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ARTICLE

Xylotomic similarities and natural habitat of the fossil remains of Bükkábrány

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ABSTRACT The unique remains of a 7.2-million-year-old forest consisting of Bald cypress and Coast redwood were found in the area of Bükkábrány in County Borsod-Abaúj-Zemplén of Hungary. The trees of the fossil remains comprising 16 stems, which were discovered in a lignite mine, were standing in their original locality, and preserved their original cellular structure. No petrification occurred, which is general characteristics of wood remains preserved for millions of years. What makes the findings unique is that they make it possible to carry out the traditional histological examination of the intact wood structure. The results of light and electron microscopic investigations definitely proved that in addition to Bald cypress, the wood species of the ancient forest remains also included Coast redwood. Today, the natural habitat of Coast redwood is definitely in North-America, but millions of years ago, they were also present in Europe including the Carpathian basin. The xylotomic analysis has unambiguously revealed that two of the investigated five trunks are Bald cypress (*Taxodium distichum)* or the already extinct *Taxodioxylon germanicum*, while the other three trunks are Coast redwood (*Sequoia sempervirens*) or a member of the already extinct family, the *Sequoioxylon sp*.
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KEY WORDS

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In the summer of 2007, miners in the Bükkábrány Lignite Mine of Mátra Erőmű Zrt. discovered the remains of an ancient forest consisting of 16 stems from the late Miocene Period (Fig. 1). The ground level of the original "forest" was covered by a layer of wet sand or mud of a height of 6 metres. A sudden geological event such as a mudslide may have been the cause of the demise, thus hermetically sealing and conserving the lower 6-metre-high section of the stems. Since no air contacted the trunks, which were surrounded by a continuously wet medium, constant humidity and the conserving effect prevented petrification of the stems, which therefore remained intact. The ancient stems were later transported to Ottó Herman Museum (Miskolc, Hungary). The fossil remains were conserved during the past few years, and six of the intact stems were displayed in the Nature Reserve of Ipolytarnóc Fossils (Ipolytarnóc, Hungary) and another two trunks were exhibited in Ottó Hermann Museum following a special conservation treatment.

During the last centuries, different species of driftwood were often discovered, however never in their own original locality or natural habitat, but within uncertain geographical circumstances. Fossil remains were found in several locations throughout Europe (Pinna and Meischner 2000) including Hungary. The most famous fossil remains ever found in Hungary is the petrified tree discovered in Ipolytarnóc, which as examination proved is such a pine species that bears no similarities to any species either living or fossilised that is having gone extinct or conserved (Tuzson 1901). Its anatomical structure resembles to species belonging to genus *Pinus* that is why Tuzson called it *Pinus tarnocziensis*. Later, Greguss (1967) labelled the petrified remains as *Pinoxylon tarnocziensis*. However, the trunks found in the marshland of Bükkábrány, which were standing in their own locality preserving their original structure, are peculiar and offer researchers a unique chance for scientific examination and interpretation.

Figure 1. Location Bükkábrány Lignite Mine (Bükkábrány, Hungary).

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Figure 2. Fossil remains in the lignite mine (Bükkábrány).

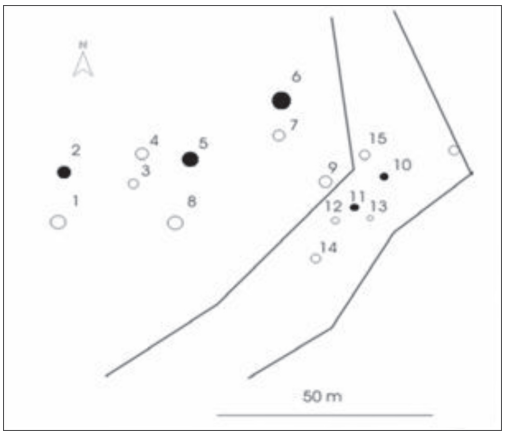

Figure 3. Location of the examined stems (Kázmér 2011).

Plant remains were already investigated after the excavation of the lignite mine in Bükkábrány in 1980. Based on the leaf fossils both coniferous and hardwood species were identified such as, *Glyptostrob us*, *Ginkgo*, as well as *Alnus* and *Byttneriophyllum* (László 1992). Investigating fruit and seed remains additional species were found such as *Glyptostrobus*, *Potamogeton*, *Ceratophyllum*, as well as *Acer*, *Alnus*, *Pterocarya* and *Spirematospermum* (László 1992). Similar fossil remains were found, however, earlier elsewhere. In the lignite mine in Gyöngyösvisonta located only 50 km from Bükkábrány a *Sequoioxylon gypsaceum* (Pálfalvy and Rákosi 1979) was found that was suggested to a Coast redwood (*Sequoia sempervirens*) of our days by Greguss.

Following the discovery of the trunks, the great majority of scientists stated that based on the visual examination of the form and characteristics of the bark, the remains were part of an ancient forest consisting of Bald cypresses (*Taxodium distichum*) (Kázmér 2007). By today it has been proved that the above theory is only partly true as the discovered forest consisted of different species. Specific morphology of the discovered trunks, characteristics of the bark, as well as earlier literature like researches of Kordos and Begun (2002) clarified, however, that the fossil remains belongs to the *Cupressaceae* family. Trunks discovered in the mine are strongly sprawling and ostentatiously ribbed (Fig. 2). The bark is deeply cracked with long vertical strips. It is rich in cork and easily peeling. The shape and size of the fossil tree trunks discovered in Bükkábrány as well as the results of the investigation of other European fossils (Kräusel 1949; Greguss 1955, 1967, 1972; Van der Burgh 1973; Dolezych and Van der Burgh 2004) angled the members of the *Cupressaceae* family such as the *Taxodium*, the *Sequoia*, the *Metasequoia*, and the *Glyptostrobus* genus. Results of the phylogenetic analysis require more or less also the study of the above genus, although the four recent genera do not compose a monophyletic clade, because the *Sequoia* and the *Metasequoia* and possibly the *Sequoiadendron* genus are more closely connected (belong to one clade). Contrarily, the *Gliptostrobus* composes another clade with the *Cryptomeria* and the *Taxodium* rather belongs to this clade (Li 1998; Kusumi et al. 2000). Analysis of the earlier European fossils proves that the *Taxodium*, *Glyptostrobus*, *Sequoia* and *Metasequoia* should not be excluded from the investigation. Phylogenetic researches may also require the investigation of the *Cryptomeria* genus but based on the morphology of the Bükkábrány fossils and the results of previous fossil analysis this genus can be excluded.

Several researchers have been engaged in wood identification, and named different species including Coast redwood (*Sequoia sempervirens*) and Bald cypress (*Taxodium distichum*) among the wood species (Molnár et al. 2007, 2008). Antalfi and Fehér (2012) said that in addition to Coast redwood and Bald cypress the discovered species might also include *Taxodioxylon germanicum* and *Sequoioxylon* sp., since from the perspective of xylotomy there was a minimal difference only between existing species and those which had already became extinct; and Hably (2008) also presumed to identify *Taxodioxylon germanicum*, a species that had already became extinct. Further studies suggested that in addition to *Taxodioxylon germanicum*, *Glyptostroboxylon sp.* might also be found among the fossil remains (Erdei et al. 2009). Furthermore, based on the examination of leaf and cone remains, *Glyptostroboxylon europaeus* was also identified. The examination of the five ancient trunks displayed in Ipolytarnóc, which was carried out by Gryc and Sakala (2010), produced similar results, and identified *Glyptostroboxylon rudulfii* and *Taxodioxylon germanicum* among the remains.

Materials and Methods

The investigations were focused on the species identification of the trunks, for which samples were collected from five different stems. Figure 3 indicates the location of the

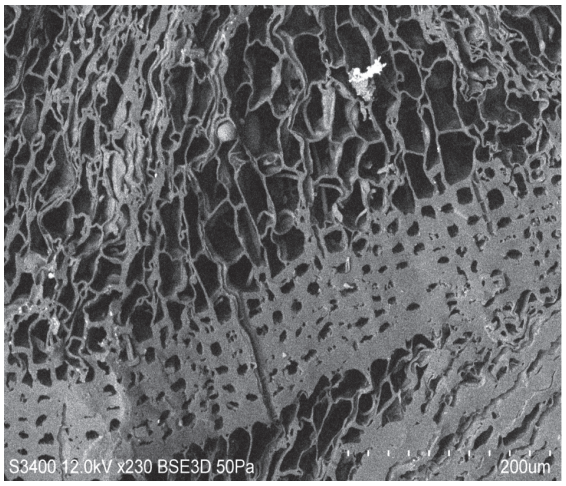

Figure 4. Cross section of sample 10 (*Sequoioxylon sp.*).

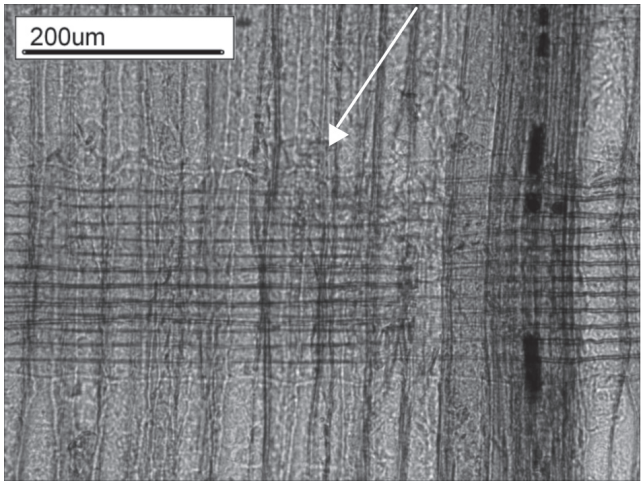

Figure 5. Rays are heterogeneous (*Sequoioxylon sp.*).

stems in the marsh forest of the Bükkábrány mine based on Kázmér (2011).

The samples were taken from the upper part of trunk No 10 and 11 so as not to damage the stems, while we received smaller specimens from trunk No 2, 5 and 6 to use during the examination.

Following the appropriate preparation of the samples, the sections were prepared by using a Leitz Wetzlar sledge microtome. For examinations required for wood species identification, a Nikon SMZ-2T zoom stereo microscope and a Hitachi S-3400N scanning electron microscope were applied. Since the wood is an orthogonal anisotropic material, analysis of all of the three anatomical directions (radial, tangential and longitudinal) is necessary to determine the wood species. The buried ancient woods have lost some of their cellulose content (Molnár et al. 2008) that is responsible for the cell wall strength. Therefore, before the light microscope analysis, samples had to be embedded into paraffin to be able to produce appropriate sections. For a good quality section, the right anatomical direction must be taken carefully. The thickness of the sections was between 15 and 20 μm. For SEM investigations, however, a different method was applied for sample preparation. The proper quality of the surfaces was achieved by charring at elevated temperature.

Results

The longitudinal tracheids on the cross sections of trunks No 2, 6 and 10 show a regular pattern, and therefore, evidently refer to pine species (Fig. 4). The borderline between the early and late wood is relatively abrupt. No real resin canal may be found in the samples. There are a great number of axial parenchymae dispersed especially in the early wood. In the tangential direction, rays are a single cell wide only, with their height ranging from 1-30 cell lines. The end wall of

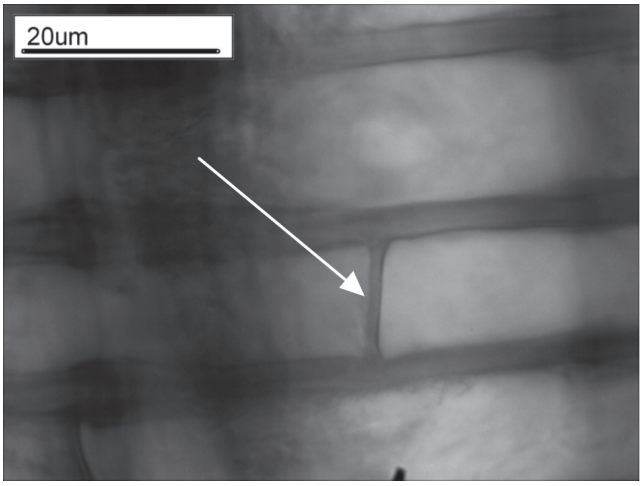

Figure 6. End wall of ray parenchyma is smooth; sample 2 (*Sequoioxylon sp.*).

axial parenchymae is smooth. In the parenchyma cells, dark-coloured substances may be observed. In the cross sections, bordered pits of longitudinal tracheids are arranged in 1-3 rows. The rays are heterogeneous, as there are ray parenchymae in the middle, and ray tracheids in the end of the ray (Fig. 5). The walls of ray tracheids are smooth or have toothlike ingrowths, but no other cell wall alteration may be observed. The tangential walls of ray parenchymae are smooth (Fig. 6), or occasionally nodular. In the crossfield, 1-3 taxodioide pits or cupressoides may be seen. The occurrence of taxodioide pits is more prevalent. The above anatomical characteristics refer to Coast redwood (*Sequoia sempervirens*), which belongs to the *Sequoia* genus, or to *Sequoioxylon sp*, one of the species of the genus, which already became extinct.

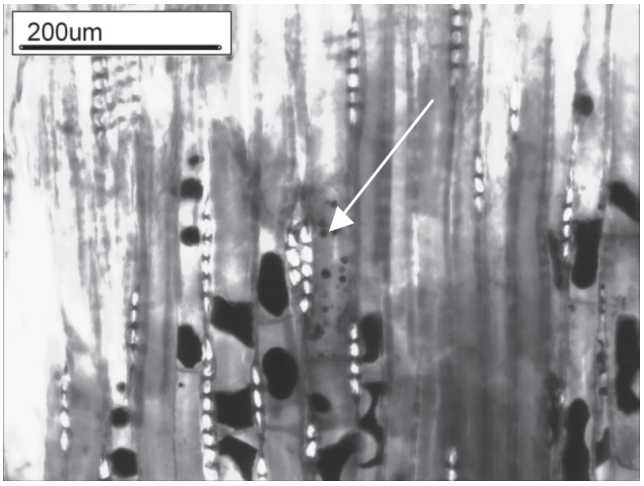

Figure 7. The rays are sometimes two seriate; sample 11 (*Taxodioxylon germanicum*).

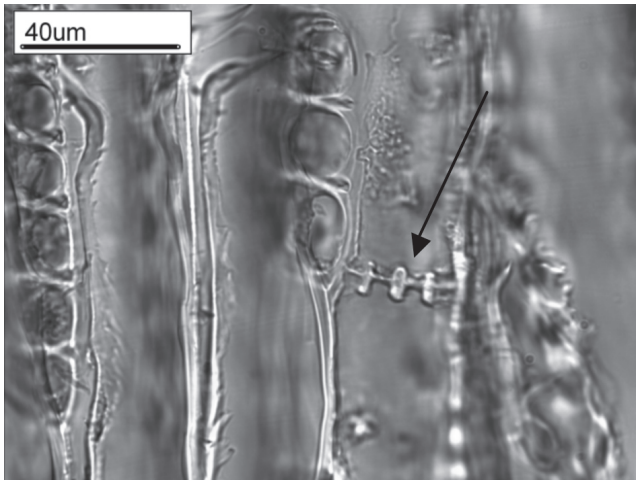

Figure 8. The end walls of axial parenchymae are nodular (*Taxodioxylon germanicum*).

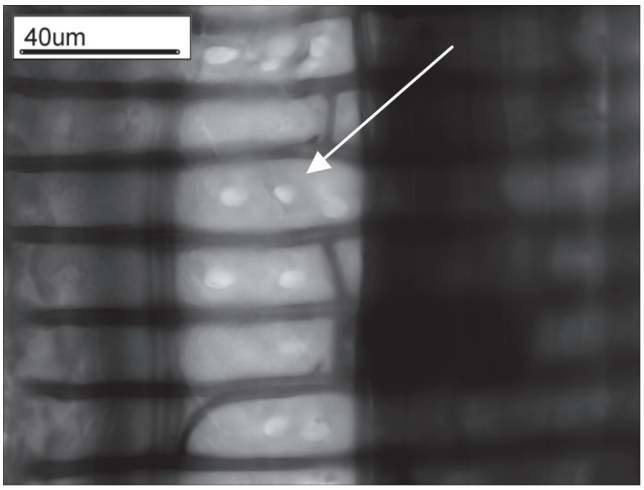

Figure 9. Crossfield pits are taxodioid; sample 5 (*Taxodioxylon germanicum*).

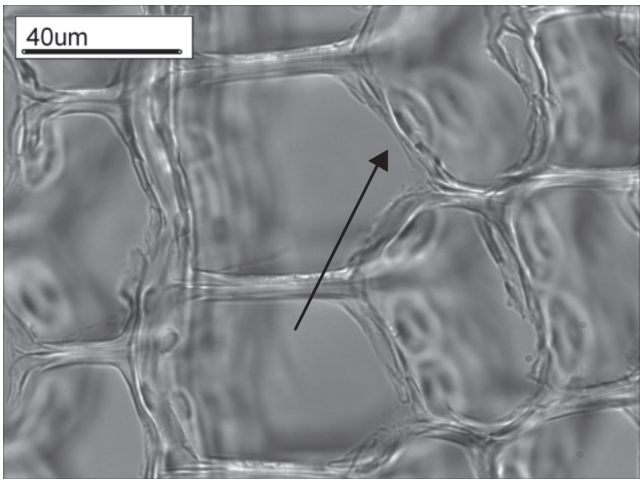

Figure 10. Tracheids are five or six-sided (*Metasequoia glyptostroboides*).

Based on their microscopic characteristics, trunks No 5 and 11 belong to a different species. The longitudinal tracheids on the cross sections show a regular pattern. The borderline between the early and late wood is abrupt. The autumn wood is very narrow. There are a relatively great number of axial parenchymae, which are either dispersed or arranged in lines in the tangential direction. In the tangential section it can be observed that the rays are mostly one or two-cell-wide (Fig. 7). As far as their length is concerned, they can be as high as 35 cell-lines. The end walls of axial parenchymae are not smooth but nodular (Fig. 8). In the axial parenchyma cells, dark-coloured substances may often be observed. In the tangential direction, the rays are homogeneous as they are composed of one cell-type only (ray parenchymae). On the cell walls of longitudinal tracheids the alteration is caused by pits only. The bordered pits are arranged in 1, 2 or 3 rows. The end walls of ray cells (tangential walls) are smooth. In the crossfield, cupressoide and taxodioide pits (Fig. 9) may be observed. Their numbers vary from 1 to 4 depending on whether being examined in the early or late wood. Based on the above, the examined two trunks belong to the *Taxodium* genus, being either *Taxodioxylon germanicum*, a species which already became extinct, or Bald cypress (*Taxodium distichum*), one of its existing relative.

In addition to the similarities, slight differences may also be observed in the xylotomic analysis of the wood species detailed in several studies, which might as well challenge the results of such examinations. The species of the *Taxodiaceae*

family have been examined by several xylotomists including Greguss (1972), Hollendonner (1913), Hoadley (2000) and Wheeler (1986), among others. The anatomic descriptions are correct, though minor differences may also be seen, that is why I applied existing control species. Based on the examination of the control species, I examined which genus of ancient pine trees or species they belong to. In the case of the control species, samples were collected by using a so-called Pressler drill from three species including Bald cypress (*Taxodium distichum)*, Coast redwood (*Sequoia sempervirens*) and Dawn redwood (*Metasequoia glyptostroboides*) as the latter species is also a member of the *Taxodiaceae* family.

From an anatomic perspective, Dawn redwood bears the most similarities to Coast redwood, therefore in our research we also compared these two species. The xylotomic data of Dawn redwood are different from both those of the ancient trunks and Coast redwood, which differences were also supported by the microscopic examinations. In the cross sections it can be seen that tracheids in Coast redwood are arranged in a regular pattern, while Dawn redwood has five or six-sided cells (Fig. 10). Another significant difference may be observed in the tangential section: in the case of Coast redwood rays are heterogeneous that is they consist of ray tracheids in addition to ray parenchymae, while in the case of Dawn redwood rays are composed of parenchyma cells only. Based on the research carried out so far, we have not managed to undoubtedly prove the presence of Dawn redwood, or one of its relative, *Glyptostroboxylon sp*, which already became extinct.

Discussion

From a histological perspective, Coast redwood is identical to Bald cypress, but there is a difference in the red colour of the heartwood cell walls, which is yellowish or golden in the case of Bald cypress. Another difference may be observed in the tannic acid content of the cell walls: the heartwood of *Taxodium* turned green only following a prolonged exposure to ferrous chloride, while that of *Sequoia* instantly went black. The reason behind this change in colour is that the reddish-brownish substances of tray cells contain tannic acid, and some yellowish-brownish substances in the tracheids are also composed of water soluble materials with tannic acid content. As it can be seen, a clear distinction may be easily made between the two species with macroscopic examination, however, they are much more difficult to differentiate by applying the method of microscopic investigation.

The results of the examination carried out on the fossil remains proved that the trunks are members of the *Taxodiaceae* family exclusively. Consequently, these species bear striking similarities from a xylotomic perspective, and those related species which became already extinct bear striking similarities to their existing counterparts.

The results of the xylotomic examination evidently proved that two (no 5 and 11) of the three trunks are *T. germanicum*, which already became extinct, while trunk No 2, 6 and 10 are *Sequoioxylon sp*, one of the extinct members of genus *Sequoia*.

The discovery of the marshland forest in Bükkábrány, which had been buried some 7.2 millions of years ago, made a unique examination of fossil remains possible. Our aim was to carry out the comprehensive anatomical and physical examination of the trunks belonging to the ancient forest, which also included determining the characteristics of the identified wood species by way of microscopic and macroscopic examinations. So far, five trunks have been identified. The histological study of the samples evidently proved that the trees discovered in the area belonged to a pine wood. It was observed as early as at the beginning of the examinations that every trunk was member of the *Taxodiaceae* family, which was also supported by the morphology of the trunks and the characteristics of the bark including its width and structure. The results of the xylotomic examinations evidently proved that two of the five trunks examined so far are *T. germanicum*, already extinct, which bears striking similarities to Bald cypress (*T. distichum*), an existing species even today, and that the three other trees are *Sequoioxylon sp*., which had already become extinct, a species closely related to Coast redwood (*S. sempervirens*). Based on the examinations carried out so far it has been proved that further investigation is required to determine whether the extinct species already identified in Bükkábrány and the strikingly similar existing wood species are the same or actually belong to different species.

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