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AEOLIAN SURFACE TRANSFORMATIONS ON THE ALLUVIAL FAN OF THE NYÍRSÉG

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Abstract

The evolution of the Nyírség and its landforms has been widely addressed by Hungarian geographers and geologists in the past and at present as well. Early works were mainly concentrating on understanding the complex, fluvial and aeolian genetics of the territory, later more specific forms and problems were studied and revealed. By the increasing number of chronological evidence derived from stratigraphic, pollen and archaeological data and absolute dating techniques (radiocarbon and optically stimulated luminescence) the geomorphological development can be reconstructed in more detail, especially in the context of climate variations and human intervention. Our study aims to summarize and outline the times of aeolian activity, with special respect to Holocene events, on the basis of the researches carried out so far. By nowadays it is obvious that sand was moving on several occasions in the Nyírség during the Holocene subsequent to the main aeolian land formation periods of the Upper Pleniglacial and the late glacial. In the first half of the Holocene sand movement can be related to dry periods, thus aeolian activity was driven mostly by climatic factors. In the second half of the Holocene the area of land affected by wind erosion decreased and in most cases events can be associated to the activity of man. Nevertheless, climatic and anthropogenic factors could be superimposed, leading to significant local sand mobilisation.

Keywords: wind-blown sand, Holocene, climate change, human impact

INTRODUCTION

Earth scientists have studied the Nyírség for over 100 years but geological and geomorphological research can still contribute to the understanding of the surface development of the area. According to Nagy (1908), the sand of the Nyírség was placed to its current location from the alluvial fans of the Ondava, Tapoly, Laborc, Ung and Latorca rivers in the foreground of the volcanic mountains, i.e. it was transported by wind from distant areas.

Cholnoky (1910) in his work entitled “Surface of the Great Hungarian Plain” discussed the sand area of the Nyírség in detail and explained also the development of the landforms. He thought also that the sand was originated from the “debris” of the Ondava-Tapoly-Ung and Latorca and according to him the “strong northern foehn winds formed semi-bond wind-blown sand forms on the loess plateau of the Nyírség”. According to these, the wind-blown sand was formed after the formation of the loess. In his opinion the sand of the Nyírség came from a long way and this explained the roundedness of the grains. One characteristic of the semi-bond wind-blown sand is that the forms develop where vegetation cannot protect the surface. Therefore it is hard to believe that grains could have been transported for such a long distance along a surface covered partially by vegetation. Nevertheless, the idea of the renowned geographer remained for decades influencing other researches as well.

The theory of Cholnoky became outdated when Sümeghy (1944) – based on borehole data – described the Nyírség as an alluvial fan built by rivers flowing from the Carpathians and Transylvania. He also noted that no loess can be found underneath the wind-blown sand but fluvial sand supplying the material blown by winds to form wind-blown sand. His theory was proved by stratigraphic and morphological research as well.

Aeolian landforms of the Nyírség

Significant differences can be found in the descriptions of the landforms in the Nyírség. Nagy (1908) considered ripple marks, hummocks and yardangs, as he called dunes dominant. He also wrote that sand moved towards the south in the form of barchans. He noticed that there are significant differences among ripple mark surfaces and that different forms can be found south and north of the watershed in the Nyírség. Formation of the landforms, however, was explained improperly by him.

According to Cholnoky (1910), sand dunes are the forms of semi-bond sand characterised by crests elongated according to the orientation of the prevailing wind and by ripple marks in between them. In his opinion westerly winds pushed the middle section of the crests slightly to the east, however, the main direction remained.

Balla (1954) writes about parabolic blowout dunes, longitudinal dunes, Kádár type Lybian dunes, ripple marks and coastal dunes. He explains the formation of the coastal dunes by eastern and northeastern winds. In his opinion, sand blown from the beds with low water level was accumulated in the form of dunes along the shores in the dry periods of the Würm.

Kádár (1956) discussed the Nyírség as well in his work studying wind-blown sand. In this publication abandoned his earlier theory related to Libyan dunes and he termed the parabola dunes elongated along their eastern wing beside inter-dune water as a marginal dune.

Borsy (1961) carried out detailed geomorphological mapping based on field-research of several years in the Nyírség resulting in the first geomorphological map of a Hungarian sand area. He studied the size, orientation and internal stratification of the landforms drawing conclusions on the palaeo-wind conditions as well. He systemized and classified the deflation and accumulation forms and described their development in detail. He discussed the areas of the Nyírség and their aeolian landforms separately.

AGE OF THE WIND-BLOWN SAND LAYERS

The first statements related to the age of the wind-blown sand landforms in the Nyírség are written in the book of Borsy (1961). When studying the surface of the Nyírség he assumed Holocene sand movements based on the more intact landforms greater in size. He also noticed the fossil soils dividing the dunes, and identified the loess layers as well. He reckoned the formation of the wind-blown sand above the loess layer took place in the Hazel phase when the climate was drier and warmer than today. He changed his views regarding sand movement in the Holocene when ^{14}C age determinations enabled the more accurate calculation of wind-blown sand movement periods (*Fig. 1*).

Radiocarbon (^{14}C) age data

The first results were obtained when the strata of the sand quarry in the western outskirts of Aranyosapáti were studied where two wind-blown sand strata of different age are divided by a loess layer (*Fig. 2*). Charcoal remnants in the fossil soil developed on the loess made ^{14}C age determination and thus the more accurate definition of the wind-blown sand movement periods possible.

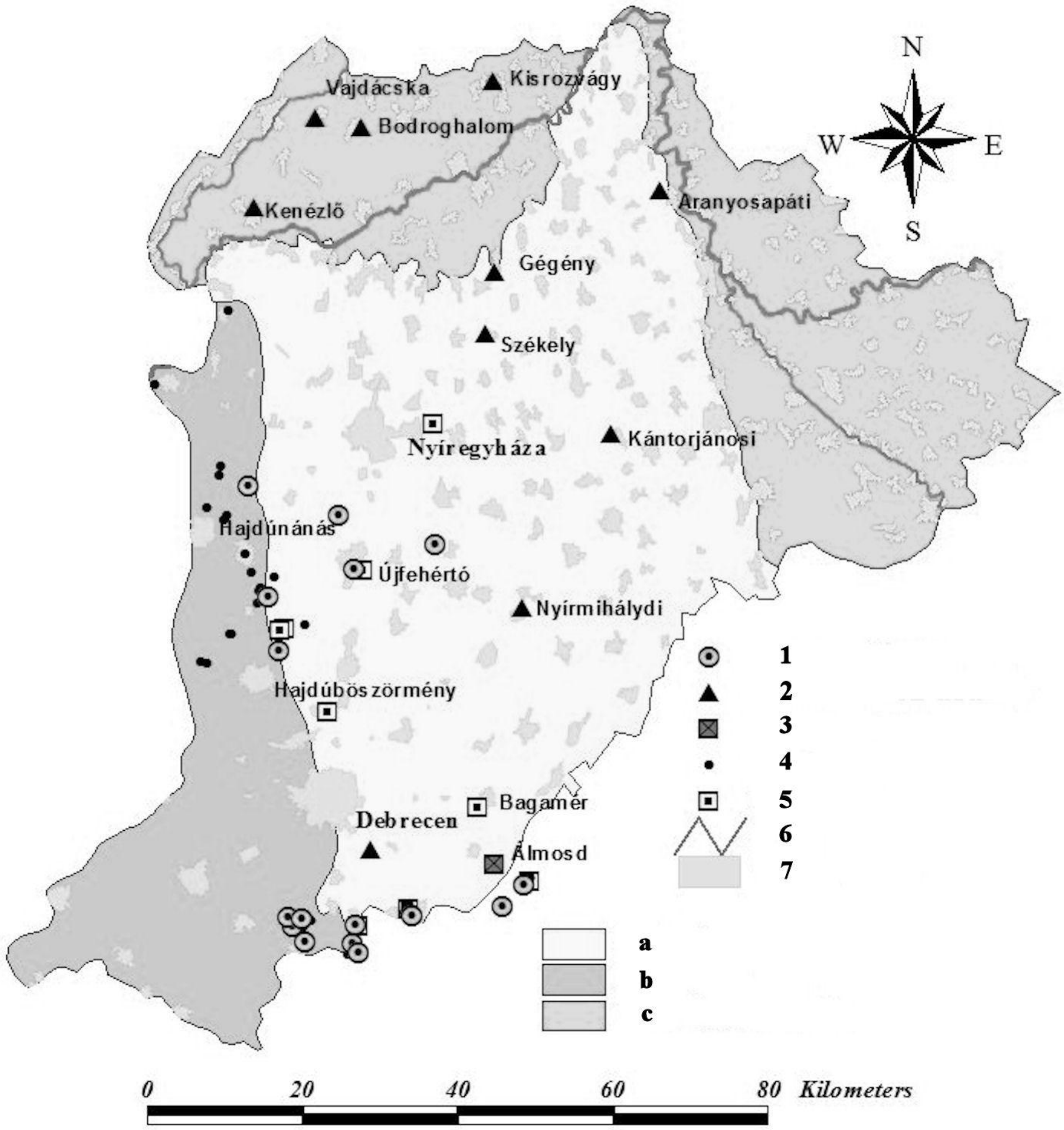

Fig. 1 Location of boreholes and outcrops in the Nyírség and in the marginal areas of the alluvial fan
1:pollen boreholes; 2:radiocarbon; 3:outcrops; 4:boreholes; 5:OSL; 6:rivers; 7:settlements; a:Nyírség; b:Hajdúhát; c:Upper-Tisza-region

Age of the fossil soil is 12900±500 years BP, i.e. it was formed in the first milder climate of the late glacial. The wind-blown sand below the loess layer was formed before this date from the fluvial sand of the alluvial fan. Based on the radiocarbon data obtained from the research carried out in the Nyírség, Bodrogköz and the Danube-Tisza Interfluve, the first major accumulation of wind-blown sand occurred in the Upper Pleniglacial and it was followed by several in the Dryas (Borsy et al., 1981, 1985; Lóki et al., 1993).

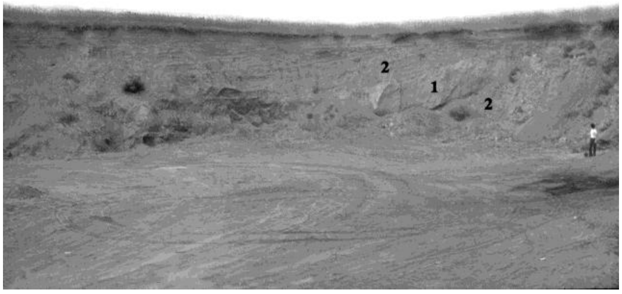

Fig. 2 Sand quarry in the outskirts of Aranyosapáti (1: loess, 2: wind-blown sand)

Based on the data gained by the research in the 1980s it can be stated that the landforms of Hungarian wind-blown sand areas were formed in the dry periods of the late glacial and sand moved only in a limited area primarily due to anthropogenic effects in the Holocene.

A humus layer at small depth underneath the surface (*Fig. 3*) is traceable in numerous outcrops in the Nyírség that is the continuation of the surface soil frequently. Several scientists (Marosi, 1967; Borsy, 1961; Borsy and Lóki 1982; Lóki, 2003) explained the burial of these soils by wind erosion as a result of deforestation in the 18th century. This correct statement has to be completed by that – on the basis of historical data – deforestations took place in the early 19th century as well in order to increase the ratio of arable lands, thus wind erosion could have made its influence felt at that time as well.

In the course of recent research (Lóki et al., 2008) new outcrops were found in which fossil soil divides the wind-blown sand strata. These, however, are thinner (*Fig. 4*) than the soils formed in the late glacial (*Fig. 5*). This suggests shorter period suitable for soil formation. In the subsequent dry period soil moved again. Radiocarbon age data of soils prove sand movements in the Holocene. Age of the fossil soil in the outcrop near Gégény is 3740±50 years (BP) and it is covered by 4 m of wind-blown sand. Age of the fossil soil in the sand quarry at Kántorjánosi is 9300±50 years (BP) and this is also covered by 4 m of wind-blown sand (*Fig. 6*).

Fig. 3 Young fossil soil in a wind-blown sand outcrop in the Nyírség

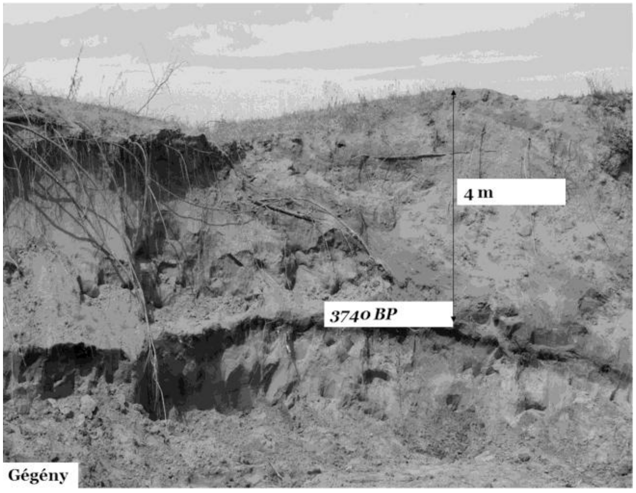

Fig. 4 Position and age of the fossil soil horizon (sand quarry at Gégény)

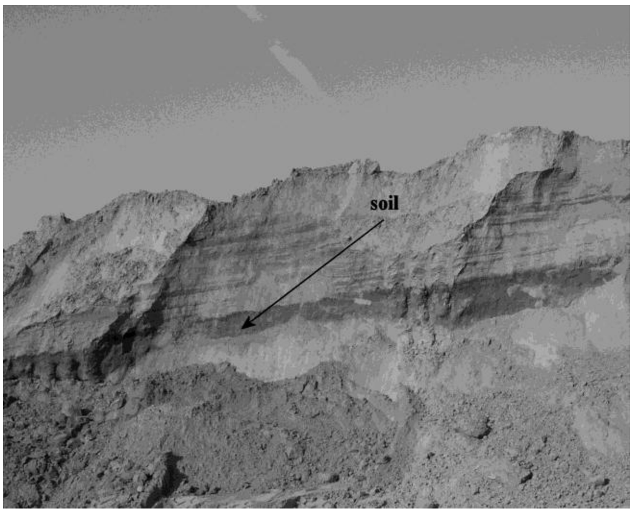

Fig.5 Late glacial soil east of Nyíregyháza

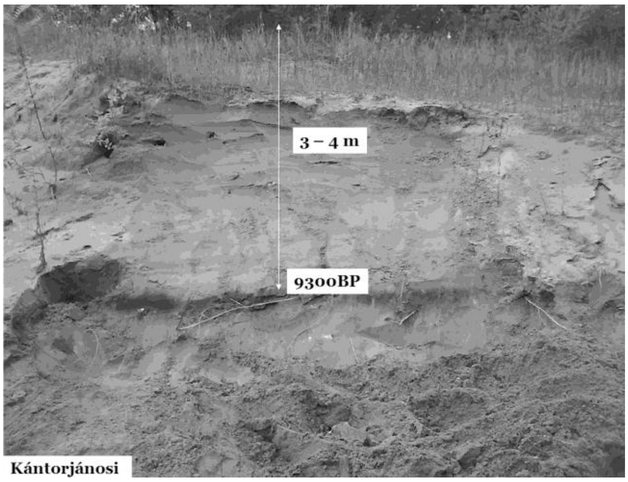

Fig. 6 Position and age of the fossil soil horizon (sand quarry at Kántorjánosi)

The two soil horizons of different age suggest that sand moved at several times in the Holocene and that wet and dry periods alternated. However, outcrops were also found in the Nyírség in which no fossil soil was detected in the 4-6 m thick wind-blown sand on top of the fluvial sand (*Fig. 7*). Age of these strata was determined by OSL measurements

Fig.7 Wind-blown sand outcrop with strata showing different grain-size distribution

OSL age data in the Nyírség

In recent years Kiss and co-workers carried out OSL measurements on samples from the Nyírség. These measurements are important because they enable the determination of the age of sand strata without soils as well. Their research at study areas near Bagamér and Erdőspuszta revealed wind erosion during the Atlantic and Subboreal phases (Kiss and Sipos, 2006; Kiss et al., 2008). Sand movement in the Atlantic phase in the Nyírség was already presumed by Borsy (1980), however, at that time measurements were not available to prove that.

Data were obtained from research in other Hungarian wind-blown sand areas in the last decade (Ujházi, 2002; Ujházi et al., 2003). Ujházi (2002) showed Upper Atlantic sand movement above the older Dryas applying luminescence measurements in outcrops at Dunavarsány. Research carried out in the Danube-Tisza Interfluve (Lóki and Schweitzer, 2001; Nyári et al., 2006; Kiss et al., 2008; Sipos et al., 2006) verified sand movements at the beginning of the Subatlantic phase, in the Iron Age and at the time of the great migrations as well. All these data indicate that aeolian land formation prevailed at several times in the Holocene.

Stratigraphic and pollen data

Changes in the stratification of accumulation forms, archaeological findings in the outcrops and alterations of the pollen content of the strata yield more data for making the reconstruction of aeolian surface development more accurate.

Considering the stratification of the wind-blown sand outcrop near Gégény mentioned above it can be stated that the accumulation of the 4 m thick wind-blown sand covering the Subboreal fossil soil was followed by another sand movement. Succession in the eastern wall of the dune (*Fig. 8*) supports this as sloping strata are covered by almost horizontal wind-blown sand strata. These are made variable by iron pan layers. Strata series with different orientations suggest changes in wind directions. The two differing strata series are not divided by a younger soil horizon because the conditions of soil formation were missing on the loose and dry sand surface.

Fig. 8 Strata series with different orientation in the sand quarry at Gégény

The stratigraphic analysis included the surfaces covered by shroud of sand in the marginal areas of the Nyírség and the river beds buried partly by wind-blown sand as well. Archaeological findings helped determining the age of sand movement (*Fig. 9*) in the strata of outcrops in the areas covered by shroud of sand (Félegyházi and Lóki, 2006).

Based on our research so far it can be stated that the sand sheet covers in the southern marginal areas of the Nyírség were formed in several periods. Sedimentological and palynological analyses verified clearly the accumulation of strata related to shroud of sand at the end of the Pleistocene and in the Holocene. Analysis of the Upper Pleniglacial Selaginella containing bog strata exposed in the outskirts of Álmosd and Kokad and south of Hajdúbagos suggests the settlement of bog pine indicating dry summer. In the periods of drought the grass vegetation bonding the surface on the dunes became dry and the sand started to move. Further movement of the sand was impeded only by the swamps and bogs developed in the marginal areas in wetter periods therefore wind spread only little sand onto the bogs and swamps.

Fig.9 Strata series in the borehole drilled near Hosszúpályi (a:wind-blown sand, b:findings of Sarmatian Age, c: findings of Bronze Age)

Stratigraphic and palynological analyses of boreholes drilled in the abandoned riverbeds in the alluvial fan of the Nyírség contributed to the more accurate reconstruction of its land development. One borehole was drilled in the depression starting from Hajdúhadház through Újfehértó and Nyíregyháza up to the Small Tisza, while another borehole is located in the bed remnant detectable from Nyíradony to Rétköz.

In the 550m deep borehole drilled in the bed remnant in the vicinity of Újfehértó the bottommost sediment that yielded pollen was found in the stratum between 520 and 480 cm (*Fig. 10*). The 20% ratio of floating red-grass and galingale (*Cyperaceae*) among the pollens indicate lacustrine conditions with low stagnating water. The 10% of spikemoss (*Selaginella*) among the pollens indicate clearly the cold, boreal climate of the Pleistocene. Dry terraines of the area were covered by steppe meadows with pine groves. The pine forests were composed of Swiss pine (*Pinus cembra*), Scots pine (*Pinus sylvestris*), spruce (*Picea*) that are characteristic for the taiga and have always been rich in the forests of the wetter taiga. Wetter climate is also supported by the presence of willow (*Salix*). Similar pollen composition was detected in the strata of the Fehér lake at Kardoskút and in the older strata of the Nagymohos bog at Kelemér from the interstadial of the Upper Plenniglacial the of which was determined to be 26000–24500 years BP (Magyari, 2002; Magyari et al., 2000; Sümegi et al., 1999; Járainé Komlódi, 2000).

At the depth between 480 and 430 cm one pollen shows a not interpretable sandy, silty sediment layer. This accumulation did not help the preservation of pollen grains. Micro-stratigraphic analyses suggest slight wind-blown sand movements that can be explained by a short dry, cold period. Sand movement of this age has not been identified in the Nyírség so far but research carried out in the Danube-Tisza Interfluve (Krolopp et al., 1995) suggests sand movement of similar age (25200±300 BP). Magyari (2002) indicates steppe–tundra vegetation between 24500 and 22700 years BP when characterising the vegetational phases of the northeastern part of the Great Hungarian Plain.

Pollen content of the sediments between 430 and 360 cm suggests wetter climate again. Pollen composition can be characterised by a mixed foliage taiga forest. This milder climate can be shown at several places in the Carpathian Basin (Járainé Komlódi, 1969, 1970; Borsy and Félegyházi, 1991; Sümegi and Magyari, 1999; Félegyházi and Tóth, 2003, 2004) characteristic for the period between 22700 and 21400 years BP. Pollens upwards in the sediment series indicate that the climate became more-and-more continental gradually. This fits well in the vegetational phase prevailed between 21400 and 18500 years BP (Magyari, 2002). Severe winters and dry, warm summers destroyed woodland vegetation and only grasses survived among herbaceous plants. This is indicated in the pollen spectra by that the ratio of pine pollens fall below 10% while that of grass species (*Gramineae*) increases up to 60%.

After this pollen accumulation was terminated, the bed was covered by a 200 cm thick wind-blown sand stratum. Vegetation composed of cold steppe grasslands, then it was dried out as well and the surface of the alluvial fan was shaped by cold, sometimes stormy winds. Formation of this sediment stratum took place around18500–14600 years BP.

The sediments containing pollen appear again at the depth of 150 cm. Pollen distribution is dominated by pine in 80% regarding arborescent vegetation. The remaining 20% is presented by deciduous trees and herbaceous vegetation with diverse taxon composition. At the time of the deposition of this stratum lacustrine conditions characterised this part of the bed.

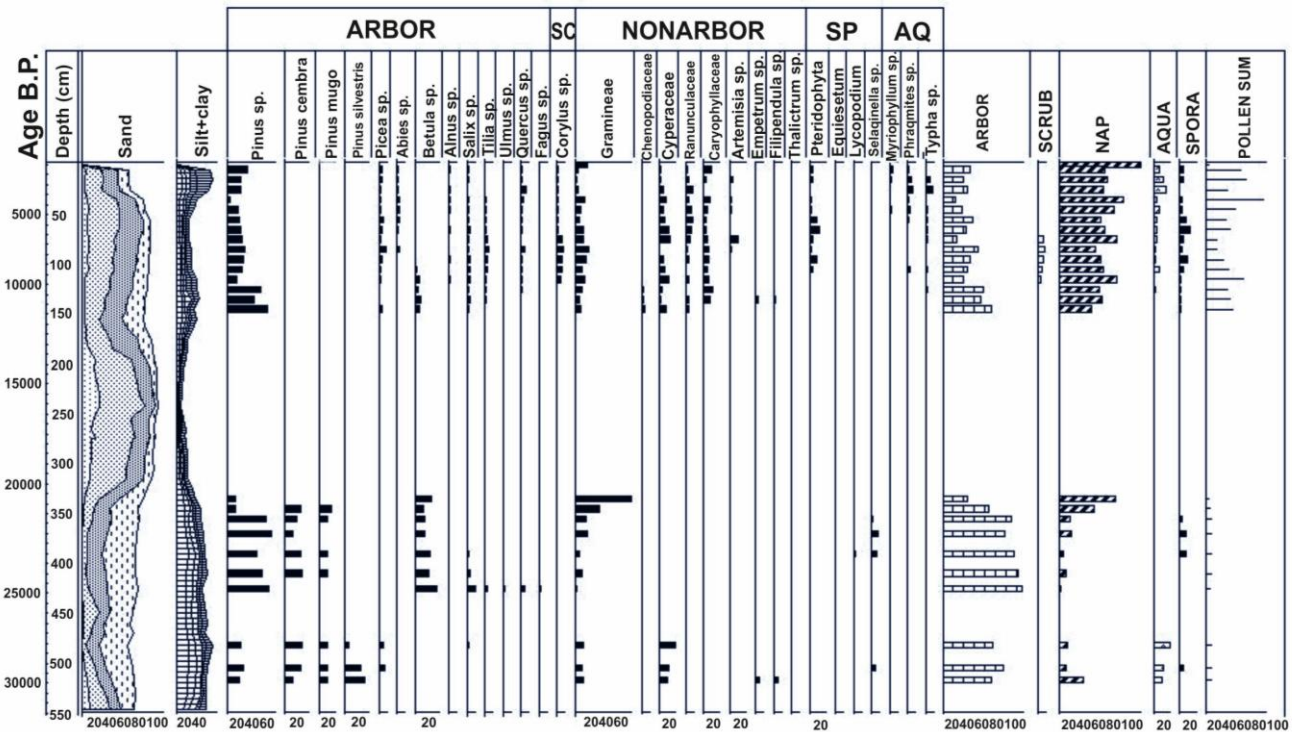

Fig. 10 Palynological and grain-size distribution diagrams of the sediments from the bed remnant in the vicinity of Újfehértó

With the gradual warming of the climate deciduous trees – birch (*Betula*) first, then alder (*Alnus*), willow (*Salix*), linden-tree (*Tilia*) and oak (*Quercus*) appeared, however, Scots pine (*Pinus sylvestris*) was still present on the sand. Hazel (*Corylus*) was present in the underwood of oak forests as well. This sediment stratum represents the forest advancement phases of the post-glacial time and the start of the early Holocene.

Results of the palynological analyses of the cores from the borehole drilled in the other bed remnant between Érpatak and Nagykálló are the same as those of the borehole in the vicinity of Újfehértó. Thickness of the late glacial wind-blown sand is almost 200 cm at both locations.

It can be also concluded from the analysis results of the samples from the two boreholes that at the time of formation of the lower sediment series lacustrine conditions prevailed instead of the previous fluvial conditions, i.e. the rivers accumulating the alluvial fan did not flow through the alluvial fan due to the depressions forming in the foreground of the mountains. In the dry period winds buried the abandoned beds completely at places or partially elsewhere. Only smaller sections of these beds can be observed nowadays.

CONCLUSION

In the development of the surface of the alluvial fan in the Nyírség wind also had an important role apart from water. Rivers accumulated vast amount of sandy sediments in the alluvial fan accumulating in the foreground of the mountains to the Körös rivers. Flow direction of these rivers changed several times during the accumulation of the alluvial fan. Winds re-worked sandy sediments on the surface in the dry periods of the Würm then fluvial sediment series covered the aeolian deposits in the wetter periods. Although there is no direct evidence for this in the Nyírség but the presence of wind-blown sand in the deeper strata of the alluvial fan was detected with the help of electron-microscopic analysis of sandy sediments from cores drilled in the Danube-Tisza Interfluve (Borsy et al., 1987). Applying electron-microscopic analysis on the sandy sediments of the alluvial fan of the Nyírség in the future the aeolian or fluvial development of the strata could be determined. Stratigraphic and morphological research of the last the decades focused only on the near surface (< 20 m) strata of the alluvial fan. Deposition and re-working of these sediments took place in the last 30000 years.

Based on the research carried out so far it can be stated that sand was in motion in the Nyírség at several times in the Holocene as well after the aeolian land formation in the Upper Pleniglacial and the late glacial determined in the 1980s (*Table 1*). In the first half of the Holocene sand movement took place in the Boreal phase and in dry periods of the Atlantic phase thus the aeolian shaping of the land can be explained by climatic reasons. In the second half of the Holocene the land shaping effect of wind probably prevailed in a much smaller area and it was associated with the activity of man. Naturally, periods of drier climate had an important role in the aeolian land shaping due to anthropogenic effects.

Table 1 Chronological order of Holocene sand movements

Climate periods of Europe	Archaeological chronology	Geochronology old	Geochronology new	Pollen climate	Sand movement (BP) climatic+anthropogenic
2000 AD		Subatlantic	Subatlantic	0	
	1700 AD modern era			Beech II	Bagamér 230-90 OSL (Kiss, T.) Bagamér 430-350 OSL (Kiss, T.)
1300-1700 AD Little Ice Age					
					Erdőspuszta OSL 900-1000 (Kiss, T.)
600 AD drying maximum	deserta Avarorum				
	450 AD time of the great migra-tions				Bagamér 1370, 1100, 960 OSL
	1 AD Roma, Sarmatians, Dacians			BP. 2000	Hosszúpályi Sarmatian pot (Lóki, J.)
				Bükk I	
300 BC climate optimum					
		2600 BP	2500 BP		Bagamér 2050 OSL(Kiss, T.)
	850 BC Iron Age Celts, Veneti	Szubboreal	Szubboreal s		Bagamér 2450 OSL(Kiss, T.)
1200 BC drying maximum	migration of marine cul-tures, defeat of Troy, Dorians, Hebrew				Gégény 14C 3740 (Lóki, J.)
2100 BC climate optimum	Palace farming in Minos, Crete				
	2800 BC Bronze Age				Hosszúpályi Bronze Age pot remnant (Lóki, J.)
3000 BC drying maximum	Nile valley, Mesopotamia irrigation agriculture			BP. 5000	
				Oak	
		5600 BP	5700 BP		Bagamér 6000 OSL (Kiss, T.)
	4400 BC Copper Age	Atlantic	Atlantic		Bagamér 7070 OSL (Kis,s T.)
		7300 BP			
		Boreal			
	6000 BC Neolithic			BP. 8000	
			8300 BP	Hazel	
			Boreal	BP. 9000	
				Silver birch	Bagamér 9200 OSL (Kiss, T.) Kántorjánosi 14C 9300 (Lóki, J.)
		9600 BP			
		Preboreal			South Nyírség pollen (Félegyházi, E. and Lóki, J.)
		10200 BP			
		Dryas	11200 BP		
	10000 BC Mesolithic		Dryas		

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