A possible Late Miocene fossil forest PaleoPark in Hungary

[Paléo-parc à créer autour d'une forêt fossile d'âge Miocène supérieur en Hongrie]

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Citation: CSÁSZÁR G., KÁZMÉR M., ERDEI B. & MAGYAR I. (2009).- A possible Late Miocene fossil forest PaleoPark in Hungary.- *In*: LIPPS J.H. & GRANIER B.R.C. (eds.), PaleoParks - The protection and conservation of fossil sites worldwide.- Carnets de Géologie / Notebooks on Geology, Brest, Book 2009/03, Chapter 11 (**CG2009_BOOK_03/11**)

Abstract: The oldest, standing fossil forest in the world preserved as wood occurs at Bükkábrány, Hungary. An open-pit mine working Upper Miocene (Pannonian) lignite revealed sixteen stumps, 1.8 to 3.6 m basal diameter, preserved up to 6 m in height, standing on top of the lignite bed. The trees were preserved by the suddenly rising water level of Lake Pannon which drowned the forest seven million years ago. Sand from a prograding delta covered the landscape, preserving the unmineralised trunks in a anoxic waterlogged condition. This fossil forest, a wonderful example of a possible PaleoPark, is a unique part of the patrimony of Hungary and Earth which could be preserved for the future, but it is endangered by lignite mining operations.

Key Words: Paleobotany; Hungary; geology; taphonomy; forests.

Résumé : ***Paléo-parc à créer autour d'une forêt fossile d'âge Miocène supérieur en Hongrie.-*** La plus vieille forêt fossile au monde préservée sous forme de bois se trouve à Bükkábrány, Hongrie. Une exploitation à ciel ouvert de lignite du Miocène supérieur (Pannonien) a révélé une soixantaine de troncs de 1,8 à 3,6 m de diamètre à leur base et préservés jusqu'à une hauteur de 6 m, dressés au toit d'un horizon ligniteux. Ces arbres ont été fossilisés par la remontée soudaine du niveau du Lac Pannon qui a noyé cette forêt il y a quelques sept millions d'années. Les sables associés à la progradation d'un delta ont ennoyé la forêt morte, maintenant les troncs dans la nappe phréatique anoxique en les préservant ainsi de toute épigénie. Cette forêt fossile est une pièce unique du patrimoine de la Hongrie et de notre planète ; elle mériterait d'être préservée pour les générations futures par la création d'un Paléo-Parc approprié, mais elle est aujourd'hui menacée par l'exploitation de la lignite.

Mots-Clefs : Paléobotanique ; Hongrie ; Géologie ; taphonomie ; forêts.

1. Introduction

The concept of preserving non-petrified tree trunks of Late Miocene age arose soon after the Bükkábrány Lignite Mine allowed the members of the Geological Society of Hungary to visit the remnants of the tree trunks discovered by the miners in a giant open pit lignite mine. The members clearly realized that an enormous amount of money would be needed to establish and maintain the tree trunks in place and that Hungary could not invest this sum for this purpose. Just before the opening of the 34th International Geological Congress in Oslo in July 2008, we noticed the PaleoParks workshop in the program. Géza CSÁSZÁR contacted and was encouraged by organizer Jere H. LIPPS to give a presentation on the fossil forest to the workshop. That presentation convinced the participants of the special importance of the site. In this invited paper, we show in detail the significance of the Late Miocene forest that developed just above a freshwater swamp. We hope that the idea of a PaleoPark preserving the

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Manuscript online since September 17, 2009

patrimony of Hungary and indeed the entire Earth will be embraced by a broader circle of palaeontologists, geologists, entrepreneurs and businessmen so that the dream of preserving the fossil forest for future generations may come true.

Figure 1: Geographic sketchmap with indication of the occurrance of the Bükkalja Lignite Formation (MADAI *et alii*, 1982; JAKUS *et alii*, 1982) and the Bükkábrány lignite open cast.

Figure 2: Aerial photograph of Bükkábrány lignite open pit mine showing the site of a geological cross section (lower left, see Fig. 4) and the outline of the location map of Bükkábrány village.

Figure 3: Simplified palaeogeographic map with the extent of Lake Pannon about 8 million years ago.

For a long time, tree trunks and logs of various sizes were known to occur and be exposed in the mine; unfortunately the huge excavating machines used in the mining operation removed them soon after their discovery. However, a series of lucky events in the summer of 2007 resulted in the discovery and excavation of a fossil forest. A new excavation along the mine face was carried out by machinery smaller than usual. The standing trees could then be recognized by miners. Upon orders of Tibor MATA, mine director, careful excavation work started and within weeks a fossil forest consisting of 16 erect trees was

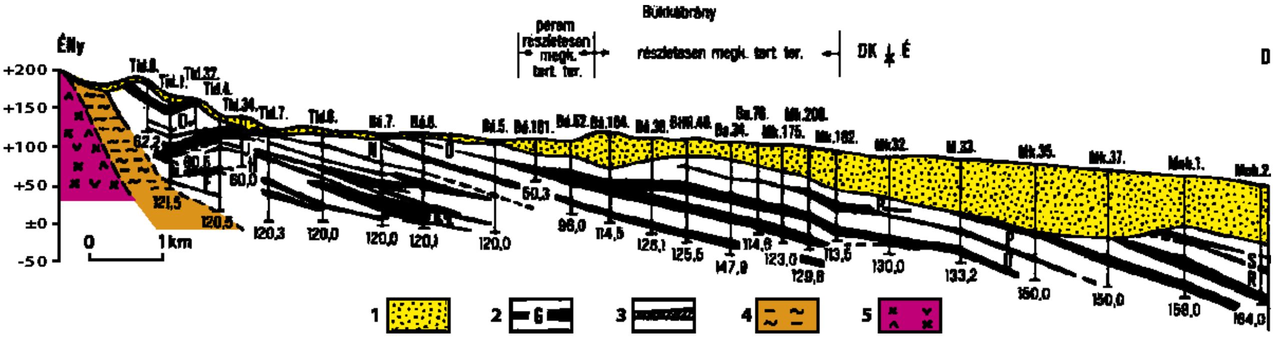

Figure 4: Geological cross section showing the lateral variation of the Bükkalja Lignite Formation (SZOKOLAI, 1981 *in* CSILLING *et alii*, 1985). 1. Quaternary sediments, 2. Upper Miocene (Upper Pannonian) succession with lignite seams, 3. Lignitic clay, 4. Upper Miocene (Lower Pannonian) clay and clay-marl, 5. Upper Miocene (Sarmatian) rhyolite tuff and brackish water sediments.

uncovered. Here we report on the geology, palaeontology and significance of this unique find, on the process of preservation of the forest in the rocks, and on the conservation work done up to now. We raise the question whether conservation in place of the fossil forest as a paleopark would be desirable and feasible. The forest is an irreplaceable part of Hungary's patrimony, both for its geology and history of life.

2. Geographic setting

Bükkábrány is a small village situated in the foothills of the Bükk Mountains in North-Eastern Hungary (Figs. 1-2), in the heart of Europe. The site lies on the northern side of Motorway M 3, coming from Budapest. Miskolc, the capital of Borsod-Abauj-Zemplén County is 35 km to the north-east. The other town Eger, the capital of Heves County is found at the other side of the Bükk Mountains, about 40 km to the west of Bükkábrány.

3. The geological settings and research history

The Bükkábrány fossil forest was unearthed from the Pannonian stage, which comprises one of the thickest non-marine Late Neogene sedimentary sequences in Europe (RASSER & HARZHAUSER, 2008). This sequence was deposited in the Pannonian Basin during the late Miocene and Pliocene, following the cessation of intermittent marine connections of the basin to the Mediterranean in the Middle Miocene (POPOV *et alii*, 2004). The closed and subsiding Pannonian Basin trapped the sediments derived from the emerging Alps and Carpathians (HORVÁTH *et alii*, 2006) with deposition taking place in a large brackish lake, Lake Pannon, and in adjacent deltaic and fluvial environments (MAGYAR *et alii*, 1999a).

In general, the Pannonian sequence in the northern part of the Central Pannonian Basin consists of seven lithostratigraphic units, reflecting the gradual filling of the basin. These include (from bottom to top) lacustrine marls (Endrod Formation), turbidites (Szolnok Formation), slope sediments (Algyo Formation), various deltaic deposits (Újfalu Formation), swamp deposits (Bükkalja Formation) and fluvial sediments (Zagyva & Nagyalföld formations; see JUHÁSZ G., 1991; CSÁSZÁR, 1997). Without marine fossils, the chronostratigraphic subdivision and correlation of the sedimentary succession is based on cross-correlations between regional aquatic biostratigraphy based on endemic Lake Pannon fauna and flora, European mammal stratigraphy, magnetostratigraphy, regional seismic stratigraphy, and radioisotopic age determinations from interbedded volcanic layers (MAGYAR *et alii*, 1999b; HARZHAUSER *et alii*, 2004). These correlations indicate that the boundaries between the lithological units (formations) are highly diachronous and progradational and that they resulted from a shift of the environments from the basin margins towards the centre, dominantly from N-NW to S-SE, which lasted for several million years (POGÁCSÁS *et alii*, 1994; VAKARCS *et alii*, 1994; MAGYAR *et alii*, 2007).

Figure 5: Miocene tree trunks in the Bükkábrány Fossil Forest horizon underlain by a thick lignite seam (under excavation) and overlain by a soft gray and yellow sand. From among the fossil stumps 6 were identified. Three of them proved to be *Glyptostroboxylon*, found on the left side, while another three *Taxodyoxylon germanicum* occur on the right side. Photo: Z. LANTOS.

The Bükkábrány occurrence of the fossil forest is located at the northern margin of the Pannonian Basin. Here, in the southern foreland of the Mátra and Bükk Mts, the basinward shift of the shoreline remained insignificant, whereas deep basinal areas to the west and to the east had been progressively filled and turned into deltaic plains. The Bükkábrány area thus became a northern embayment of Lake Pannon by about 8 million years ago (VAKARCS *et alii*, 1994; MAGYAR *et alii*, 1999a; see Fig. 3). Beginning about 7.5 million years ago the water level of Lake Pannon experienced a significant and lasting rise. Aggradation became a dominant pattern, resulting in extreme thickness of the Újfalu and Bükkalja formations (>1300 m in the Tiszapalkonya Tk-I well) (ELSTON *et alii*, 1994; JUHÁSZ E. *et alii*, 1999; JUHÁSZ G. *et alii*, 2007).

Figure 6: Angiosperm leaf remain fossilized in the Pannonian sediments of Bükkábrány (scale bar in lower right = 2.5 cm). Photo: L. HABLY.

The cyclic architecture of the Újfalu and Bükkalja formations reflects repeated deepening and shoaling of the depositional environment, with formation of huminitic clays or lignite seams at the end of each cycle. This cyclicity was apparently governed by astronomically-induced climatic cycles (JUHÁSZ E. *et alii*, 1997; KORPÁS-HÓDI *et alii*, 2000). Palaeoecological studies based on both the macroflora and vertebrate fauna indicate that the overall climate of the Pannonian Basin at this time was favourable for lignite formation. The warm temperate climate was characterized by a mean annual temperature of about 15 ºC and precipitation of about 1000 mm (BRUCH *et alii*, 2006; van DAM, 2006; ERDEI *et alii*, 2007). In the northern embayment of Lake Pannon, relatively thick (>2 m) lignite seams were deposited during the late phase of the aggradational period. These seams together with the intercalated barren beds comprise the Bükkalja Lignite

Formation. The lignite has been industrially exploited in open pits since the 1960s. The lignite-bearing succession and its heteropic changes are shown in a cross section (Fig. 4).

Deposition of the lignite-bearing succession came to a halt when the area began a gradual tectonic uplift and southward tilt at the end of the Miocene. The resulting unconformity is the most significant one within the entire Pannonian stage (JUHÁSZ E. *et alii*, 1999). It separates the lignite-bearing sediments (Újfalu & Bükkalja formations), sometimes with an obviously eroded or exposed surface from onlapping fluvial deposits (Nagyalföld Formation). The age of the unconformity was assessed by biostratigraphy and magnetostratigraphy (ELSTON *et alii*, 1994; MAGYAR & SZTANÓ, 2008). The sediments below the unconformity are Messinian in age (*Prosodacnomya vutskitsi* zone, *Galeacysta etrusca* zone, MN13); the youngest polarity zone was interpreted -with much uncertainty- as C3An2n, 6.8 Ma. The sediments above the unconformity belong to the Pliocene, as indicated by molluscs and mammals of MN14-15. The oldest polarity zone in this sequence was interpreted, with great confidence, as C3n2n, 4.6 Ma. Thus, the Bükkalja Lignite (the Bükkábrány lignite-bearing succession) can be dated as 7.5-6.8 Ma old.

Figure 7: Fossil fruits of *Trapa* collected from the intercalated clayey layers of the lignite seam at Bükkábrány (scale bar in lower right = 1 cm). Photo: L. HABLY.

4. Significance of the fossil trees

Fossil forests have been found on all continents and in several ages. Wood is mostly mineralized: turned to silica, carbonate (*e.g.* FAIRON-DEMARET *et alii*, 2003), or rarely to pyrite. Forests preserved as wood are extremely rare. Even the fossil forest of Dunarobba in the Italian Apennines (anonymous, 2000) is slightly mineralized, despite being only 2 million years old (SCOTT & COLLINSON, 2003). Mummified fallen logs and upright stumps up to 0.5 m height are known in Eocene strata of Arctic Canada (*e.g.* JAGELS *et alii*, 2005). However, the huge trees, preserved in life position as wood, makes Bükkábrány a unique location and rarity in the entire world. The Bükkábrány Fossil Forest is the only location worldwide where large trees are preserved standing, in the original forest structure, as wood (Fig. 5).

5. Palaeobotanical studies

Fossil plants of the Bükkábrány lignite mine drew the attention of researchers in the 1980s when the exploitation of lignite started. Mainly leaf and fruit remains have been collected since 1986. A fossil assemblage of relatively low diversity was preserved by clay associated with the lignite seams. Both angiospermous (Fig. 6) and gymnospermous plants were recognized based on macromorphological characters of leaves, i.e. *Glyptostrobus, Ginkgo, Alnus, Byttneriophyllum* (LÁSZLÓ, 1992). Fruits and seeds were recorded in higher diversity with taxa indicating mostly water or swamp habitats, i.e. *Glyptostrobus, Potamogeton, Ceratophyllum* but riparian vegetation was also represented by *Acer, Alnus, Pterocarya* and *Spirematospermum* (LÁSZLÓ, 1992). A nice collection of fossil fruits of *Trapa* (Fig. 7) permitted the description of a new species, *Trapa praehungarica* WÓJCICKI & BAJZÁTH (WÓJCICKI & BAJZÁTH, 1997).

Upright trunks similar to those discovered at Bükkábrány during the summer of 2007 were recorded nearly 30 years ago at the Gyöngyös-Visonta lignite mine, a coeval locality situated about 50 kilometres from Bükkábrány (PÁLFALVY & RÁKOSI, 1979). Based on wood anatomical characters, PÁLFALVY & RÁKOSI (1979) assigned the trunks to the morphospecies *Sequoioxylon gypsaceum* (GOEPPERT) GREGUSS which shows the closest similarity to the wood of modern *Sequoia sempervirens* (LAMB.) ENDL.

6. Recent studies

Recent palaeobotanical investigations have been focused on the systematic study of the trunks and the associated fossil flora and vegetation (ERDEI *et alii*, 2009). The stumps, preserved in life position, retained their original wood structure. When the trunks were discovered, first the length and diameter of each trunk were measured and their position was mapped. Samples of wood were collected from each trunk oriented upright and from one lying horizontally. The lignitic layers underlying the stumps and the sands embedding them consist of a great amount of plant debris, leaves, twigs and cones. Slabs with abundant leaf remains (leafy twigs) and cones were collected from the underlying organic sediments and from an organic rich layer in the sands embedding the stumps located at 1.5-2 m height from the top of the lignite seam (Fig. 8). Based on microscopic studies of thin sections the trunks can mostly be assigned to the Coniferae. Although poor preservation did not allow systematic assignment of some stumps, the in place fossil forest turns out to be more diverse than a pure stand; it comprises at least two morpho-taxa *Taxodioxylon germanicum* (GREGUSS) VAN der BURGH *Glyptostroboxylon* CONWENTZ emend. DOLEZYCH & VAN der BURGH & (DOLEZYCH *in* ERDEI *et alii*, 2009). *Taxodioxylon germanicum* may be related to modern *Sequoia* ENDL. It was an important element of peat-forming vegetation during the Neogene (DOLEZYCH *in* ERDEI *et alii*, 2009).

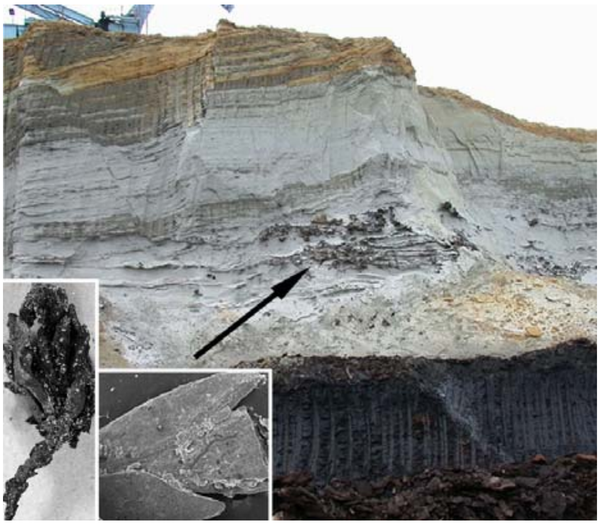

Figure 8: The locality of the organic rich layers (arrow) above the lignite seam at Bükkábrány that provided a great amount of plant debris including twigs and cones of *Glyptostrobus europaeus* (BRONGN.) UNGER (insets). Photo: B. ERDEI.

From both organic-rich layers, compressed gymnosperm twigs up to 5-10 cm in length could be separated by sieving or leaching with water. Most of the litter-like accumulation seemed to be of gymnospermous origin and *Glyptostrobus* ENDL. remains, foliage (Figs. 9-10), cones (Fig. 11) and seeds were very abundant. Modern *Glyptostrobus* develops various leaf types, but twigs recorded at Bükkábrány all bear monomorphic leaves of the cupressoid type. The mass occurrence of foliage, seed cones (nicely preserved three-dimensional cones supporting the pseudo-autochtonous origin of the plant debris) and seeds representing unequivocally *Glyptostrobus*, attests the dominant role of this taxon in forming the vegetation at Bükkábrány. Recent investigations of the sandy layers embedding the stumps resulted in a diverse seed/fruit assemblage in which gymnosperms are represented solely by seeds of *Glyptostrobus*. As attested by numerous oligotypic floras fossilized in Pannonian sediments, *e.g.* Dozmat (HABLY & KOVAR-EDER, 1996), Iharosberény (HABLY, 1992), Balatonszentgyörgy (HABLY, in prog.), Rudabánya (ERDEI, in prog.), Tiszapalkonya (HABLY, 1992), Visonta (PÁLFALVY & RÁKOSI, 1979; LÁSZLÓ, 1992). *Glyptostrobus* must have been the predominant conifer element of swamps which extensively evolved related to the succession of Lake Pannon. It was dominant in peat-forming vegetation suggesting swamp habitat with abundant water-supply. The genus is today monotypic with one species *Glyptostrobus pensilis* (STAUNTON ex D. DON) K. KOCH prevalent in SE China (Fujian, Guangdong: FARJON, 2005). It always grows near water and is restricted to tropical and subtropical coastal lowlands (FARJON, 2005). Occasionally it develops buttressed bases and pneumatophors (HENRY & MCINTYRE, 1926; ZHANG & XU, 1997). That the fossil forest is the remains of a swamp forest is corroborated by the systematic affinity of the trunks.

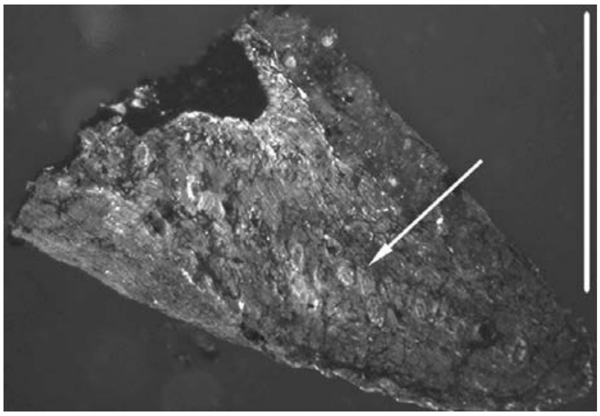

Figure 9: Cupressoid type leaf of *Glyptostrobus europaeus* (BRONGN.) UNGER. Stomata arranged in two bands (arrow) are easily observed on the upper side (fluorescence microscopy) (scale bar on right = 500 µm). (PB.2008.100.20./1). Photo: B. ERDEI.

Figure 10: Scattered stomata on the lower cuticle of a cupressoid type leaf of *Glyptostrobus europaeus* (BRONGN.) UNGER in transmitted light (scale bar in lower right = 50 µm) (PB.2008.100.20./3). Photo: B. ERDEI.

Figure 11: Three-dimensionally preserved seed cones of *Glyptostrobus europaeus* (BRONGN.) UNGER from the open pit mine at Bükkábrány (scale bar = 1 cm) (PB.2008.99.6). Photo: B. ERDEI.

Localities of autochtonous fossil woods comparable to the fossil forest of Bükkábrány have been searched for in the past. Large arboreal stumps are relatively common at Pliocene localities of central and northern Italy, *e.g.* Dunarobba in Umbria, (BIONDI & BRUGIAPAGLIA, 1991; MARTINETTO, 1994) and Stura di Lanzo near Turin (VASSIO *et alii*, 2008). Both are younger than that of Bükkábrány and the Stura di Lanzo forest comprises trunks belonging to one species, *Glyptostroboxylon rudolphii* DOLEZYCH & VAN der BURGH. The set of fossil organs (foliage, cone, seed and wood) was considered as a part of the *Glyptostrobus europaeus* "whole-plant" (VASSIO *et alii*, 2008). The stumps of both Stura di Lanzo and Dunarobba (BIONDI & BRUGIAPAGLIA, 1991) have a diameter of 1-3 m, are basally buttressed and have a general habit and position of trunks which are quite similar to that observed in Bükkábrány.

Similar to Bükkábrány an abundance of foliage and cones of *Glyptostrobus*has been reported from the Stura di Lanzo Pliocene deposits (PEOLA, 1896; MARTINETTO, 1994).

An additional noteworthy example of fossil forests is the Eocene in situ *Glyptostroboxylon* forest of Hoegaarden (Belgium, FAIRON-DEMARET *et alii*, 2003). Here the stumps are silicified, smaller (max. 80 cm in diameter) and positioned more densely, 1-3 m apart.

7. Future studies

Samples collected from the sand layers embedding the stumps resulted in a diverse seed/fruit assemblage. The systematic study of this assemblage is in progress. The investigation of dispersed plant material (leaf fragments, cuticles) of the plant debris associated to the stumps and additional palynological samples will surely greatly enhance our knowledge of Late Miocene flora and vegetation.

Systematic (carpological, palynological analyses) studies may recover additional (vegetative or reproductive) remains giving further prove of systematic diversity represented by the stumps at Bükkábrány. Furthermore, the systematic results followed by reconstructions of the vegetation will provide a fundamental base for outlining fossil forest structure at Bükkábrány.

8. Burial

The 12 m thick uppermost lignite seam (Fig. 5) underlying the fossil forest is covered by grey, well-sorted, fine to medium-grained sand (Fig. 12). It lacks certain grain-size fractions, therefore behaves as a quicksand when saturated with water, which flow into the mine continuously. During excavation work quicksand was removed every morning from the fossil forest. Dangerous cavities were formed in the mine wall where quick sand escaped.

Figure 12: Tree trunks excavated (left side) and excavated in part (right side) from the grey sand that flooded and covered the forest in life position. In the background, huge machines are removing the sand covering the remnant of the forest and the lignite seam. Photo: Z. LANTOS.

Figure 13: Gray sand with fragments of wood, tree limbs and scattered charcoal. The transition between the grey and yellow sand is seen in the left upper corner. Photo: G. CSÁSZÁR.

Figure 14: Tree stump with its rotted heart cavity filled by sand. Photo: G. RADÓCZ.

Figure 15: Southernmost tree trunks, partially excavated next to the sand wall. Photo: G. CSÁSZÁR.

More than 2 kilometre-long walls (Fig. 2) in the mine expose a stratified sand body, about 40 m in thickness. Just above the lignite bed horizontal bedding was observed up to A height of 1-2 m. Stratification is accentuated by layers of organic debris and driftwood, and occasional pebble strings. These features represent a toe-of-slope environment (Fig. 13).

Above these beds, approximately 20 m thick set of northward dipping, parallel beds follow. These are foresets of a prograding delta, covered by small-scale cross-bedding of a delta plain.

The Upper Miocene (Pannonian) delta complex is unconformably overlain by 20 m of Quaternary sediments: a few metres of coarse conglomerate, deposited by torrents running from Bükk Mountains. Mammoth teeth indicate Middle Pleistocene age. Highest member of the overburden succession is a red clay -formed in a humid, warm environment, and loess-like strata with fossil soil and abundant calcrete concretions, probably Upper Pleistocene in age.

Figure 16: A well-preserved tree trunk. Photo: G. CSÁSZÁR.

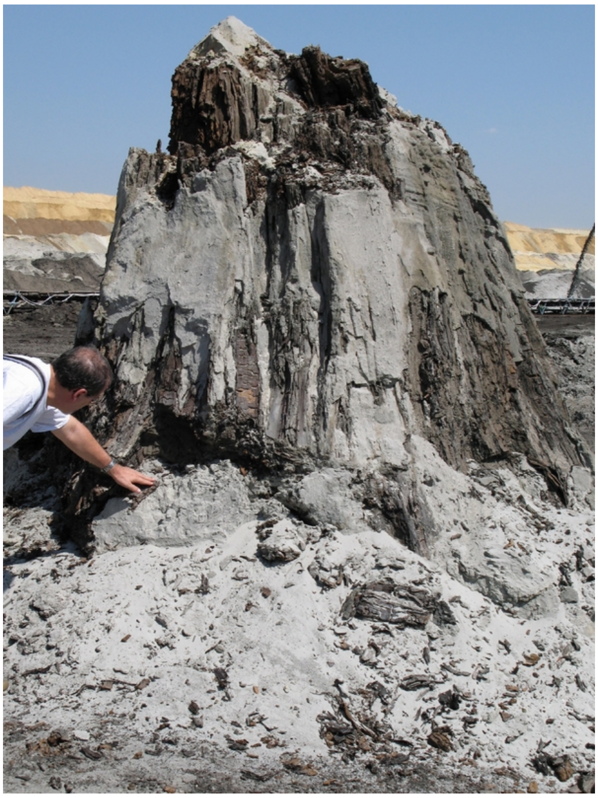

Figure 17: Tree trunk covered by fine-grained pyritic sandstone crust. Photo: G. CSÁSZÁR.

Possibly a sudden rise of 20 metres in level of adjacent Lake Pannon drowned the forest 7 million years ago. At this time some of the trees were already dead. Sand, transported by rivers, to the lake enclosed the stems, and filled hollows and cavities within the trees (Fig. 14).

For 7 million years oxygen-free, bacteria-free, upwards percolating groundwater preserved the trees and particulate organic matter. Quaternary uplift and erosion later removed part of the overburden.

9. Hydrogeology

The sand embedding trees is grey, up to a maximum of 6 metres above lignite. Above that is a yellow and brown variegated sand. The boundary of the grey and the yellow sand conspicuously coincides with the top of tree trunks (Fig. 15).

Bükkábrány mine is a 2.5 km long, 1 km wide open pit. Sixty metres thick overburden is being removed to reach 12 m of low-calory lignite. Tens of pumps depress ground water level by 80 metres so that miners and machinery can work in a dry pit.

The lignite layer is exposed in a 2 km long, less than 100 m wide strip in recent position at about 65 m below ground level. The fossil forest has been exposed only in a 50× 100 m area. As the southernmost trees are found at the foot of the sand wall (Fig. 15), they very likely continue further to the south. This exceptional preservation (Fig. 16) is due to a rare condition: grey sand, usually overlying the lignite bed in about 0.5 m thickness, is about 6 m thick here. Reducing conditions there allowed preservation of trunks up to 6 m height. Other trunks are found elsewhere in the mine from time to time, as described by the miners.

At the moment we are unaware of what site conditions, what anomaly of water seep allowed preservation of the unoxidised, grey sand up to 6 m thickness at the location of the forest.

10. Preservation

At a first glance, the trees look like normal, wet wood, and are relatively soft when pressed by the finger. Only the bark was missing except within pockets surrounded by xylem.

Living Cupressaceae (esp. *Taxodium*) is known to resist wood-degrading fungi and wood-boring insects. Despite this, several trunks display severe heartrot features, filled by grey sand and pyrite or both. The tree trunks are commonly covered by a pyritic sandstone crust (Fig. 17). Tangential cracks and fissures indicate a variety of degradation processes. The elastic cellulose of the cell walls decayed to various degrees, while plastic lignin remained so that when wet and damp trunks are exposed to sunlight and air, they fracture and contract, producing thin peels. The strong curvature is produced by high surface tension of evaporating pore water.

The forest has been continuously below groundwater level for the past 7 million years. In the summer of 2007, while excavation work was in progress, the trees were exposed to direct sunlight and started to dry. Centimetre-thick peels fell off the surface of the stems and started to curl slowly on the ground. This is a signal that much of the cellulose in wood cell walls decayed some time ago, while plastic lignin remained. Surface tension of evaporating water within cells exerted so much stress on the cellulose-poor wood that it could not resist, bending in circular form. Other trees suffered heartrot during the Miocene and their central cavity was filled by sand (Fig. 14) or pyrite. In another giant open pit at Visonta in western part of the Bükkalja Lignite field area (Fig. 1), siliceous impregnation also occurs and preserves the wood (oral communication by G. Radócz).

While no pervasive mineralization is observed at Bükkábrány, a few pyrite-filled open fissures are covered by mm-sized pyrite crystals, at least one heartrot cavity is fully filled by pyrite, and pyrite-cemented sandstone cakes are attached to the wood surfaces in places (Fig. 17).

Fragments of charcoal have been found in the sand wall and in the upper level of the grey quicksand just above the top of the tree trunks (Fig. 13) together with varied sizes of boughs and other wood fragments. This charcoal likely indicates wildfires during the life of the forests.

11. Conservation

Ten trees out of the sixteen excavated have been removed from the mine. Four of them are at the Herman Ottó Museum, Miskolc. One is embedded in wet sand, while three are in huge tanks. One tank contains clear water carried from the mine, and two contain sugar solutions of various concentration. Sugar (saccharose) concentration will be gradually increased from an initial 5% up to 70% over several years. Diffusion of sugar into the wood will be periodically checked.

Six trees were transported to Ipolytarnóc Fossil Site, where they are exhibited to the public. Internal portions of the trees were removed, while about a 20 cm thick external cylinder was retained and injected with various resins and glues in order to preserve them.

12. A PaleoPark for Bükkábrány

The fossil forest excavated at Bükkábrány is a unique discovery in the history of palaeontology. Below we argue for preservation this fossil forest, in spite of numerous, serious difficulties we face in order to bring this idea to fruition.

Arguments for a Bükkábrány PaleoPark: It would preserve

- a unique fossil assemblage of the oldest and largest fossil forest preserved as wood;
- the forest structure as it was 7 million

years ago;

- huge, upright stumps;
- the potential of discovering new palaeontological phenomena in addition to further tree trunks during careful excavation and study of the uppermost level of the sedimentary succession overlying the swamp replacing the prograding delta;
- traces and remnants of animals that lived at the base level of the swampy forest;
- the sand beds above the swamp sediment which may also contain several more other types of plants, lived next to the swamp environment;
- possible tree trunks in life position to the northwest of the open pit and beyond the exploitation area (Fig. 18) in a shallower depth;
- potentially a large number of trees in life position representing additions to the fossil forest throughout the lignite field, as yet uncovered but which were penetrated in approximately 1% of boreholes drilled by geologists who prospected in the Bükkalja lignite field;
- an abundance of fossil material that can be used to make precise reconstructions of the local palaeogeography and paleoenvironment.

What steps are needed for establishing a paleopark at Bükkábrány? The plan would depend on the site where the tree trunks are located.

1. If the trees are located within the mine pit, then we must

- seek cooperation and support of the mining company;
- develop mining and dump-forming methods in the mine to allow preservation of trees found in the future;
- secure permanent water pumping for the lifetime of the PaleoPark, keeping water table at 60 to 70 m below the surface, depending on the site of the fossil forest;
- create permanent slopes in quick sand environments;
- construct a permanent museum building;
- build paved access roads;
- find or develop appropriate methods for preservation of trees in natural condition.

2. In the case tree trunks are found in the proximity of the old cemetery and not in the mine pit, the first 4 points above are less serious questions because it is outside of the mining area and the tree trunk horizon is situated 15-20 m higher.

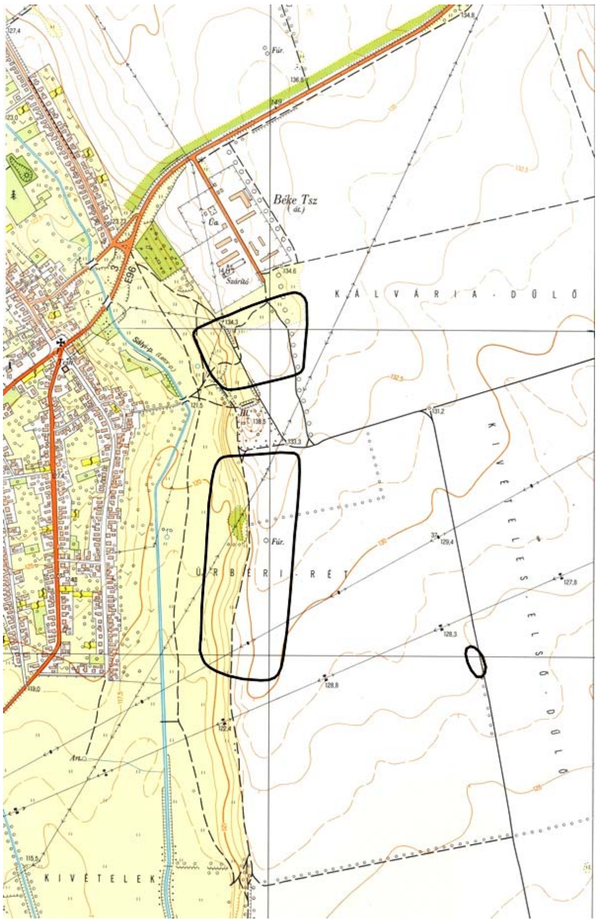

Figure 18: Location map of Bükkábrány village showing potential sites of a possible paleopark centered on the Late Miocene Fossil Forest.

Figure 19: Detail of the Fossil Forest with visiting geologists for scale. Photo: G. CSÁSZÁR.

The last three points pose serious questions. The fossil forest has exceptional heritage and scientific values for Hungary and the world, and our task is to draw the attention of all people who are interested in preservation of this kind of extraordinary product of Earth history even if it requires much effort and money. The intent of this effort is to preserve this important resource for future generations who will be able to admire this beautiful forest, just as recent geologists did it in the mine in 2007 (Fig. 19).

13. Further studies in progress

Because it is the oldest known forest on Earth preserved as wood, the Bükkábrány fossil forest deserves special study, outlined as follows:

1. age of the lignite bed and forest,
2. taxonomy of plant fossils,
3. dendrochronology,
4. forest structure,
5. carbon isotope record,
6. formation of accommodation space and burial,
7. preservation of wood,
8. neotectonics.

These studies have been in progress since July 2007 (KÁZMÉR, 2008). Results achieved so far will be published in due time.

Further tasks we face in case excavation by hand is possible:

1. to complete the collection of those types of plants that inhabited the swamp and identify them,
2. to discover and collect traces or remnants of animals that lived in the swamp and the forest and identify them,
3. to reconstruct the palaeoenvironment of the swampy forest,
4. to examine the soft sand for fossils and other findings which were transported from the land- these can aid in broadening the reconstruction area beyond the swamp.

Acknowledgments

Travellers at Mátra and Bükk Mountains do not know that a fossil forest, millions of years old, lies underground. We dedicate this paper to them with the aim that they and future generations can learn and enjoy the fossil forest of Hungary. The spirit and dedication of director and workers of the Bükkábrány mine made possible this exceptional fossil to be found, excavated, and preserved for science and for all of us. The greatest thanks goes to them!

We are grateful to Director Tibor MATA and personnel of Bükkábrány Coal Mine, Ltd. for assistance and permissions throughout our field work, and to János VERES, archaeologist at Herman OTTÓ Museum, Miskolc, for directing the excavation, packing, transporting and conserving four trees. We trust in their further kind help and hope that they are promoting the foundation of the paleopark here.

We are indebted to Gyula RADÓCZ for his remarks and suggestions, to Olga PIROS for helping us in preparation of figures and photos, to Jere LIPPS and Bruno GRANIER for encouraging us in preparation this paper and also for critically reading it.

Geological and palaeontological study was supported by the Hungarian Scientific Research Fund (K73195 and K73199).

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