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## ANTHROPOGENIC REACTIVATION OF EOLIAN PROCESSES ON THE SOUTHERN PART OF THE NYÍRSÉG ALLUVIAL FAN, HUNGARY

**ABSTRACT:** KISS T. & SIPOS GY., *Anthropogenic reactivation of eolian processes on the southern part of the Nyírség alluvial fan, Hungary.* (IT ISSN 1724-4757, 2007).

The Nyírség is the second largest alluvial fan in Hungary, built by the Tisza River during the Quaternary. Its typical geomorphic features are dunes belonging to the parabolic dune association, formed at the end of the Würm Glaciation. The Holocene reactivation of dune formation is very unlikely under contemporary climatic setting, though, human activity (deforestation, overgrazing) could lead to sand movement.

The aim of the present study is to determine the age and intensity of eolian activity in an interdune depression, in relation with natural and human-induced vegetational changes. For the investigation sedimentological and palynological analyses, radiocarbon and OSL measurements, archaeological findings and archive data were applied.

In the Atlantic Phase, despite of humid climate, forest fires were abundant as a consequence of slash-and-burn cultivation. Thus, wind could transport dune material to the studied interdune surface. In the Subboreal Phase agriculture became more and more significant in the area, and runoff and wind erosion intensified. As a result, the wetland was repeatedly covered by thin sand layers. During historical times the radiocarbon and OSL measurements indicate two erosional periods.

**KEY WORDS:** Blown sand, Human impact, Sedimentology, Dating techniques, Nyírség (Northeast-Hungary).

### INTRODUCTION

During the Pliocene and Pleistocene the Tisza River and its tributaries built an extensive alluvial fan stretching south-southwest in the foreground of the Eastern Carpathians. In the first half of the Late Pleniglacial Period tectonic movements made the Tisza shift towards the north, therefore, fluvial processes terminated over the alluvial fan (Borsy, 1990). From this date blown-sand movement could play an important role in geomorphic evolu-

tion during drier periods of the Late Würm and in historical times, when humans altered natural vegetation.

At the end of the Pleistocene on higher and drier surfaces eolian activity started, since the sparse vegetation, developing under dry and cold climate could not protect the surface from the strong northern winds (Lóki, 1981; Borsy, 1985; Sümegi & Lóki, 1990). On the southern part of the alluvial fan, where blown-sand movement was the most intensive, eolian activity lasted until the milder and more humid Bölling Interstadial. The establishment of a denser vegetation during the interstadial prevented sand movement more effectively. The following blown-sand movement phase was in the Dryas Periods. This was the time when present-day geomorphological features were formed (Borsy & Lóki, 1982; Lóki & *alii*, 1994). The dunes belong to the parabolic-dune association and the most typical forms are various parabolic and edge dunes (Kiss, 2000).

During the Holocene, in the drier Boreal and Atlantic Phases, winds reshaped the existing features in the Hungarian blown-sand regions (Kádár, 1935, 1956; Marosi, 1967; Borsy, 1972, 1977a,b, 1980; Borsy & *alii*, 1991; Gábris, 2003; Sipos & *alii*, 2006). Eolian action probably affected only smaller areas, but our sedimentary analyses show several phases (Nyári & Kiss, 2005). Most recent sand movement took place in historical times and was related to the human alteration of the natural environment (Lóki, 2003).

Bronze Age and Late Medieval sand movements were identified on the alluvial fan of the Danube (Danube-Tisza Interfluve) by Gábris (2003) and Lóki & Schweitzer (2001). Geomorphological studies on archaeological sites from the same region indicated that the most intensive eolian reactivation happened during and after the Bronze Age (2800-900 years BC), between the 5<sup>th</sup> and 8<sup>th</sup> centuries (AD) and in the 13<sup>th</sup> century (Nyári & Kiss, 2005). Our earlier research provided evidence that in the southern Nyírség the most significant historical blown-sand move-

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ment is dated to medieval times (Kiss, 2000). However, eolian activity was also strong in the late 17<sup>th</sup> century in connection with the Ottoman Occupation of Hungary, and in the 18-19<sup>th</sup> centuries due to forest clearances (Borsy, 1977a). Even nowadays in drier years deflation can erode bare sand surfaces (Lóki, 1985, 2003).

The aim of the present study is to describe the natural landscape evolution of a sand-dune area in the second half of the Holocene, and to reveal the way and rate of human impact on sand dunes in different historical periods. In order to achieve this, sedimentological and palynological analyses were performed, while blown-sand movement was dated by optically stimulated luminescence (OSL) and radiocarbon measurements.

## STUDY AREA

The study area had to meet several criteria: 1) it had to be enclosed entirely by sand dunes, because this way the eroded material (by wind or runoff) could be preserved; 2) the neighbouring sand dunes had to form a well-distinguishable catchment; 3) the sand dunes had to be high to produce intensive erosion and the interdune accumulation and 4) the basin had to be swampy, to allow palynological analyses.

An interdune depression southeast of the city of Debrecen, in the Bánk Forest fulfilled all of these criteria (fig. 1). The chosen small (ca. 0.01 km<sup>2</sup>) sedimentary basin is surrounded by parabolic dunes which are higher by 3-8 m. The deepest, waterlogged area of the basin is occupied by tussocky sedges (*Caricetum elatae*), the higher but still wet surfaces are covered by reeds (*Scirpo-Phragmitetum*), the boundary between dry dunes and wetland is indicated by willow stands (*Salicetum triandrae*), and robinias and pines were planted around the dunes. The depression had been continuously waterlogged before it was drained in 1964. Nowadays, during wet springs 0.5-0.8 m deep inundation is observed.

## METHODS

Cores were taken (10) and trenches were made along a northeast-southwest section, starting at the highest nearby dune. The maximum depth of the cores was 180-300 cm, while trenches were deepened below the groundwater table. Samples (285) were collected at every 5 cm. In the laboratory their grain size distribution (by Köhn pipette and dry sieving), pH and carbonate content were determined.

Palynological analysis was carried out on 102 samples, following the method of Zólyomi and Erdtmann. Sporomorphs were investigated at a 400-600 fold magnification and they were identified on species, genus or familia levels. The summarized pollendiagram was drawn by Tilia and TiliaGraph softwares. A sample was considered pollen-free if less than 100 grains were counted from 20 g of sediment.

For dating radiocarbon and optically stimulated luminescence were applied. <sup>14</sup>C measurements (2) were made at the ATOMKI Laboratory of Environmental Studies (Debrecen) using highly humified organic material. The OSL measurements (3) were made from blown sand at the Department of Physical Geography and Geoinformatics at the University of Szeged.

## RESULTS

The relative ages of the sedimentary layers, the prevailing climate and vegetation changes were investigated with the help of *palynology*. The determined climatic conditions provided the background of geomorphic processes (wind or water erosion). Processes were also highly affected by vegetation and the direction of changes provided information on the relative significance of natural and human factors on geomorphic evolution.

The presented diagrams are drawn on the basis of two neighbouring cores (Nos 5 and 6), as they provided the

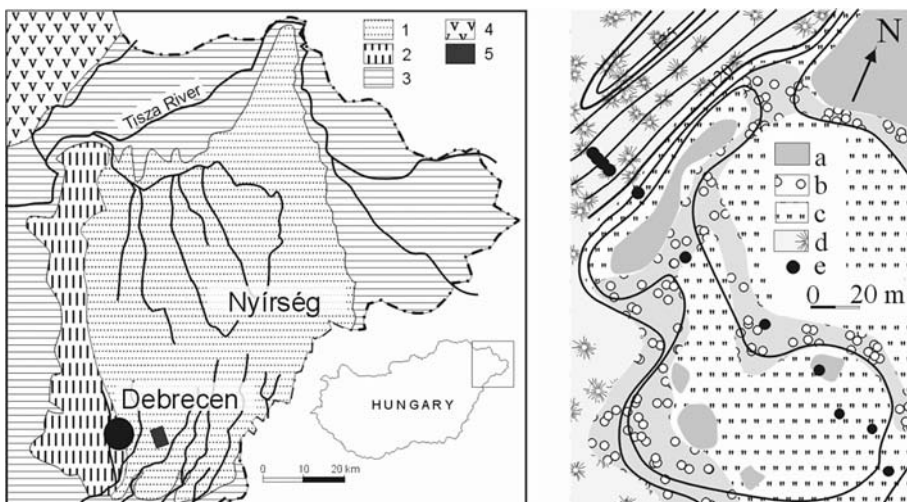


FIG. 1 - The location of the Nyírség alluvial fan and the study area. 1 - blown-sand; 2 - loess; 3 - alluvium; 4 - volcanic material; 5 - study area. 1.B. The studied interdune area, its vegetation and the sampling sites. a - tussocky sedge; b - willocks; c - xerophilous meadow; d - planted forest; e - core site.

most detailed data on the sedimentary history of the basin. Differences, however, do exist but these will be introduced during the sedimentary interpretation of the whole depression. The two cores were analysed together because core No 5 had grains in sufficient number for statistical analysis at its upper half, while core No 6 at its lower half. The pollen diagram was divided into two zones (fig. 2), delineated by entirely pollen-free samples (No 5 from 95-70 cm; No 6 from 115-55 cm).

### 1. Lower zone (represented by core No 6 - 115-290 cm)

In this zone the proportion of the sand fraction (0.6-0.05 mm) is very high ( $\geq 90$  per cent). The total amount of fine sand (0.2-0.1 mm), the predominant material of dunes anyway, is only slightly higher than the total amount of very fine sand (0.1-0.05 mm). Nevertheless, in three layers (135-125, 175-185 and 80-85 cm) a significantly greater proportion (over 60 per cent) was detected, which refers to the erosion and transportation of surrounding dune material right into the sedimentary basin. The organic content within this zone shows a great variation but usually remains under 1 per cent. Moving upward the frequency and carbon content (1.2-2.7 per cent) of organic rich layers is increasing, indicating that these layers were exposed on the surface for a longer time and soil formation could start on them. However, time to time they were buried again by fresh dune material.

The most abundant arboreal pollen in this zone belong to the *Coniferopsida* class (80-100 per cent), which may indicate a cold climate, but *Quercus sp.* and *Ilex sp.*

pollen were also found. The latter plant, typical of the Atlantic Phase (Járainé, 1966), is an Atlantic-Mediterranean species indicating moderate climate and great humidity (Gencsi & Vancsura, 1997). The *Alnus sp.* and *Sphagnum sp.* grains also indicate wet climate and the existence of a bog, while the *Phragmites* and *Carex* species mark high ground-water level. On the basis of OSL measurements, the age of this zone is  $5354 \pm 245$  years BP.

The amount of burnt and corroded *Pine sp.* pollen is large. This should be a consequence of forest fires, not just natural ones, as the Atlantic Phase was quite humid. The non-arboreal pollens (*Cirsium sp.*, *Taraxacum sp.*, *Tussilago sp.*, *Carduus sp.* and *Urtica sp.*) mark trampling and ruderal associations. All these indicate that the forest was repeatedly burnt by humans. Following each fire the bare dune was eroded by rain or wind, and the fine sandy material was displaced into the interdune basin. The process was repeated several times, which is proven by the alteration of pollen-rich and pollen-poor layers. (The transported material normally had a poor pollen-preserving capacity - Faegri & Iversen, 1989.) After the fire vegetation started to colonise the area, and mostly ruderal associations and pines appeared. During these periods finer materials were deposited, thus the sediment contains more sporomorphs and more chemically corroded pollens. Chemical corrosion and the increased amount of organic material indicate soil formation processes.

### 2. Upper zone (represented by core No 5 - 0-75 cm)

In this zone the proportion of fine sediment (clay and silt) is increasing. An iron-rich layer with limonite is also

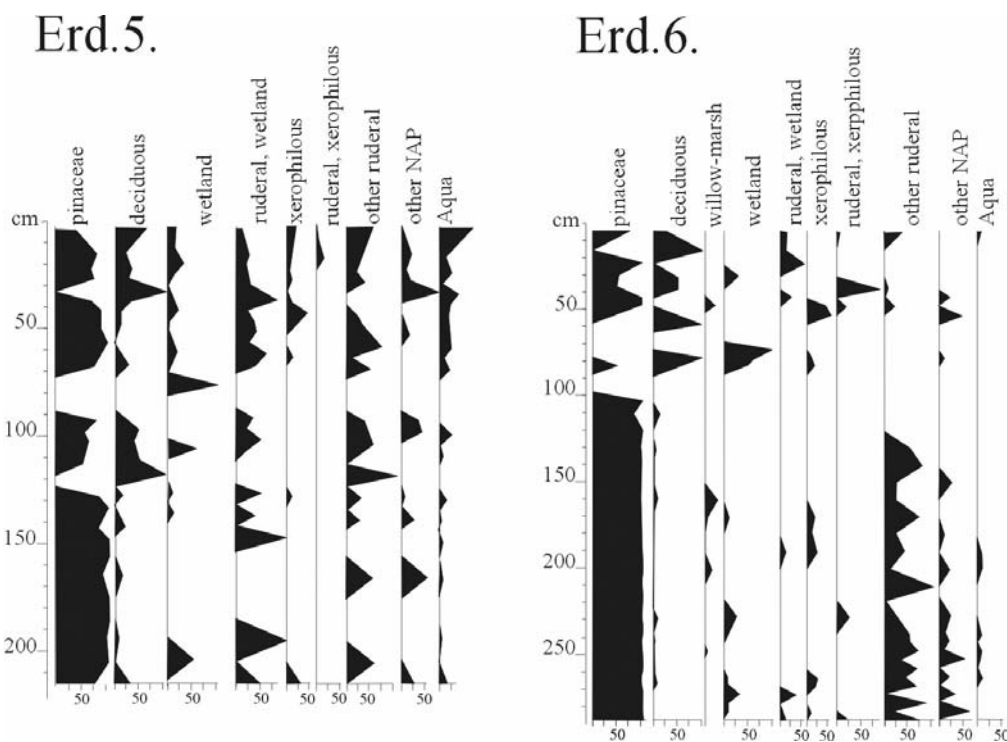


FIG. 2 - Simplified pollen diagrams of Nos 5 and 6 cores.

found (45-60 cm) here and indicated by coarser materials on the grain-size diagram. Although the sandy alluvial fan of the Nyírség is poor in carbonate, above the iron-rich layer the carbonate content rises (16-17 per cent). The amount of organic material is increasing upwards and in the uppermost 40-50 cm very dark swamp deposits are observed.

The proportion of *Coniferopsida* is falling but still relatively high (35-90 per cent). The number of broadleaf pollen (*Salix sp.*, *Tilia sp.*, *Quercus sp.*, *Populus sp.* and *Fagus sp.*) is also high. The proportion of hydrophile plants is also high and does not reflect the dry conditions of the Late Holocene. The radiocarbon date gained from pollen-sterile samples originating from the border of the two zones is  $3720 \pm 65$  years BP, while in the middle of the upper zone OSL gave a  $2509 \pm 81$  years BP age. Both reinforce that the upper zone was formed in the Subboreal Phase. The age of the uppermost samples (core No 5 - 0-25 cm) is much younger though. Radiocarbon and OSL measurements resulted  $1060 \pm 65$  years BP and  $317 \pm 213$  years BP, resp. This indicates a Subatlantic depositional phase.

The comparison of the upper zone with the lower one reflects a change in human impact. In the surrounding areas pine stands were still typical, but there were much less burnt pollen. Only *Salix* pollen are represented continuously (its wood is of no value), and hardwood pollen appear sporadically. As the climate does not explain such observations, it is highly probable that valuable trees were cut regularly. Nevertheless, pollen of planted species (e.g. *Juglans regia*, brought to the region by the Romans - Gencsi & Vancsura, 1997) also occur.

Based on the distribution of non-boreal species, the zone can be divided into two subzones. The lower one (25-75 cm) contains a great amount of *Cirsium sp.* and *Carduus sp.* pollens, pointing to the existence of pastures. This type of land use is also evidenced by the pollen of herbs which tolerate trapping (e.g. *Plantago sp.*, *Taraxacum sp.*). From the upper subzone (0-25 cm) pollen of agricultural crops (e.g. cult. *Graminea*, *Spinacia oleaces* and *Zea mays*) and ruderal species (*Convolvulus sp.*, *Melandrium sp.* and *Chenopodium sp.*) were identi-

fied. Thus, crop cultivation played an important part. In nearby areas, however, animal husbandry and gardening were also significant.

## SEDIMENTARY STRUCTURES

In order to set up the sedimentary history of the interdune area, grain-size diagrams were analysed and compared and a sedimentary cross-section was constructed. The following criteria were observed:

1. Even slight qualitative changes had to be considered.
2. The attribute of a layer (e.g. fine silt) refers primarily to the fact that the proportion of the fraction concerned shows a considerable increase here. This does not necessarily mean that the grains of the nominator fraction are the most abundant.
3. Special attention was paid to the amount of fine sand (0.2-0.1 mm). Our measurements indicated the predominance of this grain-size class (over 60 per cent) in dunes, and it is also typical of the rest of the Southern Nyírség (Borsy, 1961). Therefore, the layers with more than 60 per cent of fine sand were treated as materials eroded from the dunes. If a layer of this kind stretched along the whole section, it was considered to be an eolian deposit. Whereas, if it disappeared within a short distance (few metres), it was regarded as runoff material. (The concept of differentiation is based on our earlier erosion measurements - cf. Kiss, 1998).

Three vertical zones can be identified along the cross-section (fig. 3). The two lower zones have already been introduced above, while the upper one represents the body of the sand dune.

- I. The lowermost zone is very sandy; the total proportion of fine and very fine sand is over 80 per cent. Such layers are usually continuous all over the basin, although some of them peter out/in at the feet of dunes. The three fine sand layers identified in the analysed cores extend over the whole basin, thus they indicate eolian activity.

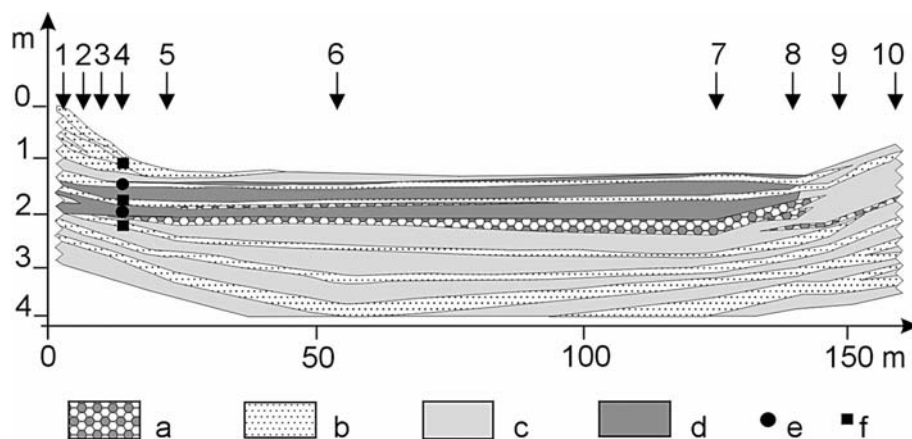


FIG. 3 - Deposits of the inter-dune basin. a = medium sand (over 0.2 mm); b = fine sand (0.2-0.1 mm); c = very fine sand (0.1-0.05 mm); d = dark swamp deposits.

- II. The middle zone is located close to the surface in the basin, but buried on the NE side by the dune. It reaches its maximum thickness (0.8 m) at core No 7. They are the most silty and clayey layers (on average 20-25 per cent of grains being finer than 0.05 mm). Organic content is also high here (max. 5 per cent). At the bottom of the zone a very fine sand layer is identified. It is covered by a limonite-rich layer, above which the carbonate content rises (its maximum is 19.5 per cent at core No 7). Surface material is very fine sand. This zone is similar to the bottom of other interdune areas where limonite cobs and high carbonate content point to a strong influence of water and hydrophilic vegetation.
- III. The upper zone, found on opposing ends of the cross-section, consists of blown sand. On the northeast it is represented by cores Nos 1-4 and on the southwest by Nos 9-10. In this zone silt and clay together do not exceed 4-5 per cent, while the proportion of fine sand (0.2-0.1 mm) is very high (over 70 per cent). This is complemented by very low organic matter content. In the northeast zone III runs over the sediment of the swamp, indicating that the northeastern dune entered the basin.

## DISCUSSION AND CONCLUSIONS

The sedimentological and palynological analyses of deposits, absolute ages, archaeological finds from the surroundings and archives helped in the reconstruction of the interdune environment, with a special attention to the significance of natural and human impacts. The history of the site can be followed up from the Atlantic Phase, when the humid and moderate climate was suitable for oak stands. However, from time to time oaks disappeared and they were replaced by pines. In the background repeatedly occurring forest fires can be suspected, as the latter species regenerate quicker after such an event. Nevertheless, natural forest fires were very rare or even impossible under the Atlantic Phase climate; therefore, it is very probable that they were induced by human activity. The Neolithic inhabitants of the area followed a slash-and-burn agricultural practice. This land use resulted in intensive soil erosion, indicated by the large number of broken or eroded pollen grains. During these times the material of sand dunes repeatedly covered the interdune basin.

The beginning of the Subboreal Phase in the sedimentary record is hardly determinable but based on the radiocarbon age; it probably coincides with the pollen-free layer below swamp deposits. In this phase the dunes were occupied by pine species and broadleaved trees, while in the interdune area the groundwater table was rising gradually. The non-arboreal pollen point to grazing. As the interdune area became wetland, it was favoured animal husbandry because green grass could grow even in dry summers. The situation was similar during wintertime, because the decomposing material provided enough heat to melt the snow; therefore, fodder was abundant for the animals. The wider area provided numerous archaeological find-

ings from the Copper and Bronze Ages, thus Mesterházy (1984) assumes a relatively dense population for this time. Furthermore, it was the period when the «Nyírség Culture» appeared. Therefore, the lack of erosion can be explained by a shift in land use from cultivation to pasturing (Kovács, 1977).

During the Subatlantic Phase a mixed, sparse forest occupied the dunes (the proportion of arboreal pollen is very low). The interdune area remained wet with sedges, reeds and willow stands. Crop cultivation intensified again, cereals and (in Modern Times) maize were grown. The high proportion of burnt pine pollen indicates forest clearances, but exotic plants were also introduced (e.g. walnut, robinia). Human impact on the natural environment acquired a large extent. As the dune became bare, erosion played an important part in remodelling it and the eroded material repeatedly reached the interdune basin. OSL and radiocarbon datings put the first major period of erosion to the 10-12<sup>th</sup> centuries (1060±65 years BP), when the neighbouring Bánk was a significant settlement, also proved by the fact that it had a church, destroyed only in the mid-16<sup>th</sup> century (Zoltai, 1932; Gyórfy, 1966). Still, it does not mean that all the fields around the village were cultivated. Contemporary descriptions mentioned the existence of large forests (Zoltai, 1932; Jakó 1940). The youngest OSL age indicates a much younger but less precisely identifiable erosional period (317±213 years BP). However, according to a description written in 1553, several new clearances appeared. Later, in the early 17<sup>th</sup> century the City of Debrecen was even compelled to enact a law on the protection of forests due to the advanced degradation caused by fires and overgrazing (Penyigei, 1980). Forest area decreased continuously, as it is shown on a military map series from the 18<sup>th</sup> century; erosion hazard grew as wind could reactivate sand movement on bare surfaces.

As a conclusion, the decrease of forest area caused by natural or human factors, and sudden changes in land use were the primary reasons for the periodic reactivation of wind and water erosion on dunes and aggradation in interdune areas.

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