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PETRIFIED WOOD OF TETRACLINOXYLON FROM CĂPRIOARA VALLEY, FELEAC, CLUJ (MIDDLE MIOCENE, ROMANIA)

STĂNILĂ IAMANDEI[1], EUGENIA IAMANDEI[2] & MIRELA SABOU DUMITRESCU[3]

Abstract. Feleac Early Sarmatian Flora has a new member described on a petrified wood recently discovered in the Căprioara valley, Feleac, Cluj. Several decimetric samples come from one petrified trunk. The paper presents the detailed description of the new fossil wood. It was described as a species of *Tetraclinoxylon,* newness within Feleac Flora.

Keywords: Early Sarmatian, Feleac Flora, petrified wood, *Tetraclinoxylon*, palaeoclimatic significance.

INTRODUCTION

New petrified wood collected within Feleac Hill area, close to Cluj Napoca, was submitted to a palaeoxylotomical study in order to identify the original tree. The new petrified wood was found within littoral - nerritic sediments considered as Early Sarmatian in Valea Căprioarei (Deer Valey), Southwestern part of Feleac Hill (Fig. 1). This is where marly to sandy clays appear, intercalated with sands-sandstones with trovants and pebble levels. These deposits are overlaying the sediments of the terminal Badenian, probably with a gap of sedimentation (Givulescu, 1997).

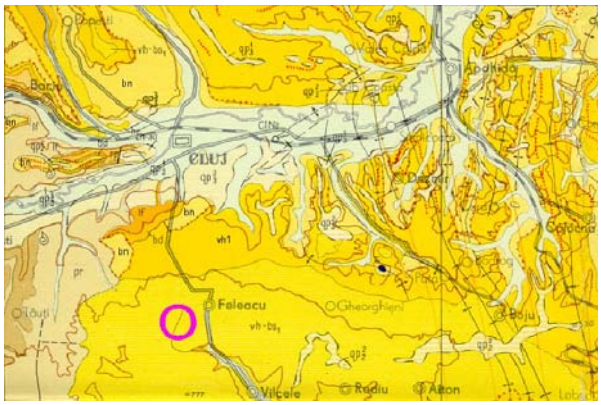

Fig. 1 - Location of Deer Valley Fossiliferous Area on Cluj-Feleac map marked with - O. (excerpt of IGR Geological map 1:200000, Cluj sheet).

These sedimentary deposits are characterized by a brackish mollusk fauna; see the following revised list from Givulescu (1997): *Irus (Papirus) gregarius gregarius, Cerastoderma vindobonense vindobonense, Gibula (Rolandiana) picta, Gibula (Gibula) pusilla, Pirenella picta picta, Cerithium (Thericium) rubiginosum rubiginosum*. This points to an Early Sarmatian age. In addition, brackish foraminifers and fish remains were described from here.

More recently, Suciu (2005) attempted to verify the real age of the sedimentary rocks from the hills of southern and northern parts of Cluj-Napoca and its neighbourhoods: Iris and Feleac Hills, and the top of Lombi Hill. These consist of already known Sarmatian and Badenian deposits, as supported by the studies and findings of Răileanu (1955), Moisescu & Popescu (1967), and Mészáros & Clichici (1988). The same age is indicated on the geological map edited by the Geological Institute, scale 1:200.000, Cluj Sheet (1968). The Sarmatian deposits were assigned to the "Buglovian", as Earliest Sarmatian, and to Volhynian-Basarabian, without reliable arguments.

Suciu (2005) investigated their micro-palaeontological content, and new foraminifer associations were outlined: the biozone with *Elphidium reginum* representing the Late Volhynian and the biozone with *Dogielina sarmatica* representing the Early Basarabian (Feleac fm.). In general the elphidiids associations are typical for the littoral facies while the association of rotaliids with red algae thalli indicates brackish shallow, agitates waters, probably in an intertidal area. The sandy sediments contain carbonate mud interlayers at several levels, which also suggest a littoral environment. Suciu (2005) brought new biostratigraphical arguments for the Late Volhinian-Early Besarabian age of the Sarmatian sediments from Lombi, Iris and Feleac Hills, but he did not explicitly order them within the Sarmatian formations previously described here.

In the above Sarmatian formation from Feleac Hill, Staub (1883, 1891), Szadeczky (1917) and Givulescu (1957-1995) described fossil leaves and fruit imprints. The collection sites were not mentioned but Givulescu (1997) admitted that over time he has personally collected samples from a number of locations along the Cluj Napoca – Turda road. The collection sites appear to have been small stone-quarries, which are very difficult to locate and identify nowadays.

Taxa previously described were revised by Givulescu (1997). He set up a list of a small, diversified flora (the so-called "Feleac Flora") which contains: *Cystoseirites partschi* Sternberg, *Pinus hepios* Unger, *Pinus felekiensis* Staub (small branch), *Sequoia abietina* (Brongn.) Knobloch, *Abies* cf. *alba* Miller, *Palaeocarya macroptera* (Unger) Mai, *Daphnogene polymorpha* (Al. Braun) Ett., *Laurophyllum* sp., *Ulmus pyramidalis* Goeppert, *Platanus* cf. *leucophylla* (Brongn.) Knobloch, *Acer tricuspidatum* Brongn, *Fraxinus* sp. (samara),

[1] National Geological Museum (IGR),2nd, Kiseleff Ave., 011345 – Bucharest, Romania. E-mail: iamandei@gmail.com
[2] Geological Institute of Romania, 1st, Caransebeş Street, 012271 – Bucharest. Romania. E-mail: iamandei@gmail.com
[3] "Babes-Bolyai" Univ. Cluj-Napoca, Faculty of Biology and Geology, Departm. of Geology and Palaeontology, 44th, Bilaşcu street, 4000015 - Cluj-Napoca, Romania. E-mail: mirelageo@yahoo.com

Phragmites oeningensis (Al.Braun), *Cyperites senarius* Heer, and *Phyllites* sp. The interpretation was that the flora was coming from a lowland mesophytic forest, of warm temperate climate. It is possible that the fossilized fruits and leaves were brought into the littoral sedimentation basin or on the sandy beach (see the presence of *Cystoseirites*) by wind or by water. Givulescu's physiognomic analysis on the material shows that the major part of the identified taxa were trees (83.33 %), with predominating "Arctotertiary" elements (~75 %) having leaves with dentate margin (?!). However, the number of described taxa is too small to provide a reliable palaeoclimatic overview synchronous to the living vegetation described above.

Petrescu (2003, p. 115) has collected and studied a lot of trunks from Căprioara Valley; conifer (*Sequoioxylon, Pinuxylon*) and dicotyledonous woods (*Quercoxylon, Laurinoxylon, Ebenoxylon, Rhisocaryoxylon*) have been identified. This material is currently stored at the Palaeontology Museum of the Department of Geology and Paleontology, Babeş-Bolyai University (BBU) Cluj-Napoca.

The current paper presents a new identified coniferous taxon based on the palaeoxylotomical study of the new samples collected, represented by several pieces of a single petrified trunk.

The authors consider the fossiliferous rock to be slightly tuffaceous. This new taxon was identified as a species of *Tetraclinoxylon,* which had a large distribution within the Carpathian area, as already demonstrated by Iamandei et al. (2000-2008). It was considered as wood of *Tetraclinis*, taxon which is missing from the list of flora revised by Givulescu (1997) as characterizing the Flora of Feleac. This identification confirms the previous palaeogeographic, palaeoecologic, and palaeoclimatic conclusions of Givulescu (1992, 1997).

SYSTEMATICS

Phyllum **PINOPHYTA** CRONQUIST, TAKHT. & ZIMMERM. EX REVEAL
Family **CUPRESSACEAE** GRAY
Subfamily **Cupressoideae** RICH EX SWEET
Genus ***Tetraclinoxylon*** GRAMBAST 1951
Tetraclinoxylon romanicum IAMANDEI & IAMANDEI, 2000
Plate I, Figs. 1-9.

Macroscopic description

The studied material was collected from Căprioara Valley, southwestern part of Feleac Hill, from some littoral - nerritic sediments considered to be of Early Sarmatian age. Several pieces of silicified wood (fig. 3) of centimetric size show light brownish colour and fibrous texture. The studied material is now stored under Inv. no. 793 at the Paleontological Museum of BBU Cluj Napoca.

Microscopic description

Growth rings – distinct, marked by 2-5 or more rows of thicker-walled and radially compressed cells in the late wood. In the early wood, there are enlarged thick-walled cells with round to oval lumina. The growth-rings are wide and the transition is gradual. Resin ducts are absent. Sometimes cracks appear at the ring boundary, most probably due to fossilization processes.

Tracheids – polygonal, rounded in cross-section or slightly radially compressed especially to the latewood. Intercellular spaces are present in the early wood. The lumina of the vessels are round to elliptical, with a diameter of approximately 15-25 µm, smaller in the latewood: 8-12 µm. The cellular walls are thick to very thick, the double wall thickness starting at 5-8 µm in the early wood and going to up to 12-16 µm in the final wood. The density of the tracheids is of 2500-2700 cells per square millimetre.

Tangentially, the tracheids are pitted with smaller pits of 5-8 µm the border diameter, and small circular apertures of about 3 µm, uniseriately or slightly irregularly disposed on the altered tracheidal wall. In radial section we observed abietoid pits slightly spaced in uniseriate rows, rarely biseriate and contiguous, with (10)14-19 µm at the round border diameter. The aperture chamber is round, of 2-4 µm. The aperture itself is not visible due to the altered tracheidal wall, however, at times *crassulae* can be observed. Occasionally, due to a wavy contour of the tangential wall, pit casts can be observed.

Axial parenchyma - in cross-section appear as a few cells dispersed within transitional wood or in short discontinuous uniseriate tangential lines to the late wood, usually with dark resins. Details in longitudinal sections are difficult observe, due to the bad preservation of the material.

Rays - in cross-section appear as rectangular parenchymatous cells full of resin compressed and deformed by the vertical tracheids in their strict vicinity. Tangentially, the rays are uniseriate, possibly with short biseriations. They are 1-15 (or more) round cells high, but most frequently they are 2-8 cells high. The cell shape appears round or slightly oval and probably simply pitted on the tangential walls. The ray-density is of 3-10 rays on tangential millimetre. Radially the ray cells are homogeneous, with relatively smooth and thin horizontal walls (2-3 µm the double wall). Tangential walls are also thin and smooth, without nodules or indentures. These procumbent cells have 10-15 µm in height, marginal cells are higher (16-25 µm). Cross-fields cupressoid, with 1-2 small cupressoid pits, in pairs horizontally disposed are visible.

Affinities and discussions

After evaluating all the xylotomical features observed on the studied material, clearly devoid of resin ducts, having low rays with cupressoid cross-fields and thick-walled tracheids even in early wood, with round lumina in cross-section, we consider it can be assigned to the Cupressaceae family. The material is most similar to the extant monotypic genus *Tetraclinis* Mast., a tree reaching 6-8-15 m in height, even if it often had a shrub habit. During the Neogene, this tree covered large areas in Europe (see Iamandei & Iamandei, 2008). However, nowadays it is present as an endangered single species - *Tetraclinis articulata* (VAHL.) MASTERS, cited in the lists of IUCN as vulnerable populations found only in the extreme-south of Spain, Morocco, North Algeria, North Tunisia, Malta, and perhaps North-Eastern Libya (see Earle, 2007, quoting Farjon, 2005).

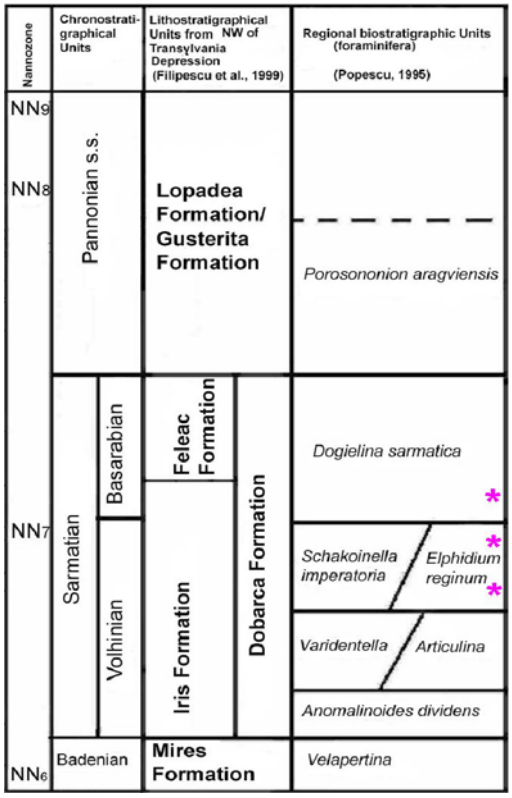

Fig. 2 - Late Mid-Miocene – Early Late-Miocene litho-biostratigraphic column in Transylvania Depression, Cluj-Napoca area (after Suciu, 2005). * - plant remains, including fossil wood.

An obligatory comparative study of the next few fossil species of the morphogenus *Tetraclinoxylon* GRAMBAST 1951 described till now also shows a great similarity even if not an identity:

- *T. boureaui* described by Grambast în 1951 from the Chattian of Paris Basin is the type species for the genus;
- *T. vulcanense* described by Catherine Privé (1973) from the Pliocene of Puy-de-Dôme, France. The same species was identified by Sakala (2003) redescribing a big petrified Late Eocene trunk from Kučlín (Czech Rep.), originally determined by Březinowá et al. (1994) as *Podocarpoxylon helmstedtianum* of Gottwald (1966);
- *T. anglonae* described by Biondi (1980);
- *T. lusitanense* reassigned by Süss (1997) to this genus, the material initially being described by Vallin as a species of *Cupressinoxylon*;
- *T. velitzelos*i described by Süss (1997);
- *T. romanicum*, described by Iamandei & Iamandei (2000) from Late Badenian of South Apuseni, but also from other pericarpathian sites (Iamandei et al., 2001, 2005, 2007, 2008) in formations of similar age (Late Badenian, Early Sarmatian) seems to have identical xylotomical features.

However, if the whole range of xylotomical features of all the described fossil morphospecies is evaluated, one can observe that there are only insignificant differences. Thus, these could be interpreted as intraspecific variability. All are very similar to one extant species, *Tetraclinis articulata* (VAHL.) MAST.

Found only in Europe so far, fossil taxa described based on fossilized remains of vegetative plant parts as leaf imprints or cones, point to only two species (Kvaček et al., 1989, 2000; Kvaček & Hablý, 1998; Givulescu, 1997; Stancu & Țicleanu, 1975):

- *T. salicornioides* (UNGER) KVAČEK, found throughout Europe, that perfectly corresponds to the present day species *T. articulata*;
- *T. brachyodon* (BRONGNIART) MAI & WALTER, as Middle Eocene to Pliocene humid subtropical element throughout, from Caucasus probably to Italy and Germany - from where it was described, it seems it represented a fossil xerophytic form.

If it is true that only two forms coexisted, it is very possible this xerophytic form had a special wood structure, which is unknown today. Further studies may add better arguments to such a hypothesis.

The comparison of the structure of our studied material with that of the species already described from the Carpathian area, either from the same locality with the holotype (Iamandei & Iamandei, 1999), or from other localities in Oltenia, in Suceava regions (Iamandei et al, 2001, 2008), or in Moldova Rep. (Iamandei et al. 2005, 2007) shows small xylotomical differences, which could also be considered as representing intraspecific variability (for example the variable frequency of the *crassulae* in our specimens).

The authors hereby assign the studied material coming from Feleac Hill, near Cluj, from Early Sarmatian deposits hosting the originall-described Feleac Flora (Givulescu 1997) to the morphospecies *Tetraclinoxylon romanicum* IAMANDEI & IAMANDEI, 2000. The wood belonged to a plant missing from the original list of Feleac Flora.

Fig. 3 - Studied petrified wood fragments (inv. no. 793 in Paleontology Museum of BBU Cluj-Napoca).

CONCLUSIONS

This paper presents a newly identified plant based on the study of pieces of petrified wood collected from a single site and a single petrified trunk by one of the coauthors ([3]). It represents a petrified wood of *Tetraclinis*: *Tetraclinoxylon romanicum* IAMANDEI & IAMANDEI, firstly described in this area. The species can be added to the list of flora revised by Givulescu (1997) and Petrescu (2003), as characterizing the Early Sarmatian Flora of Feleac, integrally listed below:

Leaves, fruits (in Givulescu, 1997)

- *Cystoseirites partschi* STERNBERG
- *Pinus hepios* UNGER
- *Pinus felekiensis* STAUB
- *Sequoia abietina* (BRONGN.)KNOBL.
- *Abies* cf. *alba* MILLER
- *Laurophyllum* sp.
- *Daphnogene polymorpha* (AL.BR.) ETT.
- *Platanus* cf. *leucophylla* (BRONGN.)KNOBL.
- *Palaeocarya macroptera* (UNGER) MAI
- *Quercus mediterranea* UNGER
- *Ulmus pyramidalis* GOEPPERT
- *Acer tricuspidatum* BROGNIART
- *Fraxinus* sp.
- *Phragmites oeningensis* AL. BRAUN
- *?Cyperites senarius* HEER

The fossil wood generically identified by Petrescu (quoted in Petrescu, 2003), are the following: *Quercoxylon, Laurinoxylon, Ebenoxylon, Rhisocaryoxylon, Sequoioxylon* and *Pinuxylon*. We add to this list a species of *Tetraclinoxylon.*

In a previous paper we showed that even if the extant equivalent form has a restricted life area, the fossil genus was spread during the Cenozoic throughtout Europe (see Kvaček et al., 1989), at least around Paratethys (Iamandei & Iamandei, 2009, in press). It indicated a warm temperate palaeoclimate, which progressively cooled: in the latest Pliocene this taxon disappeared at least from the Carpathians (Givulescu, 1997 cited the last *Tetraclinis salicornioides* (Unger) Kvaček remains as leaf imprints within Chiuzbaia Flora). The climate progressively became excessive temperate to cold temperate at the end of Neogene; correspondingly no specimen was identified east from the Carpathians of the same age.

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PLATE CAPTION

PLATE I

Figs. 1-9. *Tetraclinoxylon romanicum* IAMANDEI & IAMANDEI, 2000, material, Sm.1, v. Căprioara – Feleac, Cluj - inv. no. 793 in the Paleontology Museum, BBU Cluj Napoca.

Figs. 1-3. Cross-section – distributions of thick-walled tracheids with rounded lumina, growth rings, ring boundaries, early wood, late wood, scattered parenchyma cells.
Figs. 4-6. Tangential-section – tangential minute pitting on tracheidal walls, short rays.
Figs. 7-9. Radial section – radial abietoid pitting, homocellular rays, cupressoid cross-field pits.

PLATE I