkohlenformation (Germany) shows many xylotomical similarities with the extant species *Magnolia fraseri* and *M. sororum*, and with the fossil species *Magnolioxylon scandens* described by Schönfeld from the same deposits. The terminal parenchyma is obvious, the vessels with small sections, scalariform perforated (2-12 spaced bars), intervascular scalariform pitting, helical thickenings, pitted tracheids and fiber, banded parenchyma, heterocellular (with two rows of marginal upright ray cells), specially pitted, 2-3-seriate rays.

Taking into account the synthetic description of the available specimens, i.e., the presence of the wide marginal secretory idioblastic oil-cells in rays, and sometimes in the axial parenchyma, the semi-ring- to diffuse-porous wood-structure, the shape and the distribution of the vessels, the simple and rarely short scalariform perforations plates, the opposite to alternate vascular pitting, the opposite buttonhole-like bordered pits in 1-2 vertical rows on tracheids, the thick-walled and non-septate fibers, it gen-

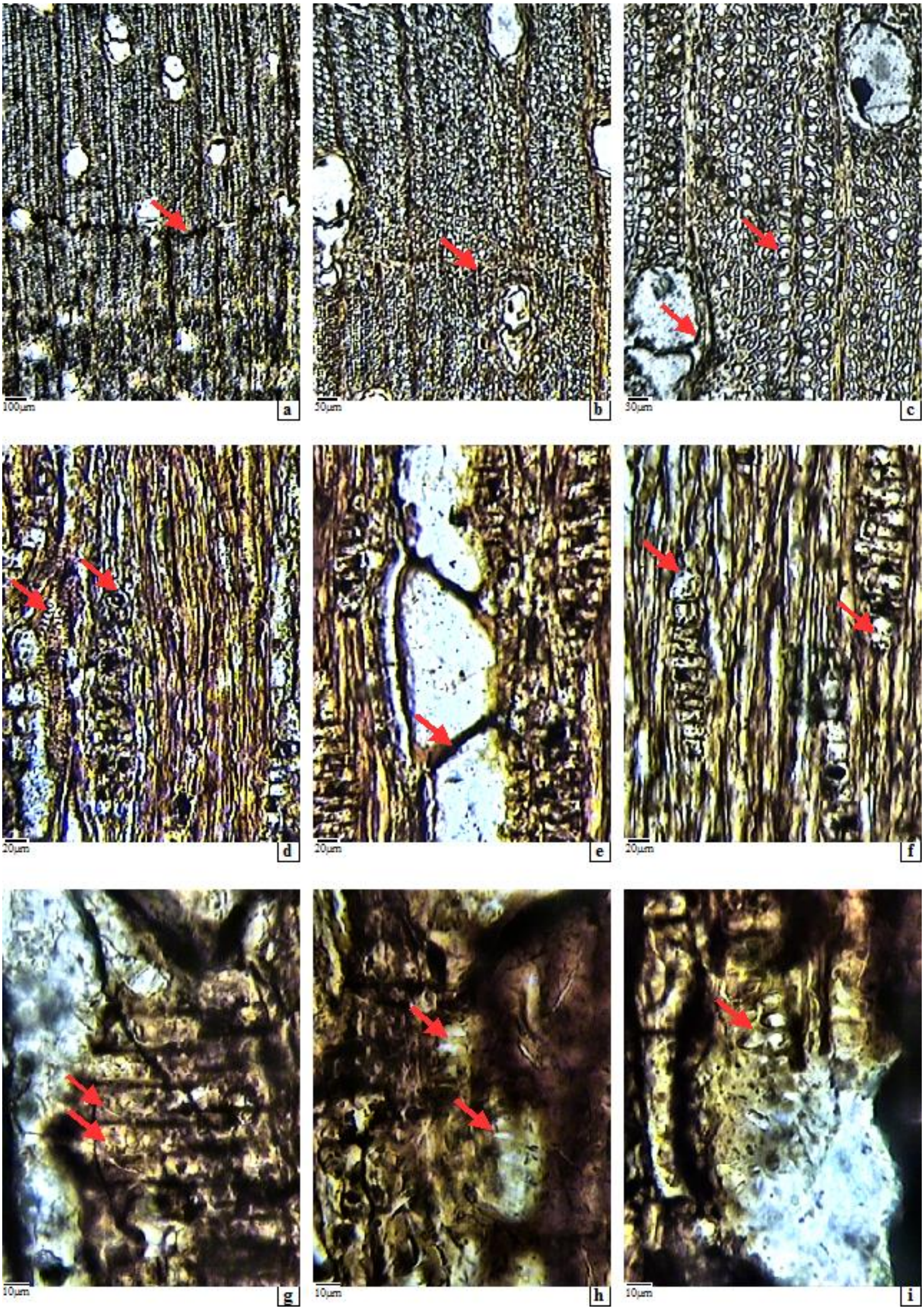


**Fig. 6** *Magnolioxylon* aff. *transilvanicum* Nagy & Mârza, sample 27614, Nanovitsa Depression, Bulgaria. **a - c** Cross section – Indistinct ring boundary, solitary and grouped thick-walled vessels and grouped, thick-walled fibers. **d - f** Tangential section – Alternate vascular pitting, short vessel elements, bi- and triseriate rays, with terminal oil cells. **g - i** Radial section – Simple perforation plates, cross-fields with round pitting, buttonhole pits on fibro-tracheid.

erally corresponds to the species diagnosis given by Nagy & Mârza, 1967; accordingly, we refer our studied specimens to the taxon *Magnolioxylon* aff. *transilvanicum*.

Family **Fagaceae** Dumortier, 1829
Genus ***Quercoxylon*** (Kräusel) Gros, 1988
*Quercoxylon intermedium* Petrescu & Velitzelos, 1981
Fig. 7: a - i.

## MATERIAL

The studied material is represented by two silicified wood fragments collected from the area of the gorge of Gabaz (Gabaz gulch), Nanovitsa Depression, eastern Rhodopes Mts. The size of the samples is 9/3/1.5 cm and 7/5/2.5 cm, respectively. Macroscopically the samples show beige to light brown color, a regular fibrous texture without vessels, thin rays and obvious annual rings. The material left after the preparation of the standard oriented thin slides are registered and kept in the collections of the National Geological Museum (NGM Coll.) in Bucharest, under the specimen numbers 27615 and 27616.

## MICROSCOPIC DESCRIPTION

*The growth rings* are not always very distinct in cross-section and the wood structure is rather semi-ring-porous.
*The vessels* are large in the early-wood, rounded or deformed by compression and relatively thick-walled, gradually diminishing to the latewood. Usually they appear exclusively solitary, arranged in radial or slightly dendritic patterns. Their lumina varies between 150–350 µm (or more) in diameter, diminishing to the latewood where these are also round to oval or almost lenticular, their lumina diameters varying between 30–150 µm. The vascular wall is thick to moderately thick (the simple wall is 3–5 µm). Simple perforations on tilted plates are present, as are numerous small, opposite, sub-opposite to slightly alternate bordered pits on the vessel walls, sometimes not very visible, corresponding to those of the paratracheal parenchyma. Helical thickenings are not visible. Mean vessel elements, difficult to measure, range up to 800 µm. Thin-walled, large and folded tyloses inside the vessels exist. The frequency of the vessels varies between 3–5 vessels per square millimeter in the early-wood, to 7–14 in the late-wood.
*The axial wood parenchyma* of apotracheal type is visible in cross-section and is either diffuse, scattered among the fibers, diffuse-in-aggregates, or in short lines. In longitudinal section, the parenchyma has dark tanninous content and often is chambered and crystalliferous.
*The fibers* appear in regular radial rows in cross-section, are relatively thick-walled and, when viewed longitudinally, pitted and non-septate.
*The rays* show two different sizes and appear linear or slightly undulated in cross-section in the early wood. There is a size class of fine, uniseriate and 2-3-seriate. low and numerous rays, and a second size class, which includes multiseriate rays (13–20 cells wide, i. e., up to 300–350 µm in width), often taller than 1 mm, compact and usually dissected by libriform fibers often giving them a typical aspect of compound-aggregate or even aggregate rays; these occur at relatively uniform and large intervals. The ray cells are rounded to polygonal, unequal in size (8–15µm) and rather thin-walled (2–3 µm the width of the double wall). The ray density is variable, varying between 10–20 rays per tangential millimeter. In radial view the rays are slightly heterocellular, showing procumbent cells in the median part, and squared ones in the external part. In the cross fields, numerous large, rectangular or vertically elliptic pits, often arranged in palisades, a condition typical for oaks, are locally visible. Sometimes, gum remains and solitary crystals are present inside the ray cells.

## AFFINITIES AND DISCUSSIONS

The wood structure of the studied specimens is semi-ring- to diffuse-porous with rare broad rays, indicating a possible member of Fagaceae, while the two-sized, broad and fine rays, the exclusively solitary vessels, and their arrangement in radial rows, or slightly dendritic pattern, strongly suggest a wood structure of oak type.
A recently published palaeoxylotomical study (Iamandei et al., 2013) of five samples taken from *in situ* petrified stumps from the same fossil site (the Petrified Forest of Nanovitsa Depression, Rhodopes Mts.), has revealed a similar woodstructure and has been identified as *Quercoxylon intermedium* Petrescu & Velitzelos, 1981.
Accordingly, as the microscopically observed features of the new material are almost identical to those identified previously by Iamandei et al. (2013), we propose its assignment to the same wood type as *Quercoxylon intermedium* Petrescu & Velitzelos, 1981, without repeating the extended discussion already made by Iamandei et al. (2013).

Family **Juglandaceae** de Candolle ex Perleb, 1818, nom. cons.
Genus ***Rhysocaryoxylon*** Dupéron, 1988
*Rhysocaryoxylon madsenii* Sakala & Gryc, 2011
Fig. 8: a - i.

## MATERIAL

The studied material is represented by a silicified wood fragment collected from the area of the gorge of Gabaz (Gabaz gulch), Nanovitsa Depression, eastern Rhodopes Mts. The size of this sample is 9/3/1.5 cm and it represents a dispersed fragment of silicified wood. Macroscopically, the sample has dark grey color, a regular fibrous texture with vessels, suggesting a dicotyledonous wood. The material left after the preparation of the standard oriented thin slides are registered and kept in the collections of the National Geological Museum (NGM Coll.) in Bucharest, under the specimen number 27617.

## MICROSCOPIC DESCRIPTION

*The growth rings* have indistinct boundaries, the wood structure is relatively porous to clearly semi-ring-porous, and the vessels are arranged in radial fascicles to slightly dendritic; their lumina as well as frequency tends to diminish gradually from early to late-wood. The usually thin rays occasionally show a slight dilation at the ring-boundary; with the long tangential bands of parenchyma,

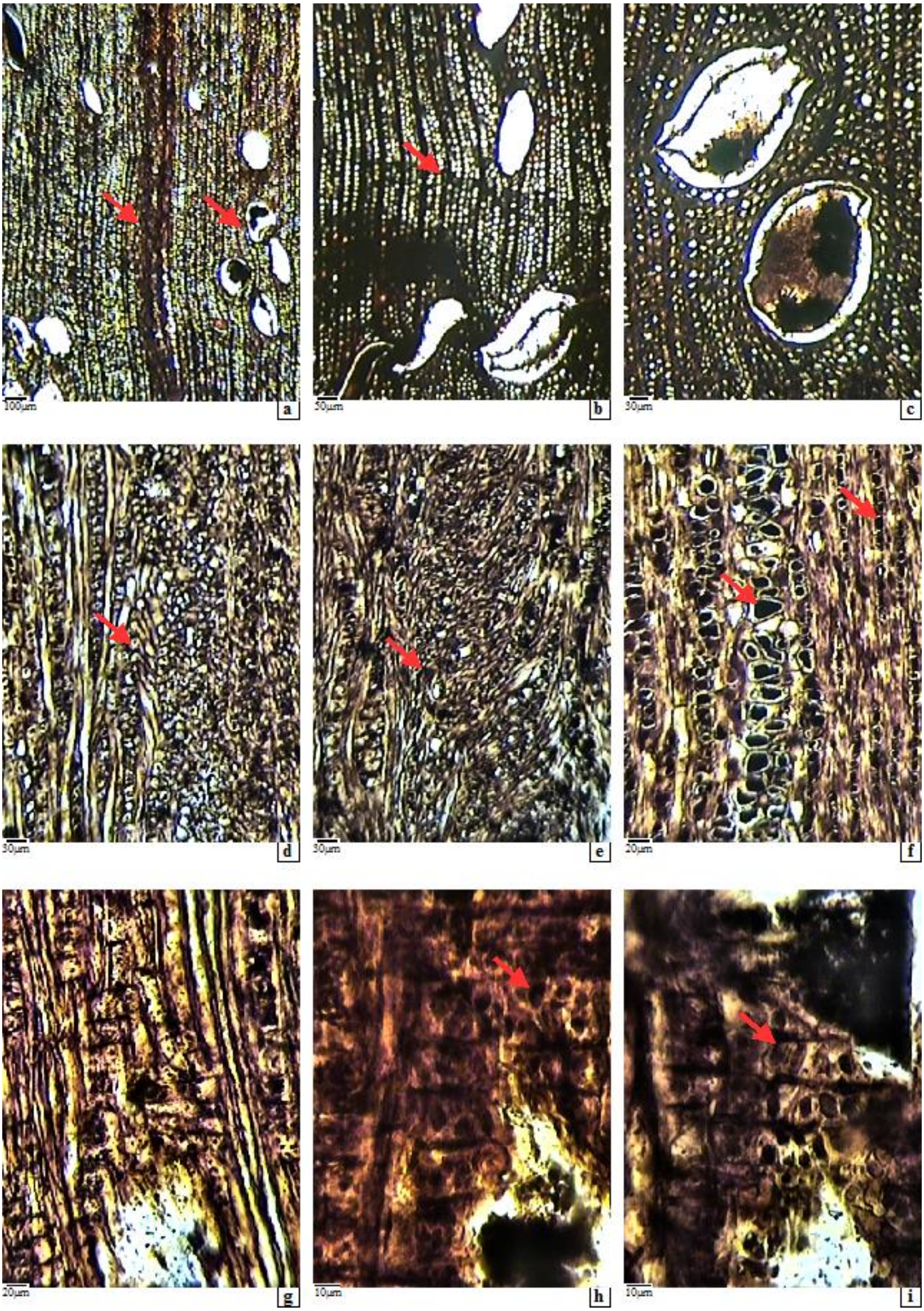


**Fig. 7** *Quercoxylon intermedium* Petrescu & Velitzelos, 1981, sample 27615, Nanovitsa Depression, Bulgaria. **a - c** Cross section – Indistinct ring boundary, semi-ring-porous structure, thick-walled solitary vessels in radial pattern, ground tissue, two-sized rays. **d - f** Tangential section – Two-sized rays, typical thick rays, unequal tanninous ray- cells. **g - i** Radial section – Typical cross-field pitting, in palisade.

these give the structure a typical reticulate arrangement (IAWA, 1989).

*The vessels* appear as solitary pores or in radial multiples of 2-3(5) in cross-section. The solitary ones are circular to radial-oval. The vascular walls are thick, of 8-15 µm the double wall, but usually even the simple wall reaches 6-10 µm in thickness. The radial/tangential diameters of the solitary pores are 88-230/90-180 µm, sometimes more, while in the late wood these are smaller (of 60-80 µm); their density, counting all the vessels, even from the groups, is of 4-8 vessels per sq. mm (see Wheeler, 1986; IAWA, 1989). The terminal tilted plates are exclusively simple-perforated and the numerous bordered pits are alternate, hexagonal, of 9-12(15) µm in diameter, with 2-3 µm apertures. The vessel elements are 220-350 µm long. Tyloses are absent or difficult to observe, due to bad preservation.

*The axial parenchyma* appears as long, continuous, tangential, 1-3 cells thick bands in cross-sections, but there is also a paratracheal type in the form of some flattened cells around the vessels. The cell diameter is usually of 14-17 µm, but is reaching 30-50(80) µm in the crystalliferous hypertrophied ones. Longitudinally, the parenchyma from the apotracheal bands normally appears in strands longer than 4-5 rectangular vertical ordinary thin-walled cells; these are often chambered and crystalliferous, or are hypertrophied showing one or several solitary rounded crystals inside.

*The fibers,* regularly arranged in radial rows, have a polygonal shape in cross-section, with rounded corners, of 17-20 µm in diameter. They have thick to very thick walls (up to 12 µm the double wall) and rounded lumina. Longitudinally, they don't appear to be pitted or septate and, due to bad preservation, their length is also difficult to be measured.

*The rays* appear as of built from rectangular radial-elongated cells in cross-section, usually full of dark granular remains. They are mostly biseriate, although some cn be uni- or triseriate, and very rarely even 4-5-seriate. The ray trajectory is usually linear, slightly curled, molding and touching the vessels. Tangentially, the 2-3-seriate rays have 13 to 32 cells (up to 650 µm) in height; the uniseriate ones are of 10-15 cells in height (i.e. 200-320 µm). In tangential view the ray cells appear usually vertically elongate; they have a horizontal diameter of 12-16 µm and a vertical one of 20-25 µm, and frequently show a dark-brown granular content. Their density is of 10-14 rays per tangential horizontal mm. The multiseriate rays are fusiform and have short uniseriate endings, with 1-4 marginal cells. Novertheless, radially they appear homocellular, with cells that are all procumbent, occasionally chambered, and with moderate-sized, solitary, rounded crystals inside; solitary hypertrophied cells can also appear, bearing either a single or several large crystal inside, similar to those in the axial parenchyma. It is also evident that the marginals are slightly taller, reaching 33-45 µm, but are procumbent as well.

## AFFINITIES AND DISCUSSIONS

The xylotomical features shown by our specimen, including the aspect and size of pores in cross-section, where a porous to semi-ring-porous wood structure is evident, with a dendritic arrangement of vessels diminishing to the late wood, the fine tangential bands of parenchyma that forms a scalariform structure with the relatively thin rays, the circular to oval pores of 88-230/90-180 µm, that are either solitary or occur in radial multiples of 2-3(5), the vessels with simple-perforations and numerous alternate bordered pitting, the dominantly banded apotracheal parenchyma and the rare occurrence of paratracheal vasicentric, but sometimes as chains of hypertrophied cells with solitary large barrel-like crystals inside, the homocellular ray cells, chambered and with solitary rounded crystals, as well as the often solitary hypertrophied "barrel-like" cells bearing a single large crystal inside, similar to the axial parenchyma, together suggest affinities with the extant juglandaceous woods, most probably of *Juglans* or *Carya* type.

According to Manning (1978) (see also Dupéron, 1988; Iamandei & Iamandei, 2000), the extant Juglandaceae includes 7 genera divided into 2 subfamilies, Platycaryoideae and Juglandoideae, which have relatively disjunct living areas in Eurasia and America. A slightly different taxonomy of the extant Juglandaceae includes the following two subfamilies:

1) Subfamily Engelhardioideae, with 3 genera: *Alfaroa* Standl. – the gaulin, *Engelhardia* Lesch. ex Blume – the cheo, and *Oreomunnea* Oerst. – the guayabo amarillo, gavilán.

2) Subfamily Juglandoideae, with 2 tribes:

- Tribe Platycaryeae (with the genus *Platycarya* Siebold & Zucc.).
- Tribe Juglandeae, consisting of two subtribes: Subtribe Caryinae with 2 genera: *Carya* Nutt. – the hickory, pecan and *Annamocarya* A.Chev., as well as Subtribe Juglandinae with 3 genera: *Cyclocarya* Iljinsk. – the wheel wingnut, *Juglans* L. – the walnut, and *Pterocarya* Kunth – the wingnut.

3) There is a further *incertae sedis* juglandacean genus: *Rhoiptelea* Diels & Hand.-Mazz.

Dupéron (1988) presented the specific xylotomical details of the main extant juglandaceous genera, specifying the presence or absence of the crystalliferous parenchyma, as well as the thickness of the vascular wall. These important discriminating details are especially important for the present study, being used for generic identification, and are thus listed below:

- *Platycarya* shows spirals of smaller vessels and of some tracheids on the walls;
- *Engelhardia*, *Alfaroa*, and *Oreomunea* have usually simple and scalariform perforations;
- *Carya* has always thick (>3 µm) vascular walls, the crystalliferous parenchyma is often present and hosts solitary crystals in some enormous, barrel-like cells, arranged as short files of 1-2-3, and the apotracheal parenchyma appear as continuous bands.
- *Pterocarya* has no crystalliferous parenchyma, the vascular walls are always thin (<3 µm), and the parenchyma appear as short, usually uniseriate bands.
- *Juglans*, shows several different structure types, according to Miller (in Dupéron, 1988):
- The Gray Walnuts (=*Trachycaryon* and *Cardiocaryon* sections) – with the species *J. ailantifolia, J.*

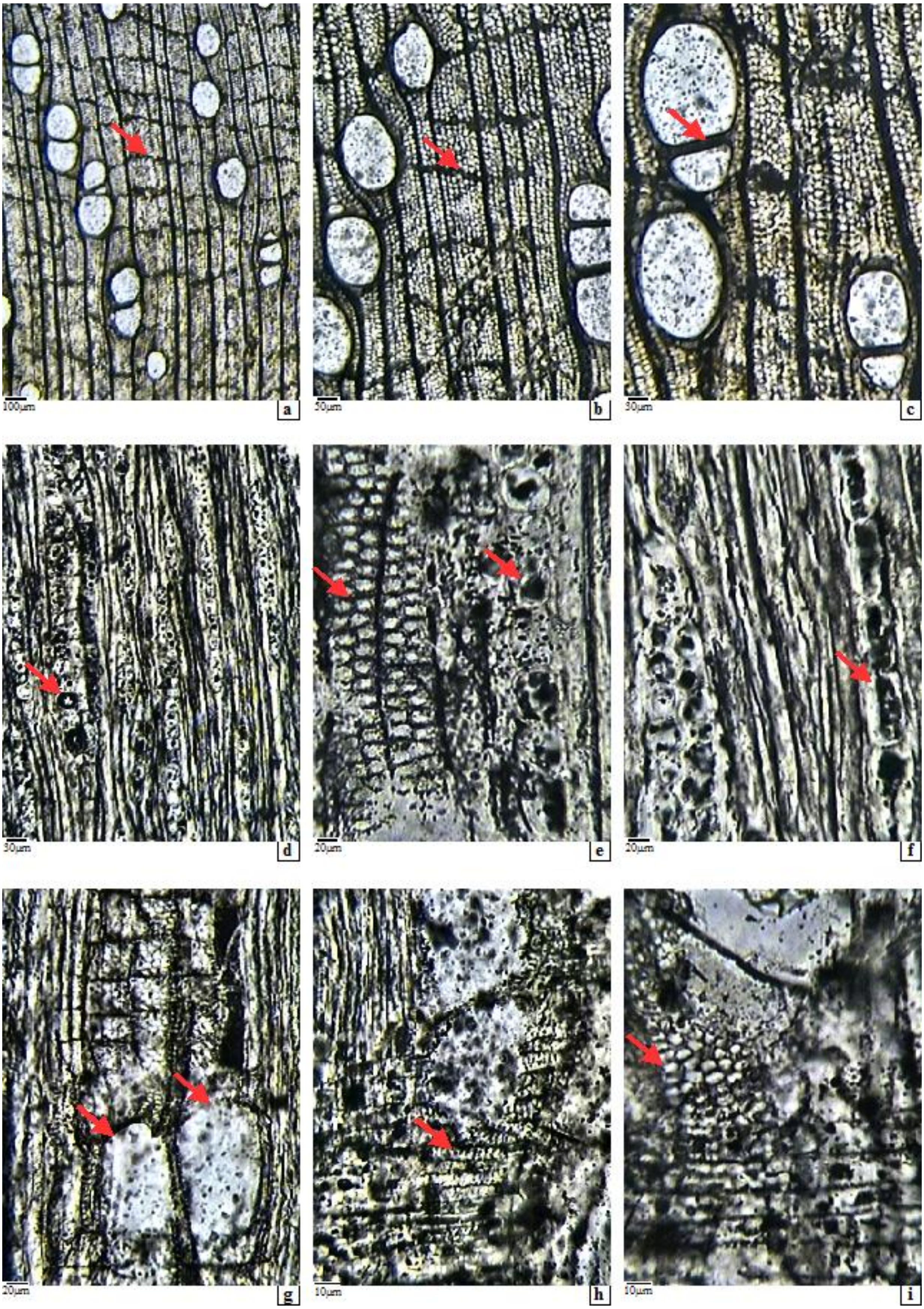


**Fig. 8** *Rhysocaryoxylon madsenii* Sakala & Gryc, 2011, sample 27617, Nanovitsa Depression, Bulgaria. **a - c** Cross section – Indistict ring boundary, thick-walled vessels, both solitary and appearing in small radial groups, ground tissue with typical reticulate structure. **d - f** Tangential section – Alternate intervessel pitting, 1-3-seriate rays, long vertical chain of crystalliferous parenchyma. **g - i** Radial section – Simple perforation plates, cross-fields with pits, alternate pitting on vessel.

*cathayensis*, *J. mandschurica*, and *J. cinerea*, have thin vascular walls and apotracheal, short banded and non-crystalliferous parenchyma; in some ways this structure resembles that of *Pterocarya*;

- The English Walnut (=*Dioscaryon* section) or Persian Walnut = *J. regia,* has rather thick vascular walls, slightly more than 3 µm, no crystalliferous parenchyma, and the apotracheal parenchyma appear most often short-banded.
- The Black Temperate Walnuts (= *Rhysocaryon* section, pro parte) – including the species *J. hirsuta, J. major, J. microcarpa, J. mollis, J. nigra, J. pyriformis, J. californica,* and *J. hindsii*, have thick (>3 µm) vascular walls, and crystalliferous parenchyma made up of short chains of cells bearing solitary crystals (<5), whereas the apotracheal parenchyma appear as continuous bands.
- The Black Tropical Walnuts (= *Rhysocaryon* section, p.p.) – with the species *J. australis, J. boliviana, J. jamaicana, J. neotropica, J. olanchana, J. soratensis, J. steyermarkii,* and *J. venezuelensis*, are characterized by thick (>3 µm) vascular wall, crystalliferous parenchyma built of long chains of cells bearing solitary crystals (>5), and apotracheal parenchyma in the form of long bands.

Dupéron (1988) also made an inventory and revision of the previously described fossil form-genera and form-species, validating and emending them whenever necessary. The following genera had been invalidated by this detailed revision: *Mirbelites* Unger, *Juglandinium* Unger, *Juglandoxylon* Kraus, *Juglansoxylon* Falqui, *Jugloxylon* Stopes and Fujii, *Caryoxylon* Andreanszky, *Juglans* L., *Carya* Nutt., and *Pterocarya* Kunth (in Dupéron, 1988).

Emphasizing the fact that fossil wood of *Platycarya* had not been found as yet, we list below the valid fossil juglandaceous genera and their diagnoses, based on Dupéron (1988) and completed with the latest described genus, *Clarnoxylon* Wheeler & Manchester, 2002.

- Genus *Engelhardioxylon* (Manchester) Dupéron, 1988; designated generally as “wood of Engelhardtieae”, having scalariform and simple perforations, as well as crystalliferous axial and radial parenchyma. There is a great amount of individual variation in these features, which makes it very difficult to separate the fossil correspondents of the extant genera *Engelhardia, Alfaroa* and *Oreomunea.*
- Genus *Pterocaryoxylon* Müller-Stoll & Mädel, 1960; comprises fossil equivalents of the extant species of *Pterocarya* as well as that of some species of *Juglans* (the Asian species and one American species of the Gray Walnut), all of which have thin vascular walls, uniseriate short apotracheal parenchyma bands and no crystalliferous parenchyma.
- Genus *Eucaryoxylon* (Müller-Stoll & Mädel) Dupéron, 1988; this is the fossil representative of the extant species of *Carya*, with porous wood, vessels solitary or in short multiples, thick to very thick vascular walls, simple perforations, alternate intervascular (relatively large) pits, paratracheal and apotracheal parenchyma regularly arranged in 1-2(4)-seriate long bands; occasionally crystalliferous parenchyma with solitary crystals in barrel-like idioblasts or in short chains of 2-3 and 1-3(5)-seriate rays; usually septate pith is recorded.
- Genus *Rhysocaryoxylon* Dupéron 1988; the fossil equivalent of the extant genus *Juglans*, is characterized by a porous to semi-ring-porous wood in cross-section, with thick-walled vessels that are either solitary or appear in small multiples, with simple perforation plates and alternate intervascular, relatively large polygonal pits; the parenchyma is apotracheal, appearing as 1-2(4)-seriate, long, regular bands, the paratracheal one is less abundant; the crystalliferous parenchyma appear as chains of shorter cells, slightly larger than the ordinary ones. The rays are 1-3(5)-seriate, slightly heterogeneous; presence of septate pith is recorded. The type-species of the genus is *Rhysocaryoxylon schenkii* (Felix) Dupéron, 1988 [revised after *Juglandinium schenki* Felix, 1884 = *Caryojuglandoxylon schenkii* (Felix) Müller-Stoll & Mädel, 1960].
- Genus *Manchesteroxylon* Wheeler and Landon, 1992; a Late Eocene formal genus, described from Nebraska, USA that shows features unknown in modern Juglandaceae, combining some wood characters of the Engelhardioideae (simple and scalariform perforation plates) and of the Platycaryoideae (vascular tracheids, but no helical thickenings and crystals, and a ring-porosity with diagonal arrangement of vessels) (see Blokhina, 2007). The type species is *M. intermedium* Wheeler & Landon, 1992.
- Genus *Clarnoxylon* Wheeler & Manchester, 2002; it is a formal genus described from the Eocene Nut Beds flora, Clarno Formation, Oregon, USA, having distinct growth-ring boundaries in cross-section, semi-ring-porous to diffuse-porous wood structure, thick-walled vessels in diagonal to radial pattern, simple perforation plates and alternate intervessel pits. Axial parenchyma scanty paratracheal to vasicentric and with long narrow, 1-3 cells thick bands. The fibers are pitted. Fine heterocellular rays of 1-3 cells, with procumbent body ray-cells and 2-4 rows of square and/or upright marginal cells, with prismatic crystals inside (Wheeler & Manchester, 2002).

Evaluating all the xylotomical features observed in our material it is evident that  it represents a *Rhysocaryoxylon* species, since the observed details are perfectly consistent with the generic diagnosis, especially in the presence of crystalliferous parenchyma with chains of more than 4 idioblasts in th form of as crystal-bearing barrel-like, sometimes slightly rounded cells,.

Furthermore, we have compared the structure of our specimen with already described fossil species, such as:

- *Rhysocaryoxylon schenkii* (Felix) Dupéron 1988, the type species, initially described as *Juglandinium schenkii*, revised later as *Caryojuglandoxylon schenkii* (see above), also including *Rhysocaryoxylon* aff. *schenkii* (Felix) Dupéron 1988;
- *Rhysocaryoxylon triebelii* (Caspary) Dupéron 1988, initially described as *Juglans* then revised as *Caryojuglandoxylon triebelii* (Caspary) Müller-Stoll & Mädel, 1960, and most recently revised by Dupéron (1988);
- *Rh. fryxellii* (Prakash & Barghoorn) Dupéron 1988, initially described as *Juglans fryxellii* Prakash &

Barghoorn, 1961, revised as *Caryojuglandoxylon fryxellii* (Prakash & Barghoorn) Müller-Stoll & Mädel-Angeliewa 1983, then revised again by Dupéron (1988) as a species of *Rhysocaryoxylon;*

- *Rhysocaryoxylon caucasicum* (Gaivoronsky) Dupéron 1988, initially described as *Juglandinium caucasicum* Gaivoronsky, 1962;
- *Rh. tertiarum* (Prakash & Barghoorn) Dupéron 1988, initially described as a species of *Carya*, subsequently revised as species of *Caryojuglandoxylon*;
- *Rh. pilinyense* (Greguss) Dupéron 1988, initially described as *Pterocaryoxylon pilinyense* Greguss, 1969; and
- specimens of *Pterocaryoxylon pannonicum* Müller-Stoll & Mädel 1960 and *P. cf. pannonicum* Müller-Stoll & Mädel 1960, that were revised by Dupéron (1988) as *Rhysocaryoxylon* sp. 1 and *Rhysocaryoxylon* sp. 2, respectively.

Further relevant taxa were more recently referred directly to as different species of *Rhysocaryoxylon*:

- *Rhysocaryoxylon pravalense* Iamandei & Iamandei, 2002.
- *Rhysocaryoxylon transylvanicum* Iamandei & Iamandei, 2003.
- *Rhysocaryoxylon madsenii* Sakala & Gryc, 2011.

Almost all of these taxa were considered to represent fossil equivalents of Black Tropical Walnuts, having parenchyma with vertical chains that are longer than 5 successive crystalliferous chambers. *Rh. pilinyense* has chains of 6-8 crystalliferous chambers of chambered parenchyma, whereas *Rh. pravalense*, and *Rh. ocii* are two typical "Black Tropical Walnuts", with long crystalliferous chains. Only *Rhysocaryoxylon transylvanicum* seems to be very similar to *J. nigra*, a species of Black Temperate Walnuts type (Iamandei & Iamandei, 2003).

Taking into account that virtually all of the described features of the studied specimen are similar to those of the species described by Sakala & Gryc (2011), such as the semi-ring-porous structure, even if devoid of a distinct ring boundary; the thick-walled vessels that are either solitary or grouped in short radial multiples, and are circular to oval in cross-section, with diameters up to 230 µm in the early wood; simple perforations and alternate pitting; banded and reticulate, typically crystalliferous parenchyma, with long vertical chains of more than 5 barrel-like cells with large, solitary, crystals; fusiform, (1)2-3(5)-seriate, heterocellular rays with uniseriate endings of 1-4 marginal crystalliferous cells and thick-walled, not pitted and not septate fibers. Accordingly, based on the similarities listed, we refer our specimen to *Rhysocaryoxylon madsenii* Sakala & Gryc, 2011.

## CONCLUSIONS

The Oligocene leaf flora described in the eastern Rhodope Mts., NE Greece – Thrace (see Velitzelos et al., 2014), near the border with Turkey, is dominated by *Eotrigonobalanus furcinervis* (Rossmässler) Walther and Kvaček, associated with Pinaceae, Cupressaceae [*Tetraclinis salicornioides* (Unger) Kvaček], Lauraceae, Betulaceae (*Alnus* sp.) and palms (*Sabal, Phoenicites*) (see Bozukov and Tsenov, 2012). In the same deposits, trunks of *Lithocarpoxylon helladae* Petrescu (a taxon that should be formally revised as *Quercoxylon helladae* (Petrescu) Selmeier, 1997), associated with *Q. intermedium* Petrescu & Velitzelos 1981, were also described, both of these potentially representing trunks of *Eotrigonobalanus furcinervis* (see Bozukov & Tsenov, 2012). Within the Bulgarian Rhodopes, a similar leaf flora was also described (Palamarev et al., 1998), and its presence is consistent with our previous identification of fossil wood remains of an evergreen oak tree, *Quercoxylon intermedium* Petrescu & Velitzelos, from the Petrified Forest (Vkamenenata Gora) in the Nanovitsa Depression, within the eastern Rhodopes Mts., Bulgaria.

The geological setting in the Nanovitsa Depression is dominated by 31 Ma old tuffs (Georgiev & Marchev, 2005) related to a series of pyroclastic acidic rocks which buried a forest with giant trees, sometimes of more than 4 m in diameter. There, *in situ* or sub-vertical silicified stumps as well as numerous smaller dispersed petrified wood fragments are found, presenting well-preserved wood structures. The palaeoxylotomical study of a new collection of dispersed petrified wood remains from this area now allows the identification of several new wood types, including *Sequioxylon gypsaceum*, *Taxodioxylon taxodii*, *Magnolioxylon* aff. *transilvanicum*, *Quercoxylon intermedium* and *Rhysocaryoxylon madsenii*.

It is, nonetheless, clear that the Petrified Forest (Vkamenenata Gora) from Nanovitsa Depression, declared a protected site, still requires systematic research efforts aimed at the identification of its complex taxonomic composition. This is especially important since currently only very few contributions on the Bulgarian petrified woods are available (see Hadžiev & Mädel, 1962).

For the moment, the few taxa identified in this area are not enough to support precise conclusions on the local Oligocene paleoenvironment. Nonetheless, a few preliminary conclusions can be drawn: the presence of fossil equivalents of *Sequoia*, *Magnolia*, *Carya* and evergreen oak suggests a warm climate, most probably of paratropical type. This is in good agreement with other paleobotanical lists of the same age, or with the paleogeographic interpretations that show the probable geographic position of this region close to the tropic, within a Mediterranean climatic belt.

## ACKNOWLEDGEMENTS

We express many thanks especially to Dr. Dimitra Mantzouka and to another anonymous reviewer, as well as to the Journal editors, for their valuable suggestions which helped us to improve the manuscript.

## REFERENCES

Afonin, M.A., 2013. Fossil Wood *Sequoioxylon dimyense* sp. nov. (Cupressaceae) from the Upper Cretaceous of Zeya–Bureya Basin, Russian Far East. Paleontological Journal, 47(6): 631–640. (Original Russian Text: M.A. Afonin, 2013, in Paleontologicheskii Zhurnal, 2013, 6: 73–82.

Akkemik, U., Köse, N. & Poole, I., 2005. Sequoioideae (Cupressaceae) woods from the upper Oligocene of European Turkey (Thrace). Phytologia Balcanica, 11(2): 119–131.

Andrews, H.N., 1936. A new *Sequoioxylon* from Florissant, Colorado. Ann. Missouri Bot. Gard., 23: 439–447.

Andrews, H.N., 1955. Index of generic names of fossil plants, 1820–1950. Geological Survey Bulletin, 1013: 1–262.

Bartling, F.G., 1830. Ordines Naturales Plantarum. Dieterich, Göttingen.

BAS-2016. Geological map of Bulgaria, available online on the website of the BAS - Bulgarian Academy of Sciences, Geological Institute "Strashimir Dimitrov", http://www.geology.bas.bg

Basinger, J.F., 1981. The vegetative body of *Metasequoia milleri* from the Middle Eocene of southern British Columbia. Canadian Journal of Botany, 59(12): 2379–2410.

Blokhina, N.I., 1986. *Sequoia* Wood from the Late Oligocene of Siziman Bay, Khabarovsk Krai. Paleontologicheskii Zhurnal, 3: 131–135.

Blokhina, N.I., 2007. Fossil wood of the Juglandaceae: Some questions of taxonomy, evolution, and phylogeny in the family based on wood anatomy. *Paleontological Journal*, 41(1): 1040–1053.

Blokhina, N.I., 1997. Fossil Wood of *Sequoioxylon chemrylicum* sp. nov. (Taxodiaceae) from the Paleogene of Chemurnaut Bay, Kamchatka. Paleontological Journal, 31(2): 235–238.

Blokhina, N.I., 2004. Fossil Wood *Sequoioxylon sachalinicum* sp. nov. (Taxodiaceae) from the Tertiary Deposits of Western Sakhalin Island. Botanicheskii Zhurnal, 89(5): 139–147.

Blokhina, N.I. & Nassichuk, W.W., 2000. Lower Tertiary Wood of *Sequoioxylon canadense* sp. nov. (Taxodiaceae) from a Kimberlite Pipe (Northern Canada). Botanicheskii Zhurnal, 85(4): 122–132.

Blokhina, N.I., Afonin, M.A. & Kodrul, T.M., 2010. Fossil wood of *Sequoioxylon burejense* sp. nov. (Taxodiaceae) from the Upper Cretaceous of the Zeya-Bureya Basin (Russian Far East). Paleontological Journal, 44(10): 1231–1239.

Boyanov, I. &. Goranov, A., 2001. Late Alpine (Paleogene) superimposed Depressions in parts of Southeast Bulgaria. Geologica Balcanica, 31(3-4): 3–36.

Bozukov, V.S. & Tsenov, B.V., 2012. Catalogue of the Cenozoic plants of Bulgaria (Eocene to Pliocene). Addendum and Corrigendum. Phytologia Balcanica, 18 (3): 237 –261.

Brown, R.W., 1962. Paleocene Flora of the Rocky Mountains and Great Plains. Geol. Survey Professional Paper, 375: 1–119.

Conwentz, H., 1885. Árboles fósiles del Río Negro. Boletín de la Academia Nacional de Ciencias (Córdoba) 7: 435–456.

Dolezych, M., 2011. Taxodiaceous woods in Lusatia (Central Europe), including curiosities in their nomenclature and taxonomy, with focus on *Taxodioxylon*. Jpn. J. Histor. Bot., 19(1-2): 26–46.

Dolezych, M. & Estrada, S., 2012. A fossil wood of *Taxodioxylon vanderburghii* Dolezych in Palaeogene sediments of Ellesmere Island (Nunavut, Canada). Zeitschrift der Deutschen Gesellschaft fur Geowissenschaften, 163(3): 283–292.

Dolezych, M., Van der Burgh, J., 2004. Xylotomische Untersuchungen an inkohlten Hölzern aus dem Braunkohlentagebau Berzdorf (Oberlausitz/Deutschland). Feddes Repertorium, 115(5-6): 397–437.

Dumortier, B.C.J., 1829. Analyse des Familles de Plantes 11, 12.

Dupéron, J., 1988. Les bois fossiles de Juglandaceae: inventaire et revision. Review of Palaeobotany and Palynology, 53: 251–282.

Fairon-Demaret, M., Steurbaut, E., Damblon, F., Dupuis, C., Smith, T. & Gerrienne, P., 2003. The in situ *Glyptostroboxylon* forest of Hoegaarden (Belgium) at the Initial Eocene Thermal Maximum (55 Ma). Review of Palaeobotany and Palynology, 126(1-2): 103–129

Farjon, A., 2005. A monograph of Cupressaceae and *Sciadopitys*. Royal Botanic Gardens Kew, 643 pp.

Felix, J., 1884: Die Holzopale Ungarns in palaeophytologischer Hinsicht. Mitteilungen aus dem Jahrbuch der königlichen ungarischen geologischen Anstalt 7:1-44.

Gadek, P.A., Alpers, D.L., Heslewood, M.M. & Quinn, C.J., 2000. Relationships within Cupressaceae *sensu lato*: a combined morphological and molecular approach. American Journal of Botany, 87(7): 1044–1057.

Gaivoronsky, V.G., 1962. A wood of walnut from the Middle Oligocene of the Western Caucasus. Palaeontological Journal, 2: 170–173 [in Russian].

Georgiev, S. & Marchev, P., 2005. Oligocene pyroclastic rocks and a petrified forest in the Nanovitsa Depression. Bulgarian Academy of Sciences, Geochemistry, Mineralogy and Petrology, 42: 47–65.

Gothan, W., 1905. Zur anatomie lebender und fossile Gymnospermen Hölzer. Abhandlungen der Preussischen Geologischen Landesanstalt, 44: 1–108

Gothan, W., 1906. Die fossilen Coniferenhölzer von Senftenberg. Abhandlungen der Preussischen Geologischen Landesanstalt, 46: 155–171.

Gottwald, H., 1997. Alttertertiäre Kieselholzer au Miozänen Schottern der ostbayerischen Molasse bei Ortenburg. Documenta naturae, 109: 1–83.

Greguss, P., 1955. Identification of living Gymnosperms on the basis of xylotomy. Akádemiai Kiádo, 263 pp.

Greguss, P., 1959. Holzanatomie der europäischen Laubholzer and Sträucher. - Akádemiai Kiádo, 330 pp.

Greguss, P., 1967. Fossil Gymnosperm woods in Hungary, from the Permian to the Pliocen. Akademiai Kiado, 152 Pp.

Greguss, P., 1969. Tertiary Angiosperm woods in Hungary. Akádemiai Kiádo, 152 pp.

Gros, J.P., 1988. La dénomination des bois fossiles identifiés a des chênes. Bulletin mensuel de la Société linnéenne de Lyon, 57: 250–260.

Hadžiev, P. & Mädel, E., 1962. Zwei neue Eichenhölzer, aus dem Pliozän Bulgariens. Paläontologische Abhandlung, I(2): 107–122.

Harkovska, A., 1992. Petrified forest in Momchilgrad region. Nauka i Znanie, 2(3): 46–48 [in Bulgarian].

Hartig, T., 1848. Beitrage zur Geschichte der Pflanzen und zur Kenntnis der norddeutschen Braunkohlen Flora. Botanische Zeitung 7: 122–128; 8: 137–141; 9: 166–172; 10: 185–190.

Hofmann, E., 1952. Pflanzenreste aus dem Phosphoritvorkommen, von Prambachkirchen Im Oberöstereich, II Teil. Palaeontographica Abt. B, Paläophytol., 92(3-6): 122–138.

Huard, J., 1967. Étude d'un bois de chêne provenant des couches a lignite d'Arjuzans (Landes). Bulletin du Muséum National d'Histoire Naturelle, sr. 2, 38(6): 969–978.

Iamandei, S. & Iamandei E., 1997. New Fossil Dicots in Pyrhoclastics of Prăvăleni, Metalliferous Mountains. Acta Palaeontologica Romaniae, 1: 113–118.

Iamandei, S., 2002. Fossil woods from the Neogene of Zarand Basin (Transylvania). PhD Thesis, University of Bucharest, Library of Faculty of Geology and Geophysics, 294 pp., unpubl. [in Romanian].

Iamandei, S. & Iamandei, E., 2000. Fossil Conifer Wood from Prăvăleni - Ociu, Metalliferous Mountains. Acta Paleontologica Romaniae, 2(1999): 201–212.

Iamandei, S. & Iamandei, E., 2002. New Juglandaceous Fossil Wood in the Miocene Lignoflora of Prăvăleni – Ociu (South Apuseni). Acta Paleontologica Romaniae, III: 185–198.

Iamandei, S. & Iamandei, E., 2003. A New Juglandaceous fossil wood From the Badenian of Prăvăleni-Ociu (South Apuseni). Studii și cercetări, geologie, Academia Română,, 48: 91–98.

Iamandei, S., Iamandei, E. & Ionesi, V., 2008 a. New petrified woods within Sarmatian Şomuz Formation, NE Romania. Acta Paleontologica Romaniae, VI: 137–144.

Iamandei S., Iamandei E., Obada T., Lungu A., Postolachi, V., 2008 b. New Sarmatian petrified woods from Moldova Republic. Acta Paleontologica Romaniae, VI, 123–136.

Iamandei, S., Iamandei, E., Frunzescu, D. & Brănoiu, G., 2012. New petrified woods from the Curvature Carpathians. Romanian Journal of Earth Sciences-RJES, 86 (2): 67–89.

Iamandei, S., Iamandei E. & Sabou-Dumitrescu M., 2013. New petrified woods from Căprioara Valley, Feleacu Hill, Cluj, Romania Romanian Journal of Earth Sciences - RJES, 8(1): 1–27.

Iamandei, S., Iamandei E., Bozukov, V. & Tsenov, B., 2014. Oligocene fossil wood from Rhodopes, Bulgaria. Acta Palaeontologica Romaniae, 9(2): 15–25.

Iamandei, S., Iamandei, E. & Ţibuleac, P., 2004. New fossil wood from Late Badenian of Prăvăleni, Metalliferous Mts. An. St. Univ. «A.I.Cuza», Iași, Geologie, 49-50: 235–247.

IAWA Committee. 1989. IAWA list of microscopic features for hardwood identification. Wheeler, E. A., Baas, P. & Gasson, P.E. (Eds.). IAWA Bulletin Leiden, The Netherlands.10 (3): 219–332.

IAWA Committee. 2004. IAWA List of microscopic feature for softwood identification. Richter, H. G., Grosser, D., Heinz, I. & Gasson, P. E. (eds.). IAWA Journal 25: 1‑70.

ING Database, 1996. Index Nominum Genericorum (Plantarum). Farr, E. R. & Zijlstra, G. (Eds.) (http://botany.si.edu/ing/) (accesed at 01.10.2016).

InsideWood, 2004-onwards: (http://insidewood.lib.ncsu.edu/search) (accessed 01.10.2016).

Jussieu, A. L., de, 1789. Genera plantarum: secundum ordines naturales disposita, juxta methodum in Horto regio parisiensi exaratam, anno M.DCC.LXXIV: 80–82.

Koutecky, V. & Sakala, J., 2015. New fossil woods from the Paleogene of Doupovske hory and Česke středohoři Mts. (Bohemian Massif, Czech Republic). Acta Musei Naturalis, Pragae, Series B Historia Naturalis, 71(3-4): 377–398.

Kukachka, F., 1960. Identification of coniferous woods. Tappi Journal 43(11): 887–896.

Kräusel, R., 1949. Die fossilen koniferen-Hölzer (unter ausschluss von Araucarioxylon Krauss). II Teil. Kritische Untersuchungen zur diagnostic Lebender und Fossilen Koniferen-Hölzer. Palaeontographica Abt. B, 89(4-6): 83–203.

Manning, W.E., 1978. The classification within the Juglandaceae. Annals of the Missouri Botanical Garden, 65:1058–1087.

Mantzouka, D., Karakitsios, V., Sakala, J. & Wheeler, E.A., 2016. Using idioblasts to group *Laurinoxylon* species: case study from the Oligo-Miocene of Europe. IAWA Journal 37(3): 459–488.

Mao, K., Milne, R.I., Zhang, L., Peng, Y., Liu, J., Thomas, P., Mill, R.R. & Renner, S.S., 2012. Distribution of living Cupressaceae reflects the breakup of Pangea. Proceedings of the National Academy of Sciences of the United States of America, 109: 7793–7798.

Metcalfe, C.R. & Chalk, L., 1950. Anatomy of the Dicotyledons, vol. II. Claredon Press, Oxford, 1500 pp.

Müller-Stoll, W.R, & Mädel, E., 1960. Juglandaceen-Hölzer aus dem Tertiär des pannonischen Beckens. Senckenbergiana Lethaea, 50(2-3): 103–115.

Müller-Stoll, W.R, & Mädel-Angeliewa, E., 1983. Fosile Hölzer mit schmäler apotrachealen Parenchymbändern. I. Arten aus der Gattung *Eucaryoxylon* Müller-Stoll & Mädel. Feddes Repertorium, 94(9-10): 655–667.

Nagy, F. & Mârza, I., 1967. *Magnolioxylon transilvanicum* sp. n. in cineritele de la Prãvãleni, Brad. Analele Universităţii din Bucureşti, sr. St. Nat., geol.-geogr., XVI, 1: 97–102.

Palamarev, E., Ivanov, D. & Kitanov, G., 1998. New data about fossil flora from Bobovdol basin and its biostratigraphic significance. Review of Bulgarian Geological Society, 59 (2):13–21.

Perleb, K.J., 1818. Versuch über die Arzneikräfte der Pflanzen, verglichen mit den äußeren Formen und der natürlichen Classeneintheilung derselben; a German translation of de Candolle's Essai sur les Propriétés médicales des Plantes comparées avec leur classification naturelle. Versuch über die Arzneikräfte der Pflanzen: 143.

Petrescu, I., 1978. Study on fossil woods from Oligocene of NW Transylvania. Mémoires (IGR), XXVII: 113–184 [in Romanian].

Petrescu, I. & Dragastan, O., 1971. Results of researches on trunk remains from Romanian Tertiary. Studii şi Cercetări de Geologie, Geofizica, Geografie, sr. Geologie, 16/1: 265–269 [in Romanian].

Petrescu, I. & Nuţu A., 1970. Alte tipuri de lemne din Miocenul superior de la Prăvăleni-Brad. Sargetia (Acta Musei Devensis), seria Stiinţele Naturii, VII: 253–258.

Petrescu, I. & Popa, V., 1971. Prezence of *Sequoioxylon gypsaceum* (Goepp) Greguss in Petroşani Basin. Studia UBB, Geologia, 2: 57–62. [in Romanian].

Petrescu, I. & Velitzelos, E., 1981. *Quercoxylon intermedium* n. sp. in the Oligocene of Thrace (Northeastern part of Greece)]. Contribuţii botanice, UBB-Cluj: 9–16. [in Romanian].

Philippe, M., 1993. Radiation précoce des conifers et bois affines du Jurassique de France. Lethaia, 27: 67–75.

Philippe, M. & Bamford, M.K, 2008. A key to morphogenera used for Mesozoic conifer-like woods. Review of Palaeobotany and Palynology, 148: 184–207.

Philippe, M., & Thévenard, F., 1996. Repartition and palaeoecology of the Mesozoic woodgenus *Xenoxylon*: palaeoclimatological implications for the Jurassic of WesternEurope. Review of Palaeobotany and Palynology, 91: 353–370.

Philippe, M., Barbacka, M., Gradinaru, E., Iamandei, E., Iamandei, S., Kázmér, M., Popa,M., Szakmány, G., Tchoumatchenco, P., Zatoń, M., 2006. Fossil wood and Mid-Eastern Europe terrestrial palaeobiogeography during the Jurassic–Early Cretaceous interval. Review of Palaeobotany and Palynology, 142: 15–32.

The Plant List., 2013. Version 1.1. Published on the Internet; http://www.theplantlist.org/ (accessed at 01.10.2016).

Prakash, U. & Barghoorn, E.S., 1961. Miocene fossil woods from the Columbia basalts of Central Washington. Journal of the Arnold Arboretum, 42: 165–203.

Privé-Gill, C., 1977. *Taxodioxylon gypsaceum* (Goeppert) Kräusel, bois fossile du Tertiaire de Limagne (France). C. R. du 102e Congrés National des Sociétés Savantes, Limoges, 1977, sciences, fasc. I: 187–196.

Quinn, C. J., 1989. Leaf and wood anatomy as data sources in the Cupressaceae s.l. American Journal of Botany, 76(Supplement): 222 pp.

Reveal, J.L., 1996. Higher Taxa Based on Family Names in Current Use. Phytologia 79: 70-72.

Roy S. K., Stewart W. N., 1971. Oligocene woods from the Cypres Hills Formation in Saskatchewan, Canada. Canadian J. of Botany, 4369: 1867–1877.

Sakala, J. & Gryc, V., 2011. A new species of *Rhysocaryoxylon* (Juglandaceae) from the Lower Eocene Fur Formation of Mors Island (northwest Jutland, Denmark). Bulletin of the Geological Society of Denmark, 59: 45–49.

Schmalhausen, J., 1879. Beiträge zur Jura-Flora Russlands. Mémoire de l'Academie de Sciences St. Pétersbourg, 27(4): 1–96.

Schönfeld, G., 1953. Mitteilungen uber Funde aus dem Bornaer Braunkohlen Revier II. Geologie, 2: 190–203.

Schönfeld, E., 1958. Eine Magnoliaceae als Treibholz im marinen Oberoligozän der Niederheineschen Bucht. Fortschritte in der Geologie von Rheinland und Westfalen, 1: 169–178.

Schulz, C. & Stützel T., 2007. Evolution of taxodiaceous Cupressaceae (Coniferopsida). Organisms, Diversity & Evolution, 7: 124–135.

Selmeier, A., 1997. Tertiäre *Lithocarpus* Hölzer aus Bad Abbach (Bayern, Süddeutschland). Mitteilungen der Bayerischen Staatssammlung für Paläontologie und historische Geologie, 37: 119–134.

Srivastava, R. & Suzuki, M, 2001. More fossil woods from the Palaeogene of Northern Kyushu, Japan. IAWA Jour. 22(1): 85–105.

Striegler, U.R. & Süss, H., 1984. Ein Mammutbaumholz aus dem Tagebau Klettwitz. Z. angew. Geol. 30: 151–153.

Süss, H. & Velitzelos, E ,1997. Fossile Hölzer der Familie Taxodiaceae aus tertiären Schichten des Versteinerten Waldes von Lesbos, Griechenland, Feddes Repertorium, 108: 1–30.

Teodoridis, V. & Sakala, J., 2008: Early Miocene conifer macrofossils from the Most Basin (Czech Republic). Neues Jahrbuch für Geologie und Paläontologie – Abhandlungen, 250: 287–312.

Tiemei, Y., Chengsen, L. & Syabryaj, S., 2013. Pliocene taxodiaceous fossil wood from southwestern Ukraine and its palaeoenvironmental implications. Journal of Palaeogeography, 2(4): 362–368.

Torrey, R., 1923. The comparative anatomy and phyllogeny of the Coniferales, part 3: Mesozoic and Tertiary coniferous woods. Boston Society of Natural History, 6: 39–106.

Van Amerom, H.W.J., (ed.), 2002. Fossilium Catalogus. II. Plantae. Pars 104. Gymnospermae (5) (Ginkgophyta et Coniferae). 1. Suplement *Sequoia* – *Ulangangia*. By S.J. Dijkstra, H.W.J. van Amerom & J. Shultze Motel. Backhuys Publishers, Leiden.

Van der Burgh, J., 1973. Hölzer der niederrheinischen Braunkohlenformation, 2. Hölzer der Braunkohlengruben "Maria Theresia" zu Herzogenrath "zukunft west"zu Eschweiler und "Victor (Zülpich Mitte), zu Zülpich. Nebst einer systematisch-anatomischen Bearbeitung der gattung *Pinus* L. Review of Palaeobotany and Palynology, 15(2-3): 73–275.

Van der Burgh, J. & Meijer, J.J.F., 1996. *Taxodioxylon gypsaceum* and its botanical affinities. Curent Science, 70(5): 373–378.

Velitzelos, D., Bouchal, J.M. & Denk, T., 2014. Review of the Cenozoic floras and vegetation of Greece. Review of Palaeobotany and Palynology, 204: 56–117.

Watson, L. & Dallwitz, M.J., 1992 - onwards. The families of flowering plants: descriptions, illustrations, identification, and information retrieval. http://delta-intkey.com/angio/ [accessed at 1st April 2016]

Wheeler, E.A., 2011. InsideWood - a web resource for hardwood anatomy. IAWA Journal, 32 (2): 199–211.

Wheeler, E. A. & Landon, J., 1992. Late Eocene (Chadronian) Dicotyledonous Woods from Nebraska: Evolutionary and Ecological Significance. Review of Palaeobotany and Palynology, 74 (3/4): 267–282.

Wheeler, E.A., 1986. Vessels per square millimetre or vessel groups per square millimetre? IAWA Bulletin 7: 73–74.

Wheeler, E.A. & Manchester, S.R., 2002. Woods of the Eocene Nut Beds flora, Clarno Formation, Oregon, USA. International Association of Wood Anatomists Journal, Supplement 3. 188 pp.

Wheeler, E. A., Scott, R. A., Barghoorn, E. S., 1977. Fossil dicotyledonous woods from Yellowstone national park. Journal of the Arnold Arboretum, 58: 280–306.