145/1, 45–52., Budapest, 2015

Upper Miocene lignite occurrences in the Oaş Depression, Satu Mare County, Romania

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Felső-miocén lignit-előfordulások az Avas-medencéből, Szatmár megye, Románia

Összefoglalás

Az Avas-medence a Pannon-tó önálló öbleként működött a környező neogén vulkáni hegyekkel körülvéve. A kristályos aljzatra paleogén és neogén üledékek települtek. A késő-miocénban az éghajlat, valamint a tó vízszintjének válatakozása következtében mocsári erdők fejlődtek ki (*Byttneriophyllum* és *Alnus)*. Így mocsarak, tőzeglápok alakultak ki, melyek jellemző növényzete a *Glyptostrobus europaeus*, *Byttneriophyllum tiliifolium* és *Alnus cecropiaefolia*, amelyek széntelepeket képeztek. Az Avas-medence szenei jó minőségű lignitek, melyek fűtőértéke átlagban 22 100 kJ/kg.

Tárgyszavak: Románia, Avas-medence, késő-miocén, mocsári erdők, szénképződés, lignit

Abstract

The present paper contains a significant amount of data concerning the geology, genesis and physical and chemical features of lignite in the Oaş Depression (North-western Transylvania, Romania). The present-day circular Oaş Depression is bordered by Neogene eruptive complexes; however, it is most likely that initially it functioned as a gulf of Lake Pannon. It was open to the west, north-west and most probably to the east as well. The age of the lignite-bearing unit is Late Miocene. Due to climate changes and lake level fluctuations during the Late Miocene, the sedimentary basin was occupied repeatedly by mires of forest swamp. Genetically, coal accumulated from the swampy forest vegetation which developed in certain areas. The presence of the swampy forest is proved by *Glyptostrobus europaeus, Byttneriophyllum tiliifolium,* and *Alnus cecropiaefolia*. In the Oaş Depression the lignite has excellent quality . The physical and chemical characteristics show an average caloric value of 22,100 kJ/kg.

Keywords: Romania, Oaş Depression, Late Miocene, swamp forest, coal generation, lignite

Ocurențele de lignit de vârstă miocen superioară din Depresiunea Oaş, județul Satu Mare, România

Rezumat

Depresiunea sedimentară a Oaşului a funcționat ca un golf al Lacului Pannonian, având o formă circulară determinată de limita cu eruptivul neogen înconjurător. Depozitele sedimentare dispuse peste un soclu cristalin aparțin paleogenului şi miocenului. Miocenul superior este dezvoltat în facies pannonic şi cuprinde resturi vegetale fosile, reprezentând flora miocen-superioară. Pentru flora miocenă sunt caracteristice biotopurile de pădure mlăştinoasă (în special Byttneriophyllum şi Alnus). Schimbările de climă, precum şi fluctuațiile nivelului apei din lac din miocenul superior unele sectoare din bazinul de sedimentare s-au transformat într-o turbărie. Prezența în aceste turbării a vegetației de pădure mlăştinoasă (*Glyptostrobus europaeus, Byttneriophyllum tiliifolium, Alnus cecropiaefolia*) este răspunzătoare de formarea depozitelor de cărbune. Cărbunii din Depresiunea Oaşului sunt ligniți de calitate superioară, caracteristicile fizico-chimice indică o putere calorifică medie de 22 100 kJ/kg.

Cuvinte cheie: România, Depresiunea Oaş, miocen superior, păduri mlăştinoase, geneza cărbunilor, ligniți

Introduction

The Oaş Depression, also known as "Ţara Oaşului", is a small basin which was formed in the western margin of the Oaş volcanic plateau with a slight westward dip. The drainage system of the basin is determined by the Tur and Talna Valleys and a series of tributaries from the surrounding volcanic mountains.

The bottom of the basin is composed of a high pediment surface developed by the erosion of andesitic rocks, volcanic agglomerate and Neogene sedimentary formations. The Upper Miocene sequence reflects a terrestrial or shallow marine origin.

During the Late Miocene, the sedimentary basin was occupied intermittently by mires of forest swamp. The centre of the forest swamp was the northern section of the basin near Târşolţ, Aliceni, Cămârzana and the south-eastern part was near Negreşti-Oaş.

In this paper a short characterization of the geology of the Oaş Depression is presented. It has a special focus on the current state of knowledge with respect to the lignite occurrences, based on recent geological research.

Geology of the depression

Based on deep borehole data (F. 4746 Remetea Oaşului, F. 4745 Valea Măriei-Vama) the metamorphic basement of the depression can be related to the Bihor Unit (Tatrides, i.e. Internal Dacides SĂNDULESCU 1986). The thickness of the Palaeogene is generally 400–650 m; however, towards the west, near Pişcolt-Carei, it exceeds 1000 m. The Palaeogene deposits are represented dominantly by marl, along with a series of silt and sandstone having sequence thicknesses of 10–40 m. According to SĂNDULESCU (1986), some lithological characters resemble very closely those of the Podhale flysch (e.g. Rusty shale).

Miocene deposits are present throughout the Palaeogene (as shown by drillings), while on the surface they are represented by the Pannonian sequences (*Figure 1*).

Badenian deposits are evident from drilling carried out in the centre of the depression and they have been found exposed in the surrounding area of Neogene volcanic rocks. The Lower Badenian formation is composed of marl and sand with an intercalation of "green tuffs".

The Upper Badenian (Kossovian) sequence is represented by, transgressive marl, sand, tuff and algal limestone (*Lythotamnium*).

Sarmatian formations have also been drilled and found exposed in the surrounding area of Neogene eruptive rocks. Sarmatian formations comprise marl, silt, clay, sandstone and volcanic tuff deposits. The macrofauna is represented by *Cardium gleichenbergense* PAPP, *Cardium pium* ZIHZH and *Mactra eichwaldi* LASK. The uppermost part of the succession is traditionally assigned to the "Pontian" (Upper Pannonian), but because of regional correlation issues in connection with Lake Pannon the deposits should be marked as being Pannonian s.l. This designation is due to results from mollusc fauna: e.g. *Congeria balatonica* PARTSCH and *Congeria czjzeki alata* (GILLET & MARINESCU) with *Unio baltavarense* HAL., *Limnocardium apertum* (MUNST.) and *Brotia vasarhelyi* HANTKEN present in the Lake Pannon deposits of Hungary (*Table 1*).

Due to the cyclic subsidence related to the tectonic instability and the climatic conditions of the area during the Late Miocene, the sedimentary basin has been occupied intermittently by peat bogs in an area of swamp forest. The centre of the forest was situated the northern sector of the basin near Târşolţ, Aliceni and Cămârzana and partially in the south-east near Negreşti-Oaş (SAGATOVICI 1967, 1968; JUDE 1986).

The earlier presence of a forest swamp is reflected by the occurrences of vegetal debris of *Glyptostrobus europaeus* (BROGNIART 1833) UNGER 1850, *Byttneriophyllum tiliifolium* AL. BRAUN 1845, *Alnus cercropiaefolia* ETTINGSHAUSEN

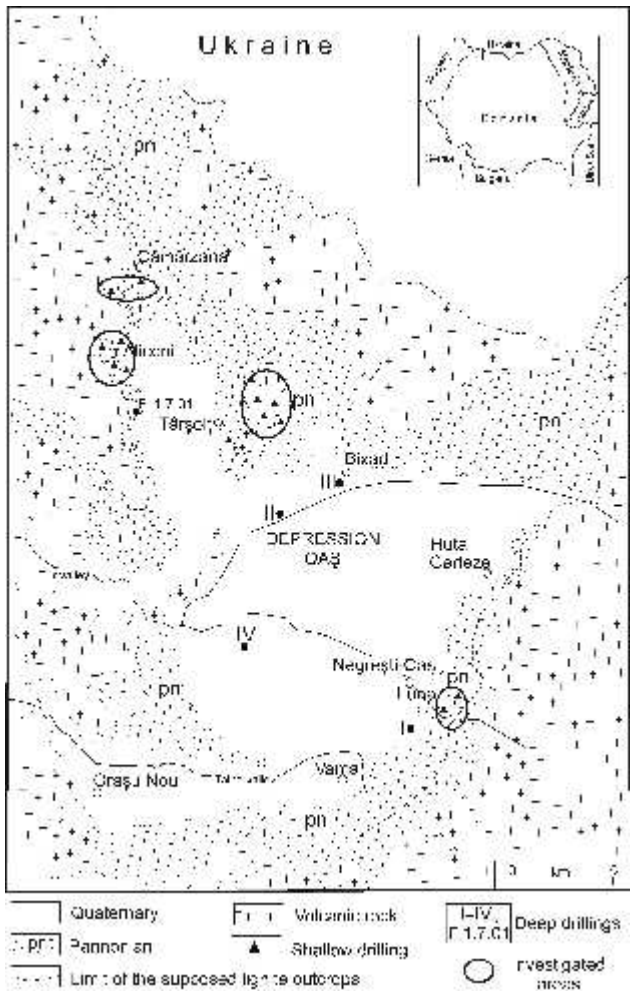

Figure 1. Geological map of the Oaş Depression. (Compiled and simplified after KOVÁCS-PÁLFFY et al. 1984)

Figură 1. *Harta geologică a Depresiunii Oaş (completată şi simplificată după KOVÁCS-PÁLFFY et al. 1984)*

Cuaternar, Pannonian, Linia aflorimentelor de lignit, Roci vulcanice, Foraje de mică adâncime, Foraje de adâncime medie, Zone investigate

1. ábra. *Az Avas-medence földtani térképe (kiegészítve és egyszerűsítve KOVÁCS-PÁLFFY et al. 1984 nyomán)*

Kvarter, Pannóniai, A lignit rétegek kibúvási vonala, Vulkáni kőzetek, Sekély fúrások, Közepes mélységű fúrások, Megkutatott területek

Table I. Pannonian s. l. from the Oaş Depression (after SAGATOVICI 1967).

Table I. *Pannonianul s. l. din Depresiunea Oaş (după SAGATOVICI 1967)*

I. táblázat. *A pannóniai s. l. az Avas-medencében (SAGATOVICI 1967 nyomán)*

Pannonian s. l.	Upper Pannonian ("Pontian")	Congeria balatonica Horizont (with lignite seams) cca. 100 m lacustrine, lagoonal facies
	Lower Pannonian	Congeria zsigmondyi and Congeria partschi Horizont cca 190 m
		Congeria balatonica Horizont cca. 60 m neritic, litoral facies

1851, *cer tricuspidatum* BRONN 1838 and *Platanus platanifolia* ETTINGSHAUSEN 1851, associated with *Salix* sp., *Betula macrophylla* GOEPPERT *1855, Alnus* cf. *glutinosa* GAERTNER 1791 (SAGATOVICI & ŢICLEANU 1974; GIVULESCU 1994, 1996) on the edges of the partially inundated areas.

This vegetation consists of the association of *Byttneriophyllum* and *Alnus.* These fossils were found within the drilling cores of F.1.7.01, Târşolţ-W (*Plate I*).

Thus the occurrence of vegetation which is typical for a forest swamp can be assumed; this is similar to the respective examples of Tiszapalkonya (HABLY 1992), Dozmat (HABLY & KOVAR-EDER 1996), Tiszapalkonya, Rudabánya (ERDEI et al. 2007), Chiuzbaia (MACOVEI 2011) and Bükkábrány, Dozmat, Felsőtárkány, Iharosberény, Kerecsend, Rózsaszentmárton, Rudabánya, Tiszapalkonya, Visonta (HABLY 2013).

In the area of Visonta (Pannonian Basin, Hungary) deciduous and swamp forests with *Glyptostrobus*, rarely with *Taxodium*, *Alnus* and *Nyssa* were formed and existed during all periods of peat accumulation (IVANOVA et al. 2004).

History of research

In 1908 some deep boreholes were drilled in the Oaş Depression and these showed the existence of brown coal seams (TELEGDI ROTH 1913, PAPP 1915):

— the oldest ones, which 1.5 and 2.1 m thickness and at depths of 551.00–552.55 and 607.60–609.70 m respectively, are considered as Upper Mediterranean (Middle Miocene) seams (II. — Boineşti),

— younger seams, of 0.28 m thickness and at depths of 135.32–135.60 m (I. — Negreşti-Oaş), are considered to be of Sarmatian age.

The systematic exploration and exploitation of lignite in the area started in 1910 by mining works at Luna–Negreşti-Oaş, Aliceni, Cămârzana, Târşolţ and Huta Certeze (from the Pannonian succession).

Due to the reduced thickness of lignite seams and the termination of the belt-line on the Satu Mare – Negreşti-Oaş narrow-gauge railway, most of the mine shafts were closed between 1950 and 1962.

In the *Negreşti-Oaş* area Pannonian lignite seams were explored, and a survey was also carried out at the Luna mine (ISPIF 1957).

SAGATOVICI (1967, 1968) examined some lignite occurrences from the Oaş Depression.

In 1980, the company IPEG "Maramureş" Baia Mare (Romania) implemented a programme of geological exploration of the Pannonian lignite. The drillings explored the lignite occurrences and thus, by correlating the Pannonian lignite seams, the areas of Târşolţ and Aliceni became of interest with regard to possible exploitation.

KOVÁCS-PÁLFFY et al. (1982, 1984) presented the main results of the exploration activity in the Oaş Depression, especially those from the Târşolţ area.

Later, MACOVEI (2000, 2011) published a series of works containing data on the geology, macro- and micro-flora, genesis and on some physical-chemical characteristics of lignite occurrences in the Oaş Depression.

Spatial distribution and features of the lignite

At *Târşolţ*, 2–9 lignite beds with respective thicknesses varying between 0.10–2.00 m were found in different boreholes at depths between 14.80 m and 67.80 m (*Figures 2 and 3*).

The IVth seam proved to be of economic interest. It has a thickness between 0.10 m and 2.00 m (*Figures 2 and 3*) and its underlying formation is comprised of marl with intercalations of pyroclastic rocks (andesitic tuffs); the cover is marl or clay-marl. Although it is characterized by high thickness variations, in most of the drillings the outlined reserves justified future exploitation.

The IVth lignite seam was formed in a large peat-forming environment with a huge forest swamp which probably existed over a long period. Thus it can be considered that the lignite seam denotes stagnation in the relative rise in the level of the lake.

According to the drilling data, the peat-forming environment related to the IVth lignite seam had an irregular shape with two extensions to the south. Its length was about 2300 m and its maximum width was about 2100 m (Figure 2).

In the middle of the area (borehole F. 2.6.03: 34.70–35.60 m — *Figure 3*) clayey lignite appears, while towards the south, north and west, the lignite seam increases in thickness. Considering the isopach data of the IVth lignite seam, the presence of a topographic elevation from NE to SW can be assumed. This probably divided the area of the peat-forming environment into two regions of vegetation and accumulation.

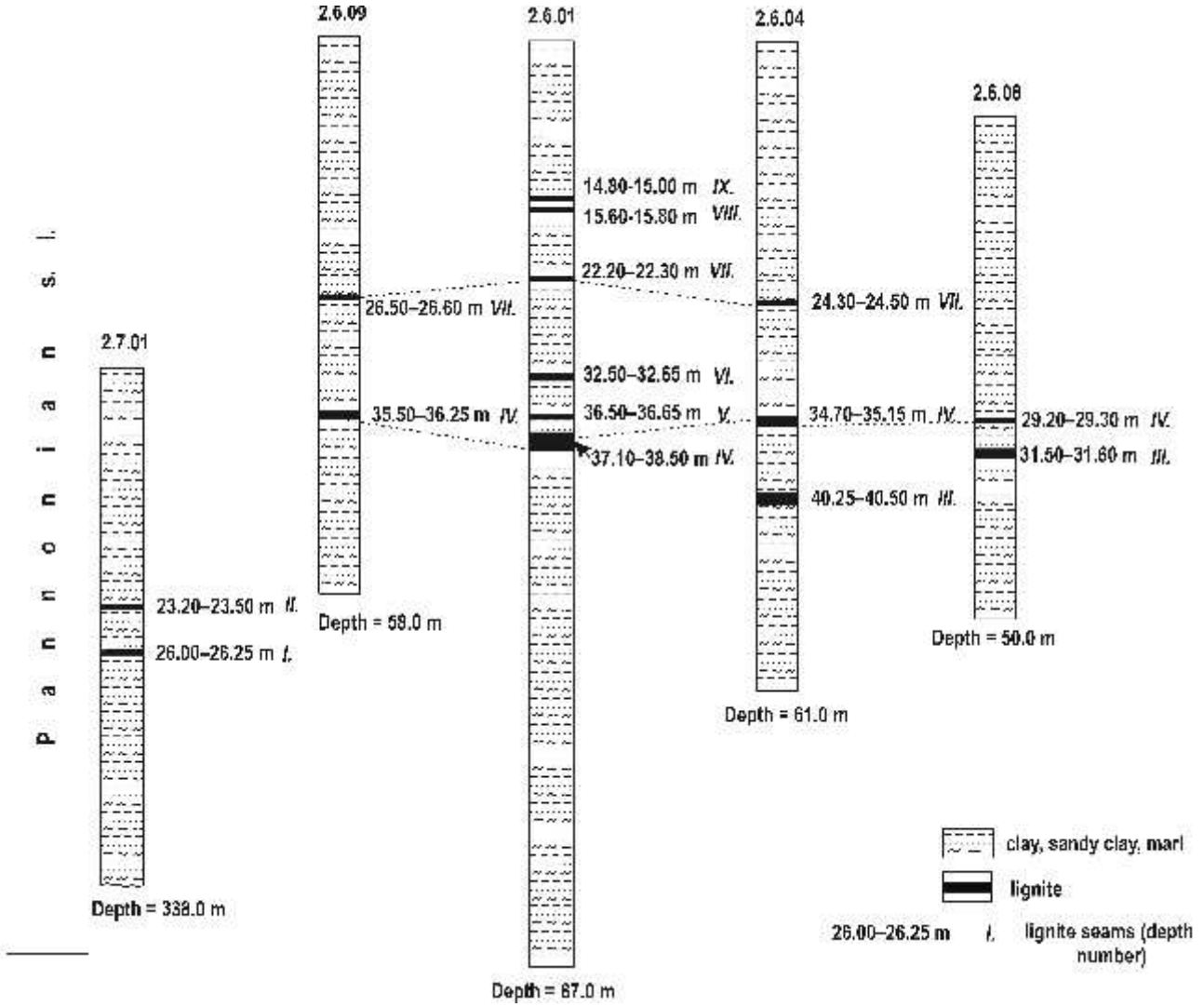

Figure 2. Geological columnar sections of lignite seams in some boreholes from the Târşolţ area (data by KOVÁCS-PÁLFFY et al. 1982)

Figură 2. *Secţiuni geologice columnare prin stratele de lignit interceptate in câteva foraje din zona Târşolţ (după KOVÁCS-PÁLFFY et al. 1982) I*

2. ábra. *Földtani rétegoszlopok a Târşolţ térségében a fúrásokkal megkutatott lignit rétegekkel (KOVÁCS-PÁLFFY et al. 1982 nyomán)*

At Aliceni 2-6 beds of lignite, with respective thicknesses varying between 0.10 m and 1.30 m, were found at a depth of 60 m. Based on deep drilling data, the reserves were outlined (northward towards Cămârzana) in the vicinity of the Neogene eruptive formations of Dealul Ursoi and towards Lechinţa.

In the Aliceni area drilling data indicate the presence of an uneconomic lignite seam that also reflects forest swamp facies. The shape of the swamp would have been oval with a N-S strike, with a length of 2750 m and width of 2000 m.

In the *Negreşti–Oaş* area the Pannonian lignite seams were explored at the Luna-mine; these seams have a thickness of between 0.23–0.50 m and are at respective depths between 19.55–51.80 m (ISPIF 1957).

Beside the above-described areas, probably two or more peat-forming mires existed in the surrounding regions. These additional mires were single swamps with two or more lignite-forming phases (GIVULESCU 1996).

The faults of the basement reactivated during the Late Miocene — and the fractures produced by intrusive and eruptive volcanic activity — have significantly affected the original position and continuity of the lignite seams. Moreover, lateral discontinuity of the lignite seams due to the palaeogeographic conditions can also be assumed. Thus the seams are fragmented and the stratigraphic correlations are frequently ambiguous.

Landslides affecting the older mining works are also present (especially in the Târşolţ area) in the sectors with lignite strata outcrops. The low productivity and the unfavourable hydrogeological conditions — i.e. the occurrence of seams below the hydrostatic level — were the main factors determining the termination and closing of the mining activity.

The lignite of the Oaş Depression is Pannonian lignite and its high quality gives it economic potential. In the areas where the lignite seams were in contact with the Neogene (Late Miocene) eruptive formations the lignite eventually turned out to be similar to sub-bituminous black coals (1–2

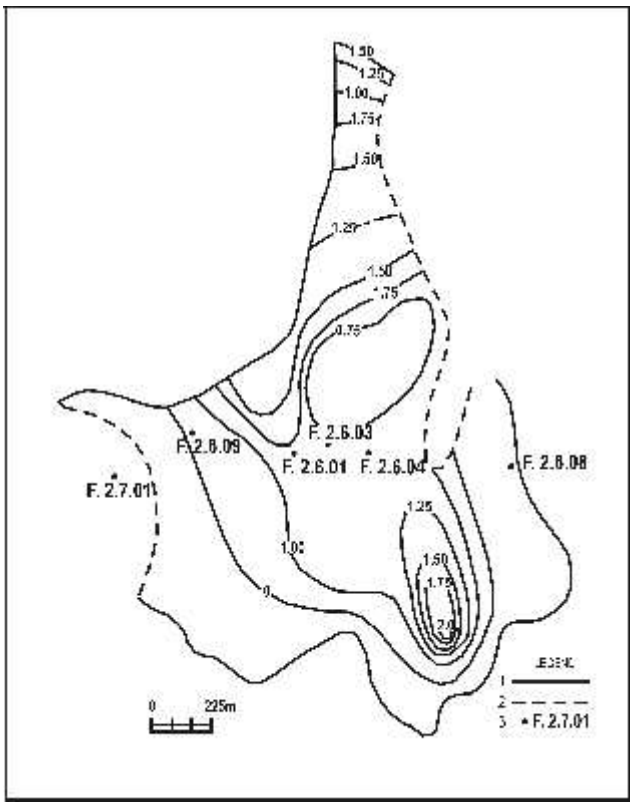

Figure 3. The IVth lignite seam isopachs at Târşolţ (data by KOVÁCS-PÁLFFY et al. 1982)

1. Limits of the outcrop area of the IVth lignite seam; 2. Limit of the supposed outcrops; 3. Drillings with indications of the lignite interception thicknes

Figură 3. *Izopahitele stratului IV. de lignit din zona Târşolţ (după KOVÁCS-PÁLFFY et al. 1982)*

1. Limita aflorimentelor stratului IV. de lignit, 2. Limita presupusă a aflorimentelor, 3. Forajele cu grosimile stratului de lignit interceptate

3. ábra. *A Târşolţ-terület IV. számú lignitrétegének izopahitos térképe (KOVÁCS-PÁLFFY et al. 1982 nyomán)*

1. A IV. réteg felszíni kibúvásai, 2. Feltételezett felszíni kibúvások vonala, 3. Fúrások a lignit-réteg-astagságokkal

m thickness); the latter is based on the consideration that the quality parameters are due to contact metamorphic processes. The colour of the lignite varies from brown to black and it is dominantly matt, being rarely semi-glossy or even glossy. It presents an example of clear stratification and the cracks in the lignite are irregular and sometimes splintered.

The features of contact thermal metamorphism were observed in some lignite samples and these features include the presence of sub-millimetre vacuoles. These vacuoles are due to slight degassing and give the coal a spongy appearance.

Petrographically, the lignite from the Oaş Depression was formed of xylite (a visible xyloid wood structure was bserved in some samples), metaxylite, xylovitrite, vitrite and also (sporadically) fuzite (IONESCU & UNGUREANU, 1981).

Among mineral components, clay minerals were noted; the proportion of these is highly variable with 1–2% in lignites, but this figure can increase up to 50% in shaley lignite or coaly shale. Sporadically, detrital minerals (quartz, muscovite and calcite) and pyrite were also observed.

Table II. Physical-chemical characteristics of the investigated lignite

Table II. *Caracteristicile fizico-chimice ale ligniţilor studiate*

II. táblázat. *A tanulmányozott lignitek fizika-kémiai jellemzői*

Occurrence	Calorific value kJ/kg	Ash %	Humidity %	Total sulphur %
II. Deleşti	26940–27900	6.78 12.79	1.65	
Câmârzani[1]	24550			
Negreşti-Oaş de Lunca-Negreşti	11590–18120 >13925	18	32.5	3.1
Târşolţ	22100	30–60	4.9–34.7	

PAPP 1915, [2]PETRESCU et al. 1987, [3]KOVÁCS-PÁLFFY et al. 1982

On a technological sample from the Târşolţ area, briquetting tests were performed. Briquettes with good cohesion, appropriate strength, reduced consumption of the binder, and a high calorific value were obtained.

The main physical-chemical characteristics of the lignite samples from different occurrences are given in the *Table 2*.

Conclusions

The Oaş Depression functioned as a distal sub-basin of Lake Pannon. The circular sub-basin is surrounded by Late Miocene eruptive formations. The basin-filling sedimentary deposits represent the Palaeogene and Neogene. Pannonian formations contain fossil vegetal debris. The Pannonian flora belongs to a forest swamp environment.

Due to the climate and the relative lake level fluctuations during the Late Miocene, the sedimentary basin was occupied intermittently by mires of forest swamp. The development of forest swamp vegetation, with the presence of *Byttneriophyllum* and *Alnus,* enabled the formation of lignite seams.

The near-surface Pannonian lignite seams of the Oaş Depression contain lignite of a high quality. The physical-chemical characteristics indicate heating values of 11 590–24 550 kJ/kg.

Some of the lignite deposits (especially in Târşolţ) are of lower economic interest, but the lignite from these deposits can still be used in thermal power plants or in industrial furnaces, and eventually in local industry.

Acknowledgements

We would like to thank our reviewers Lilla HABLY, Mária HÁMOR-VIDÓ, Imre MAGYAR, Orsolya SZTANÓ and Géza CSÁSZÁR for their constructive comments, and also for detailed and constructive criticism on a former version of the manuscript. We are also very grateful to Richard William MCINTOSH for checking the English grammar of the manuscript.

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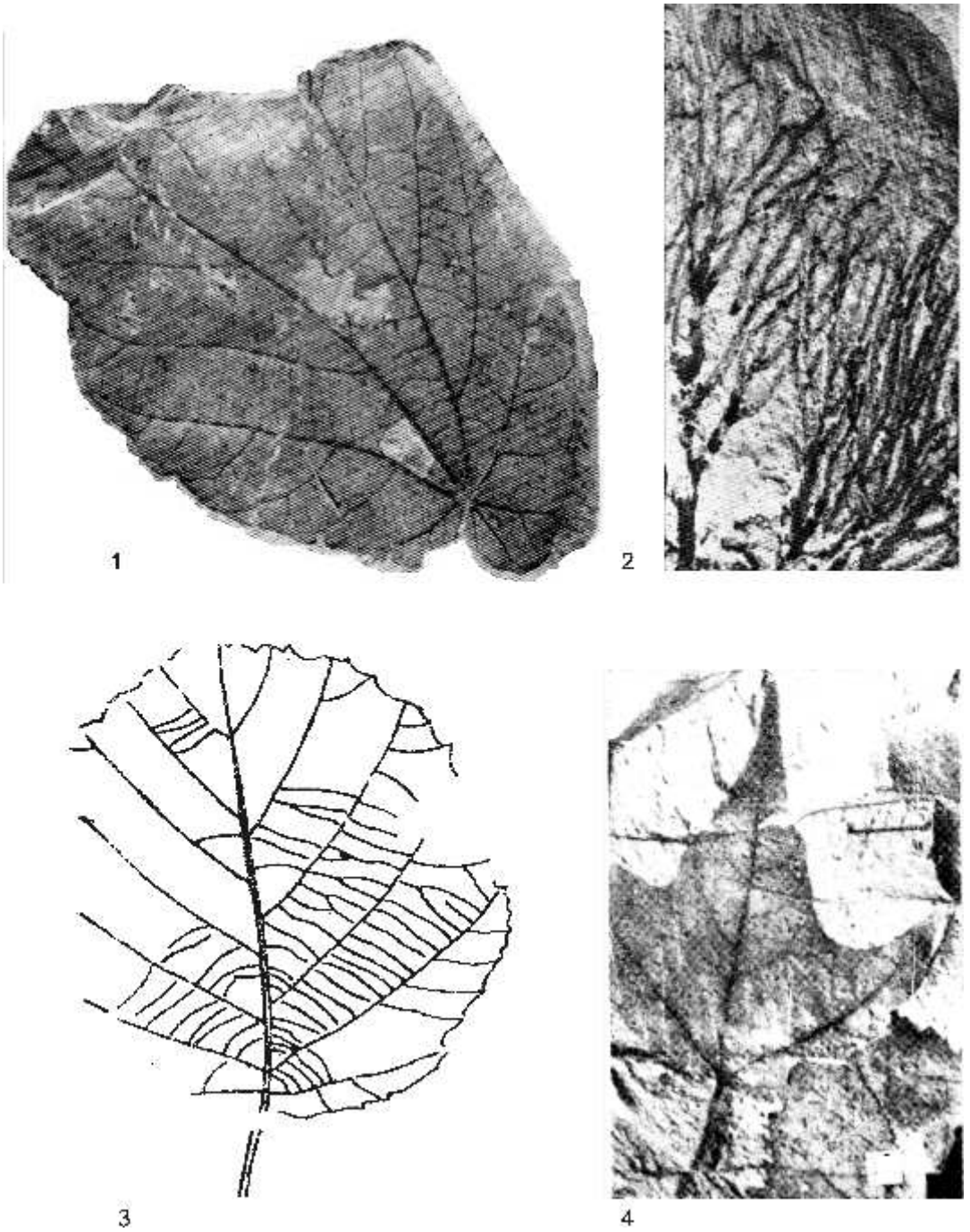
Kézirat beérkezett: 2014. 11. 06.

Plate I — I. tábla



Swamp forest plant debris collected from borehole No F. 1.7.01 (depth=354.7 m), Târşolţ-W

Resturi de floră colectate din forajul nr F. 1.7.01 (talpa=354,7 m), Târşolţ-W

Mocsári erdő növénymaradványai a 354, 7 m-es F. 1.7.01. fúrásból Târşolţ-Ny

1. *Byttneriophyllum tiliifolium* Al. Braun 1845 (23.0 m)
2. *Glyptostrobus europaeus* (Brogniart 1833) Unger 1850 (126.0 m)
3. *Alnus cecropiaefolia* Ettingshausen 1851 (after Givulescu 1996) (15.0 m)
4. *Acer tricuspidatum* Bronn 1838 (39.0 m)

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