Investigation of Holocene blown-sand movement based on archaeological findings and OSL dating, Danube-Tisza Interfluve, Hungary

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Abstract: The largest blown-sand area of Hungary is located on the Danube-Tisza Interfluve. Here the most significant aeolian activity took place in the Pleistocene, however the aeolian rework of the forms occurred also in the Holocene and even during historical times. The aims of the research were : (1) to map the geomorphology of the study area at the eastern border of the interfluve (2) to determine the periods of sand remobilisation during historical times (3) to identify the possible types of human activities enabling aeolian activity. In order to determine the exact time of blown-sand movement OSL measurements were applied. Maps (scale 1:10,000) were made in order to analyze the geomorphological setting of the area and to represent the spatial distribution of archaeological findings. Based on the results, the studied sand dune area was occupied mainly by groups grazing large livestock. The archaeology of the territory reflects that settlements were primarily established in the border zone of dry dunes and wet, marshy interdune areas. Animal breeders with large populations meant an intensive burden on the environment and the chance for over-grazing increased during their inhabitance. For these reasons, aeolian activity reoccurred several times on the territory: at the beginning of the Late Bronze Age (1400-800 y BC), in the Sarmatian period (100-500 y AD), during the realm of the Avars (500-900 y AD) and when the Cumanians inhabited the region (1200-1500 y AD).

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1. Introduction

Blown-sand areas cover approximately 20% of the territory of Hungary. The largest uniform area is located on the Danube-Tisza Interfluve (see map), where the most significant aeolian activity took place some 27,000 - 25,000 years ago during the Pleistocene (Marosi, 1967, 1970; Borsy, 1972, 1977a, 1977b, 1980, 1989, 1991; Borsy et al., 1981; 1985; Sümegi et al., 1992; Sümegi, 2005). However, researchers draw attention to the possibility of sand movement in the Holocene and in some cases during historical times. Concerning the Holocene the warmest and driest Boreal Phase was the most adequate for dune formation, though, recent investigations claim that the second half of the Atlantic Phase could also have been dry enough for the remobilisation of sand. Nevertheless, the latest, usually local signs of aeolian activity can be related to various types of human impact. As a consequence Holocene blown sand movement can only be reconstructed by considering both climatic and human factors (Table 1; Kádár, 1935, 1956; Marosi, 1967; Borsy, 1972, 1977a, 1977b, 1980; Lóki and Schweitzer, 2001; Gábris, 2003; Nyári and Kiss, 2005a; 2005b).

Year BP	Phase	Historical age	Climate	Vegetation	Human impact	The possibility of sand movement: Clim. factor	The possibility of sand movement: Human factor
	Subatlantic	From Romans to present	Cool and dry	Disappearance of beech and hornbeam Cultural landscape	Cultural landscape More intensive human impact		
		Iron Age			Application of iron plough => deeper ploughing Deforestation		
2500	Subboreal	Bronze Age	Cool and wet with dry periods	Increase of oak-forests Appearance of weeds	Rising population Permanent settlements		
5000	Atlantic	Copper Age	Warm and wet MYT.: 15-16°C Jan.(MT): 4-5°C Jul.(MT): 24-25°C	Increase of wood-lands Grasslands on sandy areas	Agriculture and animal housbandry		
		Neolithic			Farming introduced		
8000	Boreal	Mesolithic	Warm and dry Jan.>0°	Decrease of wood-lands, development of grasslands on sandy areas	Hunting, fishing, gleaning No significant human impact on the environment		
9000	Preboreal		Graduate warming up MYT: 8-9°C Jan.(MT): -2°C Jul.(MT): 18-19°C	Birch forest, wooded steppe appearance of grasses			
10200							

Table 1: The climate, vegetation, and human impact of the Holocene and the possibility of sand movement (after Borsy 1977a).

The aims of this research are threefold. Firstly, to create a geomorphological map of the study area. Secondly, to identify periods of sand movement, using different dating techniques, for the study area during historical times. Thirdly, to clarify the types of human activities responsible for the remobilization of blown-sand by applying geomorphological mapping, and assessing the archeological findings of the area.

2. Methods

Geomorphological mapping

The maps of relief and aeolian geomorphology for the study area were compiled from field measurements and 1:10,000 scale topographic maps. First major morphological units (erosional, transportational and accumulational zones) were identified. Then forms typical on stabilised blown-sand areas were allocated - blowout depressions, blowout ridges, blowout dunes or hummocks, parabolic dunes, sand sheets, dune crevasses, deflation areas and the brink lines of dunes (Table 2). Those locations prone to aeolian reactivation were selected on the basis of their morphological situation.

Investigation of the location of archaeological findings

By investigating the findings of an archaeological site the life, activities and environment of earlier inhabitants of the area can be revealed. Previous archaeological analyses for the area (Horváth, 2005) allowed us to study the morphological setting and to couple historical settlement pattern with present landforms. These measures provide the opportunity to identify possible locations of blown-sand movement. The chronology for the Hungarian culture groups set by Visy (2003), is followed.

OSL and ^{14}C dating, sedimentological analysis

By the application of optically stimulated luminescence (OSL) the last exposure of sediments to sunlight can be determined. The method is especially suitable for identifying the depositional age of wind blown sands (Aitken, 1998). Altogether five samples were collected from two profiles. Extraction and sample preparation procedures followed the steps introduced by Aitken (1998) and Mauz (2002) and aimed at the separation of quartz grains of suitable (90-150 μm) size. Measurements were made on an automated RISOE TL/OSL-DA-15 type luminescence reader at the Department of Physical Geography and Geoinformatics, University of Szeged. Throughout the measurements the SAR technique, described in detail by Murray and Wintle (2000), was followed.

Feature	Morphology (Lemmen et.al 1998)	Size (Borsy 1977a)	Occurrence
Blowout depression	Oval to elongate, variable depth	W: 25-200 m L: 20-500 m D: 1.5-8 m	Upwind of dunes and blowout ridges
Blowout ridge	Low, elongate sand ridge with gentle slopes	L: 5-300 m	Beside of blowout depressions
Blowout dune	Oval to parabolic, attached to blowout depression	H: 2-18 m	Stabilized dune areas and where dune activity is sporadic
Parabolic dune	Parabolic shape with slipface convex downwind, wings pointing upwind	H: 8-20 m	Often in large groups, axes aligned paralell to dune-forming wind
Deflation area	Sizable area free of depositional eolian features	W: 200-1000 m L: 500-2000 m	Upwind edge of dune area
Dune crevasse	Oval to elongate steep-sided depression, commonly widens downwind	W: 5-25 m L: 10-30 m D: 1-2 m	Top or side of stabilized dunes and sand ridges
Sand sheet	Low relief, varying thickness, thins away from source, lobate in plan view downwind from source	T: 50-200 cm	Locally around dunes and regionally aroun dune areas

Table 2: The definition of the features of stabilised blown-sand areas. W: width, L: length. D: depth, H: height, T: thickness.

Radiocarbon dating was performed on Planorbis gastropod shells originating from lacustrine sediments forming a well separable horizon within the blown sand profiles. Measurements were made at the ATOMKI (Institute of Nuclear Research, Hungary), and followed the classical liquid scintillation technique. In the study the calibrated ^{14}C age was applied.

Samples were obtained approximately every 30 cm of the profiles and were also analysed from a sedimentological perspective. The grain size distribution, organic and carbonate content of the samples were determined in order to find separate horizons within the sandy material of the profiles.

3. Results

Geomorphological mapping

The mapped area is 9 km^2 and situated on the eastern part of the Danube-Tisza Interfluve (see map). The altitude of the area varies between 91 and 99 m asl. Low lying flats dominate the eastern part, where smaller depressions are periodically flooded by excess waters. On the western part, a sand ridge determines the landscape. The form stretches from Northwest to Southeast, and clearly marks the direction of winds which were the most important in shaping the area (see map).

The Holocene morphological evolution of the investigated area is complex (see map). In most cases Pleistocene forms were reshaped and transformed, thus at certain locations the original morphology can hardly be identified. Remobilisation and reshaping was especially intensive during historical times, however it was restricted to smaller patches of land (Borsy, 1977a). If dominant morphological processes are considered then well definable erosion, accumulation and transportation zones can be identified but with unclear boundaries (see map). The reason for this is that smaller erosional and accumulational features are scattered all over the study area. Based on the relief map the centre of the investigated area represents an accumulation zone, where according to the geomorphological mapping the most typical forms are blowout depressions, blowout ridges and blowout dunes (hummocks). On the western part the transportation zone is covered by fewer forms, which are predominantly blowout ridges, sand sheets and parabolic dunes. Parabolic dunes can be considered the most characteristic form in this zone. The low lying erosion zone at the eastern part of the area is dominated by large deflation areas. Supplementary forms are small sized sand sheets (see map).

History of human inhabitance (archaeological findings)

In all 16 sites were excavated in the environs of the study area (Horváth, 2005). The location of the most important archaeological findings, and their origin, are marked on the map. Investigations demonstrate that the first permanent settlement was established in the Bronze Age (2700-800 y BC) and at that time the area was densely populated.

Based on the low number of Iron Age artefacts (800-0 y BC) the population dropped during this period. However there is a strong archaeological evidence for the presence of large Sarmatian populations around the 2-5th c. AD. The next major group of findings can be related to Avar tribes, arriving to the territory during the Migration Period (between 5-9th c. AD) and establishing a settlement here. However, the most abundant artefacts date back to the Middle Ages (11-16th c. AD) and originate from Cumanian settlers (13-15th c. AD), who were invited here by the Hungarian kings. The importance of the village of Csengele in the Cumanian settlement network is also demonstrated by a recently found grave of a Cumanian chief (Horváth, 2001, 2005; Sümegi, 2001).

The spatial distribution of findings suggests that the above mentioned cultural groups preferred mostly transitional zones. Relatively high and low lying, waterlogged surfaces were not inhabited but were probably reserved for pastures.

Depositional history (OSL and ^{14}C dating)

Samples were collected from a sandpit at two locations (see map). Profiles show the grain size distribution, organic matter and carbonate content of the layers, and the measured OSL and radiocarbon ages (Figure 1). OSL yielded a 3594±464 BP age for the lowermost sand layer at profile I. This layer is covered by lacustrine sediments, which can be divided into two sublayers. The lower one is composed of fine-grained carbonate silt, while the upper one exhibits a very high organic content. The organic rich lacustrine layer gets significantly thicker towards the centre of the former lake (25 cm in profile I, more than 50 cm in profile II), and contains numerous Planorbis shells (adequate for ^{14}C). According to the measurements the calibrated radiocarbon age of this layer is 3320±60 year BP.

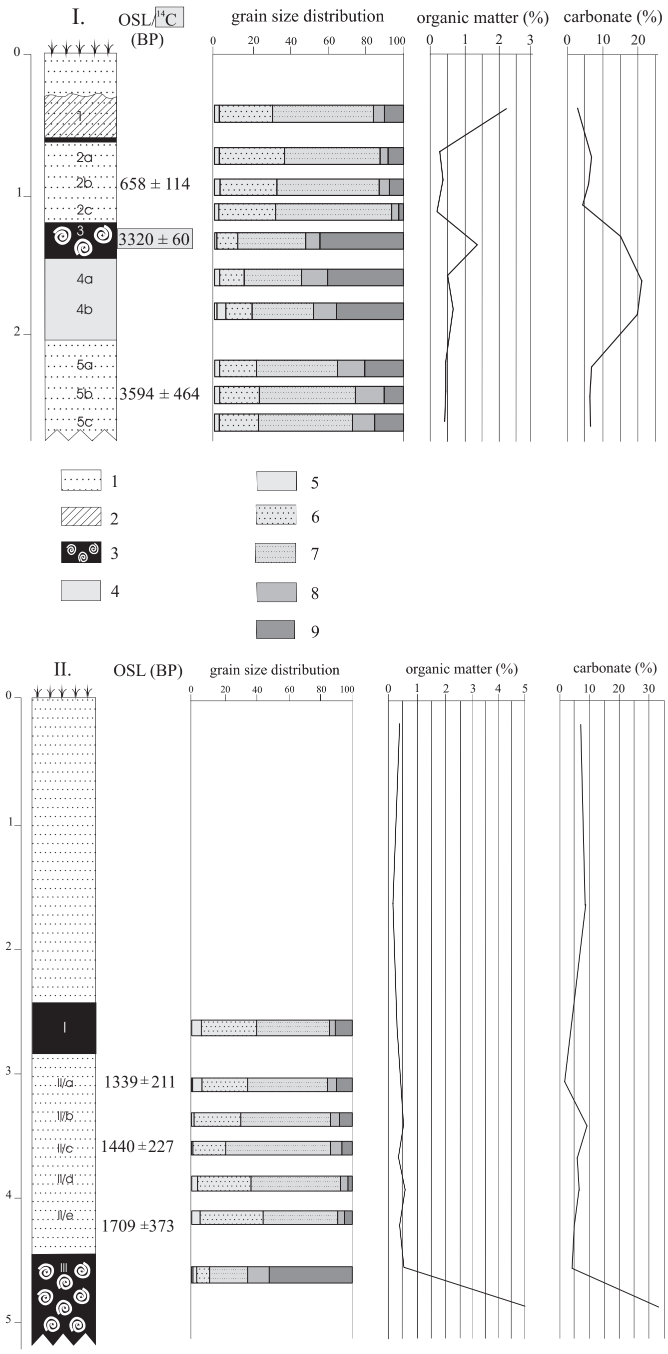

Figure 1 Profiles from the sandpit of Csengele: OSL and 14C data, carbonate and organic matter content of the samples. Legend: 1. Sand, 2. Sand with organic material, 3. Lake sediment, 4. Carbonate silt. Grain size distribution: 5. -0.32 mm; 6. 0.32-0.2 mm; 7. 0.2-0.1 mm; 8. 0.1-0.06 mm; 9. 0.06- mm

Lake sediments are superimposed by blown-sand layers of varying thickness. The first phase of sedimentation occurred 1709±373 y BP. Aeolian reactivation and subsequent deposition in the lake basin occurred repeatedly, thus lake sediments were covered by a 0.6-1.6 m thick sand layer within 300-400 years (Figure 1). Later, as the surface was stabilised again, a relatively thick soil layer could develop. However, according to the OSL measurements, around 658±114 year BP aeolian activity restarted and created a 0.5-2.5 m thick sandy deposit on the top of the profiles (Figure 1).

4. Discussion and Conclusions

Age and sedimentological data of the profiles were compared to archaeological evidence and the spatial distribution of findings. This enabled the reconstruction of the type, intensity and the results of human impact on the palaeo-environment. All age data were plotted on a historical timescale (Figure 2).

The blown-sand beneath lake sediments was deposited between 1500-1100 BC, which corresponds to the middle of the Subboreal Phase and the end of middle Bronze Age and the beginning of late Bronze Age. Since the Subboreal Phase brought a cool and wet climate (Járainé Komlódi, 1966, 1969), the role of climatic controls in the remobilisation of sand was certainly insignificant. On the other hand the existence of settlements and the large number of findings (Figure 2) provide a sound evidence for the presence of a dense population at this time (Horváth, 2005). According to the found artefacts, Bronze Age people practiced animal husbandry, and thus aeolian reactivation could only happen as a result of over-grazing. Similar processes and reasons can be suspected in case of the depositions around 100-500 AD, when the Sarmatians inhabited the territory, however in this case the role of climatic control could be more significant, as the Subatlantic Phase was drier, than the Subboreal.

The next period of blown-sand accumulation (400-900 AD) can be related to the activity of the Avar tribes (Migration Period). Based on the temporal distribution of Avar findings, their impact was long lasting (Figure 2). Meanwhile, the lack of permanent settlements, the type of excavated artefacts refer to a nomadic culture, thus probably again overgrazing was the most significant reason for repeated aeolian sand transport.

Subsequent to the settlement of Hungarians in the Carpathian Basin (Árpád period, Early Middle Ages), the region was densely populated again (Figure 2), interestingly, no evidence for blown-sand movement was found. The most probable reason for this could be the difference in landuse, as the settled population practiced mainly agriculture, and used the lower lying, wetter surfaces for production.

The importance of intensive animal breeding in launching blown-sand remobilisation is supported by the appearance and the activity of the Cumanians, who grazed large livestock in the region. As a result of possible over-grazing on higher surfaces, sand started to move again around 1200-1500 AD. By the Late Middle Ages, parallel with an agricultural shift aeolian activity ceased, and surfaces became stabilised.

Our results prove that the studied grassy sand dune area attracted primarily those cultural groups who kept large livestock and used the occupied land mainly for pastures. The spatial distribution of archaeological findings assumes that settlements were established on the border zone of the dry dunes and the wet, swampy interdune areas. Groups practicing animal breeding certainly had great populations, meaning an increased chance for over-grazing. Aeolian activity thus restarted several times: at the beginning of the Late Bronze Age (1500-1100 BC), in the period of the Sarmatians (100-500 AD), during the realm of the Avars (500-900 AD) and when the Cumanians occupied the region (1300-1400 AD).

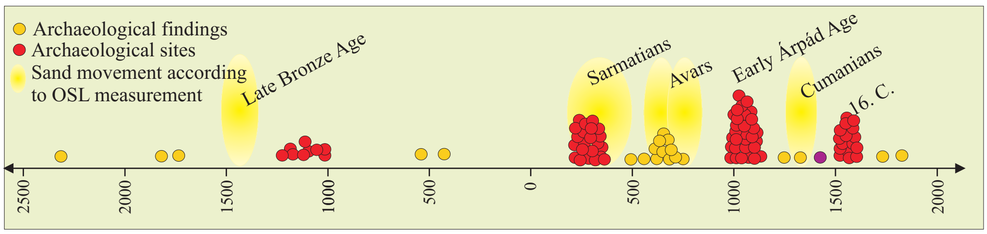

Figure 2 The age of blown sand movement according to OSL data and the number of archaeological sites and findings.

Software

Production of the relief and geomorphological maps and profiles were carried out using Corel Draw 9.0. The location of archaeological sites and sampling points were added under ArcView 3.2.

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