

## NEW TREES IDENTIFIED IN THE PETRIFIED FOREST OF MIDDLE MIOCENE FROM ZARAND, APUSENI MOUNTAINS, ROMANIA.

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**Abstract** The systematic study of the Mid-Miocene Petrified Forest of Zarand, Apuseni Mountains, Romania led till now to the identification of over 40 arboreal taxa, allowing a complex phytoecological, palaeoenvironmental and palaeoclimatic analysis during Late Badenian in Tălagiu island, of Paratethys realm, where the Zarand Basin evolved. The geological evolution of the Tălagiu caldera allowed best conditions to bury and preserve by silicification of the remains of the Mid-Miocene forest, which lived on the slopes of the volcano. From there, in the last years, species of the following genera were described: *Tetraclinoxylon*, *Thujoxylon*, *Chamaecyparixylon*, *Cupressinoxylon*, *Taxodioxylon*, *Sequoioxylon*, *Pinuxylon*, *Magnolioxylon*, *Cinnamomoxylon*, *Spiroplatanoxylon*, *Liquidambaroxylon*, *Eucaryoxylon*, *Rhysocaryoxylon*, *Pterocaryoxylon*, *Fagoxylon*, *Quercoxylon*, *Alnoxylon*, *Populoxylon*, *Salicoxylon*, *Nyssonoxylon*, *Paraphyllanthoxylon*, *Piranheoxylon*, *Aceroxylon*, *Fraxinoxylon* and *Rhizopalmoxyton*, taking into account all the palaeoxylotomical identifications. That forest was a Mixed Mesophytic Forest with Lauraceae and Conifers altitudinally storeyed, and with remains of pre-Miocene sempervirent elements of paratropical or subtropical climate. Thus, the evaluated climatic parameters suggest a humid subtropical palaeoclimate toward warm-temperate of Mediterranean type (Cfa to Csa in Köppen classification) according to the island mountainous relief, where the altitudes probably did not exceeded 1200 m

**Keywords:** Tălagiu island, Badenian petrified wood, Mixed Mesophytic Forest, phytoecological analysis, palaeoclimate.

### INTRODUCTION

The Petrified Forest of the Middle Miocene in Zarand was outlined and partially described in the Zarand basin, the Apuseni Mountains, the fossilization of which was related to the late Badenian volcanic activity, developed in Tălagiu Caldera (Fig. 1A, B), a complex island volcano which buried with its pyroclastites the tree vegetation that lived on its slopes.

The blanket of Neogene deposits of the intramontaneous depressions of Western Apuseni were deposited after the Middle Miocene transgression of the Pannonian Sea in the gulfs from inside the mountains, drowning a paleorelief formed in an active erosion stage - tending even to a peneplainization of this region formed by crystalline formations known in the surrounding mountainous areas (Highiş, Biharia, Codru Moma), from sedimentary and volcano-sedimentary rocks belonging to the Palaeozoic and to the Mesozoic as the ophiolites and the Jurassic-Neocomian limestones of Căpâlnaş-Techereu Unit, and also as Late Cretaceous (+ Paleogene?) sedimentary rocks with the banatites of the Drocea-Criş and Bucium Units, formations which appear as tectonic nappes in the neighboring mountains. Sporadically they appear from beneath the Neogene rock blanket. The Paleogene geologic evolution and the emergence of important parts of the Carpathian area were manifested in the Apuseni Mountains after the Palaeocene (probably post-Cuisian), with variable intensities. Most probably during Egerian (Late Oligocene) were intensified the movements that led to the emergence, at least for some areas of Apuseni Mountains (see Ianovici et al., 1976).

Otherwise Paucă (1954, 1976) supposed even that post-Oligocene and until Early Badenian inclusively, the intra-

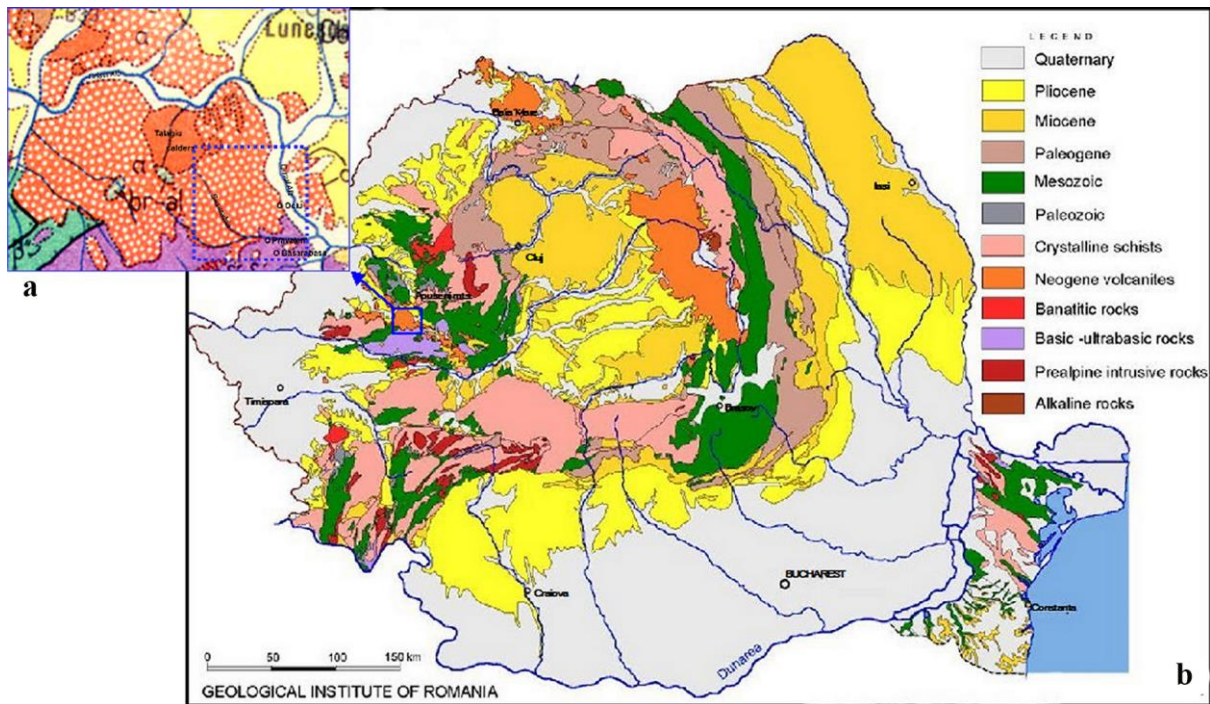
and extra-Carpathian territories were emerged, and the terrigenous formations attributed to the Early Miocene (Aquitanean and Burdigalian) corresponding in fact to the Badenian transgression. The erosion in Metaliferous Mountains (Southern Apuseni) during ca. 50 Ma of emergence led to the apparition of the hydrographic system of White Palaeocriş, corresponding to Crişul Alb river of today.

Even if fossil proves for this interval doesn't exist it is supposed that the zonal vegetation covering that emerged area was probably similar to those identified in other Badenian deposits from Romania (Țicleanu, 1986; Givulescu, 1997). The simple listing of the Prebadenian Tertiary Floras may suggests a slight trend of the palaeoclimatic evolution - by the decreasing number of the palaeotropical elements and the increasing the arcto-tertiary ones. This indicates a variation to a gradual cooling to the end of the Paleogene, a situation expressed by the MAT diagram (Mean Annual Temperatures) deduced by Givulescu (1997), both by floristic analysis and by the analysis of the morphological parameters of the leaf impressions identified in various Paleogene plant deposits in Transylvania (Givulescu, 1997).

The hydrographic basin of the White Paleocriş had a quasi-identical trajectory with the today river (Crişul Alb) and the triggering of a quasi-linear tectonic on WNW-ESE direction favored the apparition of some local crashes under the sea level and the invasion of Pannonian Sea water simultaneously with the initiation of a very active and explosive volcanic activity.

These deposits included a lot of vegetal material, even determining coal levels, sometimes quantitatively importante, even exploitable at Țebea (see Givulescu, 1997), but usually as centimetric to decimetric size as in

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**Fig. 1** a Geological sketch of Romania, with location of Tălagiu caldera in the Apuseni Mountains (Geological Institute editor); b Detail of Tălagiu caldera with the studied area, in rectangle (Excerpt from Geological Map of Romania, Scale 1:200,000 - Sheet 17-Brad, Geological Institute editor).

Basarabița valley, Măgura-Prăvăleni Valley and in many other points also (see Istocescu, 1971; Berbeleac et al., 1984).

This fact determined the deposition of a couverture having a dominant volcano-sedimentary character, attributed by palaeontological basis to Badenian, Sarmatian and Pannonian, probably partially including the Pontian (Cioflică & Popescu, 1966; Istocescu, 1971). The explosive volcanic activity, in Zarand area, was triggered at the Middle Badenian (Berbeleac et al., 1984; Roșu et al., 1997), but the presence of the volcanic rocks in the deposits from the basis of the stratigraphic succession shows that it was produced simultaneous with the birth of a new basin of sedimentation, i.e. during Early Badenian, and had a strongly explosive character, producing huge quantities of tephra (pyroclastics) rising a strato-volcanic structure. Tălagiu volcano was a typical lahar volcano. Unconsolidated deposits of tephra moved as lahar destroying, transporting and burying the vegetal remains on the volcano slopes until the neighbor aquatic basin, creating an excellent preservation environment by silicification of the vegetal remains, the volcanic ash being a perfect provider of easy levigable silica (Fig. 1 A, B).

The volcanism seems to have developed in an island area, probably in few more eruption centers, some of them unknown as localisation, but the most important were the calderas Tălagiu - Bratosin and Gura Văii - Iosășel (Berbeleac et al., 1984).

Here the volcanic activity intensely continued during all the Badenian and maybe during Early Sarmatian too (Istocescu, 1971; Berbeleac et al., 1984). Analysing the litho- and biostratigraphic data of the cited authors, and the absolute age of  $12.4 \pm 0.7 - 13.4 \pm 1.2$  Ma, given by the eruptive products of Zarand area (Roșu et al., 1997), correlated with the chrono-bio-magneto-stratigraphic scale

of the regional units of the Neogene of Paratethys compiled by Marinescu (1994), Marinescu et al. (1998) and Andreyeva-Grigorovich (2001), it is clear that the absolute ages are placed into Kossovian, representing the interval 11.8-13.6 Ma.

The volcano-sedimentary levels intercalated within the post-Badenian formations represent post-eruptive epiclastic deposits, generated by active erosion and remobilization of the unconsolidated pyroclastics of the Badenian strato-volcano or/and the products of the final volcanic stage in Zarand (Fig. 2), deposited in more distal areas of source, have a tuffaceous character which preserve a fresh water fauna and a microfauna, and also a microflora, based on which was established their relative age (Nicorici, 1963; Antonescu, 1964; Cioflică & Popescu, 1966; Nicorici & Sagatovici, 1970, 1973; Istocescu, 1971). Anyway the sedimentation processes continued up to the Pontian, and led to the entire filling of the basin. Due to the rise of the entire edifice of the Apuseni Mountains during the Pliocene, the sedimentation ceases. In the west of the basin (to the west of Gurahonț), the Quaternary terrigenous deposits (Pleistocene-Holocene) definitively end the sedimentation in this basin.

The volcanic and volcano-sedimentary deposits from the proximal areas of eruption centers have a dominant pyroclastic character, and were considered non-fossiliferous. Their Badenian-Sarmatian age was attributed by stratigraphic correlation with those documented in the rest of the sedimentation basin (Berbeleac et al., 1984). However the abundance of fossil vegetal remains was known, and mentioned in many published papers (see Istocescu, 1971; Nagy & Mărza, 1967; Petrescu & Nuțu, 1969-1972; Roșu et al., 1997). The palaeogeographic reconstructions of Paratethys area corresponding to the Badenian (see Fig. 19, in Rögl, 2001), outlines the islands in

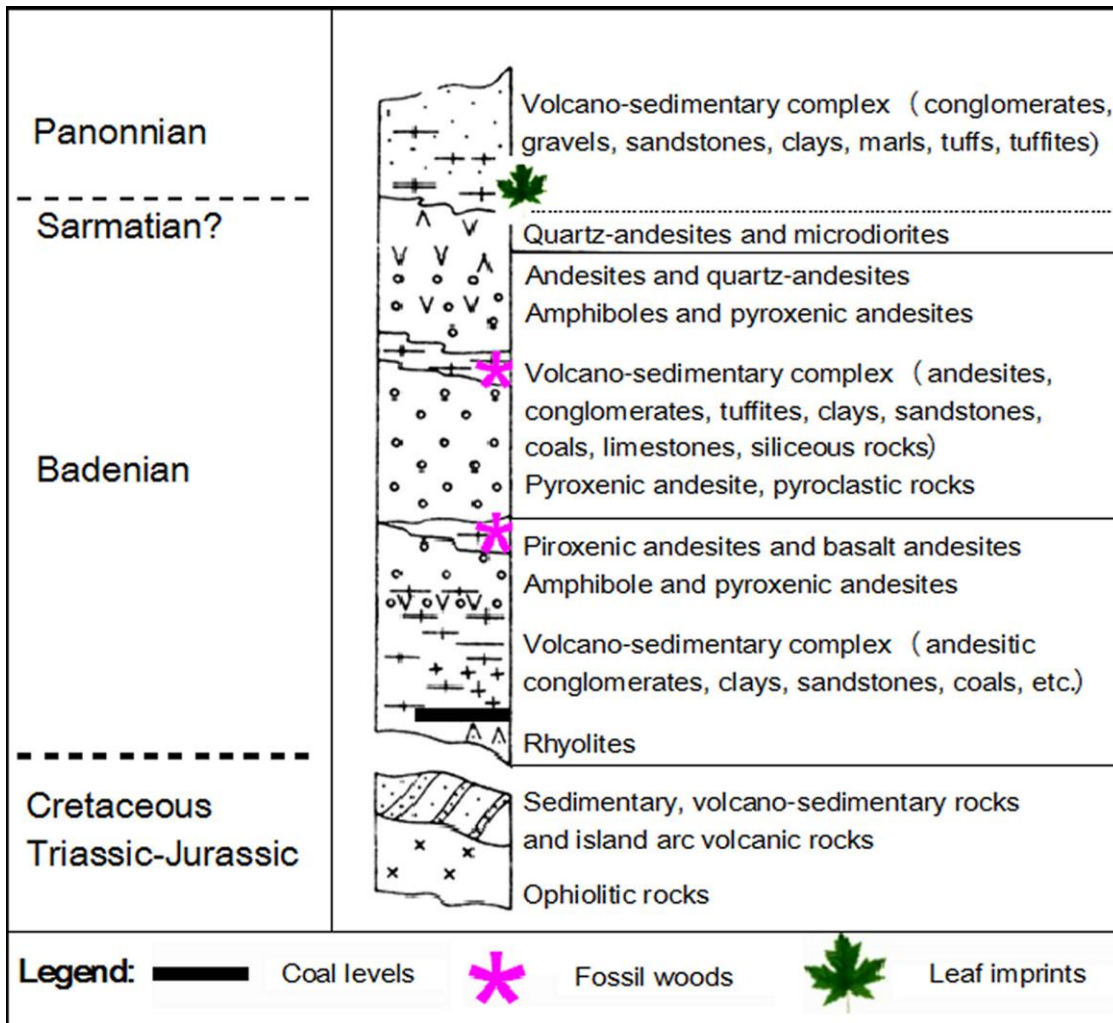


Fig. 2 Stratigraphical position of the plant remains in Zarand Mountains (from Berbeleac et al., 1984, modified).

which there was a mesophytic palaeovegetation of climax that evolved in a warm and humid climate, ensured by the vicinity of the sea, ideal conditions for the development of arboreal vegetation.

Otherwise, it is possible to follow the evolution of the Neogene vegetation during the pre-Badenian, but post-Badenian also, in the Transylvanian area, evidenced by the palaeobotanic researches synthesized by Givulescu (1997), in which we integrate the results of our research. Just the simple enunciation of the identified genera in pre-Miocene, Miocene and Pliocene deposits by studying the fossil vegetal macro-remains suggests a progressive increase in the weight of the arcto-tertiary elements, with the obvious decrease of the palaeotropical ones, as a result of the gradual decrease tendency of MAT trend from the subtropical climate(?) to the warm-temperate wet and then to the temperate-continental climate (Givulescu, 1997), similar to the present one, in the context of the obvious paleogeographical changes, through the "disappearance" of Paratethys.

Anyway, the plant association outlined by our palaeoecological studies in Prăvăleni-Ociu area indicates that during the Late Badenian in the Zarand basin the mean annual temperatures (MAT) were between 12-17 degrees Celsius. Taking into account the island palaeogeographic distribution of the Carpathian land within the Mid-

Miocene Paratethys, we can imagine that the relatively uniform palaeoclimate was marked by low mean annual rainfalls (MAR), and by a precipitation regime (MAP) of only 1100-1500 mm per year, and these parameters suggest a wet subtropical climate of Cfa type, toward an warm-temperate mediterranean climate of Csa type, after Köppen-Geiger classification (Köppen, 1900; Geiger, 1954) and in accord with the environment of island mountainous relief, where the altitudes probably did not exceeded 1200 m (see Fig. 20).

The fossiliferous site from Prăvăleni-Ociu, Apuseni Mountains, with silicified (opalised) woody macro-remains is from long time known: in a paper published in the nineteen century these petrified woods from here but also from other localities from Transylvania were mentioned (Felix, 1884; Koch, A., 1885; see also Petrescu & Nuțu, 1970), but the first taxonomic identifications by microscopical study belong to Nagy (in Nagy & Mârza, 1967) and to Petrescu (Petrescu & Nuțu, 1969-1972) who have identified and described species of the next genera: *Taxodioxyton*, *Sequoioxyton*, *Magnolioxyton*, *Perseoxyton* (revised as *Cinnamomoxyton*), *Juglandoxyton* (revised as *Rhysocaryoxyton*), *Icacinoxyton* (revised as *Spiroplatanoxyton*) and *Alnoxyton*. The studied area is outlined by Basarabița Valley at west - Basarabasa Valley at South and the Crișul Alb river at East and North and

comprises the localities Basarabasa, Prăvăleni and Ociu (Fig. 2), where the Tălagiu Formation is present, having volcano-sedimentary character, dominantly pyroclastic at least at the upper part (Berbeleac et al., 1984).

Our mapping and sampling of fossil plant material comprised the Basarabasa hill, Basarabița valley, Măgura Prăvăleni hill, Cremenea hill, Cornetu-Teiuș hills, Gruiul Mărului, Marinașu valley with its tributaries, the eastern slopes of Teiuș hill to the Criș valley (or Ociu hills), the roads and the brooks in the village of Ociu, especially the Church brook and the Ocișor brook in the northern of the village) as well as the western slopes of Măgura Ociului. More to the North of Ociu, in Teiuș valley, Paragina-Pit, Tămașu hill, Tisa valley, in Dănilă, Hodu and Prislop hills, these deposits have levels of andesite lava, which give the image of a strato-volcano and are generally devoid of fossil vegetal remains.

The systematic palaeoxylotomical study of the Badenian Petrified Forest of Zarand (Fig. 3), on Tălagiu island and all the identified fossil wood until present (over 40 taxa) represent very important elements with palaeoclimatic significance. The synthetic list of all the already identified taxa by palaeoxylological studies in the area and published is the following:

1. *Tetraclinoxylon romanicum* Iamandei et Iamandei, 2000b;
2. *Thujoxyylon* sp. (in Iamandei et al., 2017);
3. *Chamaecyparixylon* cf. *polonicum* (Kräusel) Khudaiberdyev, 1958 (in Iamandei & Iamandei, 2000b);
4. *Taxodioxyylon taxodii* Gothan, 1906 (in Petrescu, 1969);
5. *Sequoioxyylon gypsaceum* (Goepp.) Greguss, 1967 (in Petrescu, 1969; in Iamandei & al., 2000b; 2004b);
6. *Pinuxylon marinasii* Iamandei et Iamandei, 2000b;
7. *Pinuxylon paryoides* (Kräusel) van der Burgh, 1964 (in Iamandei, 2000);
8. *Pinuxylon* cf. *parryoides* (Kräusel) van der Burgh, 1964 (in Iamandei, 2000);
9. *Magnolioxyylon transylvanicum* Nagy & Mârza, 1967 (and in Iamandei & Iamandei, 1997);
10. *Magnolioxyylon scandens* Schönfeld, 1958 (in Iamandei & Iamandei, 1997; Iamandei et al., 2004b);
11. *Magnolioxyylon kraeuselii* (Greguss) van der Burgh, 1973 (Iamandei et al., 2017b);
12. *Cinnamomoxyylon intermedium* (Huard) Gottwald, 1997 (in Iamandei & Iamandei, 2008);
13. *Cinnamomoxyylon aromaticum* (Felix) Gottwald, 1997 (revised from *Perseoxyylon aromaticum* Felix, 1887, see discussion in Iamandei & Iamandei, 2008);
14. *Spiroplatanoxyylon densiradiatum* (Petrescu) Süs 2007 (Iamandei et al., 2017);
15. *Spiroplatanoxyylon bohemicum* (Prakash, Březinová & Bůžek) Süs, 2007 (in Iamandei & Iamandei, 1997; Iamandei et al., 2017);
16. *Spiroplatanoxyylon* sp. (not *Icacinoxyylon* sp. - of Petrescu, 1969);
17. *Quercocoxyylon* sp. cf. *Quercus frainetto* Ten. (Iamandei et al., 2017);
18. *Pterocaryoxyylon* sp. (in Petrescu & Nuțu, 1971);
19. *Eucaryoxyylon zarandense* Iamandei et Iamandei, 2002a;
20. *Rhysocaryoxyylon pravalense* Iamandei et Iamandei, 2002a (and in Iamandei et al. 2004b);
21. *Rhysocaryoxyylon ocii* Iamandei et Iamandei, 2002a;
22. *Rhysocaryoxyylon transylvanicum* Iamandei et Iamandei, 2003;
23. *Alnoxyylon* sp. (in Petrescu & Nuțu, 1969; and in Iamandei et al. 2004b);
24. *Salicoxyylon basilicum* Iamandei et Iamandei, 2005;
25. *Populoxyylon tremuloides* Iamandei et Iamandei, 2005;
26. *Populoxyylon* sp. cf. *Populus alba* L. (in Iamandei et al., 2005);
27. *Nyssoxyylon petrescui* Iamandei et Iamandei, 2002b;
28. *Fraxinoxyylon crisi* Iamandei et Iamandei, 2008;
29. *Fraxinoxyylon prambachense* Hofmann, 1952 (in Iamandei et al., 2005);
30. *Fraxinoxyylon komlosense* (Greguss, 1969) - (in Iamandei & Iamandei, 2008; Iamandei et al., 2004b; 2005).

In this paper, we present some new material of petrified wood collected from the area, studied and identified or reattributed to correct taxon as new combinations, trying to complete the upward list of trees of the Middle Miocene Petrified Forest of Zarand, as it follows.

1. *Cupressinoxyylon* sp.;
2. *Thujoxyylon* sp.;
3. *Chamaecyparixylon* sp.;
4. *Taxodioxyylon taxodii* Gothan, 1906 (described also by Petrescu, 1969);
5. *Sequoioxyylon gypsaceum* (Goepp.) Greguss, 1967 (also in Petrescu, 1969; and in Iamandei & Iamandei, 2000b; Iamandei et al., 2004b);
6. *Sequoioxyylon multiseriatum* Ramanujam et Stewart, 1969 comb. nov.;
7. *Liquidambaroxyylon speciosum* Felix, 1884;
8. *Fagoxyylon subcaucasicum* Privé, 1969;
9. *Fagoxyylon cristallopforum* van der Burgh, 1973;
10. *Quercocoxyylon sarmaticum* Starostin et Trelea, 1969;
11. *Paraphyllanthoxyylon botarii* sp. nov.;
12. *Piranheoxyylon perfectum* sp. nov.;
13. *Aceroxyylon zarandense* sp. nov.;
14. *Aceroxyylon pravalense* sp. nov.;
15. *Aceroxyylon palaeosaccharinum* (Greguss, 1943) emend.;
16. *Rhizopalmoxyylon* sp.cf. *sabaloides*.

## SYSTEMATICS

### Gymnosperms

#### Order **Cupressales** Link

Family **Cupressaceae** Rich. (ex Bartling), 1830

Subfamily **Cupressoideae** Rich. ex Sweet, 1826

Genus **Cupressinoxyylon** Goeppert, 1850



**Fig. 3** Samples of fossil wood from Mid-Miocene Petrified Forest of Zarand hosted in the National Geological Museum from Bucharest (photo, Iamandei, 2002).

*Cupressinoxylon* sp.  
Fig. 4, photos a-i.

#### Material

The three studied samples of petrified wood were collected from Prăvăleni area (on Hoarna Tarnița brook), from Ociu area (on Marinașu valley and on Church Brook, respectively), found in Mid-Miocene volcano-sedimentary deposits (Late Badenian-Early Sarmatian), ash-brown or whitish color and centimetric size. They represent silicified pieces of wood and display a regular fibrous texture and annual rings, suggesting a conifer. The fragments remained after the oriented slides were cut, are kept now in the Geological Institute of Romania (GIR) Collection hosted in the National Geological Museum, in Bucharest, under the inventory number: 26,388; 26,392 and 26,474 (i.e.: 114; 107b and 288 as field numbers).

#### Microscopic description

**The growth rings** are distinct, variably sized, with often crushed early wood, where the cells were big lumened gradually passing to the late wood which is formed from 12-20 thick walled cells. Normal axial resin ducts absent.

**The tracheids** in cross section are polygonal rounded, sometimes deformed, but usually have rounded lumina with radial / tangential diameters of (17)25-45(50) / 20-30  $\mu\text{m}$ , smaller in the late wood: 7.5-11 / 7.5  $\mu\text{m}$  and the walls have 4-7  $\mu\text{m}$  double wall, thicker in the late wood. Between two successive rays there are 1-7 regular radial rows of tracheids, some intermingled rows being formed from smaller ones. Their frequency is of (900)1380-2050 tracheids on  $\text{mm}^2$ . Pitting on the tangential tracheidal walls is missing. The radial pitting is in one single vertical row arranged, sometimes as opposite pairs, are spaced or contiguous and seem to be molded by the tangential

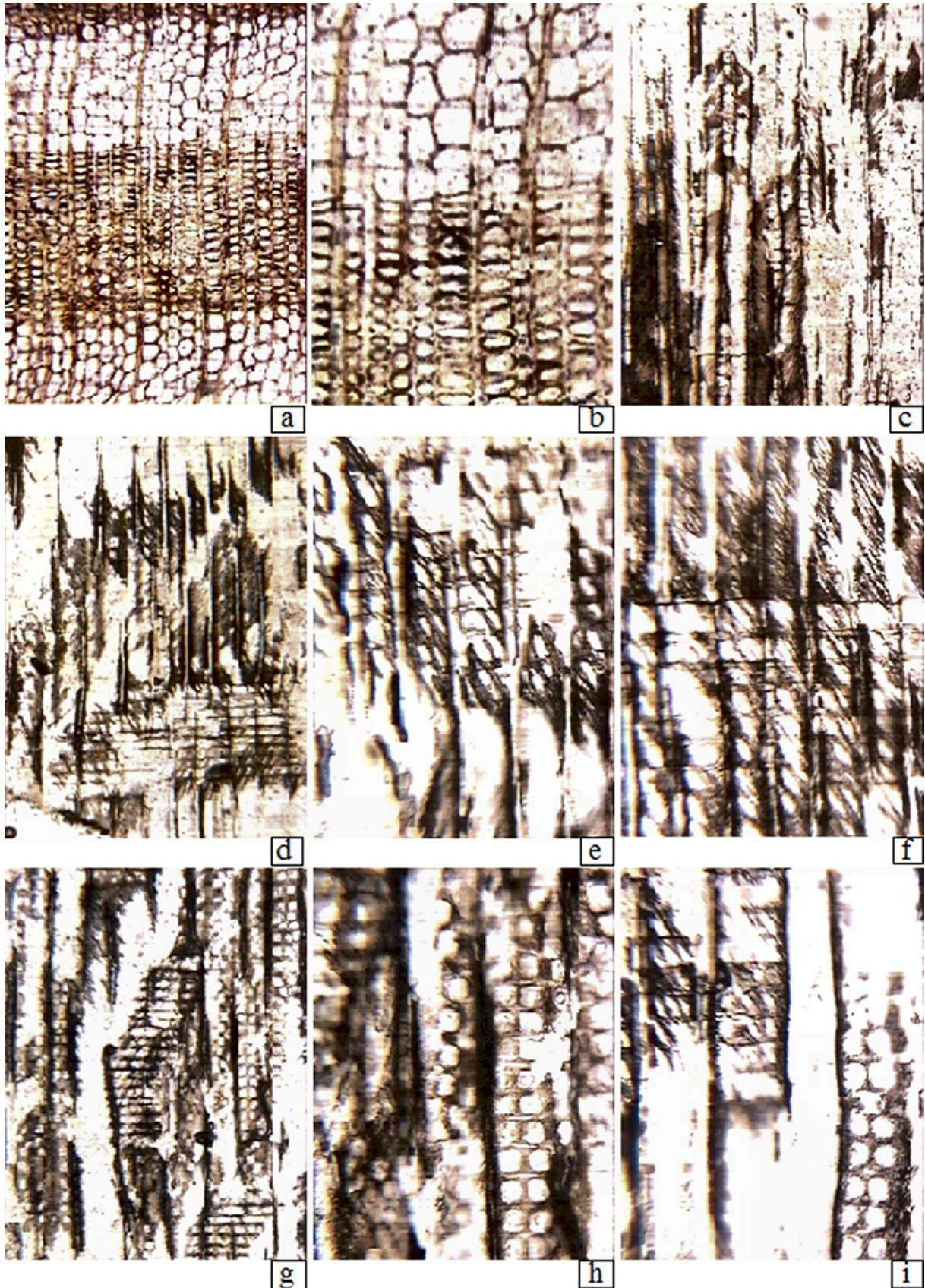
walls. The pits have round borders of 9-12-16  $\mu\text{m}$  in diameter and apertures of 3-3.5  $\mu\text{m}$ . Sometimes there are obvious crassulae, and the vertical walls radial walls of tracheids frequently have oblique striations (Fig. 4).

**The axial parenchyma**, probably diffuse, is difficult to observe in cross section, but sometimes it appear in the longitudinal sections as rectangular cells with thin and smooth walls, as the terminal (horizontal) wall also.

**The medullary rays** in cross section seen are linear, of rows of rectangular cells, slightly crushed. Tangentially appear clearly uniseriate, of 1-15(26) polygonal-rounded cells in height. Sometimes lateral intercellular spaces are present. Their density is 6-12 rays on a mm tangential. Radially seen the rays are homocellular. The parenchyma ray cells are of 13-17.5  $\mu\text{m}$  high, the marginals taller, of 20-24  $\mu\text{m}$ , with wavy outer wall. The horizontal walls are smooth, and 3-3.5  $\mu\text{m}$  double wall. Because of the bad preservation, the tangential walls and the indentures were not observed. The cupressoid cross fields have 1-2(3) cupressoid pits (or small taxodioid) of 6-8  $\mu\text{m}$  in diameter, with slightly elliptic borders, sometime lens like inclined in conformity with the striations of the tracheids. The apertures are unclear. The marginal fields can have 6-8 pits on two horizontal rows.

#### Affinities and discussions

The xylotomical study of the two samples showed badly preserved coniferous structure, and the absence of resin ducts, scarcity of parenchyma, uniseriate radial pitting and the cross field most probably of cupressoid type suggest for both of the specimens a cupressaceous structure (see Greguss, 1955; Schweingruber, 1990; InsideWood - onward) or how Vaudois & Privé (1971) showed in their key of identification of Cupressaceous wood. Most similar seem to be those of the extant *Cupressus* and *Chamaecyparis* genera (Greguss, 1955; 1969), regarding



**Fig. 4** *Cupressinoxylon* sp. **a, b** - cross section: distinct growth-ring boundary, thick-walled tracheids in late-wood - x100-x200; **c** - tangential section: uniseriate rays, striated tracheids - x100; **d** - radial section: pits and striations on tracheids, cross-fields - x100; **e, f** - radial section: striations on tracheids, cupressoid cross-fields - x200; **g** - radial section: 2-3 seriate pits and striations on tracheids, cupressoid cross-fields - x100; **h, i** - radial section: 2-3 seriate pits with crassulae on striated tracheids, cupressoid cross-fields - x200.

the tracheidal pitting, the cross field pitting and the aspect of axial and radial parenchyma. Both genera belong now to the Subfamily Cupressoideae Rich. ex Sweet (Farjon, 2005; Earle, 2017).

The comparison of here studied specimens with other forms described as *Chamaecyparixylon* (Iamandei & Iamandei, 2000; Iamandei et al., 2013), and also as *Cupressinoxylon* of *Thuja* type (see Iamandei et al., 2008a, c; 2011; 2012) shows some general resemblances, but not identity.

The comparison with other cupressaceous structures shows many similitudes with forms of *Cupressinoxylon* described by Zalewska (1953), Schönfeld (1957), Greguss (1967), Dupéron-Laudouéneix (1979) or by Iamandei et al. (2008a).

Once again, consulting the revised diagnoses of Kräusel (1949) and Vogellehner (1967, 1968), and using the identification key proposed by Vaudois & Privé (1971), we can attribute our studied specimens to *Cupressinoxylon* genus. The xylotomic details observed in our studied specimens are not identical to those of the already described species and are not sufficient to describe a new species, we attribute our studied material to *Cupressinoxylon* sp.

Genus *Thujoxylon* (Unger) Hartig, 1848

*Thujoxylon* sp.

Fig. 5, photos a-i.

### Material

From a sample of petrified wood collected from North of Ociu area, on Ocişor brook, of Mid-Miocene volcano-sedimentary deposits (Late Badenian-Early Sarmatian). The sample has brown color and centimetric size, fragmented after oriented slides cut, and is kept now in GIR Collection at National Geological Museum - Bucharest under the inventory number 26,441 (724 as field number).

### Microscopic description

**Growth rings** distinct, of 75-121 tracheids high, with gradual transition from early to late wood. The ring boundary is marked by 6-12(18) thick walled cells of late wood. Normal axial ducts are absent.

**The tracheids** have a polygonal cross section, with rounded corners. Between two successive rays there are 1-11 regular radial rows of tracheids, sometimes with intermingled rows of smaller tracheids. Usually the tracheid sizes vary between 20-48 / 20-48 µm the radial / tangential diameters, smaller in the late wood. The wall thickness is of 4-6 µm double walls, thicker in the late wood, up to 8-12 µm. The density is 1692-2116 tracheids per mm<sup>2</sup>. On the tangential walls the pitting is uni- or biserial, with pits spaced or contiguous or slightly irregularly arranged, with badly preserved round borders of 12-15 µm in diameter, to which often only the chamber is visible, round to oval of 4-6 µm giving a false "taxodioid" aspect, and with elliptic vertical apertures of 2-4 µm when visible. On the narrower tracheids the uniseriate pits are circular, of abietinean type of 8 µm in diameter and apertures of 3.5-4 µm. The radial pitting is clearly of abietinean type, spaced or contiguous arranged in 1 or 2 vertical rows, when are opposite and with *crassulae*. The

pits have round borders of 15-19 µm in diameter and round apertures of 4 µm in diameter. The pit chamber seems to be of vestured type (ornamented), has up 11-12 µm in diameter and is well preserved. The tangential walls are slightly molding the pits row, gaining a wavy appearance.

**The axial parenchyma** is absent.

**The medullary rays** are rectilinear in cross section, uniseriate in tangential view of (3)6-22(36) cells high, sometimes with 1-3 biserial storeys isolated or grouped. The ray cells are square-rounded to vertical elliptic, of 12-20 µm in diameters, some of them irregularly simple pitted (sieved) or filled of resinous content. Lateral intercellular spaces are absent. Their frequency is of 5-7 rays on tangential millimeter. Radially the rays are homocellular, with cells all procumbent having 16-20 µm in height, the marginals taller, having 20-28 µm. The horizontal walls are smooth, slightly pitted and relatively thick, of 4 µm double wall. The tangential wall has 1-3 µm (simple wall), is smooth or slightly rugose, straight, inclined or arched and the indentures are indistinct. Cross-fields badly preserved have 1-2 cupressoid pits, rounded, of 4-5 µm in diameter, with round to elliptic inclined apertures of 1-2 µm. The pair-pits are horizontally arranged or slightly diagonal. In the marginal fields 2-5(6) similar pits appear, in 2 rows arranged.

### Affinities and discussions

The essential xylotomic characters shown by the studied specimen are very similar to those of Cupressaceae family: tangential pitting uniseriate or biserial and slightly irregular, pits smaller, radial pitting 1-2 serial, typically abietinean, axial parenchyma absent, ray cells generally circular and cupressoid pitting in cross fields (see Greguss, 1955). All these details suggest a cupressaceous structure of extant "Thujidae Group", especially of *Thuja* type, even if there are similitudes also with other members of the group as *Microbiota*, *Chamaecyparis* or *Biota*. All these genera belong now to the Subfamily Cupressoideae Rich. ex Sweet (Farjon, 2005).

Evaluating the combination of the xylotomical details of our specimen we observe similitudes with those specified in the diagnosis reformulated after previous authors (as Unger, Pierce, Penny, Beyer, Jacquot and Greguss), cited by Vaudois & Privé (1971, p. 65-66), who made an identification key which explain that these cupressaceous structures have "zones d'accroissement distinctes, tracheides a ponctuations radiales abietineennes uniseriées, parenchyme absent ou rare, a parois transversales noduleuses ou ponctuéees, rayons généralement peu élevés, uniseriés, parfois bisériés sur un faible hauteur; champs de croisement contenant 1-4 ponctuations taxodioides, parfois cupressoides, indentures présentes" for *Thuja* type structure.

They specified also that *Chamaecyparis* type has a lot of parenchyma, since *Juniperus* type has specific juniperoid nodules on the inclined tangential walls of ray cells in radial view, details not observed in our specimen. The described details of our specimen are included also in the more comprising diagnosis of *Cupressinoxylon*.

Excluding the similitude with *Chamaecyparixylon* by the absence of axial parenchyma, we consider a correct attribution of our specimen to the genus *Thujoxylon*,



**Fig. 5** *Thujoxylon* sp. **a, b** - cross section: distinct growth-ring boundary, linear rays, very thick-walled tracheids in late-wood - x100-x200; **c, d** - tangential section: high uniseriate rays - x100; **e, f** - tangential section: rare small tangential pits on tracheids - x200; **g, h** - radial section: uniseriate spaced pitting - x200; **i** - radial section: cross-field pitting - x200.

the correspondent fossil morphogenus for *Thuja*, initially variably spelled as *Thuyoxylum-Thuoxylon-Thuioxylon-Thuyoxylon* was correctly spelled as *Thujoxylon* by Hartig in 1848 (see Andrews, 1955, p. 251; Dijkstra & van Ameron, 2002). In time, numerous species of *Thujoxylon* were described (see also Vaudois & Privé, 1971 who revised the Cupressaceous fossil lignotaxa). Among the last described species we cite *Thujoxylon antissum* Süss & Velizelos, 1998 described from Lesvos, Greece, a Tertiary form representing a root wood with a special pattern of growth rings and cross section. The species was quoted and discussed again by Mantzouka et al. (2013). Some badly preserved specimens were described from Romanian extra-Carpathian area as *Cupressinoxylon* sp. aff. *Thujoxylon* sp. (Iamandei et al., 2008a; 2011; 2012). Also, a Cretaceous species named *Thujoxylon beipiaoense* Ding et al., 2016 was described from China. Also, taking into account the papers of Greguss (1967), Dupéron-Laudouéneix (1979), Zalewska (1953), the revised diagnoses of Kräusel (1949) and Vogellehner (1967; 1968), using the key of identification proposed by Vaudois & Privé (1971), and since our specimen has not sufficient details to support a specific identification we simply name it *Thujoxylon* sp.

Genus *Chamaecyparixylon* Khudaiberdyev, 1958

*Chamaecyparixylon* sp.

Fig. 6, photos a-i.

### Material

The sample of petrified wood studied here was collected from Ociu area, the Church brook, from Mid-Miocene volcano-sedimentary deposits (Late Badenian-Early Sarmatian), and has ash-brown color and centimetric size. It is much silicified and displays a regular fibrous texture, and annual rings suggesting a conifer. Some fragments remained after oriented slides cut, are kept now in GIR collection at National Geological Museum - Bucharest under the inventory number 26,340 (740 as field no.)

### Microscopic description

**Growth rings** of 55-78 tracheids high, with gradual transition from early to late wood, ring boundary distinct, marked by the late wood constituted by 20-38 thick walled cells. Normal axial resin ducts are absent, but often there are tracheids full of resin and even traumatic aspects.

**Tracheids** polygonal with rounded corners in cross section, having radial / tangential lumina diameters 12-20 / 12-28  $\mu\text{m}$ , smaller in the late wood. Sometimes very large ones are intermingled in the early wood (up to 70-80/50-60  $\mu\text{m}$ ). Usually their wall thickness is of 4-8  $\mu\text{m}$  (double wall), thicker in the late wood: up to 12  $\mu\text{m}$ . Between two successive rays there are 1-7-14(21) regular radial rows, with small intercellular spaces, especially in the late wood. The density is 1616-1764 tracheids on  $\text{mm}^2$ . On the tangential tracheidal walls the pitting is uniseriate, spaced, sometimes slightly irregularly arranged, round pits with 7-8  $\mu\text{m}$  in diameter and with apertures of 3-4  $\mu\text{m}$ . The radial pitting is of abietinean type having pits of 14-16  $\mu\text{m}$  in diameter and round apertures of 4  $\mu\text{m}$  in the early wood and smaller, uniseriate, spaced of 7.5-9-12  $\mu\text{m}$  border pit diameter with aperture of 3  $\mu\text{m}$  in the late

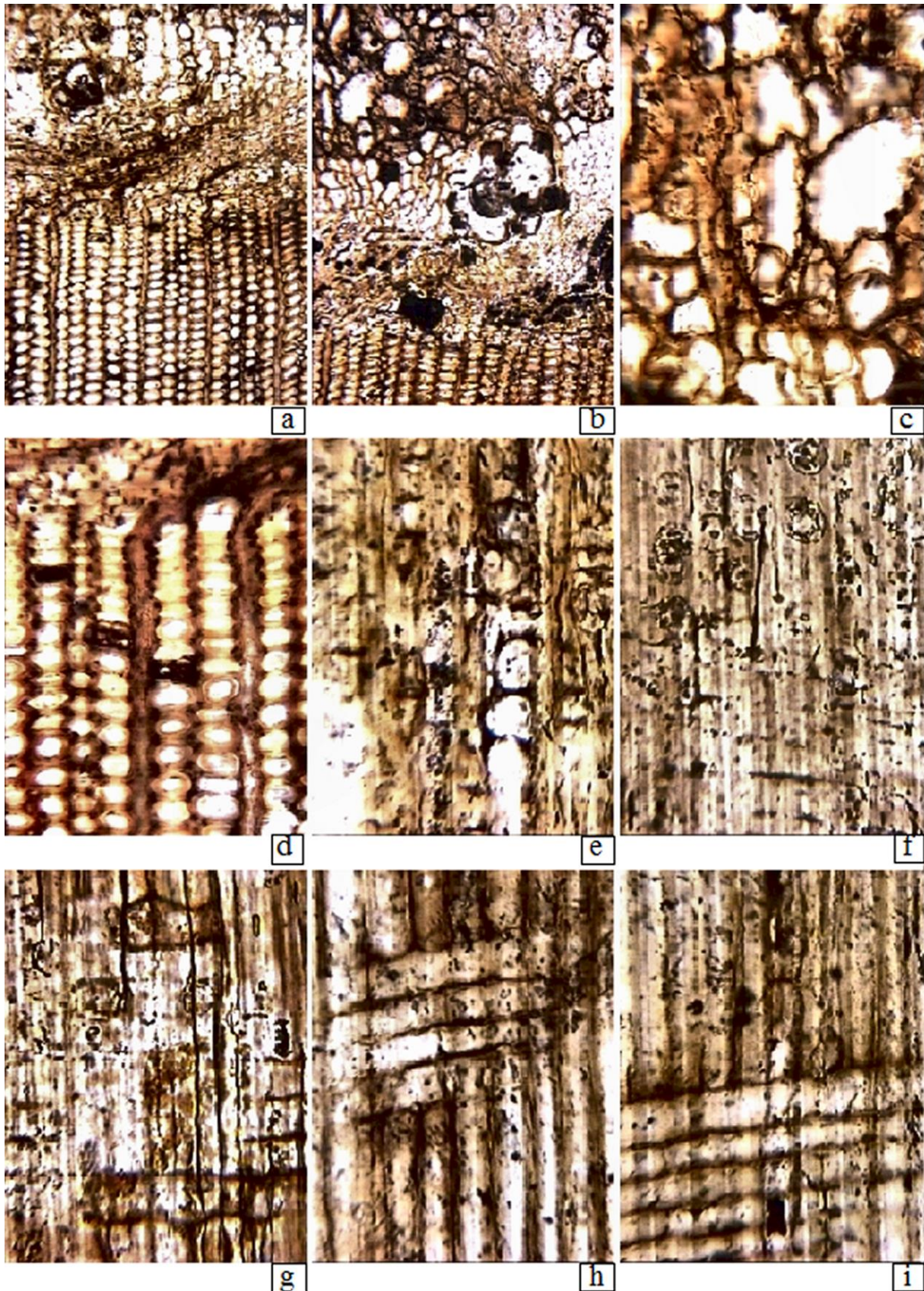
wood. Crassulae are not present, in the tracheid lumina granular resin remains appear and the tracheidal walls have striations, inclined or crossed (due to compression), and even fine spirals in the final wood.

**The axial parenchyma** in cross section appears diffuse, as large isolated polygonal or rectangular thin walled cells (of 1.5  $\mu\text{m}$  simple wall). Vertically the thin walls are smooth and slightly constricted at the end (horizontal) walls, which are also thin and smooth. Inside cells globular resin content is present, having circular empty spaces.

**The medullary rays** in cross section appear linear and in tangential section appear uniseriate, locally bi- or triseriate, and low, of 6-12 cells high. The ray cells are oval or laterally flattened, have 8-16  $\mu\text{m}$  in diameter, and without lateral intercellular spaces. Their frequency is 5-6 rays on mm tangential millimeter. Radially the rays are homocellular, cells all procumbent of 12-16  $\mu\text{m}$  high, marginal higher, of 22-24  $\mu\text{m}$ . The smooth horizontal walls are thin walled having 1.5-2.5  $\mu\text{m}$  double walls. The tangential wall is straight, vertical, smooth and thin, of 1-1.5  $\mu\text{m}$ . Indentures not observed. The cross fields present 1-2 cupressoid pits (or taxodioid small), round to oval of 3-5  $\mu\text{m}$  in diameter, with circular to elliptic inclined apertures of 1-1.5  $\mu\text{m}$ . In the marginal taller fields appear 2-4 pits in vertical pairs.

### Affinities and discussion

The xylotomic characters observed in our specimen, like form, size and distribution of tracheids, of parenchyma and of rays suggest similitudes with those of the Cupressaceae, of which most affinity seems to have with the "Thujidae group" by the clear presence of the axial thin-walled parenchyma which send more to the extant *Chamaecyparis* not to *Thuja* (see Greguss, 1955). Anyway *Cupressus* type is excluded since it has nodular aspects, or even dentate on the parenchyma end (horizontal) walls. *Juniperus* type is also excluded since our specimen has not juniperoid nodules on the tangential walls of the rays. In addition, the absence of the callitroid thickenings on the tracheidal walls excludes any comparison with members of the Callitroideae (Greguss, 1955). For the last taxonomy of the Cupressaceae Family, we used Farjon (2005). Using the identification key of Vaudois & Privé (1971), we observed that between *Chamaecyparixylon* and *Thujoxylon* is very difficult to do distinction, which is reduced to the presence or the absence of the parenchyma and of the indentures. Since our specimen have relatively abundant axial parenchyma, and the presence of indentures is doubtful we attribute our specimen to *Chamaecyparixylon* genus. The description of our specimen is in perfect accord with the diagnosis of Khudaiberdyev (1958), as it is commented by Vaudois & Privé (1971). Our specimen, coming from the same geological deposits with the form *Chamaecyparixylon* cf. *polonicum* (Kräusel) Khudaiberdyev, 1958, previously described by us (in Iamandei & Iamandei, 2002b; Iamandei et al., 2013) from which it differs at least by the thin and smooth horizontal walls of axial parenchyma, not nodular, the lower rays, the slightly different cross-fields and the absence of the indentures. Also is different of *C. privegillii* Iamandei et Iamandei (in Iamandei, E. & Iamandei, S., 2000, p. 192-194), which have also nodular horizontal walls of axial parenchyma and not very similar



**Fig. 6** *Chamaecyparixylon* sp. **a, b** - cross section: not very distinct growth-ring boundary, since early wood disorganization, very thick-walled tracheids in late-wood - x100; **c** - detail in the early wood disorganization - x200; **d** - very thick-walled tracheids in late-wood - x200; **e** - tangential section: uniseriate rays - x200; **f-i** - radial section: radial uniseriate pits on tracheids, cross-fields pits - x200.

cross fields.

After this discussion on the possible affinities, we conclude that there are no sufficient observed xylotomic details for a specific identification and we attribute our specimen to *Chamaecyparixylon* sp.

Subfamily **Taxodioideae** Endlicher, 1847 (ex K. Koch, 1873)

Genus *Taxodioxylon* Hartig, 1848 emend. Gothan, 1905

*Taxodioxylon taxodii* Gothan, 1906

Fig. 7, photos a-i.

### Material

The studied material was collected from Prăvăleni-Ociu area like this: one sample of petrified wood was collected from Ociu area, from Marinașu valley, six samples also from Ociu on the Church brook, and one sample from Prăvăleni, Bodișteanu brook from Mid-Miocene volcano-sedimentary deposits (Late Badenian-Early Sarmatian), all having beige to ash-brown color and centimetric size. It represents silicified wood and display a regular fibrous texture, and annual rings suggesting a conifer. Some fragments remained after oriented slides cut, are kept now in GIR collection at National Geological Museum - Bucharest under the inventory number: 26,383; 26,406; 26,409; 26,475; 26,417; 26,418; 26,442 and respectively 26,415 (i.e. 110; 250; 291; 440; 492; 494; 731 and 449 as field numbers).

### Microscopic description

**Growth rings** distinct, variably sized, of 10-44 tracheids with gradual transition from early to late wood, with ring boundary marked by 2-5-7 tangential rows of thick walled cells of late wood. Normal axial resin ducts are absent, but sometimes, resiniferous tissue appears, probably of traumatic origin.

**The tracheids** polygonal rounded in cross section (4-5 sides) usually larger in the early wood. Between two successive rays there are 1-11(16) regular radial rows, sometimes with larger ones intermingled. When solitary the tracheids have rounded polygonal section frequently determining intercellular spaces, and have radial / tangential diameters of 16-50(63)/(16)20-48  $\mu\text{m}$ , smaller in the late wood: 8-12/8-12-24  $\mu\text{m}$  r/tg diameters. The wall thickness is 2-5  $\mu\text{m}$  double walls, thicker in the late wood: 8-10(12)  $\mu\text{m}$ . The density of the structure is of 900-1850 tracheids on  $\text{mm}^2$ . On the tangential walls the pitting is missing or if sometimes it appear is either uniseriate, spaced, or as pairs irregularly arranged. The rounds to oval pits have 8-10  $\mu\text{m}$  with round to elliptic apertures of 1.5-3  $\mu\text{m}$ . The radial pitting is uniseriate or biseriate, pits of abietinean type, opposite, spaced or contiguous arranged, with round borders of 12-19  $\mu\text{m}$  in diameter and with round apertures of 3-5  $\mu\text{m}$ . Sometimes obvious crassulae are present, sometimes are missing. The tracheidal walls have oblique striations and inside lumina resin globules sometimes appear.

**The axial parenchyma** in cross section appears relatively frequent, sometimes even abundant in the transitional wood, diffuse or in discontinuous tangential lines of rounded cells smaller than the tracheids or similarly sized. Vertically presents thin walls of 1-1.5  $\mu\text{m}$  (simple wall), smooth and sometimes slightly constricted at the

horizontal (end) walls which appear rugose of 1.5-2  $\mu\text{m}$  or clearly nodular, with up to 8 bead-like knots, with 1-4 very obvious denticles. Inside parenchyma cells resin content of reddish-brown color appear as big and small globules, or granular, or as remains or as plugs or compact with convex empty spaces. Sometimes in the cross-fields with the ray cells display up to 4 simple pits in two superposed rows.

**Medullary rays** in cross section appear linear and in the tangential sections display the uniseriate aspect often with 1-7 biseriate storeys or even as biseriate rays, of 1-16 up to 53 cells or more. The ray cells are polygonal-rounded to round or vertical oval, of 12-18-24  $\mu\text{m}$  in diameter, with lateral intercellular triangular spaces not always very obvious. As frequency, there are 6-12 rays on tangential millimeter. Radially the rays show homocellular structure, with cells all procumbent of 16-20(24)  $\mu\text{m}$  high, the marginals taller: 20-24(32)  $\mu\text{m}$ . The horizontal walls are smooth and have 3-4(6)  $\mu\text{m}$  the double wall. The tangential walls are thin and smooth or slightly rugose straight and inclined or arcuated. Indentures indistinct or even are absent. The typical taxodioid cross fields have 1-3(4) taxodioid pits, oval to round, of 7-9  $\mu\text{m}$ , with large-elliptic apertures, inclined to horizontal, of 2-4  $\mu\text{m}$ . They are arranged in 1-2 horizontal rows or diagonal or triangular, sometimes badly preserved or covered by traces of resin globules giving an aspect of false unilaterally composed pits. In the taller marginal fields, pitting appears as vertical pairs or as up to 6 on two superposed rows. Sometimes cross-fields with parenchyma can be seen, with up to 4 simple pits in two superposed pairs.

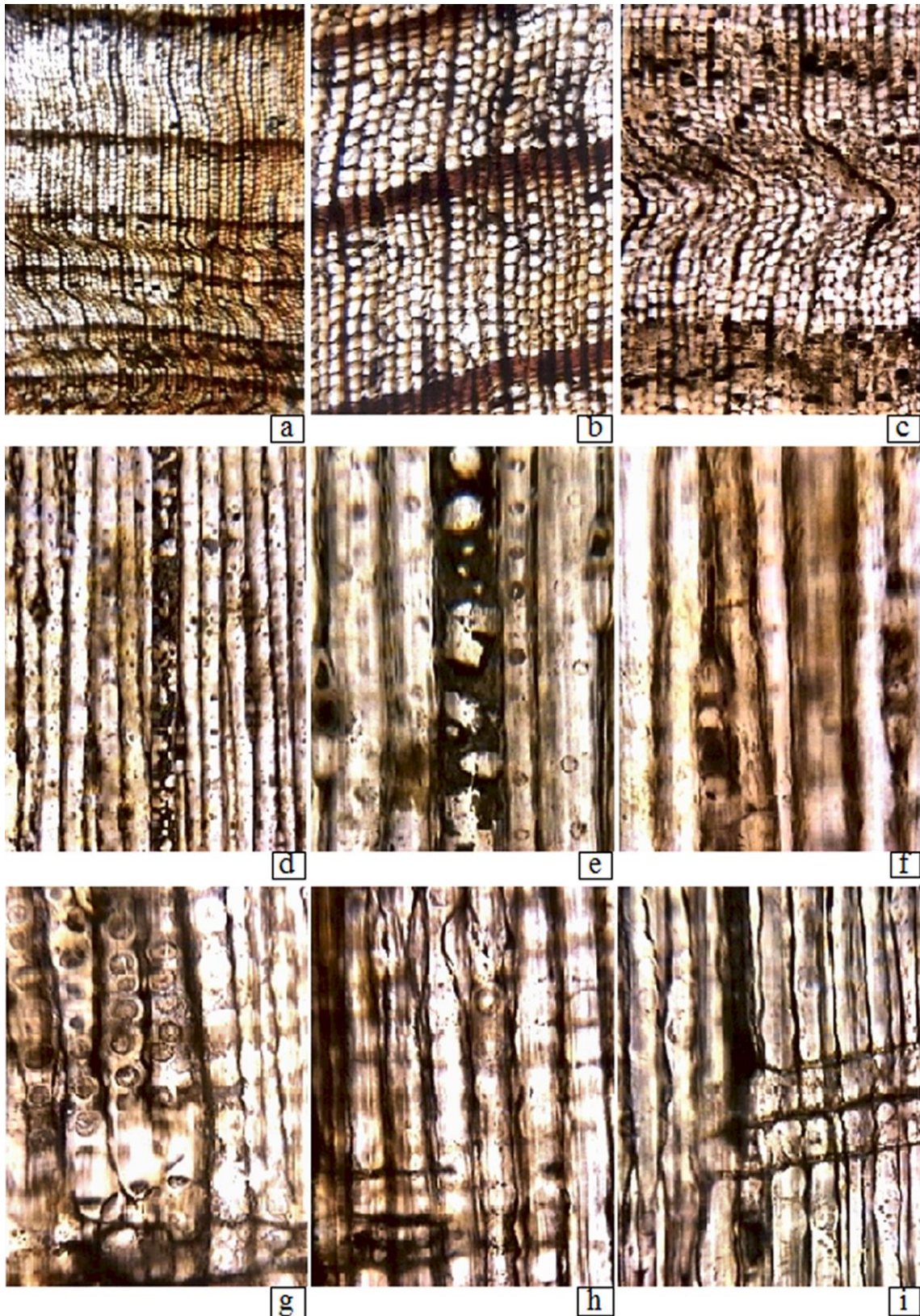
### Affinities and discussions

The xylotomic description of all the studied specimens allowed the outlining of a characters combination similar to those of the taxodiaceous Cupressaceae, namely: shape and distribution of the tracheids and of the parenchyma in cross section, the tracheidal pitting on the tangential and on the radial walls, the typical taxodioid type of the cross fields and the arrangement of the taxodioid pits.

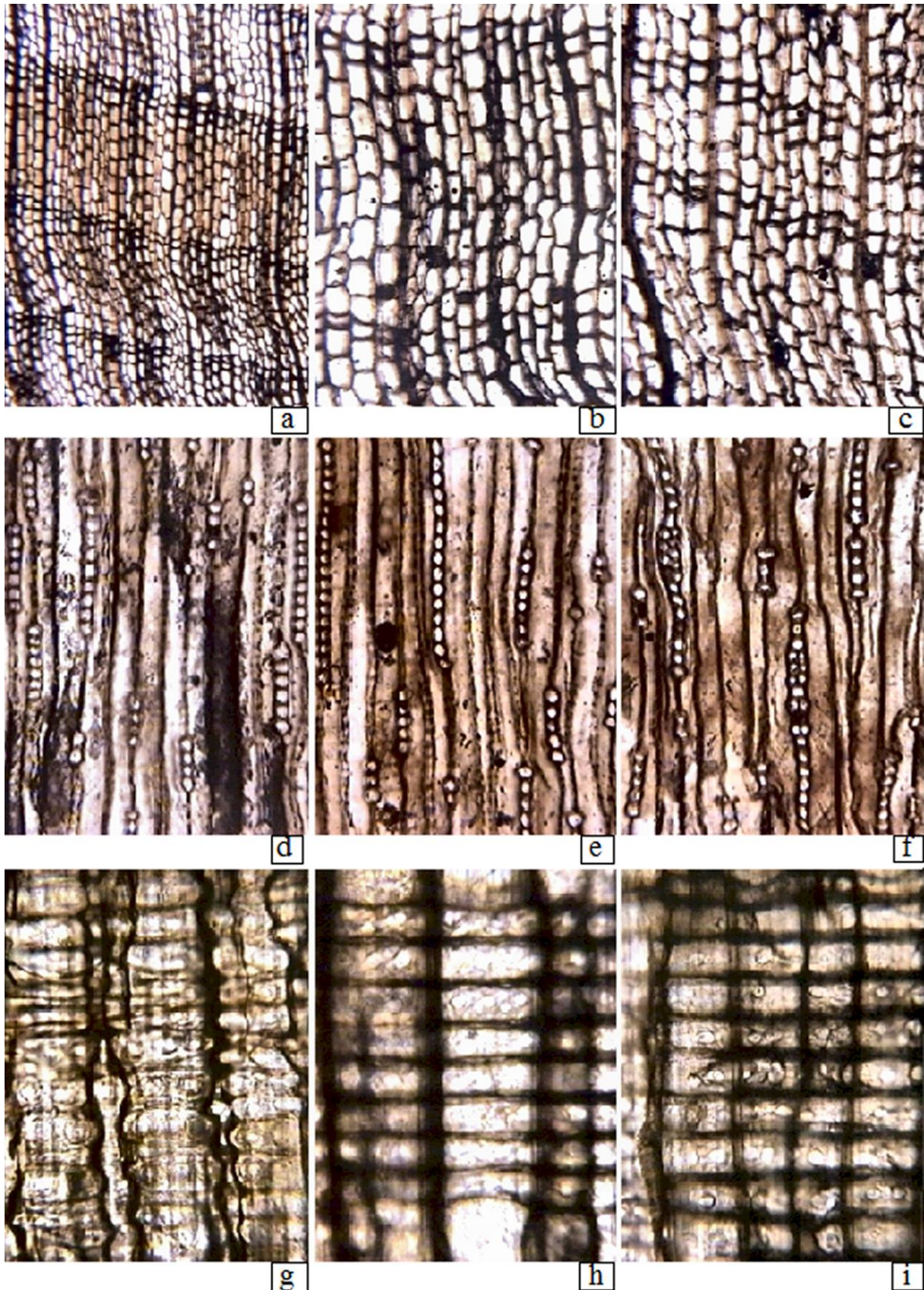
The comparison with the extant and fossil described taxodiaceous genera allowed us to establish the most affinities with *Taxodium* Rich. and respectively with *Taxodioxylon* (Hartig) Gothan, 1906, taking into account the obvious presence of the end (horizontal) walls of parenchyma, with up to 8 knots, or even denticles.

From the species of *Taxodioxylon* already described our specimens mostly reassembles with *Taxodioxylon taxodii* Gothan 1906 as is described by many authors (see Gregguss, 1967; Gottwald 1992; Selmeier, 2001), a fossil species equivalent to the extant species *Taxodium distichum* (L.) Rich., a tree living today in restricted areas in South USA, Mexico and Guatemala, within riparian and wet habitats (Earle, 2017), in which xylotomically is remarkable that the radial pitting of the tracheids, the nodular end wall of parenchyma and the typical aspect of the cross-rings are very similar. Also we have described *Taxodioxylon* specimens from Romania (Iamandei et al., 2005a; 2008c).

After this discussion on the affinities of our studied material we decided to assign all the 8 studied specimens to the species *Taxodioxylon taxodii* Gothan, 1906.



**Fig. 7** *Taxodioxyton taxodii* Gothan, 1906. **a** - cross section: distinct growth-ring boundary - x50; **b, c** - cross-section: distinct growth boundary thick-walled tracheids in late wood, dispersed parenchyma - x100; **d** - tangential section: tracheids few pitted, parenchyma with resin content - x200; **e, f** - tangential section: tracheids few spaced pitted, parenchyma with resin content (e) and end horizontal denticulate walls (f) - x200; **g-i** - radial section: radial pitting on tracheids, cross-fields with 2-4 pits on two storeys - x200.



**Fig. 8** *Sequoioxylon gypsaceum* (Goepfert) Greguss, 1967. **a** - cross-section: less distinct growth-ring boundary, parenchyma disperse - x50; **b, c** - cross-section: thin-walled polygonal tracheids, dispersed parenchyma - x100; **d-f** - tangential section: - unpitted tracheids, parenchyma with globular resin content and smooth and thin horizontal end walls, uniseriate high rays, or with biseriate storeys or even biseriate - x200; **g-i** - radial section: radial pitting on tracheids, typical cross-fields with 1-6 taxodioid pits on 1-2 storeys, sometimes alternate - x200.

Subfamilia **Sequoioideae** (Luerss.) Quinn, 1989 (see Gadek et al., 2000)  
 (former Family **Taxodiaceae** Warming, nom. cons.)  
 Genul *Sequoioxylon* Torrey, 1923, emended  
*Sequoioxylon gypsaceum* (Goepfert) Greguss, 1967  
 Fig. 8, photos a-i

### Material

The studied material represented by 48 samples of petrified wood were collected from Prăvăleni-Ociu areas, hosted now in GIR collection in the repository of the National Geological Museum - Bucharest under next specified inventory numbers (followed by the field numbers for a better identification). All the material represents silicified wood and usually displays a regular fibrous texture, and annual rings suggesting a conifer and is hosted like this:

- 8 samples of petrified wood were collected from Basarabasa hill, and are deposited in collection under the next inventory numbers: 26,460; 26,461; 26,462; 26,463; 26,464; 26,466; 26,467 and 26,468 (the field numbers: 807; 809; 810; 812; 813; 821; 823 and 824, respectively);
- 1 sample of petrified wood was collected from Prăvăleni area on Bodișteanu valley, and is deposited in collection under the next inventory number: 26364 (field number: P22);
- 5 samples were collected from Prăvăleni area on the Cremenea hill, and are deposited in collection under the next inventory numbers: 26,397; 26,398; 26,410; 26,411 and 26,412 (the field numbers: 176; 180; 371; 336\* and 376\*, respectively);
- 3 samples of petrified wood were collected from Hoarna Tarnița valley, and are deposited in collection under the next inventory numbers: 26,389; 26,394 and 26,401 (the field numbers: 115; 117 and 206\*, respectively);
- 10 samples of petrified wood were collected from Marinașu valley, south of Ociu village and are deposited in collection under the inventory numbers: 26,420; 26,421; 26,422; 26,424; 26,471; 26,348; 26,449; 26,450; 26,451 and 26,452 (the field numbers 570; 576; 583; 587; 600; 601\*; 781; 783\*; 786 and 787, respectively);
- 7 samples of petrified wood were collected from inside Ociu village, on the dirty roads and are deposited in collection under the inventory numbers: 26,386; 26,387; 26,698; 26,448; 26,349; 26,453 and 26,458 (the field numbers 113b; 113c; 113d; 747; 757; 794 and 804, respectively);
- 8 samples of petrified wood were collected from inside Ociu village, on the Church Brook, and are numbered with the inventory numbers: 26,407; 26,472; 26,474; 26,476; 26,427; 26,428; 26,430 and 26,443 (the field numbers 263; 602; 607; 651; 653; 654; 664 and 732, respectively);
- 6 samples of petrified wood were collected from the brook valley from north of Ociu village, and

are numbered with the inventory numbers: 26,431; 26,433; 26,434; 26,435; 26,436 and 26,437 (the field numbers 669; 677; 691; 692; 700 and 701, respectively).

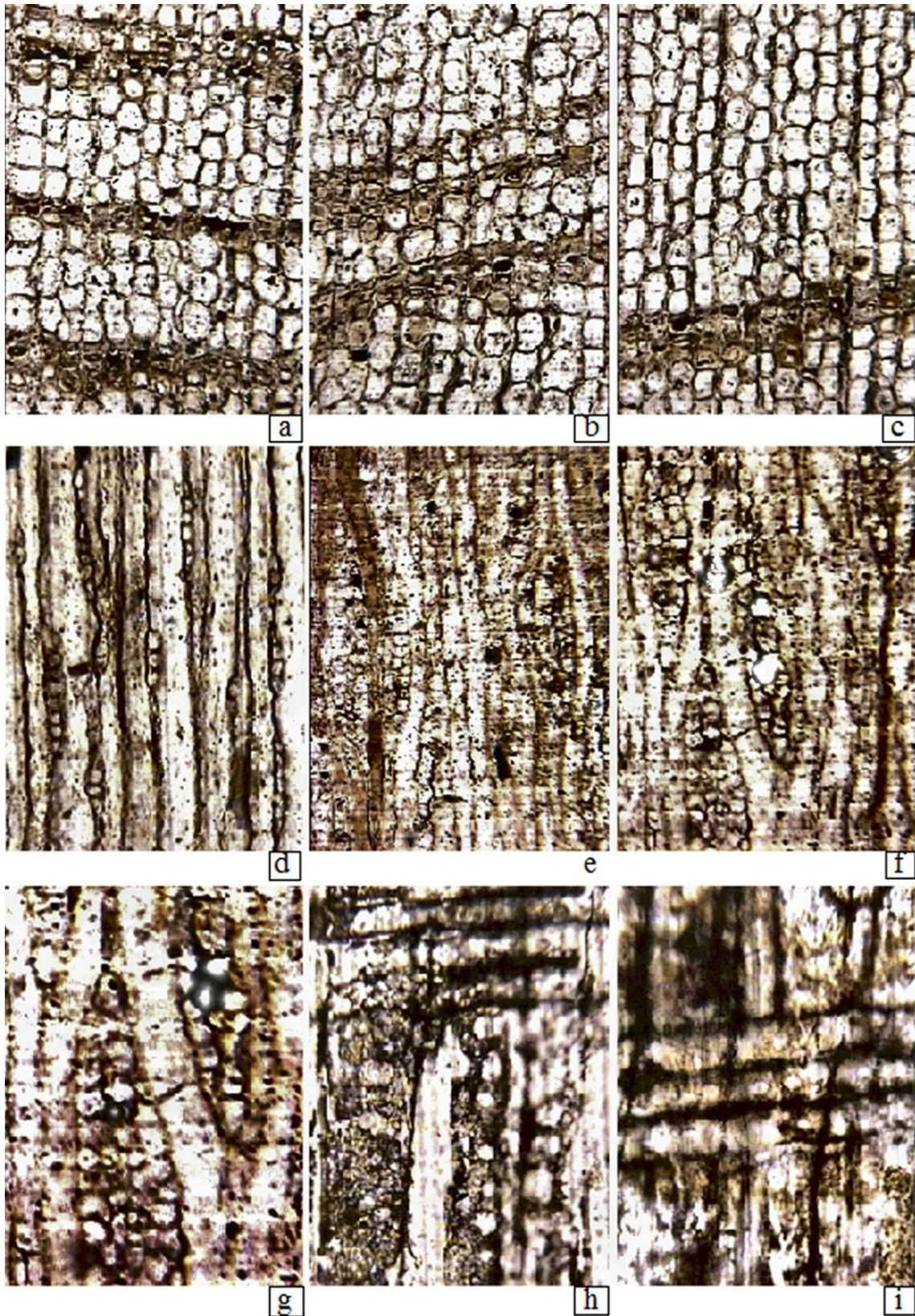
Previously (Iamandei et al., 2000) other nine specimens were already described and published also as *Sequoioxylon gypsaceum* (Goepfert) Greguss, 1967. And also all that material was collected from same area as the material studied for the present paper from the same Mid-Miocene volcano-sedimentary deposits (Late Badenian-Early Sarmatian), and is kept now in GIR collection in the repository of the National Geological Museum - Bucharest under next specified inventory numbers: 26,341-26,349 (field numbers: 32; 39; 136; 161; 169, 374; 375; 602 and 757, for a better identification).

### Microscopic description

**The growth rings** present, distinct, marked by 1-5(13) rows of small cells, often flattened and thick to very thick walled of late wood contrasting with the early wood which is constituted from larger lumina and have thin walls. Usually wide the annual rings are unequal in size having (1)3-18-39(65) cells, with gradual transition from early to late wood. Normal axial resin ducts are absent, but sometimes some with traumatic character appear, even as traumatic tissue - groups of tracheids or parenchyma - invaded by resin, which is visible in all sections.

**The tracheids** are rectangular or polygonal with 5-6 sides and sometimes, in the early wood, variably sized cells appear, rounded, deformed by compression, seeming to be intermingled or even indented with them. Their lumina have the radial / tangential diameters of 20-70(80) / 30-60(70)  $\mu\text{m}$  or more. The wall thickness is of (3.5)5-8(10)  $\mu\text{m}$  double wall in the early and transitional wood and in the late wood has of 12-15  $\mu\text{m}$  double wall, sometimes up to 28  $\mu\text{m}$  when the lumina appear point like or slit-like. Between two successive successive rays 1-13 regular radial rows of tracheids appear, and their frequency is of 425-1496 tracheids on  $\text{mm}^2$ . The tangential wall are usually unpitted and are smooth or slightly verrucose and without spiral thickenings. However sometimes on some tracheids were seen small pits of 6-9  $\mu\text{m}$  border diameter and 3-4  $\mu\text{m}$ , sparsely arranged on 1-2 vertical rows. Radial pitting of abietinean type with bordered pits slightly ornamented, of (12)16-19  $\mu\text{m}$  in diameters with apertures of 4-5  $\mu\text{m}$ , smaller in the late wood, spaced or contiguous arranged in 1-3 vertical rows rarely 4. Sometimes the opposite pits touch each other after a vertical line. Sometimes irregularities in the triseriate pitting appear as storeys of 4 crowded pits or in the uniseriate rows where appear opposite pairs of pits or small portions with biseriate alternate pits. *Crassulae* are very obvious, even if on some tracheids are missing. The structures are often badly preserved but it is clear that spiral thickenings are absent.

**The axial parenchyma** appear rather abundant in cross section, diffuse, dispersed among the tracheids of the early wood or in the terminal wood as slightly irregular short tangential lines of 2-3(5) cells, usually slightly crushed and with dark content. Vertically it appear as rectangular thin walled cells sometimes simple pitted and in radial view as weak constriction at the horizontal (end) walls which are thin (1-3  $\mu\text{m}$ ), smooth, slightly rugose or weakly nodular (1-3 small knots), and indistinct simple



**Fig. 9** *Sequoioxylon multiseriatum* (Ramanujam et Stewart) nov. comb. **a-c** - cross section: less distinct growth-ring boundary, few parenchyma disperse - x100; **d** - tangential section: uniseriate rays - x100?; **e, f** - tangential section: - broad rays 2-5-seriate, dispersed parenchyma - x100; **g** - tangential section: multiseriate rays, parenchyma with thin end wall with a single knot - x200; **h-i** - radial section: radial pitting on tracheids, cross-fields with 2-4 taxodioid pits on 1-2 storeys - x200.

pitted. The resin content appears as big globules or dark remains, or plugs, or compact, without filling the entire cell.

**The medullary rays** in cross section are relatively linear and are formed from rectangular elongate cells sometimes crushed, with small simple pits, irregularly arranged on the horizontal wall. In the tangential sections the rays appear usually uniseriate, of 1-20(32) cells high or more with local biseriation, sometimes up to 5 successive biseriate storeys, tending to an already biseriate aspect. The ray cells are usually polygonal rounded or oval of 12-16-20 µm, rarely cribrate by simple pitting. Often lateral intercellular spaces are present. The ray-density is 3-6-10 rays on tangential millimeter. Radially the rays are homocellular with cells all procumbent of 14-18 µm high, the marginals taller: 20-40 µm. The horizontal walls are relatively thin, of 2-6 µm the double wall, smooth and simple pitted and the marginals with slightly waved outer wall. The tangential walls are vertical or slightly arcuated and thin (1-2 µm), smooth or slightly rugose, rarely with few knots. Indentures absent. The cross fields have usually small pits, usually of taxodioid type or even ooporoid, of 6-9 µm in diameter, with rounded to oval borders, 1-3(4) pits in horizontal row, the pairs slightly diagonal and with oblic to horizontal elliptic small apertures, or as oblic slits to vertical in the late wood. The marginal cross fields have (1)2-6 similar pits, on two slightly irregular rows. Often the ray cells have resin content. In cross fields with axial parenchyma cells sometimes appear simple pits as 2 superposed pairs.

#### Affinities and discussions

The synthetic xylotomical description of a numerous population of similar samples revealed details that send to Cupressaceae – of "taxodiaceous" type, but from Sequoiaceae Subfamily (see Farjon, 2005; 2010), by the presence of radial pitting up to triseriate opposite and with obvious *crassulae*, the usually thin and smooth end (horizontal) wall of the parenchyma rarely rugose or with few knots and the typical cross field with taxodioid to slightly ooporoid pits (Greguss, 1955; 1967).

Some resemblances of our specimens with fossil forms already described by Greguss (1967), probably erroneously identified with *Metasequoioxylon* genus, considered equivalent to the extant *Metasequoia glyptostroboides* Hu & Cheng, a tree described in China in 1943 (see Greguss, 1955; Earle, 2017).

Otherwise most of the described characters are frequently met in other "taxodiaceous" woods also. The comparison with Schönfeld's species *Taxodiooxylon metasequoianum* Schönfeld, 1955, wrongly renamed by Greguss (1957, 1967) as *Sequoioxylon* or *Metasequoioxylon germanicum*, and with *M. hungaricum* Greguss, 1967 is unsatisfying (see whole discussion in Philippe et al. 1999, p.671), since our material have not pitted parenchyma cells and the cross field pitting is different. Also, *Metasequoia milleri* Rotwell et Basinger, 1979 described from Allenby Formation (Middle Eocene) from British Columbia, Canada as is quoted by Basinger (1981), show differences in the height of rays and pitting in cross fields. Moreover, according to many palaeobotanists (Petrescu, 1999, written communication), referring to foliar imprint data,

*Metasequoia* was probably absent from the flora of the European territory.

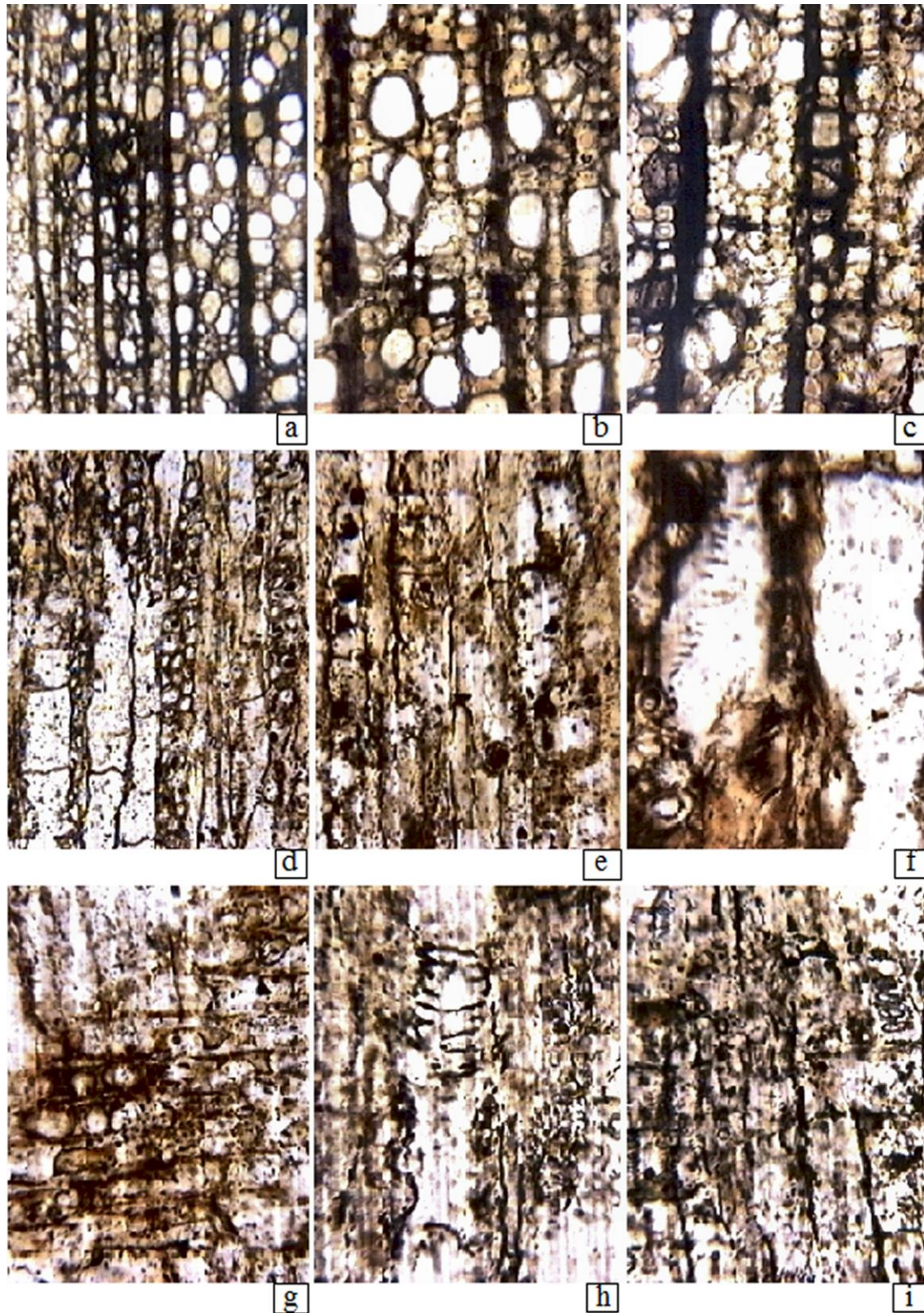
The comparison with the structure of other described "taxodiaceous woods" still shows the greatest similarities with the genus *Sequoioxylon* Torrey and partially with the genus *Taxodiooxylon* (Hartig) Gothan, 1905 and thus the separation of the two genera is still problematic. Kräusel (1949) has ruled the comprehensive form-genus *Taxodiooxylon* but this didn't solved the problem of differentiating the several types of "taxodiaceous" woods. However, there are palaeoxylogists that still contest the validity of the genus *Sequoioxylon* Torrey, considering that the diagnosis of the *Taxodiooxylon* genus is sufficiently comprehensive and that the establishment of new areas of competence of the two genera is likely to complicate the determination of fossil wood (Privé-Gill, 1977).

Greguss (1967) considered that the name *Taxodiooxylon* should remain reserved for structures characterized by the presence of numerous nodular thickening in the horizontal (end) walls of the axial parenchyma, typical of the extant *Taxodium* genus. Although the aspect of axial parenchyma seems extremely variable in the current genus *Sequoia* (Privé-Gill, 1977), it should be recalled that in the "taxodiaceous" fossil woods still comprise the genera *Glyptostrooxylon* Conwentz, 1884 and *Metasequoioxylon* Greguss, 1967 as equivalents of *Glyptostrobus* and *Metasequoia*, respectively.

Selmeier (2001) described a *Taxodiooxylon* sp. from Czech Rep. and added a pertinent note: "*Taxodiooxylon* is found throughout the whole Tertiary and is one of the most common Tertiary coniferous woods in Europe and the rest of the Northern Hemisphere. Most of the Tertiary (not Upper Cretaceous) wood remains are to be assigned to *T. gypsaceum* which is a highly variable polyphyletic species that, according to the standard literature the cross-field pits vary from taxodioid to glyptostroboid or cupressoid" (Selmeier, 2001).

More recently, Teodoridis & Sakala (2008) describing a *Taxodiooxylon gypsaceum* from Czech confirm the equivalence with the wood of modern *Sequoia*, quoting Privé-Gill (1977) and Dolezych & Schneider (2006) but send, they say, also to an extinct form *Quasisequoia couttsiae* (Heer) Kunzmann, 1999. This species was described by van der Burgh & Meijer (1996) from the Late Eocene of Schleenhain, Germany, in a coal layer with the wood of *T. gypsaceum* and leaves and cones belonging exclusively to *Q. couttsiae*. More than this, ignoring the valid genus *Sequoioxylon* Torrey, 1923, there is a proposal for a doubtful new genus, *Quasisequoioxylon*, which would be intermediate between *Cupressinoxylon* Goeppert characterized by cupressoid cross-field pits and *Taxodiooxylon* with 2-3 taxodioid cross-field pits on radial tracheidal walls (Dolezych 2005: 256, published PhD Thesis).

Otherwise, even the taxonomy of the extant "Taxodiaceae" was changed after advanced and modern studies, being included in Cupressaceae family as subfamilies: Cunninghamioideae, Taiwanoideae, Athrotaxidoideae, Sequoiaceae, Taxodiaceae (Farjon, 2005, 2010; Earle, 2017). It is clear that as belonging to different subfamilies, *Sequoia* and *Taxodium* and their fossil correspondent *Sequoioxylon* and *Taxodiooxylon* both of them valid taxa, must define different entities.



**Fig. 10** *Liquidambaroxylon speciosum* Felix, 1884. **a** - cross section: polygonal vessels, linear rays 1-3-seriate, less distinct growth-ring boundary, solitary and grouped vessels - x50; **b**, **c** - cross-section: polygonal vessels, solitary or grouped, thick-walled fibers x100; **d**, **e** - tangential section: 2-3-seriate rays, vessels - x200; **f** - tangential section: scalariform perforation - x200; **g** - radial section: cross-field with rounded crystals in the ray-cells - x200; **h** - radial section: scalariform perforation - x200; **i** - radial section: scalariform pitting in cross field marginal ray-cells - x200.

Also there are new palaeoxylologists from Russia, Canada, Ukraine, Turkey who have admitted the validity of the genus and even have described new species under *Sequoioxylon* genus (see: Blokhina, 1986; 1997; 2004; Blokhina et al., 2000; 2010; Afonin, 2013; YiTiemei et al., 2013; Ozgenc, 2018).

So, after this discussion we believe that the use of the valid genus name *Sequoioxylon* Torrey, 1923 is justified, especially since the description of a fossil taxon would have to require the systematic reference to the extant genera or species, if possible. We admit, according to ICBN recommendations, that the presence of traumatic structures has no taxonomic value, but such structures have frequently been encountered in specimens studied by us, and probably they have an environmental significance. It is appropriate in these circumstances to redefine the genus diagnosis of *Sequoioxylon*, originally described by Torrey (1923), specifying that all structures reported to the *Sequoia* type wood, generally described as *Taxodioxylon*, it is appropriate to be assigned to the genus here emended:

**Genus *Sequoioxylon* Torrey, 1923 emended diagnosis:**

Distinct growth rings, with gradual transition of early to late wood. Regular resin ducts absent. Round to polygonal tracheids of varying size, of 60-80(-100)  $\mu\text{m}$  in diameters, thin-walled, of 3-5  $\mu\text{m}$  double wall, density 425-1496 tracheids /  $\text{mm}^2$ . Tangentially the tracheids have smaller and fewer pitting, radially larger, abietineous, bordered pits of 16-19  $\mu\text{m}$  in diameter, spaced or contiguous, opposite, on 1-3 vertical rows, usually with obvious *crassulae*, walls without spiral thickening. Parenchyma abundant, diffuse or as short tangential lines; horizontal end walls (of 1-3  $\mu\text{m}$ ), smooth, slightly rugose or weak nodular, with 1 (2) small nodules; resin content as large globules or dark remains, as a plugs or compact, but without filling the whole cell. Rays with pitted horizontal walls, uniseriate, rarely biseriate, high to very high, with round to elliptical cells determining intercellular lateral spaces; density - of 3-10 rays on tangential millimeter, homogeneous and homocellular with all procumbent cells of 20  $\mu\text{m}$  tall, marginals higher up to 40  $\mu\text{m}$ , with the horizontal walls thin, smooth and simple, tangential walls vertical or arcuate, thin and smooth (1-2  $\mu\text{m}$ ), rarely nodular, without indentures, outer wall of marginals slightly wavy; the cross fields have typical pitting of small taxodioid pits, 1-3 in horizontal or diagonal pairs; the marginal cross fields have 2-6 pits on two rows.

The comparison of our specimens with *Sequoioxylon* cf. *germanicum* Greguss, 1967 was unsatisfactory but it suggested similitudes with the other forms of *S. gypsaceum* described by Greguss (1967), in which the growth rings are distinct, even if not always, the resinous parenchyma has a tendency to appear terminally, the thin-walled variably-sized tracheids reaching sometimes 100  $\mu\text{m}$  in diameter, without spiral thickenings but with spaced pitting in 1-2-3 rows on both the walls and distinct *crassulae*, the rays of 2-18 cells in height, ray-cells with diameter of 13-15-20  $\mu\text{m}$ . Also the parenchyma has end (horizontal) smooth walls, sometimes simple pitting on vertical walls and granular content, the cross-fields ray-tracheid have 3-5 taxodioid pits arranged on 1-2 horizontal rows, and

sometimes transverse tracheids are present, details most similar with the extant species *Sequoia sempervirens* L.

Among the described forms of Greguss, our studied structures mostly resemble to *Sequoioxylon gypsaceum* no. 1 (Goepp.) Greguss, 1967. The same species described by Petrescu & Dragastan (1971) from the Oligocene at Sulsânești, is also xylotomically very close to our specimens.

Also, the species of *Taxodioxylon* described by Gottwald (1992) from the Eocene of Helmstedt, Germany, have some xylotomic details very similar to our specimens, although not always identical. It also must be reattributed to *Sequoioxylon* genus.

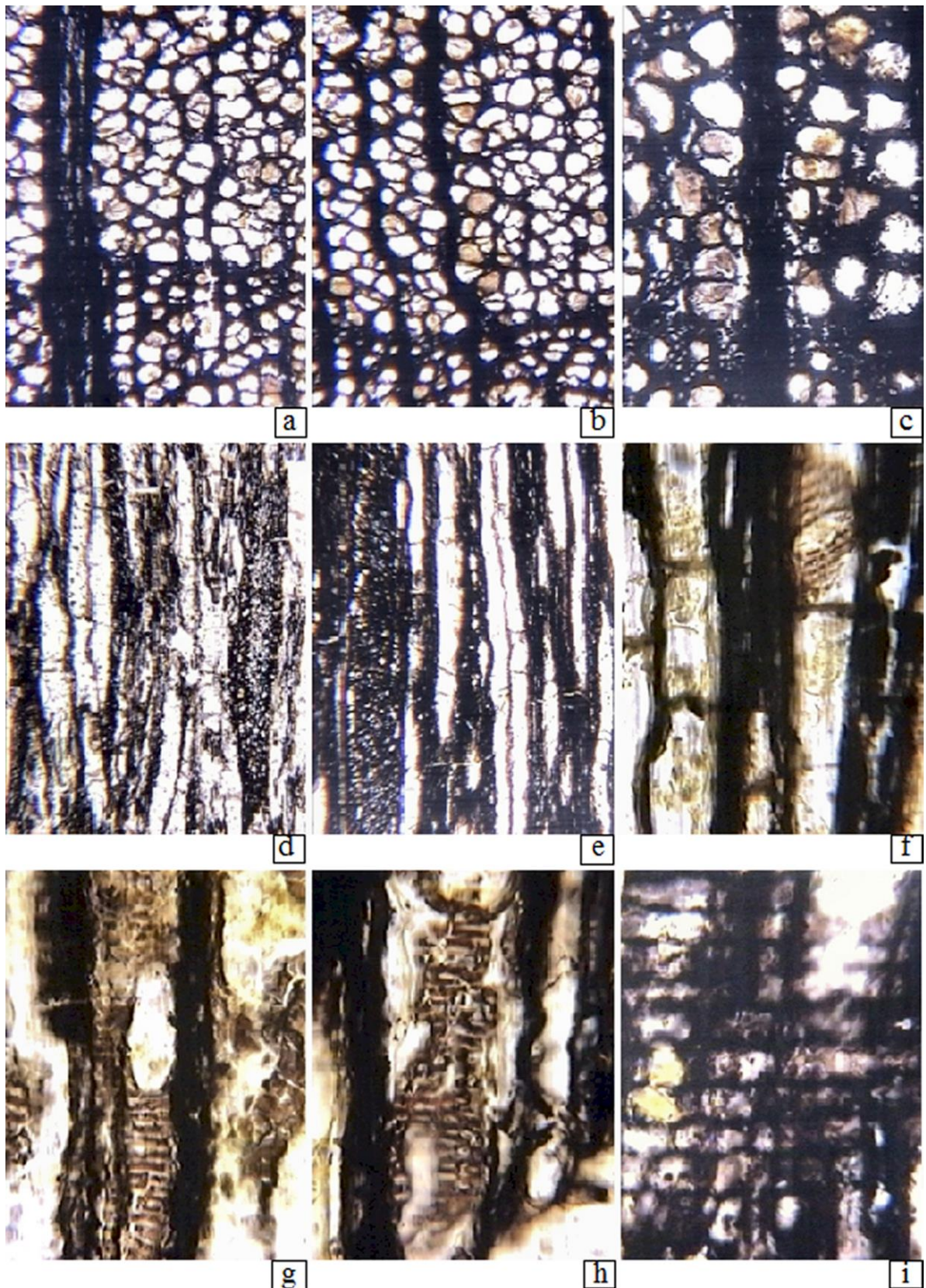
The here studied numerous specimens have sometimes traumatic resin ducts or traumatic tissue, with relatively abundant parenchyma, diffuse or short tangential lines, with 1-3 rows or bordered pits and obvious *crassulae* on the radial walls of the tracheids, with uniseriate rays, frequently with short biseriate storeys, ray cells with thin and smooth walls, the tangential ones slightly nodular, cross fields with 1-3 taxodioid pits in the ray body fields and 3-6 or more in the marginal fields, with axial parenchyma having resinous content as compact or granular masses or as round or oval globules, and the horizontal (end) walls smooth or rarely slightly nodular with 1(3) knots, allow us to assert that we are in front of a fossil of *Sequoia*, very similar to the structure of the species *Sequoioxylon gypsaceum* (Goepp.) Greguss, 1967.

This species is identical as description with *Taxodioxylon gypsaceum* (Goepp.) Kräusel, 1949, that after Privé-Gill (1977) has fairly diverse forms and has the extant correspondent in *Sequoia sempervirens* Endl. and was widely spread in the northern hemisphere (Eurasia and North America) during the Tertiary.

However the *Sequoioxylon* genus was created by Torrey (1923) on the basis of a traumatic wood (with secretory cysts). Greguss (1967) proposed the use of this genus for the structures that can be compared to the current *Sequoia* genus, characterized by the horizontal (end) walls of axial parenchyma perfectly smooth, rarely slightly thicker or rugose, or very weakly nodular, tracheidal radial pitting 1-3-seriate with obvious *crassulae*. The normal cross fields with 1-3 taxodioid or slightly podocarpoid or round pitting in horizontal row, lesser as vertical pairs, more numerous in marginal fields where they can appear on two horizontally, rarely alternating or slightly irregular rows. Studying numerous specimens Greguss (1967) attributed to this genus the species: *gypsaceum*, *medullare*, *podocarpoides* and *germanicum*, and many forms determined only generically, on a badly preserved material.

Roy & Stewart (1971) accepted this proposal as justifiable and have described *Sequoioxylon gypsaceum* from Cypress Hills Formation, Saskatchewan, Canada (Oligocene), however returning to the form of *Taxodioxylon gypsaceum* after some years (Ramanujam & Stewart, 1969) in Edmonton Formation, Alberta, Canada (Late Cretaceous), for which we propose its renaming as *Sequoioxylon gypsaceum*.

The genus name was used also by Nagy (1969), Petrescu & Popa (1971), and Petrescu (1978) for similar structures described in the Oligocene from Northwest Transylvania, Romania with *gypsaceum* and *giganteoides* species, the last one revising the taxon described by Huard (1967) as



**Fig. 11** *Fagoxylon subcaucasicum* Privé et Brousse, 1969. **a, b** - cross section: diffuse-porous wood, two sized rays, ray dilation at ring boundary - x50; **c** - cross-section: distinct ring boundary, diffuse porous structure - x100; **d, e** - tangential section: broad fusiform rays, vessels - x100; **f** - tangential section: badly preserved pitting - oval horizontal opposite pits to scalariform - x200; **g, h** - radial section: simple perforation, and scalariform pitting on vessels - x200; **i** - radial section: scalariform cross fields with vessels - x200.

equivalent to the extant species *Sequoia gigantea* Decaisne.

Other new species of *Sequoioxylon* described last years in the world as: *S. chemrylicum* Blokhina, 1997; *S. canadense* Blokhina et Nassichuk, 2000; *S. sachalinicum* Blokhina, 2004, *S. burejense* Blokhina, Afonin et Kodrul, 2010; *S. dimyense* Afonin, 2013, are quite similar with *S. gypsaceum*.

Otherwise, the species, *Sequoioxylon gypsaceum*, was described by us in the same area and in other Carpathian sites also (Iamandei et al., 2000b; 2004b; 2008a; 2012).

As a result of all these discussions, we attribute all the 48 here studied specimens to the species *Sequoioxylon gypsaceum* (Goeppert) Greguss, 1967.

*Sequoioxylon multiseriatum* Ramanujam et Stewart, 1969 nov. comb.

Fig. 9, photos a-i.

### Material

A sample of petrified wood was collected from Prăvăleni area, the Hoarna Tarnița brook, from Mid-Miocene volcano-sedimentary deposits (Late Badenian-Early Sarmatian), having whitish color with brown tents and centimetric size. It is silicified and displays a regular fibrous texture, and annual rings suggesting a conifer. Some fragments remained after oriented slides cut, are kept now in GIR collection at National Geological Museum - Bucharest under the inventory number 26359 (194 as field no.).

### Microscopic description

**Growth rings** distinct, variably sized (of 4-20 cells) but usually are low, their boundary is marked by 2-5(7) rows of thick-walled cells of late wood. The early wood is usually partially crushed. Normal axial resin ducts are absent.

**The tracheids** in cross section are polygonal rounded, without intercellular spaces. Between two successive rays there are 1-3-16 radial regular rows of tracheids, slightly alternately arranged. Their lumina have radial / tangential diameters of 40-80 / 28-60  $\mu\text{m}$ , smaller in the late wood: 4-8-20 / 20-28  $\mu\text{m}$ . Their wall thickness is of 6-8-11  $\mu\text{m}$  double wall, thicker in the late wood: 12-16  $\mu\text{m}$  double wall. The density is of 460-648 tracheids on  $\text{mm}^2$ . Tangential pitting is not distinct. Radially the bordered pitting of abietinean type, in 1-3 vertical rows, opposite, subopposite or slightly alternate, or even irregularly arranged, pits of 12-16-19  $\mu\text{m}$  the diameter and with round apertures of 5-7  $\mu\text{m}$ , and with crassulae. Sometimes brown flue resin content is present or as granular remains.

**The axial parenchyma** in cross section appear few, diffuse as round to elliptical cells smaller than the tracheids, and have relatively thin walls: 1-1.5  $\mu\text{m}$  simple wall, but it appears abundantly in the longitudinal sections, when it shows weak constrictions at the end (horizontal) wall level. The horizontal end wall is smooth and thin, having less than 1  $\mu\text{m}$ , sometimes weakly rugose. Inside cells appear resinous compact content or as globules, or plugs, or granular remains or sometimes no content but empty portions.

**The medullary rays** in cross section appear rectilinear usually uniseriate or even multiseriate more clear in the

tangential section when often appear 2-3-4-seriate rays and with fusiform aspect, made up of unequal sized cells, and have (1)2-8-12-20(54) cells in height or more. The shape of the ray cells is round elliptical, with 12-20  $\mu\text{m}$  in diameters and unpitted tangential walls. Ray density is of 3-5 rays / mm tangential. Radial they are homocellular, with cells all procumbent of 16-20  $\mu\text{m}$  in height, the marginals taller, of 20-24  $\mu\text{m}$ . The horizontal smooth walls have 4-4.5  $\mu\text{m}$  double wall, the tangential walls are thinner, of 1-1.2  $\mu\text{m}$  the simple wall are smooth, straight, vertical or inclined. The cross fields have 1-3(4) taxodioid pits to ooporoid, horizontally or diagonally arranged and similarly in the marginal fields. The pits have small round borders, or slightly oval of 5-6  $\mu\text{m}$  in diameter, with round apertures of 1-1.2  $\mu\text{m}$ .

### Affinities and discussions

The studied specimen has xybotomic characters very similar to those of the classic "taxodiaceous" woods, represented by tracheids with large cross-section (up to 80 / 60  $\mu\text{m}$  the radial / tangential diameters), radial pitting 1-3-seriate, with crassulae, axial parenchyma with horizontal walls thin and smooth (sometimes weakly nodular), rays with up to 20 cells in height or more, having straight and smooth tangential walls and cross fields with 1-4 taxodioid to ooporoid pits, characters that could suggest the resemblance of our specimen with the current species of the *Sequoia* genus.

However there is a very special character, better observable in the tangential sections: there are uni- and multiseriate rays (of 2-3-4 cells thick), made up of polygonal ray-cells of slightly uneven sizes. The height of this kind of fusiform rays ranges from 10 to 54 cells, they have frequent intercellular lateral spaces, usually are clustered and among them uniseriate rays frequently appear.

The description corresponds perfectly to the diagnosis and the figures are quite identical to that of the *Taxodioxylon multiseriatum* Ramanujam et Stewart, 1969, described on a fossil wood from the Maastrichtian of Edmonton, Alberta, Canada, a species found again by Ramanujam (1971) within the Late Cretaceous (Campanian, Oldman formation), in South Alberta. The authors point to the similarities with "taxodiaceous" structures, but especially with *Sequoia* wood type.

Following this critical analysis, we assigned our specimen to the species of Ramanujam & Stewart (1969) mentioned above, but since the predominant xybotomic characters indicate an almost perfect identity with *Sequoioxylon*, except for the presence of the multiseriate rays, which is a special character and we propose a new combination as name of the specimen studied by us: *Sequoioxylon multiseriatum* (Ramanujam et Stewart) nov. comb.

### Angiosperms - Dicots

Order **Saxifragales** Dumortier

Family **Altingiaceae** Lindley, 1846

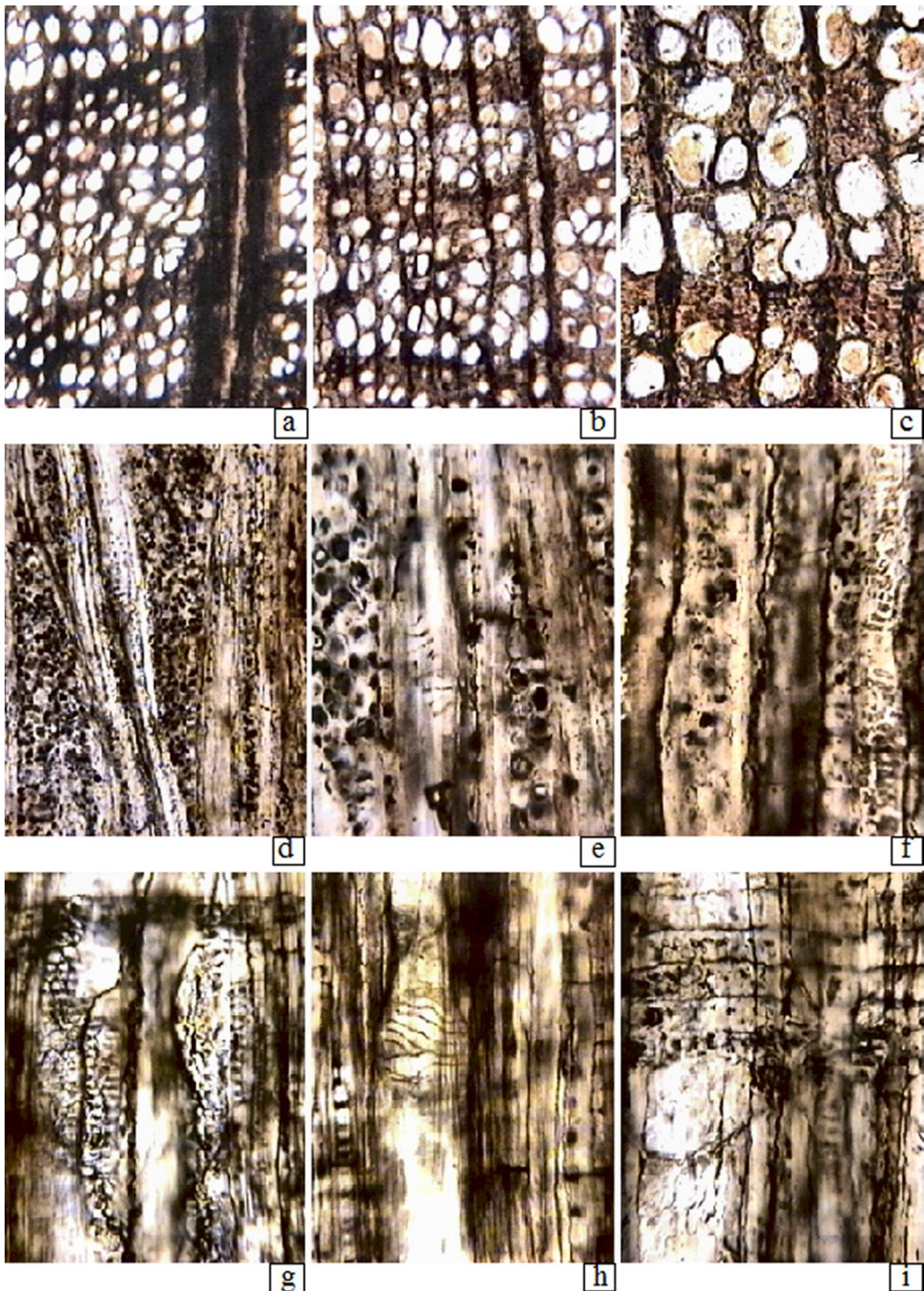
Genus **Liquidambaroxylon** Felix, 1884

*Liquidambaroxylon speciosum* Felix, 1884

Fig. 10, photos a-i

### Material

From a sample of petrified wood collected from Prăvăleni area, the right side of Hoarna Tarnița brook, to Cremenea



**Fig. 12** *Fagoxylon cristallophorum* van der Burgh, 1973. **a, b** - cross section: diffuse-porous wood, two sized rays, ray dilation at the distinct growth-ring boundary - x50; **c** - cross-section: vessels, fibres, rays - x100; Photo **d** - tangential section: broad fusiform rays, high, disected, vessels - x100; **e, f** - tangential section: fusiform broad rays, scalariform perforation (e), scalariform intervacular pitting (f) - x200; **g, h, i** - radial section: scalariform pitting on vessels (g), scalariform perforation (h), cross field with vessels (i) - x200.

Hill (field number 148) from Mid-Miocene volcano-sedimentary deposits (Late Badenian-Early Sarmatian). The sample come from a silicified trunk fragment and has beige-whitish color and centimetric size, and is kept now in GIR collection at National Geological Museum - Bucharest under the inventory number 26,296 (field number: 148). Under the magnifying glass fibrous structure, annual rings not very distinct, vessels and thick rays can be seen, typical for a dicotyledonate.

### Microscopic description

**The growth rings** of this secondary wood in diffuse porous, with less distinct, marked boundaries by the flattened fibers of the late wood slightly and slightly dilation of the rays.

**The vessels** - are usually solitary and in short multiples of 2-3 pores, radial, tangential or oblique radii, or as irregular groups of 3-4 vessels, usually radially extended by 1-3 wider fibrotracheids. The solitary pores are polygonal, rounded or oval, are thick-walled of 4-6 µm simple wall or 8-9 µm double wall. The radial / tangential diameters for the solitary pores are 50-80 / 40-65 µm. The density is 88-100 pores per mm<sup>2</sup>. The vessels have high scalariform perforations, with 10-14-16 fine bars, of 1-2 µm thick, relatively rare. The perforated plates are storied. The intervacular pits are bordered, oval opposite or horizontally elongated, to large scalariformes, of 11-16 µm long and 6.5 µm wide, and apertures of 8-11/1.5 µm. The vessels have numerous fine inclined spiral thickenings on the walls, not always very evident. The length of vascular elements is difficult to appreciate. Some vessels show large tyloses inside lumina.

**The axial parenchyma** - in cross section is apotracheally diffuse, few and paratracheal also few. In longitudinal view appears especially the paratracheal one, in vertical strands of 6-8-10 cells.

**The medullary rays** - in cross section seen consist of rectangular elongated cells, exhibit slight dilations at the boundaries of the growth rings, and have a relatively linear trajectory, sometimes touching vessels. Tangentially seen the rays are 1-2-3-seriate and have 14-25 cells in height. The ray cells have fairly thick walls (3.5-4 µm double wall), are round or slightly vertical oval, having 7-10 µm in diameters. The uniseriate endings have 1-3 cells which bear inside shriveled gum remains. The frequency is of 7-10 rays per tangential millimeter. The rays are heterocellular, constituted of cells usually procumbent in the body, with 8-12 µm in height and square or upright, having 16-24 up to 48 µm in height in the 1-3 marginal cell rows are. Sometimes, oval to scalariform pits irregularly arranged, or in 2-3 horizontal rows, on the marginal fields in 4-5 horizontal rows in 1-2 groups. Sometimes, solitary crystals and black gums are visible.

**The fibers** - have polygonal cross sections, thick walls: 8 µm the double wall and relatively wide round lumina, and do not seem septated or pitted.

### Affinities and discussions

The xylotomic characters presented by the studied here specimen are similar to those of representatives of the Altingiaceae Family (Watson & Dallwitz, 1992; Wheeler et al., 2010; APG IV, 2016) former Hamamelidaceae family (Metcalfe & Chalk, 1950; Greguss, 1959), a fami-

ly that has today ca. 28 genera with 90 species, living in temperate to tropical areas, mostly subtropical.

As fossil taxa the family includes the *Hamamelidoxylon* Lignier with 4 species described by Lignier (1907), Grambast-Fessard (1969), Greguss (1969) and van der Burgh (1973), from France, Hungary and the Netherlands, and *Liquidambaroxylon* created by Felix (1884), and a series of species and specimens were described later in Hungary, Romania, Germany by Greguss (1967, 1969), Nagy & Petrescu (1969), and van der Burgh (1973 respectively).

Here is the original diagnosis of the genus *Liquidambaroxylon* Felix, 1884, which has *L. speciosum* as type species: not too large but extremely numerous vessels, regularly distributed in narrower rings, with obvious decrease in size and number in the late wood, with scalariform perforations, thick-walled fibers, among them sporadically parenchyma and tracheids appear and large, heterogeneous rays, 1-3 seriate.

Thus, our specimen which exhibits fairly indistinct growth rings boundaries, solitary small vessels of 40-80 µm or in short radial multiples (in *Hamamelidoxylon* there are solitary or in pairs) and are very small (below 50 µm diameter). The vessels have storied scalariform perforations, with 10-16 bars (*Hamamelidoxylon* has usually higher ones, over 20 bars), bordered pitting to scalariform and spiral thickenings on vessels, rays 1-3-seriate, heterogeneous, consisting of cells with fairly thick walled, with 1-3 tall marginal cells, thick-walled fibers, fibrotracheids and few parenchyma.

Comparing the xylotomic characters of our specimen with those of some already described species of *Liquidambaroxylon* (Table 1), excluding *Liquidambaroxylon krausei* Greguss, 1969 which was redescribed as *Magnolioxylon* by van der Burgh (1973) we have seen that there is a great resemblance with our specimen with those of the species

*Liquidambaroxylon speciosum* Felix as described by Felix (1884), Greguss (1967, 1969), Nagy & Petrescu (1969) and van der Burgh (1973).

In view of the presence of the specific characters and their variation shown by the described fossil forms and attributed to the quoted species, which could be the fossil equivalent of the extant species *Liquidambar styraciflua* L., known as American Sweetgum living today in eastern North America and also eastern Mexico to Honduras, but most probably of *L. orientalis* L., known as Oriental Sweetgum or Turkish Sweetgum living today in the southwest Turkey, Greece, Rhodes and we believe that it is not wrong we attribute the studied specimen to this form species which, apparently, has dominated the European Tertiary. Therefore, the studied specimen is a *Liquidambaroxylon speciosum* Felix, 1884.

Order **Fagales** Engler

Family **Fagaceae** Dumortier, 1829

Subfamily **Fagoideae** K. Koch, 1873

Genus **Fagoxylon** Stopes et Fujii, 1911

*Fagoxylon subcaucasicum* Privé et Brousse, 1969

Fig. 11, photos a-i

Table 1. Comparative table of xylotomic characters of published *Liquidambaroxylon* species.

Species Characters	<i>Liquidambaroxylon weylandi</i> Greguss, 1969	<i>Liquidambaroxylon horvathi</i> Greguss, 1969	<i>Liquidambaroxylon magdefraui</i> Greguss, 1969	<i>Liquidambaroxylon styracyflua</i> Greguss, 1959, 1967	<i>Liquidambaroxylon speciosum</i> Felix, 1884, in Nagy & Petrescu, 1969; Greguss, 1969 and our studied specimen
Growth rings	less distinct	less distinct	less distinct	less distinct	less distinct
Vessels density	numerous	numerous	numerous	numerous, 63-73/mm <sup>2</sup>	very numerous (88-100/mm <sup>2</sup> )
solitary	present	present	present	present	present
multiples	2-3	2-3	2	2-3	2-3
shape	polygonal, oval	polygonal, oval	polygonal, oval	polygonal, oval	polygonal rounded to oval
size	60-70 µm	60-70 µm	40-50 µm	50-90 µm	50-60-80 µm
cellular wall	thick	thick	thick	thick	thick
perforations	scalariform	scalariform	scalariform, storied	scalariform	scalariform
plates	tilted	tilted	tilted	tilted	tilted
bars	18-30, fine, rare	12-20, fine, branched	35-40, thick, spaced	8-20(40), fine, branched	20-30-20, fine, branched
pitting	bordered, scalariform	bordered, scalariform	bordered, scalariform	bordered, scalariform	bordered, scalariform
apertures	coalescent	-	-	round to coalescent	round to coalescent
tyloses	-	-	present	present	present
Parenchyma apotracheal	diffuse	diffuse, terminal	diffuse, terminal	diffuse, and terminal	diffuse, and terminal
paratracheal	present	present	present	present	present
Rays thickness	1-3 seriate	2-3 seriate	2-3 seriate	1-3(4) seriate	1-3(4) seriate
height	15-40 cells	15-40 cells	35-40 cells	8-35-40 cells	4-20-25-39 cells
type	heterocellular	homo- to heterocellular	heterocellular	heterocellular	heterocellular
ray-cells	procumbent and 1-3 upright, thick-walled	procumbent, square and thickwalled	procumbent, square and 1-3 upright, thickwalled	procumbent, square and 1-3 upright, thickwalled	procumbent, square and 1-3 upright, thickwalled
cross field pitting	round, numerous	round, numerous	round, numerous	round to scalariform	round to scalariform
frequency	9-11 rays/mm <sup>2</sup>	9-11 rays/mm <sup>2</sup>	9-11 rays/mm <sup>2</sup>	9-11 rays/mm <sup>2</sup>	7-10 rays/mm <sup>2</sup>
secretory cells	?	?	?	obvious, lauraceous type	obvious, of lauraceous type
Fibres	thickwalled, scalariform pitted	thickwalled, scalariform pitted	thickwalled, scalariform pitted	thickwalled, scalariform pitted	thickwalled, scalariform pitted
Fibro-tracheids	scalariform pitting, 1-2 seriate	scalariform pitting, 1-2 seriate	scalariform pitting, 1-2 seriate	scalariform pitting, 1-2 seriate	scalariform pits, 1-2 seriate

## Material

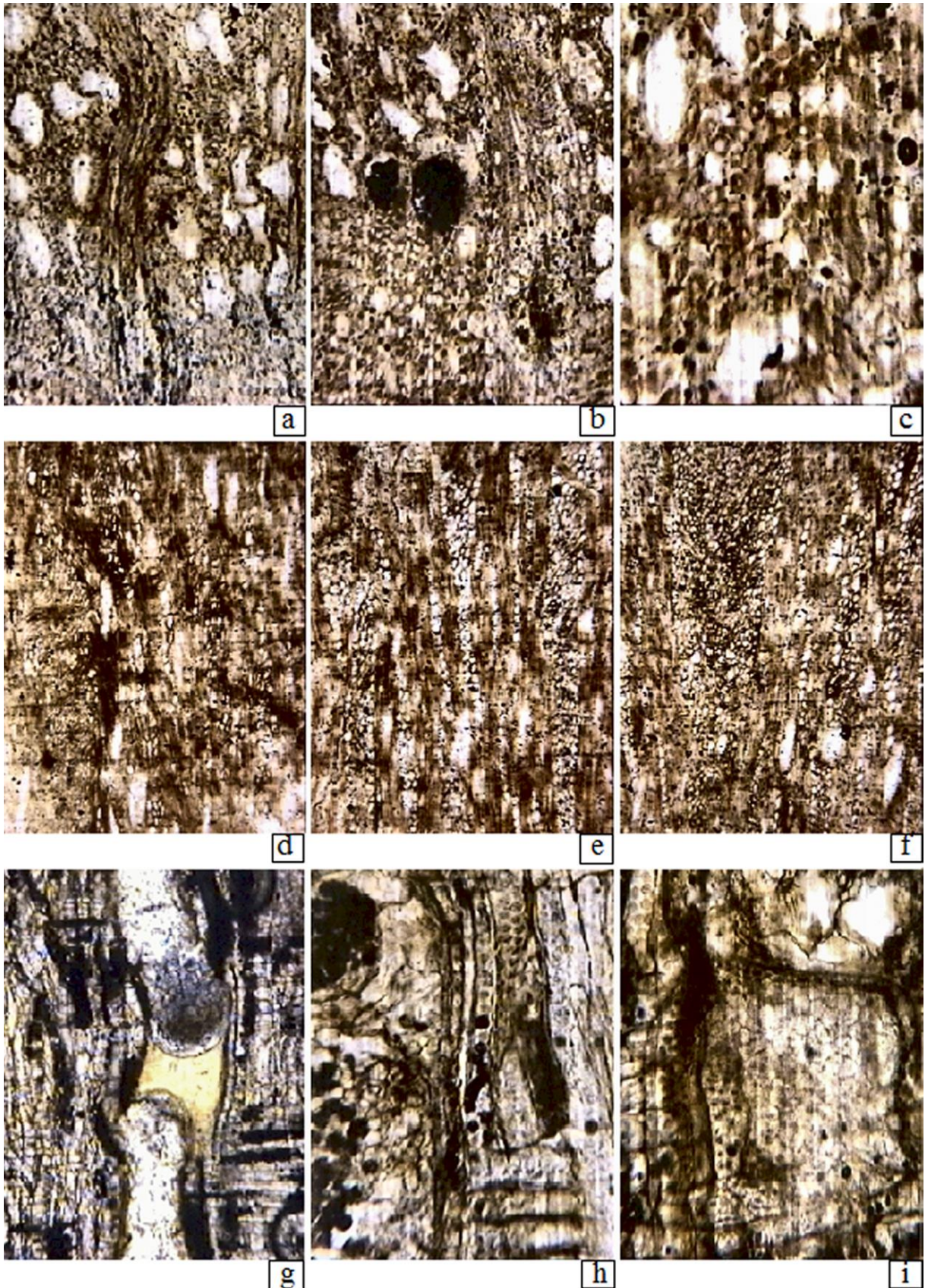
From nine samples of dispersed petrified wood collected from Prăvăleni area, at the confluence Bodişteanu brook, from the cliffs of the base of Cremenea hill from Middle Miocene volcano-sedimentary deposits (Late Badenian-Early Sarmatian). The samples represent quite friable silicified wood fragments of dark to black color and centimetric sizes, and are kept now in GIR collection at National Geological Museum - Bucharest under the inventory numbers 26,365; 26,366; 26,368; 26,471; 26,282; 26,371; 26,372; 26,376 and 26,378 (field numbers: 30; 31; 34; 42; 43; 44; 45; 55 and 59 respectively). Under the magnifying glass fibrous structure, annual rings distinct and thick rays appear, suggesting a dicotyledonate wood.

## Microscopic description

**The growth rings** - are distinct, with boundary marked by thicker walled and flattened fibers. The early wood begins abruptly, with large vessels, the wood is diffuse-

porous to semi-ring-porous, the diameter of the vessels gradually decreasing to the late wood. In the early wood predominate the groups generally radially oriented and in the late to final wood there are small, solitary pores. The rays show obvious "platanoid" dilations at the annual ring boundary. The histological elements seem to be obviously affected by the tafonomic processes, in which a probable initial wood charring is assumed, followed by silicification.

**The vessels** in the cross section are presented as solitary pores with oval-rounded or angular-rounded contour or star like, or in radial multiples of 2-5(8), or in irregular quasi-radial groups of 4-5(11) vessels, especially in early wood. In the late wood the vessels are slightly smaller, gradually decreasing and usually solitary, and the end zone of the growth ring is marked by fibers or parenchyma which seem to be arranged as terminal bands, the vessels being very small and rare or missing. The radial / tangential diameter of the vessel lumen is (13)25-60(84) / (8)20-58(76) µm. The density is quite variable, of 100-



**Fig. 13** *Quercoxylon sarmaticum* Starostin et Trelea, 1969. **a, b** - cross section: semi-ring-porous wood, two sized rays, ray dilation at the growth-ring boundary - x100; **c** - cross-section: usually solitary vessels, thick to very thick walled fibres - x200; **d, e, f** - tangential section: broad fusiform rays, high, dissected - x100; **g, h, i** - radial section: simple perforations (g, i), alternate pitting on vessels and on vascular tracheids pitted parenchyma (g, i), bad preserved cross-field (h, i) - x200.

284 pores per mm<sup>2</sup>, the vascular walls do not look too thick, they have a 4-6(8) µm double wall. Vertically, round to elliptical perforation can be seen but also scalariform, inclined, low, with 7-10-15 relatively thin bars sometimes bifurcated, and with numerous round to oval finely bordered pits, obviously passing to scalariform pits. They have circular or horizontal oval apertures to the horizontally elongated in the scalariform ones, having diameters of 3-5 / (5)8-13 up to 17-24 µm. Sometimes appear, intercalated among the horizontal scalariform pits, vertical elongated or triangular pits with relatively large apertures, breaking the order. The vessel lumina may exhibit yellow or black solid debris and also large tyloses moderately thick-walled (3-4 µm double walls) and slightly emaciated. Some vessels have isolated or grouped crystals. The length of the vascular elements is (160) 280-500 µm. In some cases, weak spiral thickenings can be seen.

**The axial parenchyma** is usually difficult to observe in cross sections, although it is present in longitudinal view as vertical strands of chambered cells with large solitary crystals. Frequently, strands of parenchyma cells devoid of crystals also appear.

**The medullary rays** - in cross section appear to be of two sizes: some finer, 1-5-seriate and some multiseriate, of 10-15 cells wide, usually with dark content in their cells. The rays have a relatively straight or slightly curved trajectory and show obvious dilation at the boundary of the growth rings. Sometimes, disjunctive aspect appear as tangential fissures of the thick rays, and is difficult to say if they are a consequence of fossilization processes or are formed during the life of the tree, although tubular processes between cells that kept alive the organ can be detected. Generally, however, the cellular structure of the rays in most of the studied samples, in particular those charred and silicified, is disorganized. In tangential view the multiseriate rays are thick (of 84-135 µm), and over 1 mm high. In the ray body, often large cells, either dark or bright-white colored, sometimes having polygonal or rounded crystals, locally outline the thick rays as incomplete cell-sheath. The thinner rays are usually low, but can have up to 30 cells in height. Ray frequency is 4-8 rays per horizontal tangential mm. Radially with tendency to heterocellular, the rays have up to 4 rows of marginal procumbent to square cells occur, slightly higher than the regular ones, rarely tall cells, of 17-22 µm. The body ray-cells are moderately thick walled and are usually narrow, procumbent, and of 8-16 µm tall in the multiseriate rays, but sometimes mixed with square cells empty or with solitary crystals or small crystals or sand of crystals, transparent, floating in a dark content. Some other cells have only yellow-orange content. The uniseriate rays have taller cells, of 18-24 µm. So, we can speak of weak tendency of heterogeneity in the ray architecture, which is however relatively homogeneous. The cross fields have small, opposite, round to oval bordered pits or elongated to scalariform, especially in the marginal fields, with diameters of 3.5-5/5-10 µm, arranged on (1)2(3) horizontal rows.

**The fibers** are sometimes difficult to observe when the structure is crushed among numerous vessels, especially in early wood, but occurs in large quantities to late wood, where the vessels are smaller, rare, or even missing. The

fibers have a polygonal cross section, usually rectangular, relatively large lumina and thick walls. In the longitudinal sections are usually difficult to observe, because they are crushed and sometimes have a black, compact content, horizontal cracks, difficult to interpret them as parenchyma or fibers.

#### Affinities and discussion

The semi-ring-porous wood, the aspect and size of vessels in cross-section, the intervacular bordered opposite pitting with pits oval-elongated to scalariform, the vessels with simple and scalariform perforations and the presence of two sized rays with dilations at the ring boundary, are good xylotomic arguments to consider that the studied sample might come from a member of the Fagaceae family (in Watson & Dallwitz, 1992). Among the current fagaceous taxa, most affinities were found to be with the genus *Fagus*, the species *F. sylvatica* L. and *F. orientalis* Lipsky whose current living area comprises western and central Europe respectively meridional-oriental Europe, Turkey, Caucasus and Iran area (see Metcalfe & Chalk, 1950; Greguss, 1959; Privé-Gill & Watelet, 1980; Schweingruber, 1990).

The correspondent fossil genus *Fagoxylon* was established by Stopes & Fujii (1911), revised Süss (1986), having *F. hokkaidense* (Stopes & Fujii) Süss, 1986 as type species and has the next diagnosis: Wood structure with wide growth rings, with clearly defined early and late wood, less obvious in root wood, usually with solitary vessels and in radial short multiples or otherwise grouped, regularly distributed within the growth ring, with a mean radial / tangential diameters of 50-90 / 35-60 µm (smaller in branches, of 30-40 / 20-25 µm), density is 70-300 vessels per mm<sup>2</sup> (for branches - up to 600). Spiral thickenings on the ends of the vessels often appear, simple perforations and scalariform with 1-30 bars, intervacular pitting opposite to scalariform, pitted fibers, irregularly arranged or radial rows (in roots and branches appear fewer). Diffuse apotracheal parenchyma, in short uniseriate bands and few paratracheal. Two sized rays either very tall and thick, of 20 or more cells wide (in roots and branches there are no more than 15), but also thinner, of 1-7 cell in thickness, with dilation at the boundary of growth ring, homogeneous to slightly heterogeneous, ray cells of 12-20 µm average diameter, with half-bordered pitting to vessels usually horizontally elongated to scalariform, opposite or irregular. Idioblasts with crystals sometimes present in rays.

Süss (1986) made a revision of the species of *Fagoxylon* previously described and described two new species, the list of the valid species is the following:

- *Fagoxylon acerinum* (Windisch) Süss, 1986;
- *F. caucasicum* (Felix) Süss, 1986;
- *F. subcaucasicum* Privé et Brousse, 1969; Privé-Gill & Watelet, 1980;
- *F. crystallophorum* van der Burgh, 1973;
- *F. francofurtense* (Mädler) Süss et Müller-Stoll, 1984;
- *F. grandiporosum* (Beyer) Süss, 1986;
- *F. hokkaidense* (Stopes & Fujii) Süss, 1986;
- *F. hondoense* (Watari) Süss, 1986;
- *F. krauselii* Hofmann (see Hofmann, 1952);
- *F. mikofalvense* Süss, 1986;
- *F. radiatum* Süss, 1986.

Generically are also considered to be well attributed some other specimens studied by Slijper, Shimakura and Andreanszky (Süss, 1986), but many species of *Fegonium* (or *Phegonium*) described by various authors (see again Süss, 1986) and also *Fagoxylon australe* Salard, 1961 - are not considered valid. In fact, the confusion was based on the fact that *Plataninium* Unger, 1842 was a too comprehensive taxon according to the diagnosis emended by Page (1968), who included fossil wood specimens from Fagaceae (*Fagus*), Platanaceae (*Platanus*), Eupteleaceae (*Euptelea*) and Icacinaceae (*Citronella*, *Ottoschultzia*), whose family relationships can not be definitely determined, but which have similar xylotomic characters (see Süss & Müller-Stoll, 1977 and Selmeier, 1996). Of these, *Plataninium aceroides* (Goepfert) Windisch, 1886 and *Plataninium* sp. (in Edwards, 1931) became *Fagoxylon acerinum* (Windisch) Süss 1986, and other valid species remained *nomen ambiguum* until a revision of the original material. In the spirit of the principles and rules of botanical nomenclature (ICBN, 1999) we believe that the invalidation of the name *Plataninium* proposed by Süss & Müller-Stoll (1977) must remain valid.

The characters taken into account by Süss (1986) in identifying *Fagoxylon* species are the following: the distribution of vessels and fibers in the cross section, the variation in size of the vessels within the growth ring and the height of the ray cells. Using the model of the cited author, we have completed the data of the material studied by us, in the Table 2:

From this table it is obvious that the specified species slightly differ of our studied material regarding the ray-cells size, the disposition of the vessels in the growth ring, and the comparison of all the described aspects of these species do not conform to those presented by the material studied by us here.

However, there is a similarity up to the identity of the figurative aspects described in our specimens with those described by Privé & Brousse (1969) from Bastide-du-Fau, found again at the same level, at Aubart (Cantal Massif), from late Miocen (Privé-Gill & Watelet, 1980). This similarity suggested us to attribute the here studied material to the species *Fagoxylon subcaucasicum* Privé et Brousse, 1969, initially considered a fossil correspondent of the extant European *Fagus sylvatica* L. even if xylotomically this fossil species has a structure mostly similar to *F. orientalis* Lipsky (Privé-Gill & Watelet, 1980), both living yet today in the Romania.

The comparative approach, in order to identify the correct taxonomy of the studied material, forced us to reconsider the determination of sample 43 (Inv. No. 26,282) which was originally published as *Platanoxylon bohemicum* Prakash, Březinová et Bůžek, 1971 (see Iamandei & Iamandei, 1997). In fact, Süss & Müller-Stoll (1977, p. 57) have invalidated this species, considering that it does not have the characters of a plane wood. The xylotomic characters of the specimens studied here are almost identical, including those of specimen 43, all representing *Fagoxylon subcaucasicum* Privé et Brousse, 1969.

Table 2. Comparative table of essential xylotomic characters of *Fagoxylon* species (after Süss, 1986).

<i>Fagoxylon</i>	Ray cells height multi-seriate rays $\mu\text{m}$	Ray cells height uniseriate rays $\mu\text{m}$	Marginal ray cells height $\mu\text{m}$	Big vessels in the early wood +/-	Big vessels in the late wood +/-	Fibers arrangement
<i>acerinum</i>	12	17	30	-	+	irregular
<i>caucasicum</i>	20	30	45	-	-	irregular
<i>mikofalvense</i>	16	17	25	+	-	irregular
<i>radiatum</i>	16	16	28	+	-	radial rows
<i>francofurtense</i>	16	?	>16	+	-	radial rows
<i>crystallophorum</i>	18	?	>18	+	-	~ irregular
<i>subcaucasicum</i>	10-35	rare	?	+	-	radial rows
Specimens: 30, 31, 34, 42, 43, 44, 45, 55, 59	8-16	18-24	17-22	+	-	radial rows
Specimens: 36, 56, 71, 72, 104, 239, 434, 444, 599, 675	8-16-18	16-20-25	20-25(28)	+	-	~irregular

*Fagoxylon cristallophorum* van der Burgh, 1973  
Fig. 12, photos a-i

**Material**

From eleven samples of dispersed petrified wood some of them collected from Prăvăleni area, the left side of Bodișteanu brook from the cliffs of the base of Cremenea hill (field numbers: 36; 56; 71; 72) and from Ociu village area (104 and 599 on Marinașu valley; 239 in Ociu; 434; 444; 736 on Church brook and 675 on North Ociu brook) from Mid-Miocene volcano-sedimentary deposits (Late Badenian-Early Sarmatian).

The samples represent silicified wood fragments of gray to whitish color or beige to brown and of centimetric sizes, and are kept now in GIR collection at National Geological Museum - Bucharest under the inventory numbers 26,355; 26,377; 26,379; 26,380; 26,391; 26,404; 26,413; 26,414; 26,425; 26,432 and 26,445 (field numbers: 36; 56; 71; 72; 104; 239; 434; 444; 599; 675 and 736 respectively).

Under the magnifying glass fibrous structure, annual rings few distinct, vessels and thick rays can be seen, suggesting dicotyledonate wood.

### Microscopic description

**The growth rings** are distinct, with the boundary marked by some rows of very thick-walled fibers, devoid of vessels. The early wood begins abruptly with large vessels, the wood is semi-ring-porous, the diameter of the vessels gradually decreasing to the late wood. In the early wood prevails the solitary pores. The rays show obvious "platanoïd" dilations at the limit of the annual rings.

**The vessels** appears in cross section as solitary pores, prevailing in the early wood, with oval-rounded or angular-rounded contour to fairly star like, with corrugated walls, or in small radial or tangential multiples of 2-3(4) pores or as irregular groups, especially in early wood. To the late wood, the vessels are slightly smaller, gradually decreasing and are usually solitary, and to the final wood become smaller or are rare or missing. The radial / tangential lumina diameters of the vessels are of 24-65(125) / 20-60(90)  $\mu\text{m}$ . Their density is 100-140(184) pores per  $\text{mm}^2$ . The vascular walls are fairly thick, having 4-7  $\mu\text{m}$  double wall (2.5-4  $\mu\text{m}$  simple wall). The vessels have round to elliptical simple perforations but also scalariform, inclined, usually low, with 7-12(17) relatively thin bars, sometimes with rare bifurcations, and pitting numerous, opposed, rounded to oval with thin borders and evident tendency to scalariform. They have circular or oval apertures horizontally elongated to scalariform (3.5-5 / 4-8  $\mu\text{m}$ ). The length of the vascular elements is 260-330  $\mu\text{m}$ . In some cases, weak spiral thickenings on the walls can be seen. The lumen of the vessels may show solid black granules or crystals, isolated or clustered, and sometimes large tyloses appear, visible even in cross sections.

**Vascular tracheids** are present, more visible in the longitudinal sections, close to the vessels, with large-round or elliptical-horizontal pits to scalariformes, on a single vertical row similar to those on the walls of the vessels.

**The axial parenchyma** - in cross section appear as obvious apotracheal, either diffuse as rare solitary cells among fibers, or as short tangential lines slightly waved, with polygonally-rounded cells or slightly deformed, larger than the very thick-walled fibers from around and have 11-15(18)  $\mu\text{m}$  in diameter. They appear also in the final wood and are visible in the longitudinal sections as obvious strands of chambered crystalliferous cells. Frequently strands of 6-8 unchambered non-crystalliferous cells appear. Paratracheal parenchyma is very few and difficult to observe.

**The medullary rays** - in cross section are two-sized and have a linear or slightly curved trajectory, and show obvious dilations at the boundaries of the growth rings. The two sized rays are: fine rays, 1-5-seriate, and thick rays, 10-17-seriate. The multiseriate rays have up to 200  $\mu\text{m}$  wide and over 1 mm in height. The ray cells usually have the horizontal diameter of 10-18  $\mu\text{m}$ , but frequently in the ray body appear wider, often with dark or bright-white content, and with white or black polygonal, slightly rounded, crystals. Their uniseriate endings have 1-5 higher cells, somewhat similar to the uniseriate rays. Frequently, the rays are dissected by fibers or do not end fusiform but round, and in the cross section give strange aspects, probably caused by the cells exposure in other positions. Thinner rays are relatively low and can have up to 30 cells in the height. The ray frequency is 4-12 rays

per horizontal tangential mm. Radially the 1-5 rows of marginal procumbent cells are slightly higher than the ordinary ones, or square or even upright 18-25(28)  $\mu\text{m}$ . The ray-body cells are usually procumbent, of 8-16-17  $\mu\text{m}$  tall in the multiseriate rays, sometimes mixed with cells almost square of the same height and are empty or with solitary crystals. The normal thick-walled cells usually have dark content, and visible crystals. The similar crystalliferous cells of marginal rows appear to be hypertrophied. The uniseriate rays usually have higher normal cells of 16-20-25  $\mu\text{m}$ . The rays are relatively homogeneous and homocellular, with tendencies of heterogeneity. The cross-fields of rays with vessels show opposite half-bordered small pits, quasi-rectangular, rounded, elongated up to scalariform, with diameters of 3-4 / 3.5-8  $\mu\text{m}$ , on 1-2 (3) horizontal rows arranged.

**The fibers** in the cross section are slightly irregular arranged. They are polygonal, with a diameter of 8-10  $\mu\text{m}$ , have very thick walls with very small, circular punctuation. On the vertical walls there are 3-5  $\mu\text{m}$  small dots, vertically contiguous, sometimes difficult to observe.

### Affinities and discussions

Not repeating the discussion of the precedent identified taxon, we must however show that the xybotomical details regarding the aspect and distribution of vessels, type and aspect of perforations, simple and/or scalariform, finely bordered pitting and the two sized rays observed in all these elven specimens studied here obviously fit with those of Fagaceae family, especially of *Fagus* L., sending to the fossil correspondent genus *Fagoxylon* (Stopes et Fujii) Süss, 1986.

Süss (1986) revised and confirmed the validity of 11 species described until the date of the revision which are the following: *Fagoxylon acerinum* (Windisch) Süss, 1986; *F. caucasicum* (Felix) Süss, 1986; *F. subcaucasicum* Privé et Brousse, 1969, found again by Privé-Gill et Watelet (1980); *F. crystallophorum* van der Burgh, 1973; *F. francofurtense* (Mädler) Süss et Müller-Stoll, 1984; *F. grandiporosum* (Beyer) Süss, 1986; *F. hokkaidense* (Stopes et Fujii) Süss, 1986; *F. hondoense* (Watari) Süss, 1986; *F. kraeuselii* Hofmann, 1948; *F. mikofalvense* Süss, 1986; and *F. radiatum* Süss, 1986.

Thus, the xybotomic characters of our studied specimens compared with those of the cited species are the next: obvious growth rings; typically solitary vessels and short radial multiples or grouped, radial / tangential diameter of 50-90 / 35-60  $\mu\text{m}$ , density of 70-300 vessels per  $\text{mm}^2$ , simple perforations and scalariform with 1-30 bars, intervascular pitting opposite to scalariform, parenchyma diffuse or in short line, two-sized rays: thin of 1-2 cells and thick of 10-17 cells, ray dilation at ring limit, homogeneity with tendency to heterogeneity, cross fields with half-bordered elongated to horizontal, opposite or slightly irregular scalariform, sometimes idioblasts with crystals present in rays, pitted fibers, irregularly arranged, or radial rows.

The comparison with the valid species of the *Fagoxylon* genus described (see Süss, 1986) showed similarity up to identity with the species *F. crystallophorum* van der Burgh, 1973, although when it was described this species, the author (van der Burgh, 1973), did not give a species diagnosis, considering the very good description, accom-

panied by the correct figuration (drawing, photomicrographs) quite suitable for comparative study. Thus, the semi-ring-porous wood described by the cited author presents solitary vessels or in irregular or ordered groups in tangential or radial thin rows, thick walled vessels with perforations simple and scalariform, sometimes reticulated, and rounded to elliptic pitting to scalariform, sometimes irregularly arranged, tracheids accompanying vessels, parenchyma paratracheal, diffuse and in tangential uniseriate bands, having a cell diameter of 15-17  $\mu\text{m}$ , or more, two-sized rays, slightly heterogeneous, with hypertrophied ray cells bearing solitary crystals and cells with very thick and pitted walls, aspects also found in our studied specimens. It is true that we have not reticulated perforations, but this is a more special character that probably does not have a very high incidence in the wood architecture.

From the table with biometric characters comparison (Table 2), also results a high similitude with the species *Fagoxylon crystallophorum* van der Burgh, 1973 which determined us to attribute the here studied specimens to this species specifying that, in the cross sections, the appearance and layout of vessels, fibers, and parenchyma are identical to those given by Schweigruber (1990) for *Fagus orientalis* Lipsky even though in the longitudinal sections the differences do not appear to be too high of *F. sylvatica* L. species, as is also reported by Privé-Gill & Watelet (1980, p. 138). Thus, the studied material, consisting of 11 samples, is identified as *Fagoxylon crystallophorum* van der Burgh, 1973.

Subfamily **Quercoidae** Ærsted, 1866

Genus **Quercoxylon** (Kräusel) Gros, 1988

*Quercoxylon sarmaticum* Starostin et Trelea, 1969

Fig. 13, photos a-i.

### Material

From two samples of dispersed petrified wood, the first collected from Prăvăleni area, the left side of Bodișteanu brook toward Cremenea hill and the second from Ociu village, on Church brook, from Mid-Miocene volcano-sedimentary deposits (Late Badenian-Early Sarmatian). The centimetric sized samples represent silicified wood fragments of beige color with whitish patches or gray, and are kept now in GIR collection at National Geological Museum - Bucharest under the inventory numbers 26381 and 26408 (field numbers: 79 and 282 respectively). Under the magnifying glass fibrous structure, annual rings distinct with visible large vessels and thick rays are visible, suggesting a dicotyledonate wood.

### Microscopic description

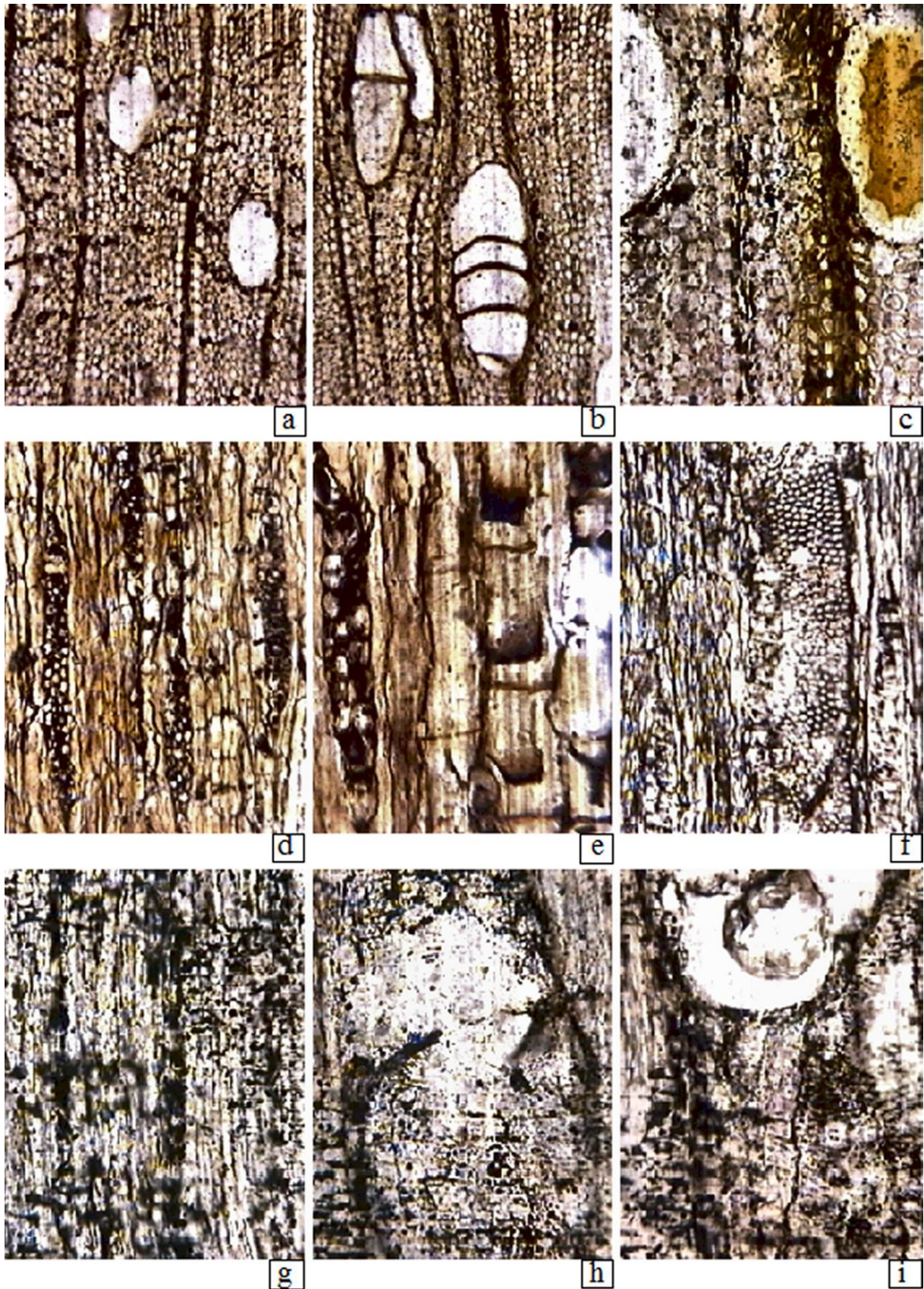
**The growth rings** are distinct, the boundary is marked by the debut of the early wood with very large vessels, solitary or in small radial multiples, which reach in the late wood to very small size that they can be confused with fundamental elements, and usually appearing as irregular groups. The structure of the wood is ring-porous, the transition from the large vessels to the narrow ones of the transitional wood is abrupt. In a specimen (no. 79) a branch trace that locally disturbs the structure can be seen.

**The vessels** in the cross sections appear usually solitary, or in small multiples of 2(3) big vessels in the early wood, and solitary or radial multiples of 2-3 in the late wood or as irregular groups, sometimes with tangential development, of 2-5 or more small vessels mixed with vascular tracheids. The large solitary pores of the early wood are oval, sometimes deformed and radially elongated, rarely circular. The smaller vessels of late wood are fairly uniform in size and are usually polygonal or slightly rounded to oval. Locally aspects suggesting a gradual decrease of the size of the vessels can be observed, but, globally appreciated, the structure has a typical ring-porous character. The vessel's walls are moderately thick, having 3-5  $\mu\text{m}$  double wall. The lumen of the solitary pores has radial / tangential diameters (80)120-280(335) / (60)90-170  $\mu\text{m}$  (even lower in the specimen 79, probably representing a branch fragment), and the late wood vessels have 35-64 / (20)32-64  $\mu\text{m}$ . The vessel density is very variable in the early woods, there are interradian fascicles devoid of large vessels, but in the late wood, the vessel frequency is higher. In the longitudinal sections it is evident that the vessels have simple perforations on relatively inclined plates and intervascular bordered pitting, pits of 3-3.5 / 3.5-4  $\mu\text{m}$  diameters, opposite, subopposite to alternate, numerous and relatively spaced, and with horizontal elliptical apertures of 1-2  $\mu\text{m}$ . The pits to the ray cells are similar. The length of the vascular elements, difficult to measure, seems to be variable, of 80-450  $\mu\text{m}$ . Inside the vessels tyloses with recrystallised silica can be seen, and sometimes a dark content.

**The vascular tracheids** are very common, having similar pitting to the intervascular one, with pits rounded, or horizontal elliptical, spaced arranged in 1-3 vertical rows, with a diameter of 4-5  $\mu\text{m}$  and large apertures of 3.5-4  $\mu\text{m}$ .

**The axial parenchyma** - in cross section appear diffuse of apotracheal type, often difficult to observe, mixed between vascular tracheids, together constituting thick bands in early wood, but thinner, 1-2 seriate in the late wood. The parenchyma cells have of 16-20  $\mu\text{m}$  in diameters, and generally have a dark content. Sometimes some parenchyma cells touch the vessels. In the longitudinal sections the parenchyma appear in strands of over 8 rectangular vertical cells with small, simple pitted, usually chambered and with large solitary crystals or small crystals and gum remains.

**The medullary rays** - in cross section seen have a wavy trajectory and are clearly two-sized. In tangential view they are either slender, numerous, 1(2-4)-seriate and of 6-16 cells tall. The ray-cells are rounded to oval, of 8-16  $\mu\text{m}$  in diameter. The multiseriate rays have 7-17 or more cells thickness (i.e. 80-380  $\mu\text{m}$ ) and are higher than 1 mm, vertically counting 94-115 or more rounded or polygonally shaped cells, relatively uneven in size (9.5-13-20 / 12-20  $\mu\text{m}$ ) and with relatively not too thin walls (3-5  $\mu\text{m}$  double wall). The frequency is 4-10 rays per tangential mm, the multiseriate rays are compact or composite, are rare and at relatively uniform distances in structure. In radial view the rays are homocellular, with cells all procumbent. In the cross fields with vessels numerous small bordered pits of 2-4  $\mu\text{m}$ , spaced, sometimes indistinctly bordered or simple, rounded or oval, in 1-2 horizontal rows arranged, usually badly preserved. The ray cells are



**Fig. 14** *Paraphyllanthoxylon botarii* sp. nov. a, b - cross section: semi-ring-porous wood, solitary and grouped vessels, 1-3-seriate rays, parenchyma as short tangential lines - x50; c - cross-section: solitary vessels, thick-walled fibres - x100; d-f - tangential section: 2-3-seriate fusiform, parenchyma, septate fibers, alternate, numerous intervascular pitting - x100; g, h, i - radial section: simple perforations, cross-fields with numerous simple pitting - x200.

frequently crystalliferous and sometimes the crystals are slightly rounded.

**The fibers** - have a polygonal cross section with a fairly wide lumen of 8-13 µm in diameter and are moderately thick walled, of 4-5 µm double wall. Vertically are unsepted and unpitted.

**Affinities and discussions**

The appearance of the cross sections of the studied specimens is somewhat typical for the Fagaceae family in general (the wood with the ring-porous structure), and the presence of two sized rays, multi-seriate rays and numerous slender rays, especially uniseriate, and the aspects and the arrangement of the large vessels in the early wood and of the small vessels of the late wood are typical of quercineous taxa, especially for the genus *Quercus* L. Shimanji (1962) made a comparative synthesis (Table 3) of the essential xylotomic characters of the extant fagaceous taxa, based on the anatomical studies on phylogenetic relationships between the genera *Fagaceae* (in Suzuki & Ohba, 1991):

According to Hadziev & Mädler (1962) xylotomically there are four types of oak wood:

- Type "White oak" (Weisseichen) - the majority of the species of *Lepidobalanus* Endl. sectio, having ring-porous structure, polygonal vessels in the late wood, small and thin-walled;

- Type "Red oak" (Roteichen) - the species of *Erytrobalanus* Schwarz sectio and some species of *Lepidobalanoideae* - with ring-porous structure, round late-wood vessels, large and thick-walled;

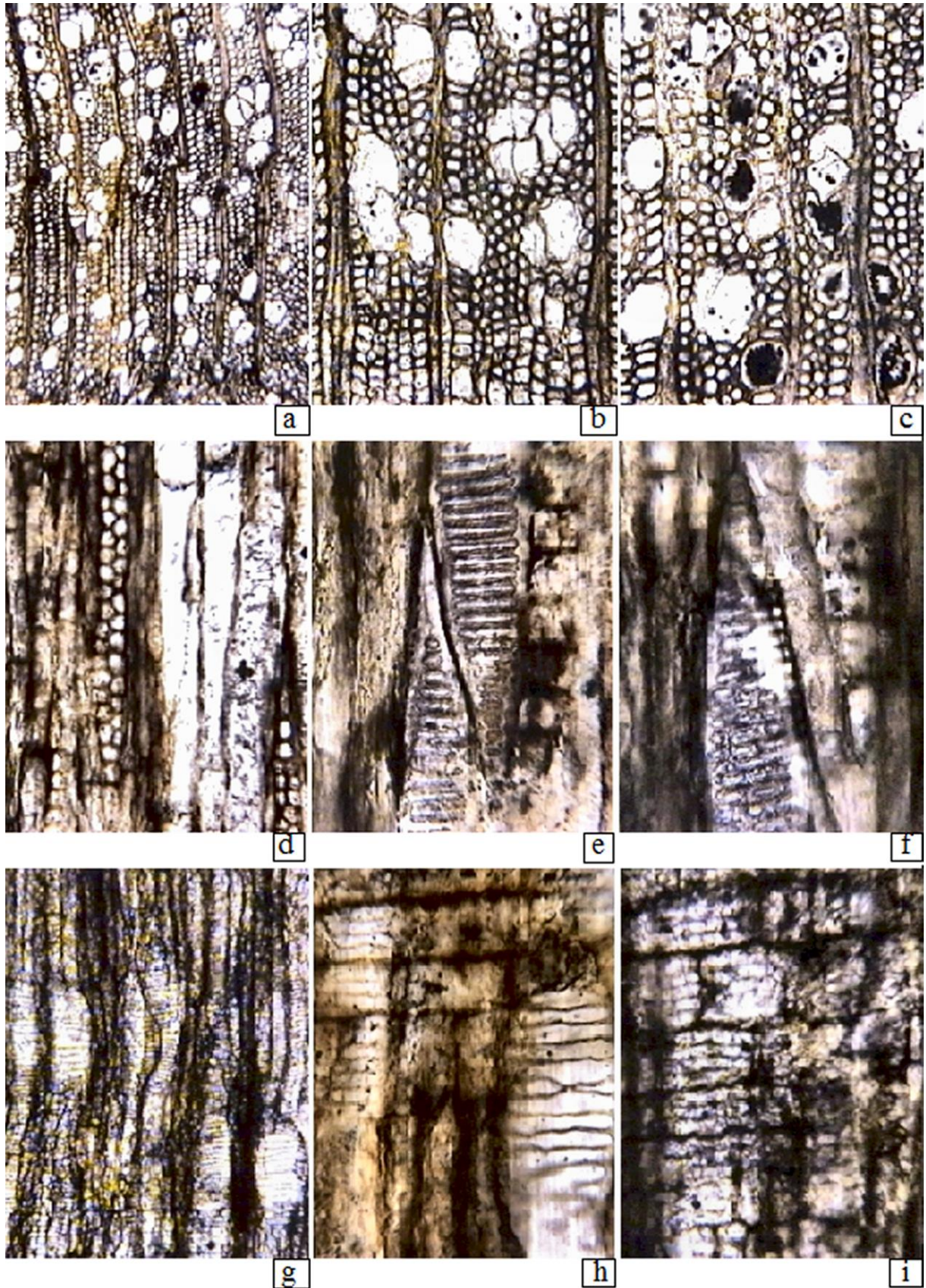
- Type "evergreen oak" - species of *Quercus* and *Lithocarpus* with diffuse-porous or semi-ring-porous structure, relatively small and rare vessels, most often radially arranged;

- Type "root wood oak" - corresponding to all the other wood types having diffuse-porous structure, with crowded large pores.

In the same idea, Privé (1975) stated: the oak wood is characterized by vessels arranged in radial rows, more or less anastomosed (i.e. dendritic distribution), having simple perforations, two-sized rays, very thick, multiseriate,

Table 3. Comparative table of essential xylotomic characters of *Quercus* types (after Suzuki & Ohba, 1991).

Genus	Subgenus	Section	Pores' arrangement (cross-section)	Pores' aspect in late wood (cross-section)	Scalariform perforations	The thick rays	Wood type
<i>Quercus</i>	<i>Cyclobalanopsis</i>		Radial	Round, thick-walled	absent	composed (+aggregated)	Evergreen oak
<i>Quercus</i>	<i>Erytrobalanus</i>	<i>Stenocarpaea</i>	Radial	Round, thick-walled	absent	aggregated (+composed)	Evergreen oak
<i>Quercus</i>	<i>Erytrobalanus</i>	<i>Phellos</i>	Ring	Round, thick-walled	absent	composed	Red oak
<i>Quercus</i>	<i>Erytrobalanus</i>	<i>Nigrae</i>	Ring	Round, thick-walled	absent	composed	Red oak
<i>Quercus</i>	<i>Erytrobalanus</i>	<i>Rubrae</i>	Ring	Round, thick-walled	absent	composed	Red oak
<i>Quercus</i>	<i>Quercus</i>	<i>Suber</i>	Radial	Round, thick-walled	absent	aggregated (+composed)	Evergreen oak
<i>Quercus</i>	<i>Quercus</i>	<i>Ilex</i>	Radial	Round, thick-walled	absent	aggregated (+composed)	Evergreen oak
<i>Quercus</i>	<i>Quercus</i>	<i>Aegilops</i>	Ring	Round, thick-walled	absent	composed	White oak
<i>Quercus</i>	<i>Quercus</i>	<i>Galifera</i>	Ring	Angular, thinwalled	absent	composed	White oak
<i>Quercus</i>	<i>Quercus</i>	<i>Quercus</i>	Ring	Angular, thinwalled	absent	composed	White oak
<i>Quercus</i>	<i>Quercus</i>	<i>Prinus</i>	Ring	Angular, thinwalled	absent	composed	White oak
<i>Lithocarpus</i>		Type A	Radial	Round, thick-walled	absent	aggregated (+composed)	Evergreen oak
<i>Lithocarpus</i>		Type B	Ring	Angular, thinwalled	rare	aggregated (+composed)	<i>Castanopsis</i>
<i>Castanopsis</i>		Type A	Radial	Round, thick-walled	absent	aggregated (+composed)	Evergreen oak
<i>Castanopsis</i>		Type B	Ring	Angular, thinwalled	often	absent	<i>Castanopsis</i>
<i>Castanea</i>			Ring	Angular, thinwalled	often	absent	<i>Castanea</i>
<i>Fagus</i>			Diffuse	Angular, thinwalled	common	composed	<i>Fagus</i>
<i>Nothofagus</i>			Diffuse	Angular, thinwalled	common	absent	<i>Nothofagus</i>



**Fig. 15** *Piranheoxylon perfectum* sp. nov. a - cross section: diffuse-porous to semi-ring-porous wood, solitary and grouped vessels - x50; b, c - cross-section: 2-3-seriate rays with obvious dilations at the ring boundary, solitary vessels, thick-walled fibres - x100; d - tangential section: biseriate rays, tall - x100; Photos e-f - tangential section: scalariform intervascular pitting - x200; g - radial section: storeyed scalariform perforations - x100; h, i - radial section: scalariform perforation (h), cross-fields with numerous scalariform pitting - x200.

and slender, uni- or biseriate, such as in *Quercus* L. and *Lithocarpus* Bl. (= *Pasania* Oerst.), fagaceous taxa represented by several dozen species in the temperate and warm regions of the northern hemisphere and islander also. The diffuse pore distribution characterizes at the both genera - the evergreen species; the ring-porous arrangement characterizes the *Quercus* deciduous species and most of the species of *Lithocarpus* from northern hemisphere. In root wood, the deciduous species often tend to lose their ring-porous arrangement, becoming similar to the evergreen species, and the thick rays are sometimes divided into false rays, i.e. aggregate rays (Privé, 1975).

Thus, there are useful observations for the identification of the wood structures of fossil Fagaceae that can be systematized (after Petrescu, 1976 - with modification, since *Lithocarpoxyton* was invalidated by Selmeier, 1997) as it follows:

**I.** Structures with solitary vessels and grouped (2-3 or more), fine rays (or 1-3 seriate) and multiseriate compact and with simple and scalariform perforations (*Fagus*, *Nothofagus* - *Fagoxyton*, *Nothofagoxyton*);

**II.** Structures with solitary vessels, with simple perforations (sometimes scalariform, with few bars):

- Rays exclusively uniseriate =  $\square$  *Castanoxyton*;

- Rays uniseriate and multiseriate compact (sometimes compact-composed or partially aggregated) =  $\square$  *Quercoxyton* of deciduous type;

- Uniseriate and multiseriate aggregate rays =  $\square$  *Quercoxyton* of evergreen type as equivalent of the extant *Quercus* of evergreen type and of *Lithocarpus*.

Studies on the fossil oak wood remains are numerous, and we cite only what we have consulted: Müller-Stoll & Mädél (1957); Brett (1960); Gottwald (1966); Greguss (1969); Nagy & Petrescu (1969); Kramer (1974); Hadziev & Mädél (1962); Petrescu (1969a,b,c, 1976; 1978); Petrescu & Dragastan (1971); Petrescu & Liszkay (1974); Petrescu & Nuțu (1981); Starostin & Trelea (1969; 1984); Lupu (1984); Privé (1975); Privé & Brousse (1976); Gros (1983; 1988); Privé-Gill (1984; 1990); Samuel (in Lamouille et al., 1985); Selmeier (1958; 1971; 1992; 1997); Suzuki & Ohba, (1991).

The fossil genus *Quercoxyton* was created by Hofmann (1929), but defined by Kräusel (1939) and emended by Müller-Stoll & Mädél (1957) and then by Gros (1983; 1988). Some authors consider Kräusel (1939) the author of the genre (see Selmeier, 1997). We could not consult the work published by Elise Hofmann (1929, in Ann. Sabariensis, 3: 81-87, plates 1-4) as is quoted by Müller-Stoll & Mädél (1957), by Greguss (1969), by Privé-Gill (1984; 1990) or by Suzuki & Ohba (1991), but because that first author has not designated a type-species and did not give a generic diagnosis, the genus name proposed was considered *nomen nudum*. Until to be established and broadly accepted genus name *Quercoxyton*, authors such as Goepfert, Felix, Unger, Conwentz, Mercklin, Schleiden, Edwards, Schuster, Platen, Knowlton, Pampaloni, Webber, Nee, Ogura, Watari, Shimakura used for fossil wood of *Quercus* type, names such as *Kloedenia*, *Quercinium*, *Quercites* or *Quercus* (see Müller-Stoll & Mädél, 1957).

The generic diagnosis for *Quercinium* was given by Unger (1842), and reviewed by Felix (1884). The diagnosis

of the genus *Quercoxyton* was established by Kräusel (1939), having as a type species *Q. retzianum* Kräusel, 1939, not mentioning that Hofmann (1929) has described the species *Q. cerris*, even without defining the newly created genus. However, the description of these species, reconsidered as a typical species, could have replaced the generic diagnosis. Anyway, denying Hofmann work and perhaps not knowing Kräusel's work from 1939, Andreánszky (1952) makes a new definition of the genus *Quercoxyton*, having the type *Q. avasense* Andreánszky 1952.

Anyway, the correct generic diagnosis given by Kräusel (1939) was reviewed by Müller-Stoll & Mädél (1957) and is the following: Secondary wood with a porous or annular structure, with more or less obvious growth rings, usually with solitary vessels with simple perforations, large, alternate vascular pitting, increased to the parenchyma or to the ray cells, irregularly oval to polygonal, usually vertical, the ground tissue comprises libriform fibers, tracheids and vessels, parenchyma variably arranged, diffuse or in short tangential uniseriate bands, rays two-sized, the uniseriate not too tall, sometimes forming false rays.

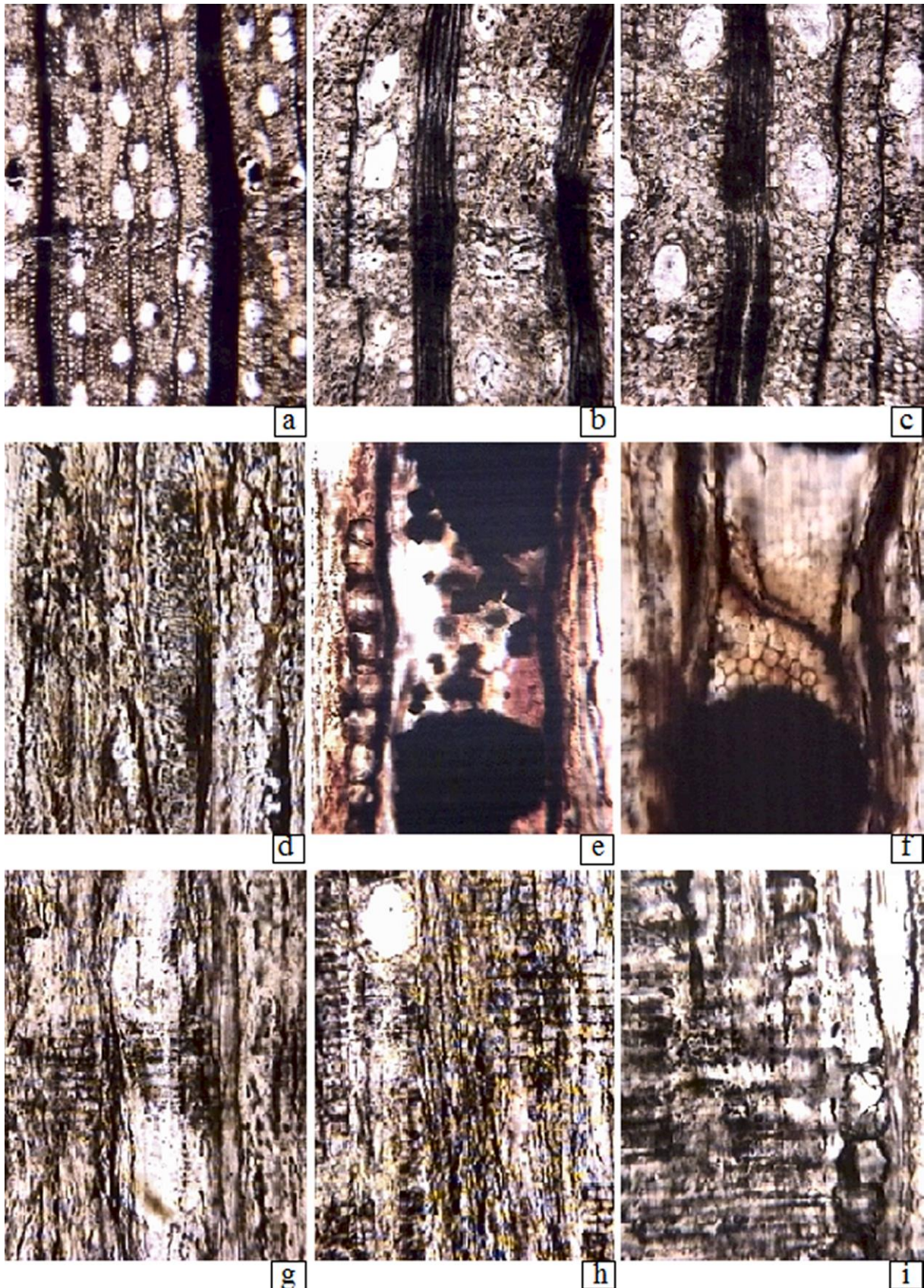
The genus is however emended once again by Gros (1983, 1988), who confirm the correct fossil genus name as *Quercoxyton*. Ignoring this work, a new revision is made by Suzuki & Ohba (1991), who, describing a new species proposed to get out from confusion of all the quercineous generic fossil names. But they admit, and even emend, the genus *Lithocarpoxyton* Petrescu, 1978 later invalidated by Selmeier (1997). They also created new combinations by reviewing *Quercoxyton* species, coming back to the linnéan name of *Quercus* L., proposing the synonymy of *Kloedenia*, *Quercinium*, *Quercites* and *Quercoxyton* genera. Their proposal was not consistent with the ICBN recommendations, and was not taken into account by the scientific community. Of course, the use of the subgeneric taxonomic categories as is suggested by the authors may be interesting, but the proposal to return to the generic botanical name of fossil wood taxa was not followed by paleoxyzologists in papers published after this "revision", which used only the name *Quercoxyton* (see Selmeier, 1997). The analysis of the characters presented by the here studied specimens shows their belonging to the *Quercus* - type white-oak ("Weisseichen"), of the *Lepidobalanus* section, because they present in the cross section the ring-porous structure and the vessels in the late wood are small, polygonal, thin-walled, and their distribution seems to be very diverse, as was observed also by previous authors, especially by Selmeier (1971) and Privé (1975). The combination of characters observed in the studied specimens, send to *Quercoxyton bavaricum* Selmeier, 1971, a species where the author also observed a rather big variation in the vessels distribution in the late wood, separating even five types aspects found also by Privé (1975):

- Net dendritic arrangement, as radial complexes separated by fiber rows;

- Diffuse arrangement;

- Few or absent vessels, of any arrangement;

- Late wood vessels separated by a fibrous area of the early wood;



**Fig. 16** *Aceroxylon palaeosaccharinum* Greguss, 1943 emend. a - cross section: diffuse-porous to semi-ring-porous wood, solitary vessels, two sized rays, ray dilation at the ring boundary - x50; b, c - cross-section: multiseriate rays with obvious dilations at the ring boundary, solitary vessels, thick-walled fibres - x100; d - tangential section: multiseriate fusiform rays, tall - x100; e-f - tangential section: crystalliferous parenchyma, alternate vascular pitting - x200; g, h, i - radial section: simple perforations, cross-fields, chambered parenchyma with rows of crystals - x200.

- Gradual decrease of vessels' size arranged in radial complexes separated by fibers.

The different types of distribution of the vessels in the late wood can correspond to some environmental variations that have affected the growth of the trunk. The final (latest) wood well-developed wood indicates an irrigated soil, when a dry climate is manifested by the reduction of the final wood. In addition, the location of the sample in the tree can influence the different proportions of final wood, which appears to be larger at the base of the trunk, than just below the crown and to the trunk periphery. Also, the growth rings in the branches are smaller than those in the trunk. Privé (1975, p. 125), continues showing that the review of the species of "white oak" described shows that the divergences found from one species to another often represent intraspecific variations also observed in the extant oaks. However, as the *Quercus* genus shows a great interspecific anatomical homogeneity, we cannot determine the basis on which we can draw the boundary between the fossil species, so that they often have only a descriptive value.

Selmeier (1997) observes that the diameter of the vessels, the thickness of the rays, their frequency as well as their arrangement are variable, and even in the same species of fossil wood species different numerical values can be found. For this reason in the anatomical descriptions and in the current tree or shrub identification papers, no updated measurements are available. As a result, accurate measurements made with the usual paleoxylotomic descriptions are not always very useful in the identification process. The more, we believe that the normative indications contained in the "IAWA List of Microscopic Features for Hardwood" (Wheeler et al., 1989) require some method differences, to the expression mode of older measurements. Even in these conditions, comparing the structure highlighted by our specimens, with those already described, we believe that it is not wrong to attribute them to a genre that seems to have dominated the European Tertiary. However similar forms, even identical (see Petrescu, 1976), were described in the Pannonian space by Felix (1884), Andreanszky (1952), Hofmann (1929), Greguss (1969), Müller-Stoll & Mädler (1957). Also from the Carpatho-Balcanian region by Starostin & Trelea (1969), Lupu (1984), Nagy & Petrescu (1969), Petrescu (1969a,b,c; 1976; 1978), Petrescu & Dragastan (1971), Petrescu & Liskay (1974), Petrescu & Nuțu (1981), Iamandei & Iamandei (2011a, b), Iamandei, E. et al. (2001; 2011), Iamandei et al. (2008b; 2012; 2013; 2014; 2016; 2017) some of them already cited upward.

In the spirit of ICBN Rules, we believe, as Petrescu (1976) did, that the species *Quercoxylon bavaricum* Selmeier, 1971 and *Q. sarmaticum* Starostin et Trelea, 1969 are identical, and we think that the species described in Romania, published by Starostin et Trelea (1969) with two years ago that the species of Selmeier (1971) has priority, so that the specimens described here will bear the name *Quercoxylon sarmaticum* Starostin et Trelea, 1969. This type of oak corresponds most likely to the species *Quercus robur* L., a species present in the extant Romanian flora.

Order **Malpighiales** Juss. ex Bercht. et J.Presl.

Family **Phyllanthaceae** Martynov, 1820

Genus ***Paraphyllanthoxylon*** Bailey, 1924

*Paraphyllanthoxylon botarii* sp. nov.

Fig. 14, photos. a-i.

### Material

A sample of silicified wood, of 8/8/6 cm was collected from a petrified tree stump of 70 cm in diameter and 40 cm tall, which seemed to be in growing position, found in Ociu village on Marinașu Valley, the left side, in middle Miocene volcano-sedimentary deposits (Late Badenian-Early Sarmatian). Although the rest of the trunk, representing the basal part, as a tree stump which suggest to have thick roots and it seems to be preserved in a natural (erect) position, it is unlikely that the trunk is in situ, because we have not observed any traces of fossil soil, and the host volcanic-sedimentary formation presents many other arguments, indicating the movement of the material from which it is constituted a lahar. The color of the silicified wood is beige-white with some dark gray areas, and are kept now in GIR collection at National Geological Museum - Bucharest under the inventory number 26,352 (field number: 109). Under the magnifying glass fibrous structure, annual rings, vessels and not too thick rays are visible, suggesting dicotyledonate wood.

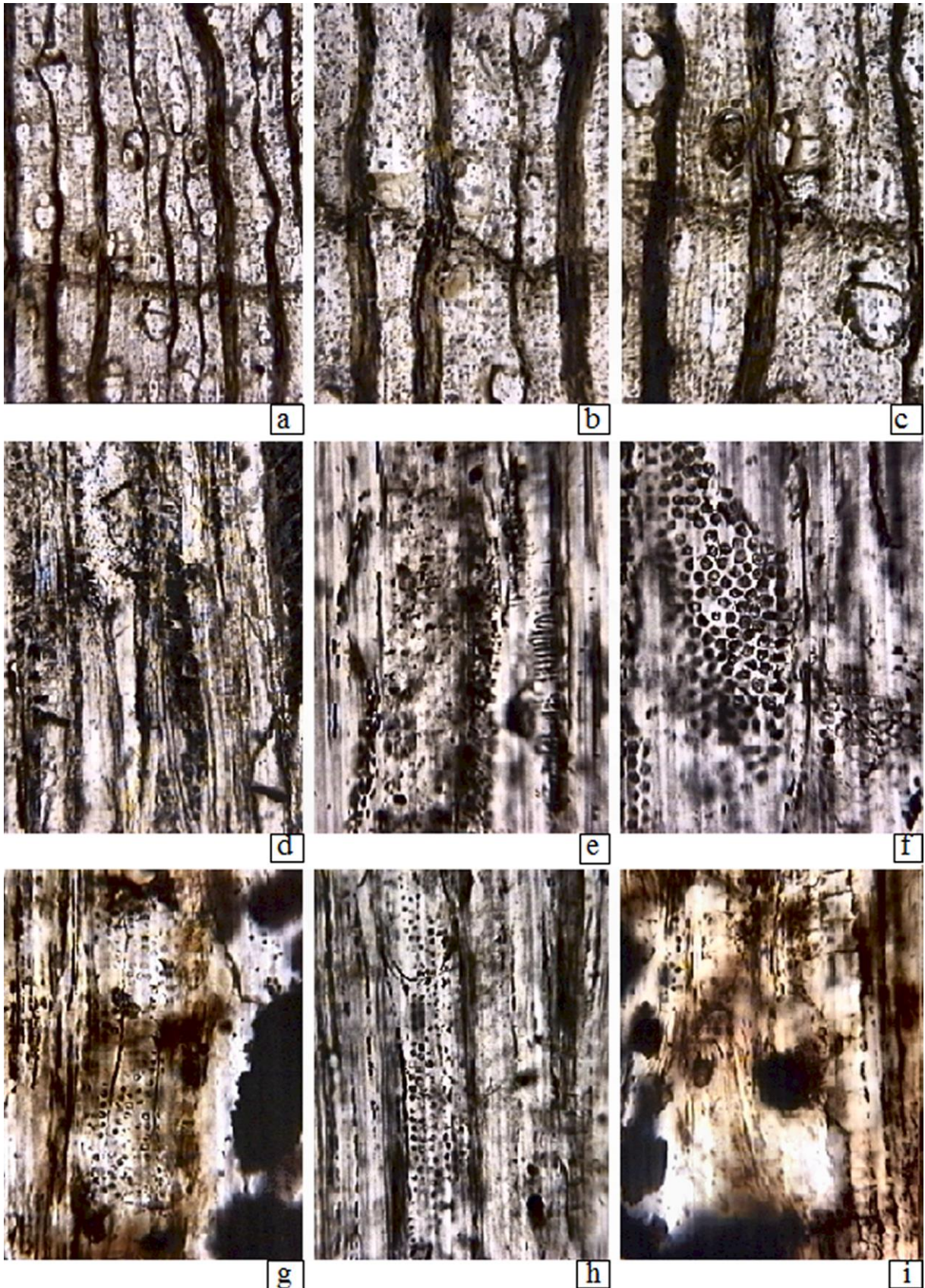
### Microscopic description

**The growth rings** are distinct, with the boundary marked by few rows of radially thick-walled flattened fibers and terminal parenchyma. The structure of the wood is semi-ring-porous, the diameter of the vessels gradually decreasing to the late wood, and in the late wood the pores are very small and solitary.

**The vessels** are predominantly solitary and in radial multiples of 2-3(7), sometimes as tangential pairs. The solitary pores have a polygonal oval shape, with moderately thick walls, of 2-3 μm (5-8 μm the double wall). The lumen of solitary pores has that is 140-200(260) / 80-120(165) μm radial/tangential diameters (average values 156 / 87 μm). The size of the pores gradually decreases to the late wood, up to 135 / 1□□ μm. The density is 2-7 pores per mm<sup>2</sup>. The vessels have simple perforations on tilted plates, and intervascular bordered pitting as sub-opposite to alternate, hexagonal pits with small apertures, sometimes only as horizontal slits. The length of the vascular elements is 234-406 μm. On the vessels ends fine spiral thickenings appear.

**Axial parenchyma** - in cross section is of the apotracheal type, diffuse, in short, uniseriate bands, more obvious in the late wood, when presents a dark matter. Sometimes, few cells touch the vessels suggesting even incomplete sheaths (parenchyma of scanty-paratracheal type). In longitudinal section, the parenchyma occurs in strands of 4-8 rectangular vertical cells or nearly square, with thin walls, showing a slight constriction at the level of the horizontal walls. Some cells contain dark gums and 1-3 crystals.

**Medullary rays** - in cross section show radially elongated rectangular cells and linear trajectory, sometimes touching vessels, and having dark content in the late wood. In tangential view the rays show the 1-3(4)-seriate aspect. The uniseriates are low, of 3-10 cells tall (i.e. 38-136 μm), the bi-triseriate have 17-26 cells in height (i.e. 117-273 μm). The frequency is (2)4-6 rays per tangential horizontal mm. The ray cells appear round, oval or slightly



**Fig. 17** *Aceroxylon zarandense* sp.nov. **a** - cross section: diffuse-porous wood, solitary and small grouped vessels, two sized rays with slight dilation at the ring boundary - x50; **b, c** - cross-section: fine and multiseriate rays with slight dilations at the ring boundary, solitary and grouped vessels - x100; **d** - tangential section: fine and multiseriate fusiform rays, tall, vessels with tilted simple perforated plates - x100; **e-f** - tangential section: remains of spiral thickenings and badly preserved pitting (e), intervascular alternate pitting - x200; **g, h, i** - radial section: simple perforations (h), bad preserved cross-field (i), bad preserved alternate pitting (g, h) - x200.

polygonal and uneven in size. In the radial view the rays are heterocellular, made up of cells all procumbent in the ray body (of 10-15  $\mu\text{m}$  high), with 1-2(4) marginals higher, or even upright (of 10-13-15  $\mu\text{m}$  in height). In the cross-fields of the ray cells with vessels sometimes small simple pits appear and small gum remains, often granular. **The fibers** - have a polygonal cross section, uneven lumina, with rare, horizontal or slightly inclined septa, and fairly thick walls (of 5-8  $\mu\text{m}$  double walls). Vertical the fibers have simple, rare, very small pitting, relatively irregularly arranged on an irregular vertical row and rare, horizontal or slightly inclined septa.

#### Affinities and discussions

Some xylotomic features observed in our sample similar to the "euphorbiaceous" wood structures of phyllanthoideus type as it was known in the former taxonomy. Today such taxa belong to Family Phyllanthaceae, not to Euphorbiaceae, both family being now inside the Malpighiales order (APG IV, 2016).

The fossil genus *Paraphyllanthoxylon* was created by Bailey (1924), to define a tree belonging to phyllanthaceous structures in which the perforations of the vessels are simple as the genera *Antidesma*, *Hymenocardia*, *Bischofia*, *Phyllanthus* or *Securinega* (some other cited forms belong today to other taxa). Some representatives having only a shrub character (Metcalf et Chalk, 1950, p.1221; Mädél, 1962, pp 284-288). The collective genus *Paraphyllanthoxylon* has a series of xylotomic characters that allowed the inclusion by synonymy of *Phyllanthinum* Ogura, 1932 and *Glochidioxylon* Ramanujam, 1956 genera. Otherwise *Glochidion* is included now in *Phyllanthus* (Gregory et al., 2009).

The xylotomical characters described in the species on which Bailey created the genus (i.e. *Paraphyllanthoxylon arizonense* Bailey, 1924), have many similarities to those of the here studied specimen. However, our specimen has an obviously semi-ring-porous structure, with distinct growth rings, solitary vessels and in small radial multiples, or irregular groups, with medium to big sized lumina, and are frequently accompanied by rows of narrow vessels, vascular tracheids or fibro-tracheids. Vessel density is higher, and inter-vascular pitting is sub-opposite to alternate. The axial parenchyma is scanty-paratracheal, diffuse, poor and has gums and crystals. The rays have dilations at the boundaries of annual rings, are 1-3(4)-seriate and 3-26 cells in height, radially all body cells procumbent, and 1-4 marginals slightly higher or even upright, with simple pitting, small and larger, visible especially on marginal cells. The fibers are septated and have simple pitting.

It is clear that the species of *Glochidioxylon* (described by Ramanujam (1956) and Prakash (1959) in the Indian Tertiary and revised by Mädél (1962), as *Paraphyllanthoxylon sahnii*, is different, by having narrower, shorter, thinner-walled, and more numerous vessels, parenchyma absent, two sized rays very high, of 75-80 cells in height.

*Paraphyllanthoxylon pfeferi* and *P. capense* of Mädél (1962) have small vessels distributed in large multiples of up to 10 pores, giving a high density of vessels. Besides this, the rays are higher, and they have 1-6 upright marginals, so is different of our specimen.

*P. teldense* (Privé, 1975) has short vessels with simple perforations but also scalariform, so is different. *P. yvardi* (Koenigieur, 1970) has the porous structure without obvious rings, small vessels in short multiples and unsepted fibers, so is different.

The American species are also different: *P. idahoense* Spackman, 1948 which has metatracheal parenchyma which forms concentric lines or bands seen in cross-section; *P. kerriense* Dayal, 1967 and *P. alabamense* Cahoon, 1972, have 2-3 seriate rays, rarely uniseriate and with 1-(2-3) marginal rows of upright cells.

*P. lignitum* (Daniou & Dupéron-Laudoueneix, 1978) has some affinities with our specimen but presents small vessels and high rays of up to 50 cells and unpitted fibers but abundantly septated.

*P. romanicum* Petrescu (in Petrescu et al., 1978), has large vessels to very large, and almost exclusively grouped, so is different too.

The comparative analysis of the described species and the structural particularities shown by our Mid-Miocene specimen from the Southern Apuseni, lead us to believe that it represent a new species, that we named: *Paraphyllanthoxylon botarii* sp. nov. in honor of the owner of the land where the trunk was found, Mr. Remus Botariu.

**Diagnosis of *Paraphyllanthoxylon botarii* sp. nov.:** Distinct growth rings, wood semi-ring-porous, usually with solitary vessels and radial multiples of 2-3(7). Solitary pores oval-polygonal, thick-walled, of 2-3  $\mu\text{m}$  simple wall or 5-8  $\mu\text{m}$  double wall, and radial / tangential mean diameters 156 / 87  $\mu\text{m}$ , density 2-7 pores/ $\text{mm}^2$ . Simple perforations on tilted plates, bordered pitting, opposite-subopposite to alternate, pits hexagonal and with small apertures sometimes as horizontal slits. The length of the vascular elements is 234-406  $\mu\text{m}$ . Fine spiral thickenings appear on the vessel ends. Axial parenchyma few, apotracheal diffuse, as short tangential uniseriate bands, and paratracheal few, as vertical strands of 4-8 cells, sometimes with dark gum remains and 1-3 crystals. Medullary rays 1-3(4)-seriate, of 3-26 cells in height (i.e. 38-273  $\mu\text{m}$ ), and with frequency of 4-6 rays/ $\text{mm}$  tangential. Ray heterocellular with cells all procumbent, and 1-4 marginal higher or even upright. Cross fields of ray cells with vertical elements having sometimes small simple pits and small gum remains, often granular. Fibers polygonal in cross-section, having uneven lumina, with rare, horizontal or slightly inclined septa, and fairly thick walls of 5-8  $\mu\text{m}$  double wall, with simple, rare, and very small pits on an irregular vertical row.

Family **Picrodendraceae** Small, 1917

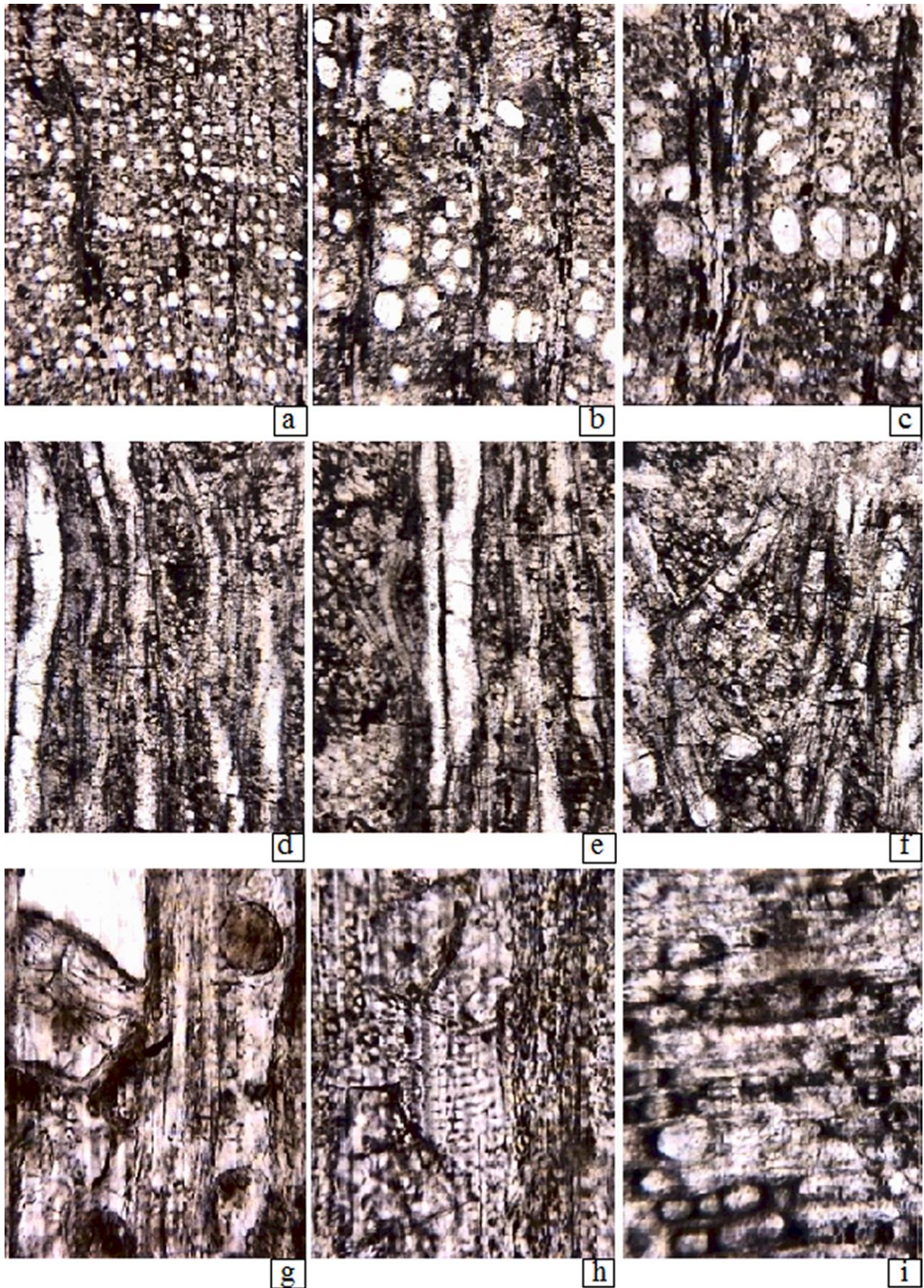
Genus ***Piranheoxylon*** Grambast, 1961

*Piranheoxylon perfectum* sp. nov.

Fig. 15, photos a-i.

#### Material

From a sample of dispersed petrified wood collected from Prăvăleni area, from Cremenea Hill (field number 171) from Mid-Miocene volcano-sedimentary deposits (Late Badenian-Early Sarmatian). The centimetric sized sample represent a silicified wood fragment of beige color or beige with rusty tint and is kept now in GIR collection at



**Fig. 18** *Aceroxylon pravalense* sp.nov. a - cross section: semi-ring-porous wood, solitary vessels, fine to broad rays, less distinct ring boundary - x50; b, c - cross-section: fine and multiseriate rays, solitary vessels, less distinct ring boundary - x100; d, e, f - tangential section: fine and multiseriate fusiform rays, vessels with almost horizontal simple perforated plates - x100; g, h, i - radial section: simple perforations (g), bad preserved opposite pitting (h) crystalliferous cross-field (i) - x200.

National Geological Museum - Bucharest under the inventory number 26,354 (field number: 171). Under the magnifying glass fibrous structure, less distinct annual rings and visible vessels and rays can be observed, suggesting dicotyledonate wood.

### Microscopic description

**The growth rings** are less distinct in the secondary wood, slightly marked by terminal (latest) parenchyma as tangential discontinuous bands of 2-9 cells thick, devoid of vessels and rays slightly dilated at the limit of the annual ring. Some local traumatic aspects (as disorganizations) disturb the porous wood structure.

**The vessels** are usually solitary and in radial multiples also or irregular groups of 2-5, sometimes with tangential pairs included, defining a porous wood type. Sometimes the vessels are separated by a short radial row tracheid, or radially continue with 1-5 smaller vessels or vascular tracheid. The solitary vessels have polygonal-rounded or oval shape, sometimes irregular or star like, even crushed in the disorganized areas. The vascular walls are moderately thick, of 4-8  $\mu\text{m}$  double wall. The lumen of solitary vessels has the radial / tangential diameters of 40-80(96) / 40-50  $\mu\text{m}$  (mean values: 52 / 42  $\mu\text{m}$ ). The pores' size is relatively constant within a growth ring, from which the appearance of diffuse-porous wood and the density is 64-90 pores per  $\text{mm}^2$ . The vessels have scalariform perforations relatively high, with 8-30 bars, sometimes corrugated, with bifurcations and vertical anastomoses. The pitting is scalariform or with oval bordered pits, opposite or horizontally elongated, often coalescent to scalariformes and numerous, especially on the the vessel endings, since the vascular elements have length of 450-975  $\mu\text{m}$  and present high "tails". Sometimes very short vessel elements, of 80-90  $\mu\text{m}$ , appear. Frequently spiral thickenings on the narrower vessels appear and also on the vessel tails and even on the thicker vessel body. On some vessels, rare, large tyloses appear and content of granular gums isolated or agglomerated up to compact, clogging the lumen. In addition, fungi as hyphae and fruiting corps appear.

**The axial parenchyma** - is very few, diffuse or of scanty-paratracheal type as 1-2 (3) cells, crushed to the vessels, and as discontinuous bands of 2-9 cells in the latest wood, sometimes with cells wider than the fibers. Vertically is relatively difficult to detect, it occurs in strands of 6-8 vertical rectangular thin-walled cells, with rare simple pits, irregularly arranged. The terminal parenchyma appears as bundles of numerous rectangular vertical cells (more than 16), storied. Sometimes dark granular gum-remains of and hyphae and fruiting corps of fungi are present. Dispersed among the fibers, chambered cells with rounded solitary crystals inside appear.

**The medullary rays** are uni- or biseriate, rarely triseriate, and in cross section appear constituted by radially elongated rectangular cells. The rays have linear trajectory and slight dilations and deviations at the annual ring boundary, and sometimes touch vessels. Tangentially they are frequently tall, of 2-52 cells in height or more (i.e. up to 1270  $\mu\text{m}$ ), compact and rarely articulated. The uniseriate rays have sometimes short biseriate storeys, with pairs of the same thickness as the uniseriate part. The ray-body cells appear rounded to polygonal and the

uniseriate endings consist of 1-12 vertically elongated cells, the last being more elongated triangular. The frequency is 7-10 rays per mm tangential. Radially the rays are heterocellular, the ray-body cells having all procumbent cells, of 16-18  $\mu\text{m}$  in height, and the marginals slightly higher or even upright, of 18-32  $\mu\text{m}$ . In the cross fields with vessels the pitting is round or elliptical, to scalariform of 5-6.5 / 8-11  $\mu\text{m}$  especially on marginal fields. In the ray cells also 1-3 crystals or more and gum remains appear.

**The fibers** - in cross section appear arranged in 1-15 radial rows between two successive rays. The fiber cells are moderately thick-walled, 4-5.5  $\mu\text{m}$  double wall, and have a polygonal section rounded at the corners, causing frequent triangular or rhombic intercellular spaces, and have large polygonal-rounded lumina, of 8-25  $\mu\text{m}$ . Often there are narrower fibers dispersed among the others, which sometimes can be confused with the intercellular spaces, since often they form discontinuous radial rows. In the areas with disorganized structure the fibers are also deformed, even crushed. Vertically, inside fibers, the septa are rare, and the longitudinal walls have rare pits in an irregular row.

**The fibrotracheids** have vertical bordered oval pitting to slightly horizontally elongated, even scalariform on the **vascular tracheids** of the rows with narrow vessels from the complex multiples of large vessels already observed in the cross section. They are obviously wider than the ordinary fibers and even the length of the tracheidal elements is smaller (length 40-250  $\mu\text{m}$ , diameter 15-28  $\mu\text{m}$ ).

### Affinities and discussions

The xylotomic characters of the studied specimen are similar to those of the "euphorbiaceous" woods of "phyllanthoideae group" type as it is presented in Metcalfe & Chalk (1950) and in Mädél (1962), and in a first instance would appear that genus *Securinega* is xylotomically similar to our specimen since it presents scalariform perforations, but also another "euphorbiaceous" genus, namely *Piranhea*. However, using the old taxonomy Metcalfe & Chalk 1950 (p. 1222) separated the Phyllanthoideae from a group of special characters (called "other phyllanthoideae") that includes the current genera *Piranhea*, *Uapaca*, *Savia*, *Androstachys*, *Breynia*, *Dissilaria*, *Longetia*, *Mischodon*, *Oldfieldia*, *Petalostigma*, whose xylotomic characters appear to match those of our specimen.

Comparing our specimen with the fossil correspondent genus *Piranheoxylon* Grambast, 1961 which was created based on a species described from the Eocene of Belgium (*Piranheoxylon stockmansi* Grambast, 1961), we found many similitudes related to the shape, size and distribution of the vessels in cross-section, the types of pitting and the perforations, the type of parenchyma and the presence of the crystalliferous chambered parenchyma cells, the type, the height and the cellular composition of the rays as well as the appearance of the fibers.

Our specimen has also some specific characters such as follows: the presence of growth rings marked by 2-9 cell parenchymal terminal bands, the slight dilation of the rays at the ring boundary, the predominant scalariform pitting, spiral thickenings on the vessel tails, on the narrow and on the large vessels also, the crystalliferous

unchambered ray-cells, ray usually biseriate, higher, with elliptic to scalariform pitting on the marginal cross fields, fibers thick-walled, with polygonal-rounded section, oval elongated to scalariform pitted.

Following this critical discussion we believe that the studied specimen is a new species which we have named *Piranheoxylon perfectum* sp. nov., for the perfection of the anatomical details offered.

**Diagnosis of *Piranheoxylon perfectum* sp. nov.:** Porous wood with less distinct growth rings and terminal parenchyma. Solitary vessels and in radial multiples with indentations, and in irregular groups of 2-5 small vessels and tracheids, fibrotracheides. Solitary vessels rounded-polygonally shaped, to oval or irregularly star-like with moderate thick walls, radial/tangential diameters of 52/42  $\mu\text{m}$ , density of 64-90 pores on  $\text{mm}^2$ . Scalariform perforations, storied, with 8-30 thin bars, corrugated, bifurcated and anastomosed. Intervascular pitting scalariform or oval bordered to horizontally elongate up to scalariform pits. Vascular elements length of 450-975  $\mu\text{m}$ , having spiral thickenings on the high tails and tyloses. Parenchyma diffuse, scanty-paratracheal and in discontinuous bands in the latest wood. Storied vertical strands of 6-8-16 cells with simple pitted walls, and chambered with rounded crystals inside. Rays 1-2(3)-seriate, with platanooid dilations, of 2-52 cells in height, uniseriate, with short biseriate storeys of the same size as uniseriate. Radially the ray cells appear all procumbent, with 1-12 marginal rows of slightly higher or even upright cells and with round or elliptical pits to scalariformes. Ray frequency is 7-10 rays on tangential mm. Often 1-3 or more crystals on fields and gums appear. Fibers with rounded polygonal large section of lumens (8-25 $\mu\text{m}$ ), relatively thick walled, severed, rare septa and irregular pitting. Fibrotracheids and vascular tracheids with oval bordered pits, elongated to scalariformes.

Order **Sapindales** Dumortier

Family **Sapindaceae** Jussieu, 1789

Subfamily **Hippocastanoideae** Dumortier, 1829

Genus **Aceroxylon** Hofmann, 1939

*Aceroxylon palaeosaccharinum* Greguss, 1943, emend.

Fig. 16, photos a-i.

### Material

From four samples of dispersed petrified wood collected from Ociu village area on the Church brook and on the slope of Teiuș hill (field numbers 642, 800, 801, 806), from Mid-Miocene volcano-sedimentary deposits (Late Badenian-Early Sarmatian). The centimetric sized samples representing silicified wood fragments of beige color or brownish and are kept now in GIR collection at National Geological Museum - Bucharest under the inventory numbers 26,426; 26,454; 26,455 and 26,459 (field numbers: 642; 800; 801 and 806, respectively). Under the magnifying glass fibrous structure can be seen, annual rings few distinct, vessels and medullary rays, suggesting dicotyledonate wood.

### Microscopic description

**The growth rings** are relatively distinct, wood diffuse porous, ring boundary marked by 2-4 terminal rows of

fibers and parenchyma tangentially flattened cells and by the obvious ray dilation at the ring boundaries.

**The vessels** in cross section appear solitary and in radial multiples of 2-3-5 pores, and sometimes as false tangential due to the overlapping of the vessel endings. They are rounded to a radial oval, and some contain dark-brown solid deposits, granular to compact. Vessel walls are moderately thick, of 5-8  $\mu\text{m}$  double wall. The radial/tangential diameters for solitary pores are of 42-84(120) / (25)40-55(84)  $\mu\text{m}$ . The density is 30-56(80) vessels per  $\text{mm}^2$ . The vessels have simple perforations on inclined plates. The vertical walls of the vessels show the bordered pits round, numerous, small, of 7-9  $\mu\text{m}$  in diameter, alternate, touching each other or not, the apertures small, of 1-2  $\mu\text{m}$ , round or horizontally oval or even point like, helical thickenings usually absent, although sometimes they can appear as fine and almost horizontal spirals. The length of the vascular elements is (190)285-420  $\mu\text{m}$ . In the vascular lumen, there are large thin-walled tyloses and reddish-brown crystals or granular content up to compact or reddish-brown-matte colored.

**The axial parenchyma** - appears to be of apotracheal type, as few short tangential uniseriate chains, or radial, eventually in the terminal wood also, or as long bands of 2-3 cells thick, and diffuse also. Parenchyma cells appear also of paratracheal type more visible in the longitudinal sections where appears as vasicentric, of more than 8 rectangular empty cells per strand, with simple pits of 2-3.5  $\mu\text{m}$  in diameter, in 1-3 vertical rows, or as hypertrophied chambered cells with solitary crystals.

**The medullary rays** - in cross section are relatively linear even if can touch vessels, and show more or less obvious dilation at the boundary of the growth rings. In tangential section the rays are 1-6(8) cells thick. The uniseriates have 4-11(31) cells in height, sometimes with biseriate storeys. The ray-cells have polygonal-rounded or oval section, of ray-cells 7-10  $\mu\text{m}$  in diameter and 8-16  $\mu\text{m}$  in height. The thicker rays have over 1 mm in height and are made up of mixed round to oval cells vertically elongated and the last cell is short triangular, sometimes higher. Their frequency is (6)8-10 rays per tangential horizontal mm. Radially they are homocellular with tendency to heterocellular, having in ray-body all procumbent cells, of 8-12-14  $\mu\text{m}$  in height, the marginals higher or upright, of 15-20-28  $\mu\text{m}$  in height. The cross fields present simple, small, of 3.5-5  $\mu\text{m}$ , rectangular pits slightly spaced and alternately arranged on 2-3 horizontal rows. Sometimes the ray cells have dark content with round empty spaces, probably representing crystals. Some cells seem to preserve dark gums or mucilages.

**The fibers** - are in regular radial rows arranged, have a polygonal section of (8)12-22  $\mu\text{m}$  diameter, with relatively thick walls, of 4-5-7  $\mu\text{m}$ , large polygonal rounded lumina. Vertically they have small, bordered pits, in a single vertical row arranged, slightly irregular, and helical inclined thickenings.

### Affinities and discussions

The xylotomic characters presented by the studied specimens are very similar to those described and figured by Metcalfe & Chalk (1950), Greguss (1959), Schweingruber (1990) in the extant members of the former Aceraceae family, which in the more recent APG IV

classification system are included in the Sapindaceae family, more specific in the Hippocastanoideae subfamily (APG IV, 2016), within the *Acer* genus, which has numerous species whose living areas cover temperate regions of the northern hemisphere and tropical mountain areas.

The general xylotomic characters of the secondary wood structure of *Acer* are the following: diffuse-porous wood with obvious growth rings marked by some rows of flattened fibers, pores solitary, spaced or in short multiples, vertically having spiral thickenings, alternate pitting, simple perforations and scanty apotracheal parenchyma diffuse, occasionally paratracheal, rarely terminal, rays slightly dilated to the ring boundary, 1-3-5(6)-seriate, of 40-50(60) cells in height, radially of homocellular appearance, the marginal cells rarely square and with enlarged pitting (Schweingruber, 1990; Watson & Dalwitz, 1992).

The current *Acer* genus is quite extensive, organized in several sections exemplified below (from Watson & Dalwitz, 1992):

- Platanoidae section: *Acer campestre*, *A. heldreichii*, *A. platanoides*, *A. pseudoplatanus*, *A. tataricum*;
- Goniocarpa section: *A. granatense*, *A. hyrcanum*, *A. monspessulanum*, *A. obtusatum*, *A. opalum*, *A. semper-virens*;
- Negundo section: *A. negundo*;
- Saccharina section: *A. saccharina*, *A. saccharum*.

Xylotomically, as fossil correspondents two genera were erected: the first genus, *Acerinium* Unger (in Endlicher, 1842), described by Unger from the Miocene of Austria, based on the species *Acerinium danubiale* Unger (non vidi). The situation of this fossil genus is relatively uncertain, because it did not benefit of a revision even if some species were described under it.

The second correspondent genus, *Aceroxylon*, could also have some problems of validity. Thus, the genus *Aceroxylon* was proposed by Elise Hofmann (1939) as xylotomically identical with the extant *Acer* L. (see ING Database). The type species of *Aceroxylon* Hofmann, 1939 is designated *Aceroxylon abbreviatus* (Feistmantel) Hofmann, 1939, species found again by Hofmann (1944) from the Oligocene phosphorites of Prambachkirchen, Austria. From the same site Hofmann (1952), described an *Aceroxylon* sp., which has distinct growth ring, solitary vessels and in radial multiples of 2-5 pores, fine and thicker rays, up to 5-seriate or more and thick walled fibres.

It is good to remark that Loubière (1939) described in the same time an *Aceroxylon madagascariense* Loubière, 1939 from Africa, Cretacic (non vidi), without specifying it is a new genus.

Another species described by Elise Hofmann (*Aceroxylon campestre* Hofmann, 1939) was taken in discussion by Greguss (1943) who proposed another identification *Aceroxylon* cf. *palaeosaccharinum*? (See Greguss 1943), which is admitted as a new combination.

*Aceroxylon* cf. *palaeosaccharinum* was found again by Greguss (1969) in the Sarmatian of Fuzerkomlos (Hungary) having also similitudes to the extant North-American species *Acer saccharina*, as vessels arrangement and frequency and 1-2-seriate rays, even if the fossil specimen show the uniseriates predominating. From the same site

it was described also an *Aceroxylon* cf. *abyssinica* (Hochst. ex Benth.) Greguss, 1969.

However relatively few fossil species of Tertiary *Aceroxylon* were described until present in the area, and Gregory et al. (2009) cite:

- *Aceroxylon* sp. described by Andreánszky (1955) from the European Miocene, with some additional references in Andreánszky & Sárkány (1955);
- *Aceroxylon* sp. described by Selmeier (1957) also from the European Miocene;
- *Aceroxylon* sp. cf. *Acer pseudoplatanus* L. and *Aceroxylon* sp. cf. *Acer trilobatum* L. were described by Andreánszky (1959) also from the European Miocene;
- *Aceroxylon pennsylvanicum* Prakash, 1968 described from the North American Miocene;
- Other forms of Aceraceae were described from Japan under linean name *Acer*: *A. momijyamense* and *A. watarianum*, by Takahashi & Suzuki (1988), but not respecting ICBN Rules regarding the fossil wood nomenclature.

- Also, two new species from the same area of that are described by us in this paper as *Aceroxylon zarandense* and *A. pravalense*, which are slightly different of the specimens studied here.

- Under these circumstances, the comparison with the extant species seemed to us the most appropriate solution to identify the studied material. The comparative analysis of the xylotomic patterns observed in the specimens studied here indicates a great similarity regarding the vessels' distribution, their shape and size, the aspect of the parenchyma, of the fibers and of the rays, the perforations, pitting and spiral thickenings in vessels - with the extant species *Acer opalus*, whose area is Southern European (or Mediterranean), or with *A. tataricum*, the Tatarian maple, which is widespread across Eurasian areas, from Austria to Turkey and even Russian Far East and Japan, and also with *A. ginnala*, a species with the living area in East Asia (China, Manchuria, Japan).

- Also similitudes appear to have with and *A. saccharum* and *A. saccharinum*, which have a North-American area marked by a temperate-warm Mediterranean climate (Greguss, 1943; 1959). The rays of the North American *Acer negundo* are biseriate, those of *A. obtusatum* and *A. saccharinum* 1-2 seriate, those of *A. ginnala*, however, only 1, more rarely 2-seriate and with some differences in the arrangement of the vessels. These species, characterized by the 1-2-3-seriate rays, which distinguishes them from the other types, as in the absence of spiral thickenings on the vessels and points the alternate, hexagonal intervascular pitting, the presence of solitary crystals of oxalate in the parenchyma, very obvious in all the specimens studied by us and clustered here.

- The similarity with the species described by Greguss in 1943 (reprinted in 1969) is also evident, which is why we attribute the studied material to the species *Aceroxylon palaeosaccharinum* Greguss, 1943, emended here, and which we consider appropriate of our studied specimens, and similar to the extant species *Acer saccharinum*, *A. saccharum*, *A. opalus* and *A. ginnala*, whose possible fossil correspondent could be.

**Emended diagnosis** of *Aceroxylon palaeosaccharinum* Greguss, 1943 emend.

(New type: inventory number: 26426 and supplementary material: 26454; 26455 and 26459 - are kept now in GIR collection at National Geological Museum - Bucharest). Diffuse-porous secondary wood, with relatively distinct growth rings, rays with dilation at the limit of annual rings, vessels usually solitary and radially grouped in 2-5 pores, round to oval when solitary, small (42-84 / 40-55  $\mu\text{m}$  radial / tangential diameters), with thick walls (5-8  $\mu\text{m}$  double wall), density of 30-80 vessels per  $\text{mm}^2$ , simple perforations, polygonal or round bordered pitting, as numerous, small alternates pits (7-9  $\mu\text{m}$ ) with round to horizontally-oval apertures of 1-2  $\mu\text{m}$  or even point-like, spiral thickenings usually absent, vascular elements 285-420  $\mu\text{m}$  length, with large thin-walled tyloses, and colored crystals. Apotracheal parenchyma diffuse as short or long lines, sometimes few in the final wood or very few paratracheal, simply pitted and with crystals. Rays usually 1-3-seriate, rarely thicker, the uniseriates have 4-11(31) cells in height, ray cells polygonal-rounded or oval-vertical, with biseriate storeys, the thicker rays are fusiformes with short unicellular ending. Their frequency is of 8-10 rays per tangential mm. Radially are slightly heterocellular, ray body cells all procumbent of 8-14  $\mu\text{m}$  high, the marginals higher to upright (15-20  $\mu\text{m}$ , up to 28  $\mu\text{m}$ ), with content of crystals and gums. Cross-fields with simple small pits of 3.5-5  $\mu\text{m}$ , on 2-3 horizontal rows. Radial regular rows of fibers with polygonal section and wide lumen, of 12-20  $\mu\text{m}$  diameter, thick walls of 5-7  $\mu\text{m}$  double wall, with pitted, septed and with spiral thickenings.

*Aceroxylon zarandense* sp. nov.

Fig. 17, photos a-i.

### Material

From a sample of dispersed petrified wood (field number 26), collected from Prăvăleni area from the left side of Prăvăleni valley at the confluence with Bodișteanu brook from Mid-Miocene volcano-sedimentary deposits (Late Badenian-Early Sarmatian). The centimetric sized samples representing a silicified wood fragment of whitish-beige color with brownish and is kept now in GIR collection at National Geological Museum - Bucharest under the inventory number 26,279 (field number: 26). Under the magnifying glass fibrous structure can be seen, distinct annual rings, short thin and sinuous medullary rays, and vessels, typical for a dicotyledonate wood.

### Microscopic description

**The growth rings** are relatively distinct in cross section, not very wide, the boundary marked by the presence of a terminal wood made up of mainly ground tissue. Otherwise, the structure is diffuse-porous, smaller vessels appear only in the close proximity of the terminal wood, and the rays are slightly dilated at the boundaries of the annual rings.

**The vessels** in cross section are solitary and in radial multiples of 2-3, or groups of 4-5 pores. The solitary ones have an oval or circular cross section and show sometimes solid brown deposits. The walls are moderately thick of 4-8.5  $\mu\text{m}$  double wall. The radial / tangential diameters for solitary pores are of 42-75(84)/42-51(60)  $\mu\text{m}$  and their density is 35-60(85) vessels per  $\text{mm}^2$ . The

vessels have simple perforations on inclined plates. The vertical walls of vessels, especially of those vessels with lower lumen, exhibit relatively thick spiral thickenings, with repeated and obvious turns. Rounded to oval bordered pitting, relatively numerous, small of 4-7  $\mu\text{m}$ , alternate to sub-opposite without touching each other, with circular apertures of 2-3.5  $\mu\text{m}$  in diameter horizontally elongated or point like. The average length of the vascular elements is 500-640  $\mu\text{m}$ . Inside vessels, rarely large thin walled tyloses appear.

**The axial parenchyma** - is of apotracheal type, a few short or long uniseriate lines interleaved with fibers, constituting the terminal bands of 3-4 cells thick, which are marking the distinct boundary of the growth ring. It occurs also diffuse, as cells dispersed among the fibers within the annual ring, and also as vasicentric uniseriate. In the longitudinal sections the parenchyma consists of nearly square empty rectangular cells in vertical strands of over 8 cells, pitted and sometimes with solitary crystals.

**The medullary rays** - in cross section appear 1-3(4)-seriate, and have a special behavior: the thicker rays have continuity on 2-3 annual rings, the uniseriates have continuity only on an annual ring. Near the vessels they have a slight inflection and may come in contact with them, but generally have a linear trajectory, and the thicker ones show a slight dilation at the boundary of the growth ring. Also, the cells have a dark content. In tangential section, the uniseriates appear relatively numerous, they have 3-12 cells in height (up to 125  $\mu\text{m}$ ), the ray cells round or slightly vertically elongated, mixed. The 2-4-seriates rays have 15-77 cells in height, that is, 192-500  $\mu\text{m}$  and have uniseriate endings of 1-8 rounded cells, the last being narrower and elongated. The ordinary ray body cells tend to be more rounded and more equal in size (8-11  $\mu\text{m}$ ), and contain residual gums. Sometimes marginal, noticeably larger rounded cells (of 15-24  $\mu\text{m}$  in diameter) and brighter, which appear to be mucilaginous cells. The frequency is 8-10 rays per horizontal tangential mm. Radially the rays are homocellular, formed from procumbent cells whose length varies from the early to late wood, when the cells can be squared with the same height. Ray cells have very small spaced pits of 2  $\mu\text{m}$  on two rows in the early wood, or a single, larger, round or oval pit with small circular aperture, in the late wood. Sometimes, the ray cells contain large, solitary crystals.

**The fibers** have a polygonal cross section of 15-20  $\mu\text{m}$  in diameters, relatively thick walled of 4-6  $\mu\text{m}$ , especially in the late wood made up of 6-10 radial rows. Vertically are pitted and sometimes have long rows of crystals.

### Affinities and discussions

The xylotomical characters observed in this specimen are very similar to those described by Metcalfe & Chalk (1950), Greguss (1959), and Schweingruber (1990) for members of the former Aceraceae family, especially of *Acer* type, now belonging to the Sapindaceae family, the Hippocastanoideae subfamily (APG IV, 2016).

We do not repeat the discussion on the affinities of the specimens described above to whom also we have seen similitudes, but note the description of the generic xylotomic characters of the *Acer* genus from Schweingruber (1990), which is more similar to our spec-

imen description: the obvious growth rings, marked by some rows of flattened fibers, the diffuse-porous wood, with spaced solitary pores or as short multiples, with simple perforations, alternate pitting and spiral thickenings with diffuse apotracheal parenchyma, occasionally paratracheal, rarely terminal, slightly dilated rays at the ring boundary, 1-3-5(6)-seriate, of 40-50(60) cells high, homocellular, cells all procumbent, rarely marginals square with increased pits.

Comparing the xylotomy of our specimen with the fossil aceraceous species previously described, including the species described in this paper, we think we have studied here a wood structure more similar in terms of distribution and shape of the vessels, parenchyma, fibers and rays, the type of perforations, pitting and spiral thickenings with the current species *Acer cappadocicum* Gled, a species with a living area comprising the southern regions of Central and Eastern Europe and Asia, a maple native to central Turkey (ancient Cappadocia), east along the Caucasus, the Himalaya, to southwestern China, areas marked by a temperate to warm-temperate climate up to the subtropical of the Mediterranean wetlands.

An advanced comparison with respect to other fossil forms described until present maybe could suggest a possible identification, but in the present case we believe we are in the face of a new species, which we named *Aceroxylon zarandense* sp. nov., according to the name of the region where it was found the holotype (inv. no. 26,279), as a fossil equivalent of the extant maple *Acer cappadocicum*. The material studied here was initially wrongly identified as a member of the Meliaceae family (Iamandei & Iamandei, 1998), with which it has possibly similar features, but the revision of the original material and the taxonomic reidentification, have denied the assignment of this specimen to the *Carapoxylon* cf. *porosum* (Felix) Mädel, 1960.

#### Diagnosis of *Aceroxylon zarandense* sp. nov.

(Holotype: inv. no.: 26,279 kept now in GIR collection at National Geological Museum - Bucharest).

Secondary wood diffuse-porous with relatively distinct growth rings, marked by slightly flattened terminal fibers and dilated rays at ring boundary. Vessels solitary and in radial groups of 2-3(5), the solitary oval or circular in cross section, of 42-75(84) / 42-51(60)  $\mu\text{m}$ , and thick-walled of 4-8.5  $\mu\text{m}$  double wall, density of 35-60(85) vessels on  $\text{mm}^2$ , simple perforations, spiral thickenings frequent and relatively thick, bordered pitting, pits round to oval, numerous, alternate to sub-opposite without touching each other, small of 4-7  $\mu\text{m}$ , with circular apertures of 2-3.5  $\mu\text{m}$  to horizontally elongated, or point like. The vascular elements have 500-640  $\mu\text{m}$  in length, large thin-walled tyloses inside and solitary crystals or colored crystal-sand. Parenchyma apotracheal diffuse, as short or long uniseriate bands interleaved in the latest wood, and rarely paratracheal. Vertically the parenchyma appears as near square empty cells in vertical strands of 2-4 cells, sometimes pitted and with crystals. Rays 1-4-seriate, the uniseriates of 3-12 cells tall, the 2-4-seriates fusiform, of 15-77 cells tall, with endings of 1-8 cells. In the ray-body sometimes larger mucilaginous cells appear. Ray frequency is of 8-10 rays on tangential mm. Rays homocellular, with ray-cells all procumbent, sometimes square,

with spaced simple, very small pits, of 2  $\mu\text{m}$ , on two rows arranged in the cross-fields with vessels and with solitary crystals. The fibers have polygonal section of 15-20  $\mu\text{m}$  in diameter, thick walls, spiral thickenings, septa, and rare, small, simple pitting in a vertical row.

*Aceroxylon pravalense* sp. nov.

Fig. 28, photos a-i.

#### Material

From two samples of dispersed petrified wood (field numbers 52 and 213), collected from Prăvăleni area from the left side of Prăvăleni valley at the confluence with Bodișteanu brook and respectively from Ociu area, Marinașu Valley, from Mid-Miocene volcano-sedimentary deposits (Late Badenian-Early Sarmatian). The centimetric sized samples representing a silicified wood fragment of whitish-beige color, gray tinted and is kept now in GIR collection at National Geological Museum - Bucharest under the inventory numbers 26374 and 26402 (field numbers: 52 and 213, respectively). Under the magnifying glass, fibrous structure can be seen, distinct annual rings, short thin medullary rays, and vessels, which suggest a dicotyledonate, as wood fragments of trunk and of branch.

#### Microscopic description

**Growth rings** distinct, wood semi-ring-porous, the rays are obviously dilated at the ring boundary and darker at the limit of the annual rings. One specimen preserves the axial area where the pith is resorbed suggesting a branch fragment.

**The vessels** in the cross section are almost exclusively solitary, or as radial or slightly irregular of 2-5 pores, rarely as small tangential groups of 2-3 pores. They have a round, polygonal or radial-oval section and some of them contain dark-brown solid deposits, granular to compact. The radial/tangential diameters for the solitary pores are (25)40-75(128) / (17)30-65(112)  $\mu\text{m}$ , the walls are not too thick, of 4-6  $\mu\text{m}$  double wall, the density is 68-138-146 vessels per  $\text{mm}^2$ . The vessels have simple perforations on inclined plates, the vertical walls have spiral thickenings, with thick, slightly tilted, nearly horizontal, quite obvious turns. The pitting is shallow, hexagonal, numerous, small (7-8  $\mu\text{m}$ ), alternate, with very large chamber (5  $\mu\text{m}$ ), sometimes quite badly preserved. The average length of the vascular elements is 88-182  $\mu\text{m}$ . In the lumen, you can see large thin-walled tyloses, and granules or crystals brown colored, dispersed, locally to compact.

**The axial parenchyma** - is of apotracheal type and appears as few short uniseriate lines or diffuse, as 1-2 cells dispersed among the fibers and paratracheal few also visible especially in the longitudinal sections as large, polygonal cells attached to the vessels, with many opposite pits, or as numerous strands with more than 6 rectangular empty cells, not too thick walled, sometimes bearing solitary crystals.

**The medullary rays** - thin to thick in cross section show obvious dilation at the growth rings boundary. They are relatively linear and can touch vessels. The ray cells appear pitted on the horizontal walls. In tangential section have 1-12(16) cells thick. The rays of 1-4 cells thick are not very tall, appear relatively numerous around the thick

rays and are formed of round or oval or slightly elongated vertical oval cells, (of 12-16-20  $\mu\text{m}$  in diameters), mixed or arranged marginally as incomplete sheaths. The thicker rays are frequently dissected by 1-3 fibers and have uniseriate endings of 1-3 rounded cells, the last being triangular and elongated. The body cells tend to be more rounded and more equal in size of 7-11  $\mu\text{m}$  in diameters. The frequency is of 8-10 rays per horizontal tangential mm. Radially the rays have all procumbent cells, with varying height of 11-16-20  $\mu\text{m}$ . On the ray-cells small simple pits of 2  $\mu\text{m}$  punctuation, slightly irregular in 1-2 horizontal rows arranged, quite badly preserved. Sometimes the ray cells have 1-3 large crystals, polygonal to oval-rounded, floating in a dark mass. Sometimes, only their contours are visible.

**The fibers** have a polygonal section of 10-12  $\mu\text{m}$  in diameter, relatively thick walled 3-6  $\mu\text{m}$  to very thick and with round to point like lumen. Vertical have spiral thickenings and rare small, numerous bordered pits in a single vertical row, slightly irregular, and rare septa.

#### Affinities and discussions

The comparative study of the xylotomic characters observed in the here studied specimens suggested big similarities with the typical features of the former Aceraceae family, especially of *Acer* type, as is described by Hofmann (1952). Now this genus belongs to the Sapindaceae family, the Hippocastanoideae subfamily (APG IV, 2016).

So, the xylotomic details of our studied specimens are mostly similar with those specified in *Acer* diagnosis: the obvious growth rings marked by some rows of flattened fibers, the diffuse-porous wood with solitary pores spaced or in short multiples, with simple perforations, alternate pitting and spiral thickenings, the apotracheal parenchyma few, diffuse, occasionally paratracheal, rarely terminal, the rays slightly dilated at the ring boundary, 1-3-5(6)-seriate and of 40-50(60) cells in height, homocellular, cells all procumbent with simple pitting, and rarely square in the marginal rows and with enlarged pitting (after Hofmann, 1952).

Such characters we have also observed in our sections. Only the rays show larger thicknesses, up to 16 cells, and this character appears at some *Acer* species, such as *A. campestre*.

The comparison with other fossil forms reveals the same difference, the thickness of the medullary rays. Hofmann (1952), shows that *Aceroxylon* sp., described by her, has fine and thick rays, of 5 cells or more, without further specification, and the figuration is deficient. The other xylotomic patterns observed in our specimens, regarding the round to oval shape and the size of the vessels in a diffuse-porous structure, the crystalliferous parenchyma thin-walled and pitted, the fibres are pitted and with spiral thickenings, and the rays are fine to broad of 1-16 cells, the multiseriate are taller and fusiform, the cross fields with small simple pitting increased on the marginals and also the vessels with simple perforations, alternate pitting and the spiral thickenings, show a great similarity with the current species *Acer campestre* L., which has an European and western Asian life area, both marked by a temperate climate. The species described in this paper: *Aceroxylon palaeosaccharinum* Greguss, 1943 emend.

and *A. zarandense* sp. nov. are both clearly different, so, after this comparative analysis we think we are in front of a new species, which we named *Aceroxylon pravalense* sp. nov., after the name of the area where the specimen designed holotype (specimen with inventory number: 26,374) originates.

A similar form was described by us under the same name on some material from another collection (Iamandei et al, 2004b). Since at that time the name proposed in an unpublished PHD Thesis, so it was not validly published assign also that material to this species *Aceroxylon pravalense* sp. nov., now correctly published. The studied material is deposited in GIR Collection under the inv. Nos. 26,709; 26,711 and 26,715 (=samples L.22, L.24 and L.28 – Țibuleac Coll.).

**Diagnosis of *Aceroxylon pravalense* sp. nov.** (Holotype: inv. no.: 26,374; Paratype: inv. no.: 26,402 - both kept now in GIR collection at National Geological Museum - Bucharest).

Semi-ring-porous secondary wood with distinct growth rings, rays dilated at the ring boundaries. Vessels almost exclusively solitary or in rare tangential groups of 2-3 or radial multiples of 2-5 pores. The vessels have round, polygonal or radial oval shape, radial/tangential diameters have 40-75 / 30-65  $\mu\text{m}$ , cellular wall thickness is 4-6  $\mu\text{m}$  double wall and density of 68-146 vessels per  $\text{mm}^2$ . Vertically the vessels have simple perforations, spiral thickenings frequent and slightly tilted to nearly horizontal, alternating, hexagonal bordered pits, numerous, small, of 7-8  $\mu\text{m}$ , with large apertures, of 5  $\mu\text{m}$ . The vascular elements of 88-182  $\mu\text{m}$  length have large thin walled tyloses and colored crystals. The parenchyma is of apotracheal type, diffuse or as short lines and few paratracheal. Vertically it occurs in numerous strands of 6 rectangular cells or more, sometimes crystalliferous, or as large polygonal cells, attached to vessels, with numerous, opposite pitting. The rays have cells pitted on the horizontal walls and are fine to broad of 1-12(16) cells wide. The 1-4-seriates are not very high, and occur grouped around the thick rays of up to 16 cells, which are dissected by fascicles of some fibers, and have short endings of 1-3 cells. Ray frequency is of 8-10 rays on horizontal tangential mm. Radially are homocellular with cells all procumbent with variable height, of 11-20  $\mu\text{m}$ , bearing 1-3 large, polygonal oval-rounded crystals, floating in a dark mass. In the cross-fields with vessels there are numerous, small pits of 2  $\mu\text{m}$  in 1-2 horizontal rows arranged. The fibers with polygonal section, of 10-12  $\mu\text{m}$  in diameter, with wide lumen, round to point like, with thick walls and rare spiral thickenings, small, numerous bordered pitted in a vertical row and sometimes septate.

#### Angiosperms – Monocots

##### Order Arecales Bromhead

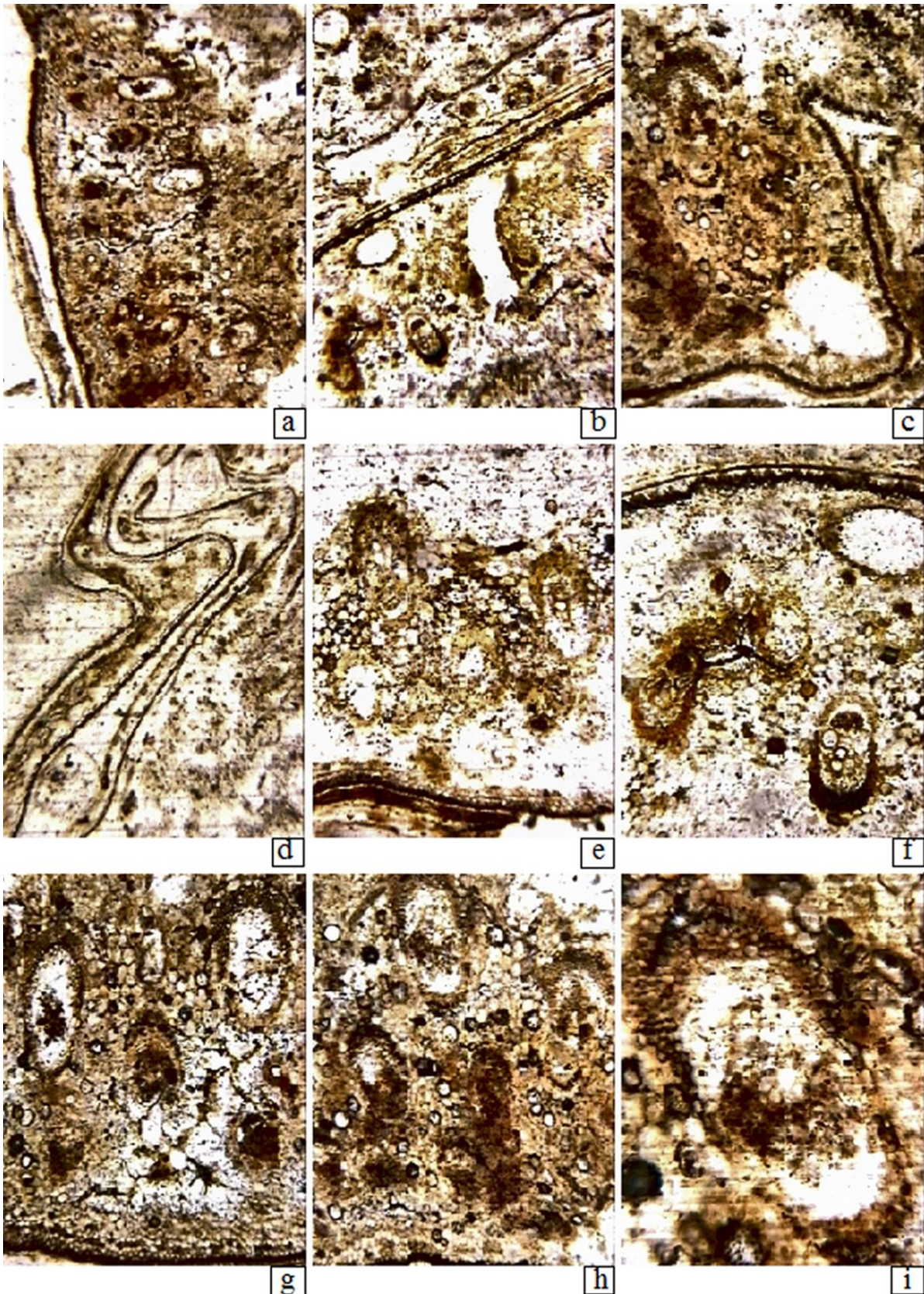
Family **Areaceae** Bercht. & J.Presl, 1820, nom. cons.

(= **Areaceae** Schultz-Schultzenst.); (= **Palmae** Juss., nom. alt.).

Genus *Rhizopalmoxylon* (Felix) Gothan, 1942

*Rhizopalmoxylon* sp. aff. *sabaloides*

Fig. 19, photos a-i.



**Fig. 19** *Rhizopalmoxyylon* sp. aff. *Sabaloides*. **a, b** - cross-section: fascicular structure, with fibrous and fibro-vascular bundles, parenchymal ground-mass, aeriferous tissue - x50; **c** - cross-section: fibro-vascular bundle, fibrous bundles, parenchyma, aeriferous canal - x100; **d** - cross-section: median cortex between radicular areas - x50; **e-h** - cross-section: fibro-vascular bundles with obvious metaxylem and protoxylem vessels, undivided floem plate, sclerenchyma cap of "lunaria" type, aeriferous canals, parenchymal ground-mass, cortex, - x100; **i** - cross-section: fibro-vascular bundle with sclerenchyma cap of "lunaria" type, destroyed floem plate, apparently undivided, metaxylem and protoxylem areas partially destroyed, protoxylematic parenchyma appear sclerified, ground-mass with undirected parenchyma - x200x

## Material

A sample of dispersed petrified wood (field number 814), collected from Basarabasa Hill in Basarabasa village area, from Mid-Miocene volcano-sedimentary deposits (Late Badenian-Early Sarmatian), having centimetric sizes and representing a silicified (opalised) wood fragment of yellowish color. The material remained after the oriented thin sections were realized is kept now in GIR collection at National Geological Museum - Bucharest under the inventory number 26,465 (field numbers: 814). Under the magnifying glass a fascicular structure is guessed, suggesting a monocotyledonate.

### Microscopic description

The studied silicified wood fragment appears to originate from a palm tree, with a typical fascicular microscopic structure: it presents in the transversal section a very thin cortical zone and a central cylinder with fibro-vascular bundles and remains of a parenchymal ground tissue. The transverse sections in which the cortical zone appears reveal its development outlining on relatively small portions groups of fibrovascular bundles and ground tissue inside the structure, which is not characteristic of the palm tree trunk, but rather to the root zone.

**The cortical zone** is marked towards the outside by several rows of thick-walled fibrous cells following an irregular trajectory representing, of course, the irregular contour of a small rootlet developed in competition with the others, numerous in this plant portion. There follows an opaque blanket of parenchyma in which small, dispersed fibrous bundles appear and this aspect similarly appears to the outside of the area, beyond a limit area relatively irregular as thickness of some cells rows, which is probably the rootlet exodermis. The median cortex is marked by the presence of large round elliptical hollow spaces with diameters of 60-168/105-50  $\mu\text{m}$ , tangentially oriented, probably representing aeriferous channels, again characteristic of root structures. The inner cortex is hard to delimit as an entity, as it make the transition to the following area.

**The outer + intermediate zone (=dermal + subdermal zone)** have a thickness of a few millimeters (i.e. 1/3 of the total half-thickness of the structure because they cannot be separated as specific entities here). In this portion appear radially oriented oval-elongated fibro-vascular bundles of 190-220 / 80-112  $\mu\text{m}$  the radial/tangential diameter and the f/v ratio is 0.21 / 1 - 0.27/1 (i.e. part fibrous / vascular part ratio). The fibrous bundles are also present, and the parenchymal tissue comprises dispersed sclerenchymal cells and large round cells most probably representing idioblasts filled with mucilages. It is interesting to note that the fibro-vascular bundles exhibit sclerenchyma cap oriented to the axial part of the structure and not to the external part. The fibro-vascular bundles are relatively few (4-5 per  $\text{mm}^2$ ), are oval-shaped, are of the closed collateral type, have the sclerenchyma cap of lunaria type (see Stenzel, 1904; Greguss, 1968), the floem plate seems to be undivided, the metaxylem is represented by 5-7 vessels of 16-35  $\mu\text{m}$  in diameter, of circular shape or slightly oval and thick walled (2-3.5  $\mu\text{m}$  simple wall). The protoxylem consists of 9-11 vessels with a narrower lumen (of 4.5-6.5  $\mu\text{m}$  in diameter), circular shape and thick walls (2.5-3.5  $\mu\text{m}$  simple wall), relative to the small diameter of the vessels. In longitudinal section, the com-

plicate trajectory of the fibro-vascular bundles does not provide important anatomical details. Tabular parenchyma not observed. The parenchyma that surrounds the protoxylem has on its outer side two or three layers of cells having thickened and sclerified walls, so completing the protective sheath of the bundle whose growth has ceased. There are also cellular inclusions as long rows of stegmata with spherical silica corpuscles on disperse fibers.

**The central zone** represents about 2/3 of the half-thickness of the structure, and is constituted from the parenchymal fundamental mass with rare fibrous or fibro-vascular bundles and comprising probably also, aeriferous spaces.

## Affinities and discussions

Based on the typical anatomical characters of our studied specimen representing a monocotyledonous woody structure of Palm type (Arecaceae, APG IV, 2016), especially of the basal part where the root system appears (or the rhizotillic part, after Cook, 1941 - in Tomlinson, 1961), by having fascicular structure of the central cylinder, with closed collateral fibro-vascular bundles, typical for a palm, and on the particularities observed indicating a radicular pattern determined us to attribute it to *Rhizopalmoxyton* organ-genus.

This fossil taxon created by Felix (1883), including such woody root structures, usually difficult to assign to a taxon comparable to a current genus. It was revised by Gothan (1942), who described a material from the Tertiary coals from Bohlen, Germany as *R. glasseli* and *R. bohlenianum* (Gothan, 1942). Few other forms were described from European area, by Grambast, L. (1962) as *Rhizopalmoxyton* sp., and by van der Burgh & Meulenkamp (1966) as *R. pilosum*. From Africa is reported by Koeniguer (1970) a *R. libycum*.

From the New World, Tidwel et al. (1972), reported some palm woods and described some forms of *Rhizopalmoxyton* (as *R. behuninii*, *R. blackii* and *R. scotii*) from the Tertiary of Redmond, Utah, US. The forms *R. huepaciense* and *R. teguachachiense* described by Cevallos Ferriz & Ricalde-Moreno (1995) and interpreted as Palm rhizomes, represent another plant-part.

Much more forms were described from India as *R. indicum* Sahni, 1938; *R. sundaram* Mahabale & Rao, 1973; *R. borassoides* Awasthi et al., 1996; *R. macrorhizon* (= *Palmoxyton macrorhizon* Stenzel, 1904) Bonde et al., 2008; *Rhizopalmoxyton angiorhizon* (= *Palmoxyton angiorhizon* Stenzel, 1904) Bonde et al., 2009 and *Rhizopalmoxyton singulare* Bonde et al., 2009 and recently Kathal et al. (2017) described a new species identified as *R. nipoides*, clearly sending to the extant mangrove palm rhizome of *Nypa* Wurm.

In the specimen studied here, we observed fibro-vascular formations that are distributed to some "central cylinders" separated by an epidermal area that probably means a thin cortical zone, a structure found only in the basal part of the palm-stem where the root system appears as a basal pillow of rootlets, or rhizotil (Tomlinson, 1961, quoting Cook), in which the adventitious rootlets are inserted, a relatively common aspect of many palm-trees. The presence of the aeriferous spaces observed in the structure of these "central cylinders" is also specific to the root

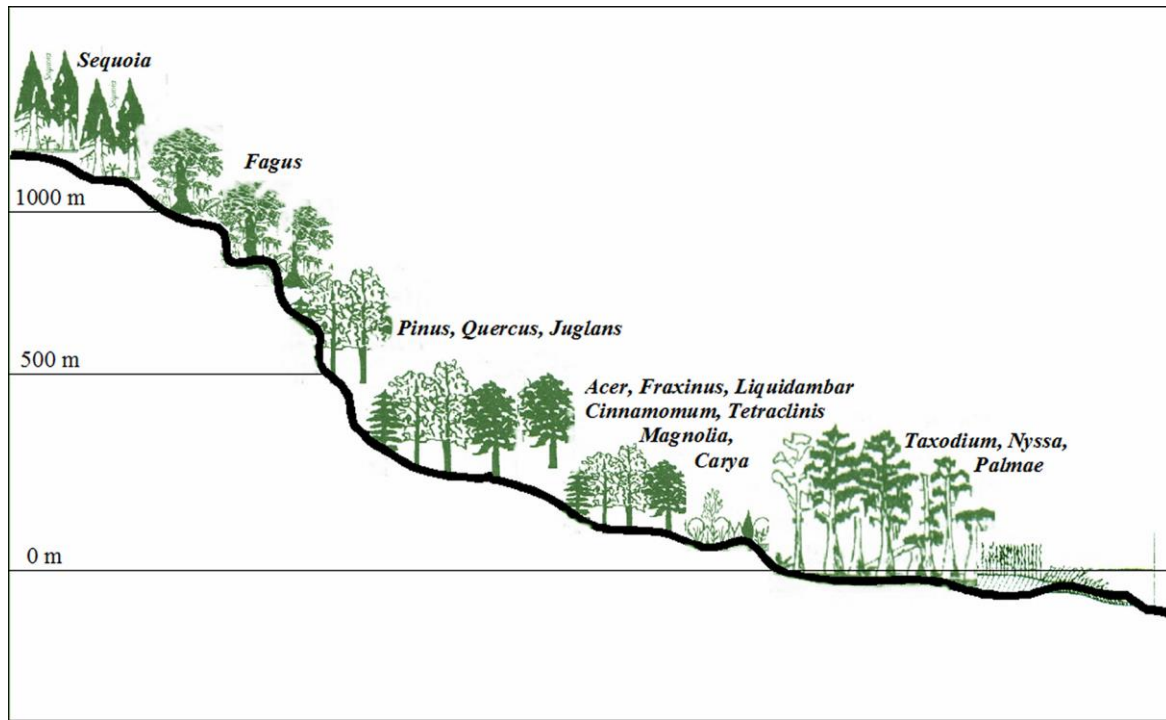


Fig. 20 A transect by the reconstructed Badenian forest of Zarand (from Iamandei, S., 2002).

structure. Also, the structure of fibro-vascular bundles may suggest the current group of palm trees as extant relatives (Tomlinson, 1961, 1990).

The sclerenchyma cap of "lunaria" type (Stenzel, 1904), the f/v ratio less than 1, the sieved plate of undivided type, the metaxylem vessels in number of 5-7, of which two are larger and laterally arranged, the group of 7-11 smaller protoxylem vessels with thickened walls, protected by a sheath of parenchyma whose the marginal cells are thickened and sclerified walls, the absence of the tabular parenchyma could suggest some resemblance to our specimen with a current Sabaloid Palms.

The comparison with fossil taxa described until now shows a possible resemblance to the form described by Grambast (1962), but since the longitudinal sections are not very revealing and due to the xybotomical similitudes of our specimen with the current Sabaloid Palms, we name it *Rhizopalmoxyylon* sp. aff. *sabaloides*.

## CONCLUSIONS

Twenty years ago we started the study of the Middle Miocene Petrified Forest from Zarand, Apuseni Mountains, and it still remained an important topic of further researches even after many field trips in the region. Thus, many hundreds of petrified wood samples collected from there were prepared and studied, and much of them are still in various stages of study. Their identification increase the number of fossil trees from the Badenian forest of the Tălagiu island.

This study could support a more precise palaeoenvironmental and palaeoclimatic reconstruction. The geological evolution of the Tălagiu caldera allowed the best conditions for silicification of the remains of the Mid-Miocene forest occurring on the slopes of the volcano. Over 40

identified tree species allow a phytoecological analysis, revealing the plants' thermal tolerance, the soil and air

humidity, the palaeoaltitude, the relationships and interactions within the biocoenosis, the palaeophytocoenosis itself, the succession of phenophases in a mixed coniferous forest, and the dynamics of the local vegetation during the Late Badenian. The paleoclimate analysis is related to the neighborhood of the Paratethys, where the Zarand Basin evolved. That forest was a mixed mesophytic forest, attitudinally storied, with remains of pre-Miocene sempervirent vegetation of paratropical or subtropical climate, suggesting a Miocene pluvial mixed mesophytic forest of warm-temperate climate.

This mixed mesophytic forest with Lauraceae and Conifers, include the following genera: *Tetraclinioxyylon*, *Thujoxyylon*, *Chamaecyparixylon*, *Cupressinoxyylon*, *Taxodioxyylon*, *Sequoioxyylon*, *Pinuxylon*, *Magnolioxyylon*, *Cinnamomoxyylon*, *Spiroplatanoxyylon* (not *Icacinoxyylon*), *Liquidambaroxyylon*, *Eucaryoxyylon*, *Rhysocaryoxyton*, *Pterocaryoxyylon* (?), *Fagoxyylon*, *Quercoxyylon*, *Alnoxyylon*, *Populoxyylon*, *Salicoxyylon*, *Nyssoxyylon*, *Paraphyllanthoxyylon*, *Piranheoxyylon*, *Aceroxyylon*, *Fraxinoxyylon*, and *Rhizopalmoxyylon*, taking into account new palaeoxylotomical identifications.

In this paper we present some newly identified woods or reattributed to other taxon as new combinations from the Mid-Miocene Zarand Petrified Forest of Zarand that will complete the upward list with 15 new taxa, as it follows.

**Conifers:** *Cupressinoxyylon* sp., *Thujoxyylon* sp., *Chamaecyparixylon* sp., *Taxodioxyylon taxodii* Gothan, *Sequoioxyylon gypsaceum* (Goepp.) Greguss, *Sequoioxyylon multiseriatum* Ramanujam et Stewart, comb.nov.

**Angiosperms:** *Liquidambaroxyylon speciosum* Felix, *Fagoxyylon subcaucasicum* Privé et Brousse, *Fagoxyylon cristallophorum* van der Burgh, *Quercoxyylon sarmaticum* Starostin & Trelea, *Paraphyllanthoxyylon botarii* sp. nov.,

*Piranheoxylon perfectum* sp. nov., *Aceroxylon zarandense* sp. nov., *Aceroxylon pravalense* sp. nov., *Aceroxylon palaeosaccharinum* (Greguss) emend. Iamandei and a sample with structure of monocotyledon attributed to *Rhizopalmoxyton* sp. aff. *sabaloides*, as a very important element with palaeoclimatic significance.

The absence of elements of sclerophyllous vegetation excludes a typical subtropical paleoclimate, and the occurrence of some thermophilic elements in the identified association excludes a cold palaeoclimate.

The growth conditions are further confirmed by the absolute thickness of the growth rings, which is generally quite high in the studied flora. False growth rings rarely appear, due to probable frosts outside the winter or drought during vegetation season. The ratio of early / late wood indicates an increased level of summer precipitation. The ratio of arctotertiary / palaeotropical taxa is 84 / 16 and it is included in the known parameters of the Middle Miocene vegetation representing a mixed mesophytic forest with conifers and deciduous dicots. Some evergreen types also occur, similar to the warm temperate climate forests in eastern China and in southern United States.

This association indicates that during the Late Badenian in Zarand basin the average annual temperatures (MAT) were between 12 and 17 degrees Celsius. Taking into account the island palaeogeographic distribution of the Carpathian land within the Middle-Miocene Paratethys, the relatively uniform palaeoclimate was marked by a low mean annual rainfall (MAR), and by a mean annual precipitation regime (MAP) of 1100-1500 mm per year. These parameters suggest a humid subtropical toward warm-temperate climate, fairly damp of mediterranean type: Cfa to Csa in Köppen classification (Geiger, R., 1954) according to the island mountainous relief (Fig. 20), where the altitudes probably did not exceed 1200 m (Iamandei, 2002).

After this short palaeoecological analysis we conclude:

1. Obviously, the vegetal assemblage defines for the Late Badenian time, a Mixed Mesophytic Forest living, very possibly, in an insular palaeogeography of Carpathian Mountains and in a region marked by an intense local volcanism.
2. The palaeovegetational and palaeoclimatic reconstruction made on the basis of the reconstructed vegetation from Zarand area shows the possible zonal climate during the Late Badenian in Carpathians: Zonal Paleoclimate is Warm Temperate (see Scotese, 2002, <http://www.scotese.com/miocene1.htm>).
3. Palaeoecologically evaluating the Late Badenian vegetational assemblage of arboreal plants from Zarand, through the presence of some taxa with 16% typical thermophilic extant correspondents is suggested: a warm temperate paleoclimate of Mediterranean type, with MAT = 12<sup>0</sup>-17<sup>0</sup> and MAP = 1100-1500 mm annual precipitations.
4. Evaluating the ecological requirements of the paleotropical taxa present in the fossil association, and taking into account another palaeogeographic and latitudinal reconstructions, we can say that the Badenian arboreal vegetation from Zarand represents an altitudinally storied Mixed

Mesophytic Forest with Lauraceae and Conifers with *Sequoioxylon* the dominant taxon, living in an insular mountainous environment and a Warm Temperate Palaeoclimate of Mediterranean type.

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