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A PETRIFIED WOOD FROM THE LOWER MIOCENE OF VALEA MARE (FĂRĂOANI, BACĂU)

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Abstract A fragment of petrified wood was collected from the upper drainage basin of Valea Mare Creek, from the east side of the Ghimelci Hill (Fărăoani, Bacău County). The specimen comes from the sedimentary succession of the Pericarpathian Nappe, the outermost of the Moldavide Units within the Eastern Carpathians. There, the 'upper menilites' and the Pietricica Conglomerates form the core of an anticline belonging to the Valea Mare Digitation of the Pericarpathian Nappe. The paleoxylotomical study of the fossil wood fragment indicates a species of pine, identified as *Pinuxylon* sp. cf. *Pinus sylvestris* L.

Keywords: *Pinuxylon*, resin canals, Early Miocene, Pericarpathian Nappe, upper menilites, Pietricica Conglomerates.

INTRODUCTION

In the Outer Flysch of the Romanian Carpathians, the remains of land flora are mainly represented by spores and pollen (Petrescu et al., 1989; Ţabără & Popescu, 2012; Ţabără & Chirilă, 2012), whereas the plant macroremains, especially the fossil wood, are rare. Only a few plant macroremains were described previously from the uppermost Oligocene deposits of the eastern Pericarpathian Nappe (Petrescu et al., 1989; Iamandei et al., 2012). Based on the available information regarding the known Late Oligocene to Early Miocene extra- and intra-Carpathian paleoflora, Givulescu (1997) and Petrescu (1969, 2003) noticed an invasion of temperate taxa which indicates a slight cooling of the climate. Based on the microflora identified from the Gura Șoimului Formation (uppermost Aquitanian?-Burdigalian), Ţabără and Chirilă (2012) have calculated a mean annual temperature (MAT) of 15.6–21.3°C, a mean annual precipitation (MAP) of 897–1613 mm, and a coldest month temperature (CMT) of 9.6–16.3°C, values that are slightly higher than those known from the Aquitanian. The fossil wood specimen described in this paper adds to the short list of Early Miocene plant occurrences recorded in the peri-Carpathian area, and may contribute to the reconstruction of the land vegetation during this time interval.

GEOLOGICAL SETTING

The petrified wood specimen studied in this contribution was found in the upper Valea Mare drainage basin, on the eastern side of Ghimelci Hill, close to Fărăoani locality, Bacău County (Fig. 1). It was discovered detached, at the base of an outcrop exposing a succession made up of menilites and conglomerates. According to Săndulescu (1962), the so-called 'upper menilites' are exposed in this area, an informal lithostratigraphic unit of Late Oligocene age. It must be emphasized that, at the time of publication of the previously cited contribution, the Oligocene-Miocene boundary was a matter of debate (Drooger, 1966; Berggren, 1969), the Aquitanian Stage being considered either part of the Oligocene or as belonging to the Lower Miocene (Berggren, 1971). Apart of the upper menilites, the Oligocene (in the ambiguous meaning mentioned before) sedimentary succession consists of several other informal lithostratigraphic units besides the upper menilites (Săndulescu, 1962, 1984): the older 'upper dysodilic shales' and the younger 'lower salt formation'. All of these informal units are now included in the Aquitanian-Lower Burdigalian (Săndulescu et al., 1995). According to Săndulescu (1962), they represent the basement of the Lower Miocene sedimentary succession, characterized mainly by a conglomerate facies (Pietricica Conglomerates) and a reddish facies (Tețcani Beds), overlain by gypsum. The conglomerates overlie an angular unconformity, the entire sequence being part of a faulted anticline (see Săndulescu, 1962).

In their publication, Frunzescu & Brănoiu (2004) included the Tețcani Facies (or Tețcani Beds) in the upper Burdigalian succession. Younger deposits are also known in the area (Fig. 1) but these are not of interest for this report because they crop out downstream of the fossiliferous locality yielding the fossil wood. It is also possible that the Oligocene rocks represent, in fact, a huge olistolith similar to those described in the Gura Șoimului Formation, a lithostratigraphic unit defined for the more internal Vrancea Nappe. Both the Pietricica Conglomerates and the Gura Șoimului Formation belong to the lower Burdigalian, being possible lateral equivalents, although their age needs to be better constrained. In the Gura Șoimului Formation, which is interpreted as a mega-olistostrome by Amadori et al. (2012) and Guerrera et al. (2012), there are several olistoliths of Oligocene rocks (Ionesi et al., 1994) varying from decimeter to tens of meters in size.

According to Miclăuș et al. (2009), the sedimentary area of the Vrancea Nappe was related by the forebulge, whose basement consists of Dobrogea-type greenschists and a thin sedimentary cover. In their opinion, the Moldavide Basin was a foreland basin system that evolved during the Late Cretaceous-Miocene time interval. The

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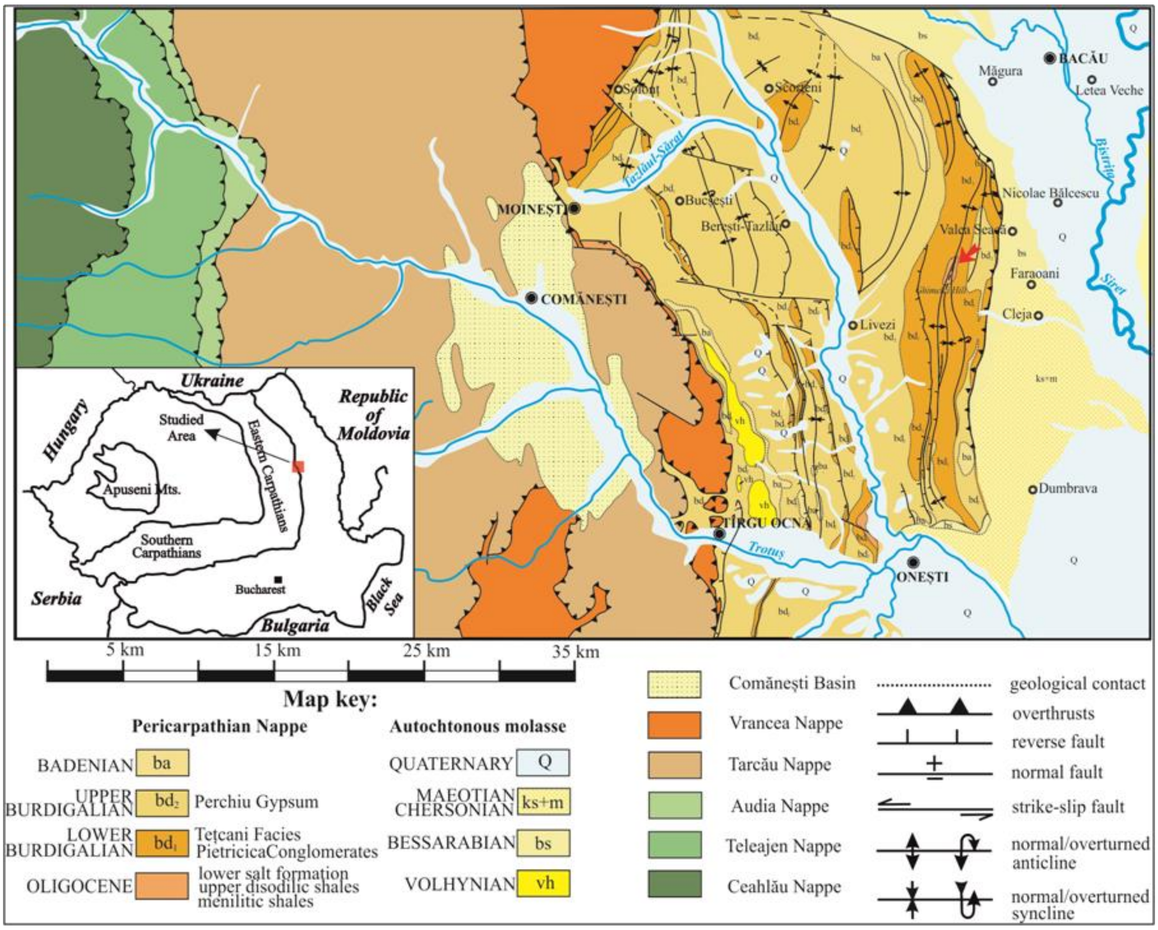


Fig. 1 Geological sketch of the area yielding the fossil wood, fossiliferous site marked by red arrow (redrawn after the Geological Map of Romania, sc. 1:200,000 - Bacău Sheet and Săndulescu, 1962).

increasing supply of coarse clastic material (mainly greenschist clasts) in the outer part of this foreland basin, especially beginning with the Oligocene, indicates the fragmentation of the raised forebulge as a result of basin shortening (Guerrera et al., 2012, and references therein). In this scenario, the conglomerates from both external nappes would be supplied by the forebulge during the shortening phase corresponding to an Early Miocene tectogenetic event. This sedimentary area was subsequently deformed in later (Middle Miocene) shortening episodes into what is known as the Pericarpathian Nappe, the outermost of the Moldavide Units. Săndulescu (1984) recognized three digitations in the structure of the Pericarpathian Nappe, namely the Scăriga-Perchiu, Pietricica, and Valea Mare digitations arrayed from the internal to the external part of the unit; the source rocks of the studied fossil wood belong to the outer digitation.

The petrified wood described in this contribution represents a large detached bioclast which could be sourced either from: 1) the upper menilites (which may be either in normal succession or form an olistolith); or 2) the conglomerates. As discussed above, the age of the menilite unit is poorly constrained, being loosely included in the Aquitanian-lower Burdigalian succession. The younger conglomerates are also considered part of the lower Burdigalian succession. As such, the fossil wood specimen from the Valea Mare valley represents a sample of an Early Miocene flora from the peri-Carpathian area. As concerning the origin of the wood fragment in the menilites, these are marine deposits in which the fossil wood could have arrived as a drifted log. Meanwhile, the Pietricica Conglomerates were interpreted as deposits of alluvial fans (Mărunțeanu, 1985), a more likely sedimentary environment for terrestrial plant debris like tree trunk fragments, which could be then silicified by mineralizing solutions that circulated within the sediments.

Few data exists currently regarding the Oligocene-Early Miocene palaeoflora from the Carpathian area. This flora is documented especially based on pollen assemblages (Ţabără & Chirilă, 2012). In the Carpathian Bend Area, in the Kliwa Sandstone Formation, Petrescu et al. (1989) described an assemblage consisting of: conifer pollen (*Taxodium*, *Sciadopitys*, *Picea*, *Abies*, *Tsuga*, *Cupressus*, *Podocarpus?*), angiosperm pollen (*Myrica*, *Engelhardia*, *Quercus*, *Ulmus*, *Alnus*, *Nyssa*, *Carya*), also including Compositae, Sapotaceae, and even Palmae pollen. All these taxa indicate a Mixed Mesophytic Forest, otherwise typical for the Oligocene vegetation known in the Carpathian and Transylvanian areas. In the same general area, Petrescu et al. (1989) also described several lignotaxa from around Colţi locality, in the Faţa Budei fossiliferous site along Aluniş Brook; this assemblage includes: *Sequoioxylon gypsaceum* (Goepp.) Greguss, *Laurinoxylon murgoci* Petrescu, and *Icacinoxylon* sp. (the last one recently revised as *Spiroplatanoxylon* sp. by Iamandei et al., in press). In the Carpathian Bend Area, Iamandei et al. (2012) reported fossil woods belonging to taxa such as *Cupressinoxylon* sp. aff. *Thujoxylon* sp., *Sequoioxylon* *gypsaceum* (Goepp.) Greguss, *Quercoxylon* sp. and *Ulmoxylon* sp. cf. *Ulmus carpinifolia* Gled from the Oligocene Kliwa Sandstone Formation and reworked in the Middle Miocene salt breccia (Cosmina Breccia, in Frunzescu & Brănoiu, 2004). This short list of petrified wood taxa is complemented now by the specimen that forms the topic of this paper, assigned to *Pinuxylon* sp. cf *Pinus sylvestris* L. based on its palaeoxylotomy.

Family **Pinaceae** Lindley
Genus *Pinuxylon* Gothan 1906
Pinuxylon sp. cf. *Pinus sylvestris* L.
Plate I, figs. 1-9.

MATERIAL

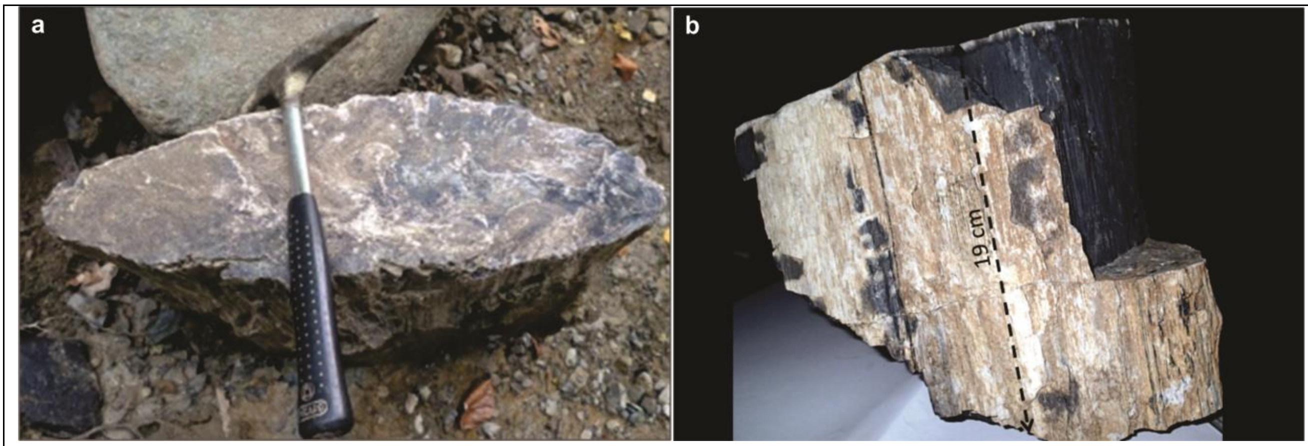
The studied material is represented by a decimetric-size fragment sampled in the field from a large and detached petrified trunk (Fig. 2A), collected at the base of an outcrop exposing the upper menilites and the Pietricica Conglomerates, on the eastern side of Ghilmeci Hill, in the upper drainage basin of the Valea Mare Creek (Fărăoani, Bacău County). The sample is black-colored inside, with a whitish coat due to superficial alteration, and has a fibrous structure (Fig. 2B), suggesting a petrified coniferous wood. The sample (Fig. 2B) is deposited in the Paleontological Museum of Al. I. Cuza University, Iaşi, under the index 8025.

MICROSCOPIC DESCRIPTION

The growth rings are distinct, well developed, consisting of more than 60 cells. These are large and relatively thin-walled in the early-wood and often compressed and deformed in the transitional wood. In the late-wood, 3-8 rows of tangentially flattened thick-walled cells appear. Normal resin canals are present; the canals are circular or radial oval in shape, large (90-150/80-170µm the radial /tangential diameters) and often surrounded by destroyed thin-walled epithelial parenchyma cells. The canals appear isolated inside the growth ring, often at the beginning of the transitional wood, sometimes also inside the early-wood or inside the transitional wood, but not close to the ring boundary. The radial canals are narrower, less than 30µm in diameter, grouped as 1 to 3 inside the ray body, and sometimes present within uniseriate rays.

The tracheids in cross-section are polygonal-rounded or irregularly deformed in the early-wood, having 20-70/20-60µm radial/tangential diameter, and relatively thin walls: 5-7 µm the double wall. In transitional to late-wood the tracheids have oval or tangentially flattened section of 15-35 µm in diameters and are thick-walled: 8-17 µm the double wall.

Sometimes triangular or irregular intercellular spaces appear. Often, intermingled radial rows of narrower lumened tracheids are also present, with a frequency of 964-1369 tracheids/mm^2.



F**ig. 2 a**, **b** Field photo of the large fossil trunk (a), and of the studied sample (b).

Between two rays, 2-15 tracheid rows can be counted. The tangential walls have small round to oval pits of 5-8µm in diameters, with small round aperture. Radially, abietineous pits of 12-15(17) µm in diameter, with round apertures, were observed in a single vertical row, spaced, and without *crassulae*.

The *wood parenchyma* is usually absent, or difficult to observe in cross-section, but occasionally it appears in longitudinal view as a few dispersed rectangular vertical cells that are moderately thick-walled, with thick, rough transverse walls, and with granular resin content variably present or absent.

The *rays* are usually uniseriate, with 5-15 tall cells. Two-three-seriate fusiform rays also appear, having 1-2(3) resin canals, 15-20 cells in height, with 3-6 cell long uniseriate endings.

Lateral, triangular intercellular spaces are common. The ray density is of 4-6 rays on tangential millimeter. In radial view, the rays appear heterogeneous, with 20-25 µm high cells. The horizontal walls are thin, with smooth or slightly rough double wall of 2-3.5 µm thickness, , while the tangential walls, of 1.5-2 µm, are rough or nodular (with 6-7 knots).

The indentures are indistinct or absent. In cross-fields, pitting is difficult to be seen due to bad preservation, but rarely 1-3 horizontally arranged, small, inclined taxodioid pits of 4-6/8-10µm in diameters, with lens-like apertures of 3-4.5µm, were observed. The transversal tracheids, often difficult to separate from the ray body-cells, usually appear either inside the ray or marginally arranged. These are 25-32µm in height, and show slightly wavy and rough outer walls.

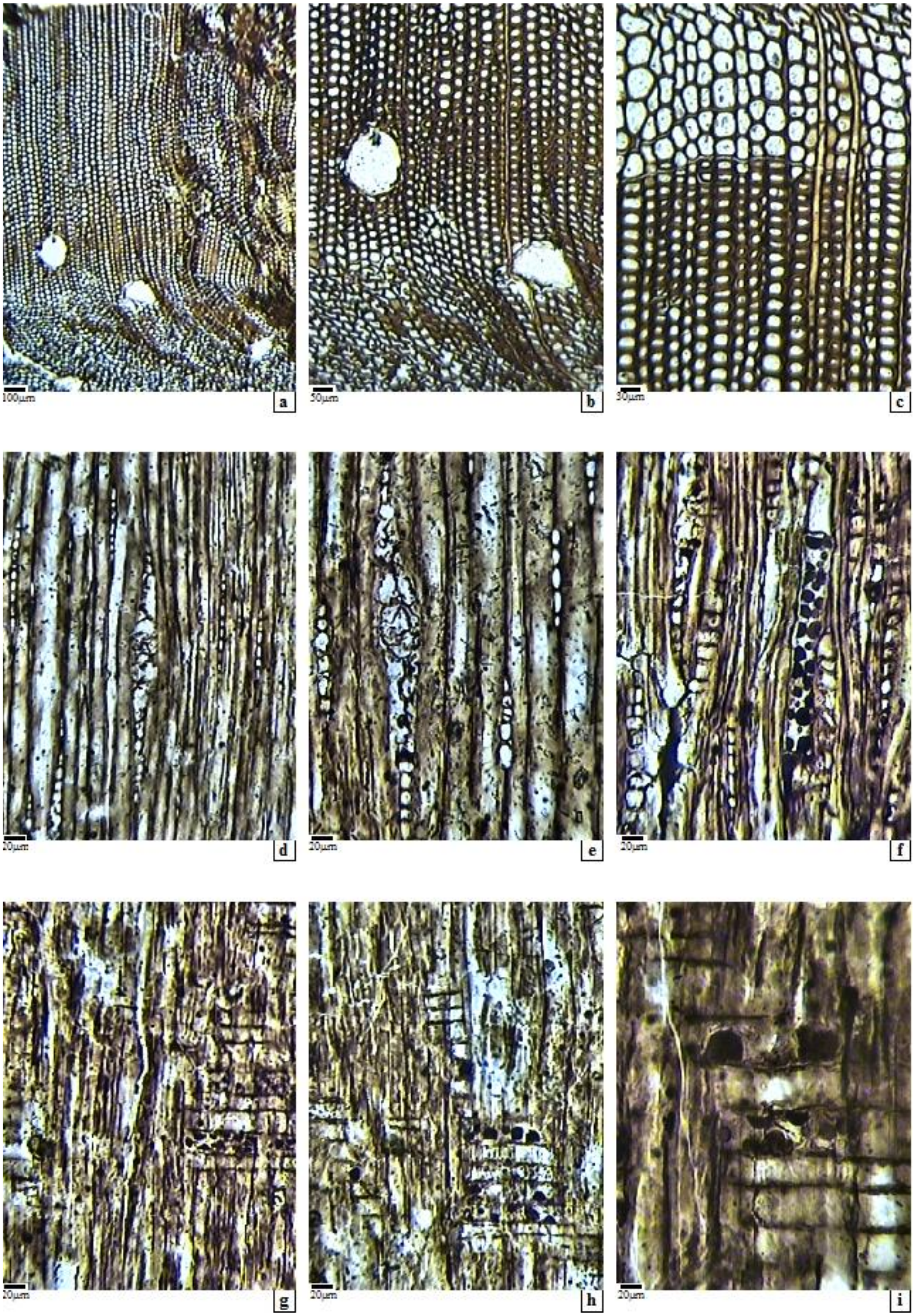


Fig. 3 *Pinuxylon* sp. cf. *Pinus silvestris* L., Ghilmeci Hill, Bacău County, Romania. a-c. Cross section – Distinct growth rings, early-wood and late-wood tracheids, resin canals. d-f. Tangential section – 1-3-seriate rays with radial canals, axial canal with granular content. g-i. Radial section – Radial canals with resin graines, pinoid cross- fields.

Spiral thickenings or pitting was not observed on them due to bad preservation. The radial canals, numbering 1-2(3) inside the ray-body, are 20-27µm in diameter; a few isolated resin grains were observed inside them.

AFFINITIES AND DISCUSSIONS

The presence of normal axial and radial resin canals allows a general referral of the studied specimen to a conifer from Family Pinaceae. Generally, the resin canal-bearing extant pinaceous genera can be separated into the following genera (Greguss, 1955; Earle, 2015): *Pinus* (the pine), with large axial canals surrounded by frequently destroyed thin-walled epithelial cells, and smaller, very specific radial canals, reminiscent of the morphology present in our specimen; *Pseudotsuga* (the Douglas-fir), with axial resin canals surrounded by 5-7 thick-walled epithelial cells; *Picea* (the spruce), having axial resin canals with 8-10 thick-walled epithelial cells around; and *Larix* (the larch), with 10-14 thick-walled epithelial cells around the axial resin canals. Further details regarding the characteristics of the *Pinus* wood-type were derived from the papers of Phillips (1941), Hudson (1960), Patel (1971) and Ickert-Bond (2001), supplemented with information hosted on the online site of Earle (2015) concerning the classification of the genus.

The genus *Pinuxylon* was defined by Gothan (1906) and since then, a large number of European species were referred to it. For example, Rössler (1937) described the species *Pinuxylon paxii* Kräusel, *P. cembraeforme* Rössler and *P. vateri* (Platen) Rössler from Germany. Later, Kräusel (1949) made a useful synthesis of all the previously reported *Pinuxylon* species, a work consulted by us alongside the papers of Brezinova (1981) and Süss (1989). Tidwell et al. (1986), describing a new species of *Pinuxylon* (*P. woolardii*), made a useful analysis of the extant species of *Pinus*, as well as of some of the already described fossil ones.

Certain forms of Tertiary fossil pines, with taxodioid or round pits in cross-fields, were described by Greguss (1954, 1967) as *Pinuxylon haploxyloides*, *P. albicauloides*, *P. tarnocziense* and *Pinuxylon* sp., all of these probably of *Haploxylon* type. Some other pines, characterized by small pinoid and even fenestriform pits in cross-fields, were identified as *Pinuxylon* sp. by Petrescu & Nuţu (1970) or Comble et al. (1973).

Vozenin-Serra (1971) has described a pine structure with large axial resin canals of 102-216/92-216µm in diameter, characterized by taxodioid to ooporoid pits in the cross-fields, usually with marginal transversal tracheids that are thin-walled and without denticles, and created a new species of fossil *Pinus* of *Haploxylon* type, namely *Pinuxylon nightigalense* Vozenin-Serra.

Another frequent European pine of *Haploxylon* type, *Pinuxylon parryoides* (Gothan) Kräusel emend. Van der Burgh 1964, was also identified by Gotwald (1966), Van der Burgh (1973), Privé (1976) and Iamandei (2000). This taxon is characterized by 1-2-3-seriate radial abietineous pitting with *crassulae* and high uniseriate rays (up to 36 cells), with piceoid or taxodioid pits in the cross-fields. Privé-Gill & Watelet (1980) described a *Pinuxylon* sp., quite similar to the *parryoides* type, while Iamandei and Iamandei (2000) reported a new species of pine of *Haploxylon* type – *Pinuxylon marinasii* Iamandei and Iamandei 2000– quite similar, but not identical, to *P. parryoides* or to the extant *Pinus pinea* L, with large resin canals, radial uniseriate pitting, sometimes irregularly paired or already biseriate, spaced or contiguous, and small taxodioid pits in cross-fields.

Studying a charcoalified material collected from the salt of Ocna Dej, Petrescu & Bican-Brişan (2004) described a *Pinuxylon* sp. It is a pine structure with resin canals, with typical cross-fields with two or three small pinoid pits, arranged in horizontal row, and horizontal tracheids, suggesting a *Diploxylon* type. Finally, by palaeoxylotomical study on a petrified wood collected from Bala, Mehedinţi County, a pine also showing affinities with the *Diploxylon* wood-type, characterized by large normal axial resin canals with moderately thick-walled epithelial cells, was assigned to *Pinuxylon* sp. cf. *Pinus sylvestris* L. (Iamandei et al., 2011), as a fossil member of the *Diploxylon* subgenus, *Pinus* section, and *Sylvestres* subsection.

The specimen studied here also shows large axial resin canals (90-150/80-170 µm in their radial/tangential diameters), surrounded by often destroyed, thin-walled epithelial parenchyma cells. The canals are positioned in the early-wood, at the beginning of the transitional wood, or inside the late-wood, but not close to the boundary. High fusiform rays with 1-2(3) radial canals occurs, sometimes present also in the uniseriates ones. Transversal tracheids, slightly taller than the body ray-cells, are present and show wavy and rough outer walls. In the cross-fields, 1-3 horizontally arranged taxodioid pits occur. All these details suggest a resemblance of our specimen to *Pinus* of the *Diploxylon* type, as it is described by Greguss (1955) and Schweingruber (1991). Based on this comparative analysis, and taking into account the scarcity of other observed xylotomical details, due to their bad preservation, we assign the studied specimen to *Pinuxylon* sp. cf. *Pinus sylvestris* L.

CONCLUSIONS

The here studied petrified wood specimen is identified as a species of *Pinuxylon*. It was found as a loose bioclast supplied either by upper menilites or, more probably, by the Pietricica Conglomerates from the Valea Mare digitation of the Pericarpathian Nappe. Considering the small number of lignotaxa, or other plant remains, that were identified up to now in the Carpathian area from this time span (Aquitanian-Early Burdigalian), this record adds a new fossil wood site, potentially of great interest for paleo-climatic and paleo-environmental reconstructions.

The Oligocene Flora of the Carpathian area described in previous studies indicates a warm climate which became slightly cooler during the Early Miocene, as suggested by the invasion of temperate taxa (see Mai, 1989; Givulescu, 1997). The *Pinuxylon* sp. cf *Pinus sylvestris* L. identified in the present paper, based on the palaeoxylotomical study of a petrified wood from the Valea Mare Digitation of the Pericarpathian Nappe (Bacău County), also supports such an Early Miocene climatic cooling, considering that the extant relatives of this taxon are typical for altitudes higher than 1200 m in Eurasia.

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