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# Assessing Late Pleistocene and Holocene phases of aeolian activity on the Nyírség alluvial fan, Hungary

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ABSTRACT

There have been several studies addressing the timing and extension of Late Pleistocene and Holocene Aeolian activity in the Nyírség, the former alluvial fan of the Tisza River. Some of these already applied numerical dating techniques, however usually focused on one dune form or one site. This paper is an attempt on the one hand to review former age data and on the other hand to add new data from various sites to the landform evolution of the second largest sand dune area of the Carpathian Basin.

The paper focuses on the Late Pleistocene–Holocene landform evolution of the second largest sand dune area of Hungary (Nyírség). Recent age data were obtained from investigations applying several methods (radiocarbon, OSL and palynological examinations) in order to determine the periods of sand movement and paleosoil formation in the area more accurately.

According to the results, six sand movement periods can be identified during the Late Glacial and Holocen (Oldest Dryas, Younger Dryas, Preboreal Phase, Boreal Phase, Atlantic Phase, Subatlantic Phase).

In between periods with intensive aeolian activity paleosoil formation occurred in the Bølling-Allerød Interstadial and in the Preboreal and Subatlantic Phases.



## 1. Introduction

The Nyírség is a sand dune area in the northeastern part of the Carpathian Basin. Several scientists studied the development of the Nyírség in the early 20th century. Nagy (1908) and Cholnoky (1910) were the first discussing the dune formations and the evolution of the area, however, the first still acceptable theory was established by Sümeghy (1944). Based on the stratigraphic analysis of cores from boreholes, he found that the Nyírség was an alluvial fan of rivers arriving from the Carpathians. The alluvial fan was uplifted by tectonic forces (cca. 15–25 m) in the Upper Pleniglacial (29–23 ka), meanwhile the surrounding regions were sinking so rivers gradually slipped down and in dry periods wind could blow out sand from fluvial deposits.

By considering pollen analyses and sedimentological observations, at the beginning of his research Borsy regarded the Boreal phase (9–8 ka) as the primary period of sand dune formation in the Nyírség (Borsy, 1961). In the 1980s, based on radiocarbon data, the age of the first major sand movements was placed into the end of the Upper Pleniglacial (ca. 29–23 ka) and in the Late Glacial (10–15 ka; Borsy et al., 1981; Lóki et al., 1994) when the climate was cold and dry. More recent researches (Lóki, 2006; Kiss et al., 2012) have indicated that the transformation of the sand surface in the Nyírség did not cease at the end of the Pleistocene but continued in the Holocene during drier periods. In areas where vegetation cover was reduced sand started to move again. First major sand movements in the Holocene were dated to the Preboreal (10.2–9 ka) and to the drier period of Atlantic Phase (8–5.3 ka) (Félegyházi and Lóki, 2006; Kiss and Sipos, 2006; Kiss et al., 2008, 2012).

Sand movement in the Atlantic Phase (8–5.3 ka) and Subboreal Phase (5.3–2.9 ka) was detected at Bagamér in the Nyírség (Kiss and Sipos, 2006; Kiss et al., 2008, 2012).

Sand started to move at several times in Hungarian wind-blown sand areas in the Subatlantic Phase (2.9 ka), primarily in the Iron Age (Lóki and Schweitzer, 2001; Gábris, 2003; Ujházy et al., 2003; Nyári and Kiss, 2005; Félegyházi and Lóki, 2006; Sipos et al.,

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2006; Nyári et al., 2006a,b, 2007a,b; Kiss et al., 2012) as a consequence of anthropogenic activities: deforestation, pastoralism and ploughing.

In order to extend arable lands, deforestation was widespread in the 18th and 19th centuries too. As a result, sand started to move again in areas of deforestation. Soils covered by shallow sand layers reflect such sand movements (Marosi, 1967; Borsy, 1980, 1987, 1991; Lóki, 2003).

Optically stimulated luminescence (OSL) dating has proved to be a very useful technique to determine depositional ages of aeolian sediments around the world (Clemmensen and Murray, 2006) because it directly dates the time of deposition of sediments (Duller, 2004). The results of OSL measurements could support (or not) the age data given by C14 method.

This area of Hungary provide a good opportunity to similar the results of OSL method to sites where independent age control is available from radiocarbon-dated charcoal horizons within the sand dunes.

Therefore, a major aim of the present study is to refine the chronology of aeolian activity in the Nyírség and to set up a consistent framework for further research in the region. In the meantime it was also possible to attest OSL and radiocarbon dating and to provide data not only for aeolian activity, but also for paleosoil formation.

## 2. Study area

### 2.1. Geomorphology

In the Carpathian Basin the Nyírség is the second largest sand dune area (ca. 4600 km$^2$), formed on the alluvial deposits of the Tisza River and its tributaries. At around 25 ka, fluvial processes terminated on the territory; and during the rest of the Pleistocene, aeolian processes prevailed (Borsy, 1991). The strong northwesterly, northerly, north-north-easterly winds formed mostly blowouts, oval shaped sand hummocks and residual ridges. Parabolic sand dunes also evolved on a larger scale in the Nyírség (Lóki, 2006).

There are two major types of blowout depressions: 1) the first group consists of elongated depressions, usually running parallel to each other, frequently for hundreds of metres, with dam-like residual ridges between them. These forms are frequently cut into the original alluvial fan material. 2) The other type of blowout depressions has an oval shape. Their development is related to sand surfaces with a relatively denser vegetation, the sand blown out of the oval windrift accumulated immediately at the end of the windrift in the shape of a sickle (Fig. 1).

The sand blown out from the windrifts was usually ordered into dunes, however, it was occasionally deposited as a sand blanket in the foreland of the windrifts.

The second depositional landform is the oval shaped sand hummock. It does not join the windrift in sickle-shape, but is located behind it. The oval shaped hummocks are congested into one another in many places (Borsy, 1991).

Parabolic dunes also evolved on a larger scale in the Nyírség. The majority of these parabolic dunes are asymmetric and their wings show northern-northeastern directions indicating the prevailing wind direction during their formation. The parabolic dunes are mostly the type with underdeveloped western wing. The asymmetry is mainly the result of the north-north-easterly winds forming an acute angle with the predominant north-north-westerly, northerly winds. The asymmetric parabolic dunes in the Nyírség are large in size, the eastern wings sometimes reach a length of 1.5–1.6 km. Parabolic dunes reaching the edge of an abandoned river frequently got straightened as wings continued to migrate while the head of the dune became already fixed (Borsy, 1991; Kiss, 2000). At several places the asymmetric parabolic dunes were congested onto one another and now form a closed field of dunes.

Another characteristic feature of the Nyírség is the larger deflation depressions and deflation flat areas evolved in the Upper Pleniglacial period. The large amount of sand blown out from the deflation flat areas accumulated into aeolian sand fields.

The area's climate is warm, temperate and wet; the average annual temperature is 9–10 °C, and the rainfall averages 550–650 mm a year. However, occasionally the area is susceptible to drought; during such periods the annual rainfall is less than 400 mm. The typical land usage forms are arable lands and forests. The arable lands mainly produce autumn-sown cereal crops and corn, and because of this in the first half of the year – which is by coincidence also the period of the fastest and strongest winds – the extensive bare lands suffer substantial wind-erosion damage (Lóki, 1985).

## 3. Methods

### 3.1. Sample collecting

Because most of the former age data is derived from southern part of the Nyírség, we try to find exposures where the age of sand movement is definable in other part of the area. To collect samples for C14 age determinations, such outcrops of dunes were chosen where buried soil layers were clearly observable (Fig. 2; Table 1). These outcrops (totally 7) were set up in sand dunes (parabolic dunes, hummocks). After careful cleaning samples were taken for sedimentological analyses from sand walls of these outcrops (quarries) which contained buried soil layers. From outcrops (Fig. 2: Lövőpetri, Nagyvarsány, Máriapócs II, Nyíradony) where the buried soil contained enough charcoal, samples were collected for radiocarbon age determination. The age of the wind-blown sand under and above the buried layer was determined by OSL measurements as well. Where buried soil was not occurred only OSL age determinations were performed (Fig. 2: Baktalórántháza).

Abandoned beds (paleo-valleys) of the ancient rivers building the alluvial fan were partially or completely filled up with sandy material (Fig. 2: Nyírtag, Nyírbéltek, Máriapócs I., Nyírábrány) so samples were taken for grain size analyses from borehole cores to set up the stratigraphy of the site and also for pollen analyses. Sediment samples were taken at every 10 cm. With pollen analyses our aim was to explore the accumulation rate of abandoned beds and to set up the evolutionary of vegetation in the area. The pollen grains got into these wetland environment from the surrounding area's vegetation, giving the possibilities for the identification of the past environment. Under dry climate these abandoned river remnants dried out, but the accumulation continued, however these became unsuitable for pollen conserving. By synchronizing the pollen sterile layers with the layers with high fine sand (100–200 μm) content we can conclude the time of sand movement.

### 3.2. Sediment analyses

Sediment samples were taken at each site and they were analysed in the sediment laboratory of the Institute of Earth Sciences, University of Debrecen. Grain size distribution was determined using Köhn's pipette (Köhn, 1929) and dry sieving. Total organic carbon content was measured according to Tyurin's method (Seo et al., 2004).

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