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Identification of a fossil trunk from Achlada Mine (Florina, Greece) newly installed at the entrance of the coal mine

Stănilă IAMANDEI[1*], Eugenia IAMANDEI[1], Evangelos VELITZELOS[2]

[1]*Geological Institute of Romania (GIR), 1st, Caransebeş Street, 012271 – Bucharest, Romania*

[2]*National and Kapodistrian University of Athens, Faculty of Geology and Geoenvironment, Athens, Greece*

Abstract: Huge trunks were discovered in the open cast lignite mine of Achlada, which is situated in the late Neogene intramontane basin Florina-Ptolemais-Servia, northwestern Greece. One stump of six meters tall found there was removed and installed in front of the administrative building of Achlada mine, while the remained part was preserved in situ. By palaeoxylotomical study on a sample of the exposed stump, the original tree was identified as *Taxodioxylon taxodii*, which represents the fossil equivalent of the extant *Taxodium distichum*. A few considerations on the palaeoenvironment in which the Achlada lignite deposits were formed are added.

Keywords: Late Miocene, xylite, *Taxodium,* palaeoenvironment, Achlada, Greece

1. Introduction

Achlada is an important Neogene coal deposit (lignite deposit) in Greece, beside of Florina, Ptolemais, Megalopolis and Drama, formed within an intramontane basin (Florina-Ptolemais-Servia Basin), which extends over a distance of 120 km from Bitola (Macedonia) to Servia in northwestern Greece (Fig. 1), generated by the neotectonic activity within this area.

The basin developed in the Late Miocene in the Pelagonian Zone, the westernmost part of the Internal Hellenides, in response to NE–SW extension, and was subsequently fragmented, during Pleistocene, resulting in some sub-basins, *i.e.*, Florina, Ptolemais and Servia (see Pavlides and Mountrakis, 1987). The Neogene-Quaternary sediments that fill the Achlada basin unconformably overlay both Palaeozoic metamorphic rocks and the Mesozoic crystalline limestones (Oikonomopoulos et al., 2008). This stack of sediments can be divided into three lithostratigraphic units starting with coarse sediments (basal conglomerates with elements of metamorphic rocks), followed by a coaly sequence of marls, sandy marls, sands, clays and lignite layers. The age of this unit has been defined by fossils (Velitzelos and Petrescu, 1981) as latest Miocene (Pontian) to early Pliocene (see Fig. 2). The middle unit is entirely a coaly one and contains thick lignite beds in alternation with clays, marls, sandy marls, and sands. The Ruscinian age for this unit was obtained by pollen analysis and microfaunal and macrofaunal study (Weerd, 1979; Koufos, 1982; Ioakim, 1984). The upper unit is terrigenous and represented by Quaternary terrestrial and fluvioterrestrial conglomerates, lateral fans and alluvial deposits (Pavlides and Mountrakis, 1987). The tectonic structure of Achlada coaly sediments respects the tectonic style of the basin, defined by normal faults with two main directions: a NE–SW direction and a NW–SE one, the latter being almost perpendicular on the first one (see Pavlides and Mountrakis, 1987).

Anyway, Oikonomopoulos et al. (2008) remarked the scarcity of detailed researches, especially palaeobotanical, and started a multidisciplinary study (palaeocarpological, palynological, coal-petrographic, mineralogical and sedimentologic) trying to interpret the palaeoenvironmental conditions associated with Achlada lignite deposits, as well as the role of the palaeoclimate in the evolution of the

* Corresponding author
email: *iamandei@gmail.com*

particular lignite deposits. Maybe palaeontological studies would still be useful, even if few animal remains like fossilized cocoons and coprolites were observed but no shells were found. Anyway, Weerd (1979) described Early Ruscinian rodents and lagomorphs (Mammalia) from the lignites near Ptolemais.

Even if the study of Oikonomopoulos et al. (2008) cover only a part of the coaly sequence, it is obvious that the palaeobotanical, coal-petrographic, sedimentologic, and mineralogical features of the Achlada lignite deposits suggest that the general area was a floodplain environment in the Neogene to Quaternary, which was traversed by a principal meandering river system. The lignite-bearing sequences are marked by matrix-dominated lithotype, or by mixed xylite-rich/matrix lithotypes and xylite horizons and constitute the main characteristic of the Achlada coal deposits, and occur in both sections with either autochthonous or allochthonous origin. Both length and frequency of the xylite horizons indicate the occurrence of many independent xylite bodies that significantly contributed to peat formation (Oikonomopoulos et al., 2008).

Palynological and palaeocarpological analyses revealed that the peat-forming vegetation was represented by a forest of mixed type, typical for reedmoor in the lower unit to open water in the upper unit. Peat was accumulated in a wet forest swamp under telmatic to limno-telmatic conditions and increased inorganic influx of clay minerals which prevail in all the samples, with illite-muscovite being the dominant phase, followed by kaolinite and chlorite. The combination of mineralogical composition and the plant communities identified in the studied area, suggests a humid and warm climate conditions during the Achlada peat accumulation (Oikonomopoulos et al., 2007).

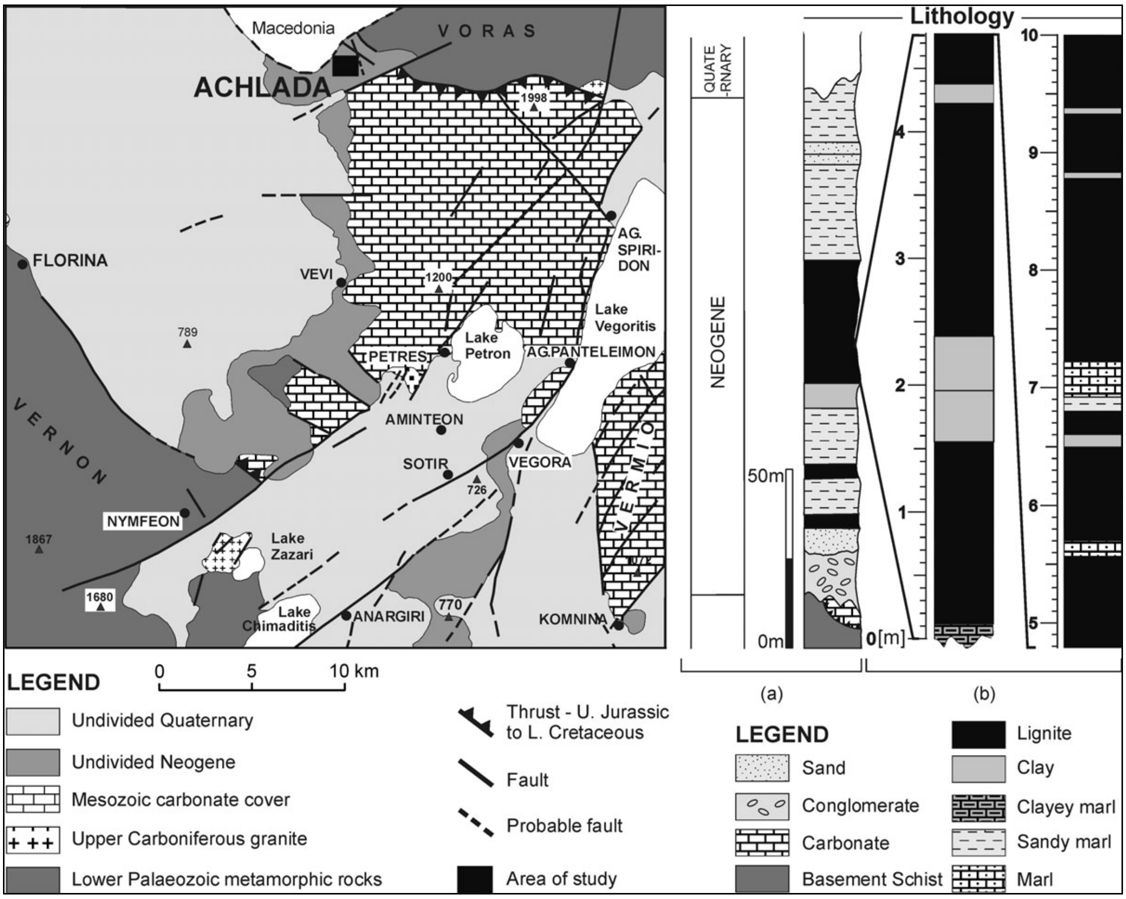

Fig. 1. Geological map of the Florina Basin with the location and generalized lithological column of (a) the study area (after Pavlides and Mountrakis, 1987) and (b) Achlada lignite deposits, NW Greece (reproduced from Oikonomopoulos et al., 2008).

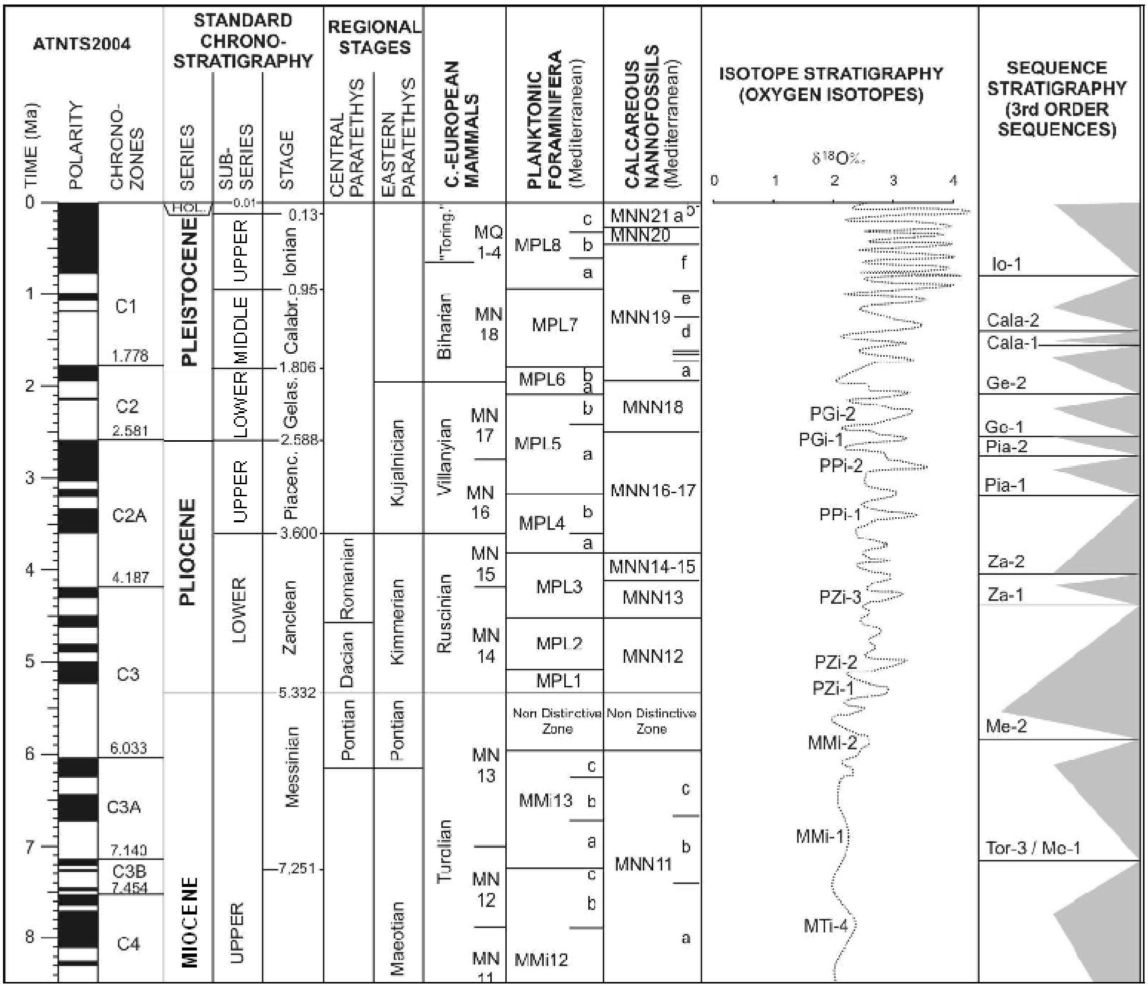

Fig. 2. Latest Miocene-Pliocene chart (from Harzhauser and Piller, 2007, modified according to Walker and Geissman, 2009).

As a whole, the coal-generating flora is poor in species and specimens. A preliminary palynological analysis at Achlada lignite seams shows the following association: Phytoplankton (*Ovoidites*) and pollen of Conifers (Taxodiaceae, Polypodiaceae, Pinaceae), of Angiosperms Monocots (*Sparganiaceae, Gramineae, Cyperaceae, Palmae*) and Dicots (Magnoliaceae, Cyrillaceae, Compositae, *Fagus, Acer, Tilia, Myrica, Carpinus, Alnus, Betula, Ulmus*). The palaeocarpological analysis, also informal, showed: Epiphytes, Algae, Nymphaeaceae, *Potamogeton, Batrachium, Sparganium, Decodon, Epipremnites, Glyptostrobus, Actinidia, Meliosma, Pterocarya, Rubus, Sambucus, Symplocos* (Oikonomopoulos et al., 2008).

The presence of lignified wood fragments of various sizes is well known in this coal deposit and Oikonomopoulos et al. (2008) gave particular emphasis "to the presence of xylite, which is found in large amounts in the Achlada lignite deposits" as "well-preserved horizontal xylite layers of various thickness (from 2-12 cm up to 15 m) or isolated xylite parts present in the lignite mass" as fragments of branches of various size, stems or roots with well-preserved tissue. Big stems, sometimes in growing position in a huge inorganic clayey bed, often continues into the overlying lignite horizon, suggesting an autochthonous character.

In such conditions, a big fossil trunk of about 10 m long and 2 m in diameter was recuperated from this area and a portion of 6 m was installed upright just in front of the administrative building of Achlada mine (Fig. 3). The remained part of 4 m was preserved *in situ*.

2. Materials and methods

The found fossil wood is weakly coalified (it could be better considered mummified) and probably an effort of conservation will be necessary since, exposed to air, temperature and wetness variations, it will be destroyed.

Fig. 3. The stump exposed in front of Achlada mine (left) and detail (right)

As it was specified, a portion of ca. 6 m of the found fossil trunk was installed as a stump, like a trophy, in front of the administrative building of Achlada mine, while the other portion, of about 4 m, remained in the original place. A palaeoxylotomical study was necessary at least to know the original tree.

After field observations and photos, a small sample from the outer part of the trunk was taken by one of the authors for palaexylotomical study. From it, standard oriented sections were obtained by two methods: firstly a small piece was boiled in water to become softer, then cut with a razor blade and mounted in glycerine jelly; secondly, oriented polished surfaces were impregnated with a synthetic resin (araldite) and thin section have been made by the classic petrographic method.

The microscopic study was made in transmitted light using a Nikon Eclipse 400 microscope, and a camera. The anatomical descriptions were made in accordance with the IAWA standard for softwood (IAWA Committee, 2004). The thin sections described herein are deposited in Velitzelos Collection, NKUA. (National and Kapodistrian University of Athens).

3. Results

The investigations of the fossil trunk, both macroscopic and at the microscope (Plate I, Plate II) led to the following diagnostic:

Family **Cupressaceae** RICH. ex BARTLING, 1830
Subfamily **Taxodioideae** ENDL. ex K. KOCH 1873
Genus ***Taxodioxylon*** (HARTIG) GOTHAN 1905
Taxodioxylon taxodii GOTHAN 1906

3.1 Origin and macroscopic description

The massive trunk (originally more than 10 m in length, at least 2 m in diameter) was found in the coaly formation from Achlada open cast mine, in a level of Late Miocene age (equivalent to Pontian). The studied sample represents a small fragment taken from the outer part of the huge trunk. It is grey in color, fibrous in texture and with conspicuous annual rings, suggesting a coniferous wood. The wood seems not to be very lignified, still keeping a typical coniferous smell.

3.2 Microscopic description

The growth rings are distinct, marked by 2-6 thicker-walled cells flattened in the final wood, in contrast with the early wood constituted from bigger lumened thinwalled cells, which are very compressed and folded. The rings are 24-35 or more cells wide and the transition from early to late wood is gradual. Normal resin ducts are totally absent.

The tracheids are polygonal in cross section, usually rectangular in latewood, showing rounded lumina with radial/tangential diameters of 30-50(75)/40-60 µm, more tangentially flattened in the late wood where the radial diameter is less than 40 µm. The cellular wall is 3-6 µm thick and the double wall is thicker (7-10 µm) in the final wood. There are 1-6 radial regular rows between two rays. Their frequency on square mm is difficult to count because of the folded structure. The tangential pitting is present and is represented by small bordered pits of 8-12 µm in diameter, with apertures of 3-4 µm, spaced and slightly irregularly arranged in a single vertical row. The radial pitting is badly preserved, is represented by abietineous pits 12-16 µm in diameter and round apertures of 4-5 µm in diameter, are spaced arranged in 1 vertical row on the tracheids of transitional and late wood, when are smaller than 12 µm in diameter. On the tracheids of early wood, the pits are bigger, arranged in 1-2 vertical rows and closer to each other but not contiguous. *Crassulae* were not observed, most probably these are absent.

The axial parenchyma i s hardly discernible in cross section, since it is similar to the tracheids but sometimes is filled with resin. However, it is fairly frequent in the longitudinal sections, as vertical strands of rectangular cells with 1.5-3 µm-thick double walls. The transverse end walls are 1-3 µm thick or even thicker, smooth or nodular, with 3-5(7) nodules. The resin content appears as small or large balls and plugs with rounded endings.

The rays seen in cross section are folded in the early wood, but rectilinear in the latewood and are constituted by rectangular cells sometimes crushed laterally. Vertically, they are uniseriate, rarely with short biseriations, and are of 1-27 or, more frequently, 3-19 cells tall. Seen tangentially, the ray cells are circular or vertically elliptic and usually empty. The density is of 3-6-10 rays on tangential mm. The rays are homogeneous, the parenchyma ray cells are 15-20 µm high, with the marginals sometimes taller (20-24 µm); the horizontal walls are relatively thick (2-4.5 µm double wall), smooth and probably pitted, the marginals with outer wall slightly wavy. Their tangential walls are vertical, oblique or slightly arcuate and thin (0.5-1.5 µm), smooth to slightly rugose or delicate nodular. Indentures are indistinct or absent. The cross fields are usually blurred, pitting is very indistinct and hardly can be guessed 1-2(3) blurred taxodioid pits of 6-7 µm in diameter, with rounded to oval borders and small apertures. They are arranged in horizontal or slightly diagonal pairs.

4. Discussions

The xylotomical study of this specimen allowed the identification of a combination of features, typical for the Cupressaceae of “taxodiaceous” type. By comparison with other extant or fossil “taxodiaceous” taxa, we found that the investigated specimen shows most affinities with the genus *Taxodium* Rich, respectively of *Taxodioxylon* as a fossil genus, because of the presence of some typical structural details: no resin ducts, tracheidal pitting, taxodioid cross fields, presence of axial parenchyma. And, despite some supposed confusion inside the *Taxodioxylon* as fossil morphogenus concerning the modern affinities (Dolezych and van der Burgh, 2004), the generic identification is correct.

Although the wood is badly preserved, the studied specimen shows the presence of uniseriate, rarely biseriate radial pitting and typical taxodioid cross fields. The parenchyma presents the transverse end walls (“horizontal walls”) relatively thick and nodular, with 3-5(7) nodules, even if sometimes are smooth, details which are typical also to the extant *Taxodium*, a genus with few species usually living in wet habitats. *Taxodium distichum* (L.) RICH. is living now in Southern USA, Mexico and Guatemala, in riparian and wetland habitats, usually occupying swampy regularly-flooded forests from the south-eastern area of the USA. Another species *T. mucronatum* TEN. (Montezuma Cypress) prefers not too wet environment and is known better as an element of mountain swampy forests from Mexico (Teodoridis and Sakala 2008).

The comparison with fossil taxodiaceous woods already described showed that there are some affinities with *Taxodioxylon cuddalorense* RAMANUJAM, 1960, but this one presents bi- and triseriate radial pitting on the tracheids. Most similar seems to be *Taxodioxylon taxodii* GOTHAN (as was described by Zalewska 1953, Greguss 1967, Gottwald 1966, 1992, Iamandei et al. 2001a,b,c), a perfect equivalent of the extant *Taxodium distichum* (L.) RICH., considering the radial pitting, the cross fields and other details.

The fossil wood studied here is devoid of resin ducts, has diffuse parenchyma with nodular horizontal walls and tracheidal pitting uni- to biseriate without crassulae, uniseriate rays and typical taxodioid pits cross fields with 1-2 pits per field, and based on this is identified to *Taxodioxylon taxodii* GOTHAN 1906.

5. Conclusions

The big trunk found in Achlada mine area and partially exposed as a stump of 6 m tall was identified as *Taxodioxylon taxodii* GOTHAN, a fossil tree equivalent to the extant *Taxodium distichum* (L.) RICH. as nearest living relative, named today the Bald Cypress living in Central America and the south-east area of North America, but which, during the Miocene, was one of the largely spread "taxodiaceous" taxa in Europe, very implied in the Neogene carbogenesis (Ţicleanu, 1992; Teodoridis, 2001, 2002; Kvacek *et al*., 2004).

The late Miocene flora in Achlada area had not too numerous taxa. Analyzing all the palaeobotanical findings i.e. pollen, seeds, charcoal as fusinite, fungal perithecia and other plant debris, the palaeoenvironment in which the Achlada lignite deposits were formed was reconstructed (Oikonomopoulos et al., 2008).

Frequent cysts of Zygnemataceae *(Ovoidites)*, some green algae indicating a reedmoor environment also confirmed by the presence of *Phragmites communis* and divers Sparganiaceae accompanied by Polypodiaceae (spores) indicating semi-fresh reedmoor environment similar to recent peat deposits on eastern American shoreside areas (see Riegel quoted by Oikonomopoulos *et al.,* 2007).

The pollen of Taxodiaceae, Pinaceae Aceraceae, *Tilia*, *Myrica* and *Betula*, indicates a mixed forest environment living in warm and humid conditions.

This kind of vegetation allowed to suppose for the area a wet and warm climate with average temperatures of the coldest winter month +6 °C for *Taxodium* and +5 to +10 °C for *Glyptostrobus*, while for the warmest months temperature could reach +30°C (Kloosterboer-van Hoeve quoted by Oikonomopoulos *et al.,* 2007), since these taxa were found in other coal deposits from the basin.

New researches in progress may evidence a rhythmic deposition of lignite-grey clay and the distinction of six sedimentological cycles, which probably correlate with orbital forcing – Milankovitch Cycles (Oikonomopoulos *et al.,* 2007).

Anyway, thoroughly systematic palaeo-palynological and palaeobotanical (palaeo-xylological included) studies could give a more complete reconstruction of the palaeoenvironment in which the Achlada lignite deposits were formed.

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References

Dolezich M., Burgh, J., van der, 2004. Xylotomische Untersuchungen an inkohlten Hölzern aus dem Braunkohlentagebau Berzdorf (Oberlausitz, Deutschland). Feddes Repertorium. 115, 397-437.

Gothan, W., 1905. Zur Anatomie lebender und fossiler Gymnospermen - Hölzer. Abhandlungen der königlichen preussichen geologischen Landes-Anstalt, 44, 1-108, Berlin.

Gothan W., 1906. Fossile Hölzer aus dem Bathonian von Russisch-Polen. Verhandlungen der Kaiserlichen mineralogischen Gesellschaft. 44, 435–458. St. Petersburg

Gottwald, H., 1966. Eozäne Hölzer aus der Braunkohle von Helmstedt. Palaeontographica, B, 119, 76 – 93.

Gottwald, H., 1992. Hölzer aus Marinen Sanden des Oberen Eozän von Helmstedt (Niedersachsen). Palaeontographica, B, 225, 27-103.

Greguss P., 1967. Fossil Gymnosperm woods in Hungary, from the Permian to the Pliocene. Akademiai Kiado, 1-152, Budapest.

Harzhauser, M., Piller, W. E., 2007. Benchmark data of a changing sea. Palaeogeography, Palaeo-biogeography and events in the Central Para-tethys during the Miocene. Palaeogeo-graphy, Palaeoclimatology, Palaeoecology, 253, 8–31.

Iamandei, S, Iamandei, E., Ionesi, V., 2001a. Sarmatian fossil wood from from Fălticeni-Su-ceava region. Analele Ştiinţifice ale Universi-tăţii "Al.I.Cuza" din Iaşi (serie nouă), Geologie, 47, 235-240.

Iamandei, S., Iamandei, E., Ţibuleac, P., 2001b. Fossil Wood from Coal-layer "B" of Volhinian Formation in Leucuşeşti - Fălticeni area. Ana-lele Ştiinţifice ale Universităţii "Al.I.Cuza" din Iaşi (serie nouă), Geologie, 47, 211-218.

Iamandei, S., Iamandei, E., Lupu, A.I., 2001c. Some fossil woods in the Iaşi Botanical Garden. A-nalele Ştiinţifice ale Universităţii "Al. I. Cuza" din Iaşi (serie nouă), Geologie, 47, 267-274.

IAWA Commitee. (2004): IAWA List of microscopic features for softwood identification. IAWA J, 25, 1-70.

Ioakim, C., 1984. Analyse palynologique des dépôts lacustres du Pliocène de Ptolemais (Grèce septentrionale): un élément nouveau dans la reconstitution de l'histoire paléoclimatique des régions méditerranéennes orientales. Paléobio-logie continentale 14(2), 315–332.

Koch, K., 1873. Taxodieae. Dendrologie 2(2): 186.

Koufos, G.D., 1982. Hipparion crassum Gervais, 1859 from the lignites of Ptolemais (Macedonia, Greece). Proceedings. Koninklijke nederlandse akademie van Wetenschappen, Series B 85, 229–239.

Kvaček, Z., Böhme, M., Dvořák, Z., Konzalová, M., Mach, K., Prokop, J., Rajchl, M., 2004. Early Miocene freshwater and swamp ecosystems of the Most Basin (north Bohemia) with particular reference to the Bílina Mine section. Journal of the Czech Geological Society, 49, 1-40.

Pavlides, S.B., Mountrakis, D.M., 1987. Extensional tectonics of north-western Macedonia, Greece, since the late Miocene. Journal of Structural Geology, 9, 385-392.

Oikonomopoulos, I., Peraki, T., Kaouras, G., Antoniadis, P., 2007. Mineralogical study of inorganic intercalated seams at Achlada lignite deposits (NW Greece). Bulletin of the Geological Society of Greece, 40, 906–917.

Oikonomopoulos, I., Kaouras, G., Antoniadis, P., Perraki, T., Gregor, H.-J., 2008. Neogene Achlada lignite deposits in NW Greece. Bulletin of Geosciences 83(3), 335–349.

Teodoridis, V., 2001. Further revision of Tertiary floras of Central Bohemia (the localities Na Bendovce /Sv. Antonín/ near Rakovník, Klínec upon Všenory and Na Sulavě near Černošice). Bulletin of Czech Geological Survey, 76, 243-252.

Teodoridis, V., 2002. Tertiary flora and vegetation of the Hlavačov gravel and sand and the surroundings of Holedeč in the Most Basin (Czech Republic). Acta Musei Nationalis Pragae, (B), 57(3-4), 103-140.

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

Ţicleanu N., 1992. Main Coal generating paleophytocaenoses in the Pliocene of Oltenia. Rom. Journ. of Paleontology, 76, 145-152.

Velitzelos, E., Petrescu, I., 1981. Rare plant fossils from the Neogene ligniferous basin of Vegora. Annales géologiques des pays helléniques 30, 767–777.

Walker, J.D., Geissman, J.W., 2009. Geologic Time Scale (compiled). Geological Society of America.

Weerd, A., van der, 1979. Early Ruscinian rodents and lagomorphs (Mammalia) from the lignites near Ptolemais (Macedonia, Greece). Koninklijke Nederlandse Akademie van Wetenschapen, Proceedings, Ser. B, 82, 127-180.

Zalewska, Z., 1953. Treciorzedowe szczatki drewna z Turowa nad Nysa Luzycka. Acta Geologica Polonica, III(4), 481-543.

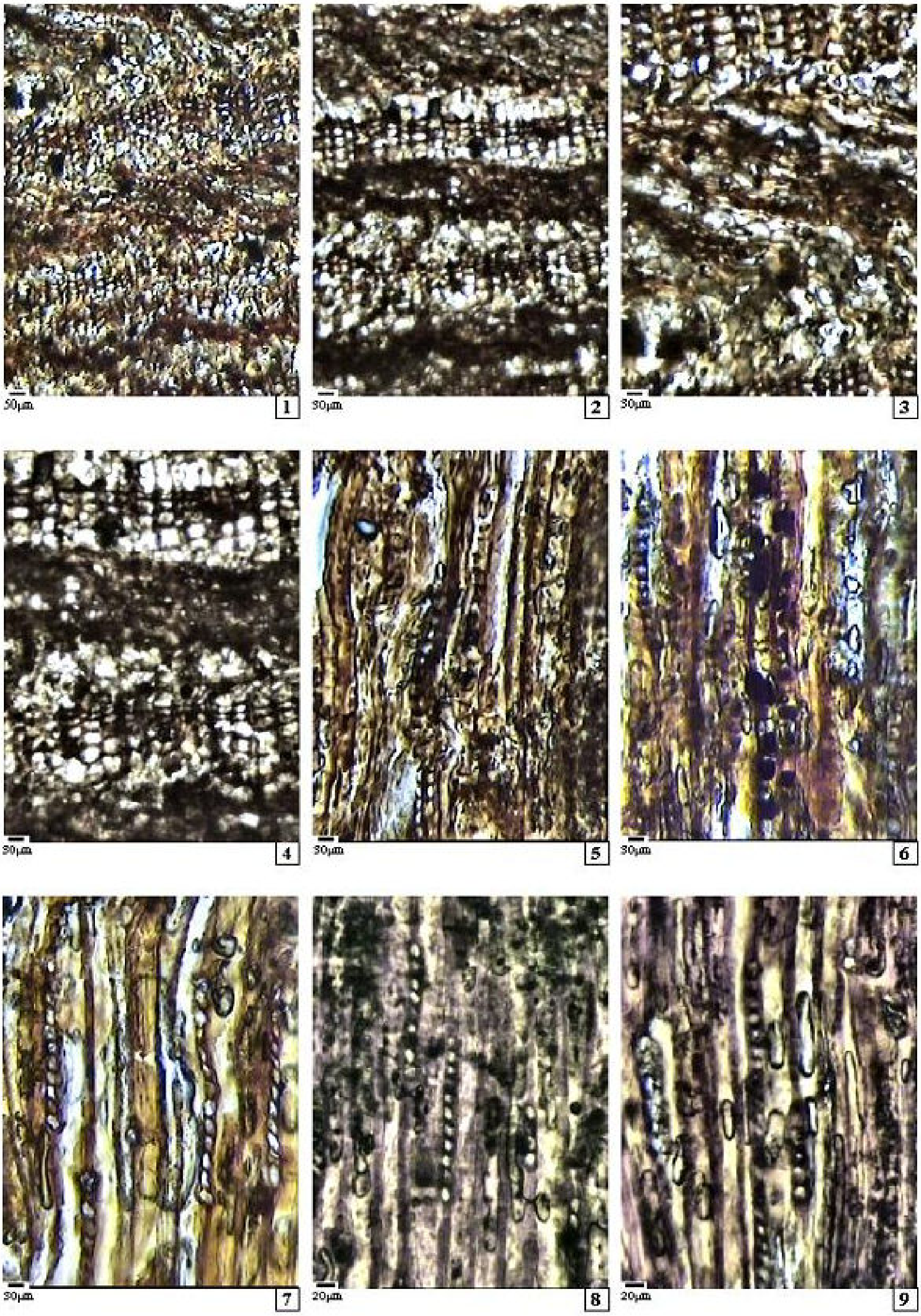

Plate I. *Taxodioxylon taxodii* GOTHAN 1906 (graphic scale). 1-4. Cross section, polygonal tracheids folded in early wood and disperse parenchyma cells. 5-9. Tangential section, small pitted tracheids, uniseriate rays medium tall, knotted horizontal parenchyma wall.

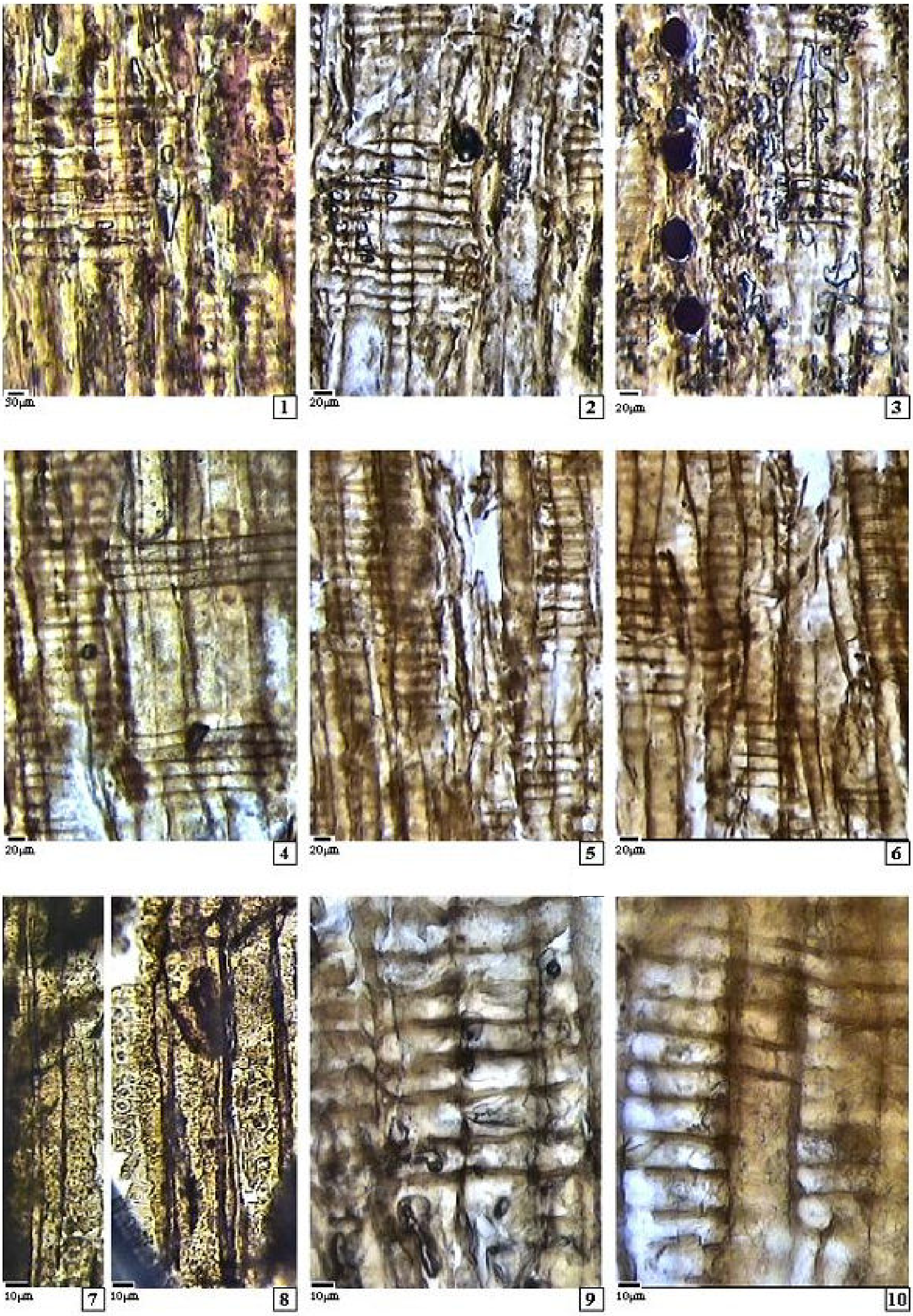

Plate II. *Taxodioxylon taxodii* GOTHAN 1906 (graphic scale). Radial sections, 1-2-radial pitting, parenchyma with globular resin deposits, taxodioid cross fields.