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MORPHOLOGICAL GROUPING OF FOSSIL FLOODPLAIN FORMS IN THE NORTHEASTERN PART OF THE PANNONIAN PLAIN

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Abstract
The Bereg Plain is located in the northeastern part of the Pannonian Plain, close to the Carpathian Mountains. Clarification of the evolution of its topography is essential for the development of the whole area. The former single alluvial cone has been fragmented, some parts of it subsiding and others rising. The displacements of the subsided parts of the area were dominated by erosion processes, as in the Bereg Plain. As a consequence, a significant part of the sand in the area has been degraded and only traces of it remain in the Bereg Plain. The existing sand patches have been identified and classified using DEM. In the area identified 10 floodplain islands not yet mentioned in the scientific literature. The investigation of the numerous islands – hitherto unknown and be-longing to different morphological types – enabled us a reconstruction of the surface development of the Bereg Plain that is more differentiated and precise than ever before. Based on their morphogenetic properties, these floodplain islands can be divided into three main types: (1) erosion islands, (2) point-bars, (3) coastal dunes. In the area, I could recognize no pattern or re-gularity in the position of the individual forms of any type. In many cases, the direction of the longitudinal trends is perpendicular to one another, which excludes their Aeolian origin. The sediment of the floodplain islands mainly consists of medium-, small- and fine-sized sand, but the settlement of loess-mantled and loess-like layers among the sandy sediment of certain forms can also be observed. The layer with 15 % lime content and 53–60 % loess fraction (0.05–0.01 mm) – found in the 110–50 cm high section of the erosion island called the Homok-tanya in Mátyus – can be considered a typical loess, based on the detailed parameters. Its formation in all probability took place at the same time and under similar conditions than that of the more than 2 m thick aeolian loess mantle found in the Nyírség area, some 10 km west from there, which had accumulated before the Bölling period. In case of an erosion island 2.5 km to the south and lying some 2 m lower, such a loess mantle cannot be found anymore, despite the fact that the sandy layers of the two sediment series are almost completely identical. The background of this phenomenon is the more active and frequent, mainly erosional fluvial processes – because of the lower position –, which eroded the loess mantle.
The composition of the surface sediments is de-termined by the absolute altitude as well. The cover sediment of the lower-lying islands is identical to the finishing silt-clay deposits found at the alluvial parts of the Bereg Plain, whereas the surface of higher-lying forms that have not seen flood for ages, is covered by sand or loessy sand.

Keywords: alluvial fun, DEM, erosin island, point-bar, coastal dune

1. Introduction

The Beregi Plain is located in the north-eastern part of the Pannonian Plain, between the Tisza River and the Hungarian-Ukrainian border, along the Carpathian Mountains, about 30-50 km away. The north-south course of the Tisza River has developed along a structural line, the Kraszna River, which separates the Beregi and Szatmár Plain from the Nyírség (Fig. 1). The plain is covered by loose, alluvial sediments of late Pleistocene and Holocene age, except for two small volcanic cones. The surface tilts downwards in a South-East to North-West direction, with a maximum elevation of 114 m and a minimum elevation of 105 m.

At the end of the Tertiary period, the Pannonian Sea, which covers the central basin of the Carpathian Basin, was completely filled up by the delta-building activity of the Carpathian rivers (Somogyi 1967, Borsy 1995, Rónai 1985, Sümeghy 1944, Magyar et al. 2016). At the beginning of the Quaternary, the paleo-Tisza and its tributaries built up a large alluvial fun in the northern part of the Pannonian Plain (Sümeghy 1944, Urbancsek 1965, Borsy et al. 1989). At the beginning of the Würm, more recent structural movements caused the Tisza and the Szamos to leave the Nyírség alluvial fun and to shift to the Érmellék (Borsy et al. 1989). In the middle of the Würm, about 45 thousand years ago, the northern part of the Szatmár Plain, the Bereg Plain and the Bodrogköz began to sink, while the Érmellék began to rise (Borsy et al. 1989). With the incision of the Tisza, it secured its course in the Éremllék for a longer period, but in the first phase of the Upper Pleniglacial it left the area and turned towards the Bereg-Szatmár Plain. Its appearance in the Bodrog interfluves, supported by absolute age data, dates back to about 20,000 years ago, when it cut through the area in the direction of Záhogy-Tokaj (Borsy et al. 1989). Other theories dated it much later, around 14-18 thousand years ago, during the last glacial maximum (Nádor et al. 2005, 2011, Sümegi et al. 1999). The course of the Tisza, which is roughly the same as today, took up the eastern branches of the paleo-Bodrog (Tapoly, Ondava, Laborc), which until then had built up the deeper eastern part of the Nyírség alluvial cone (Borsy et al. 1988). During the Pleistocene, 50-100 m thick layers of gravel, later coarse and then medium- and fine-grained sand, rhythmically varying but generally fining upwards, accumulated on the Bereg Plain and 70-90 m thick in the Bodrog basin (Rónai 1985, Vaszkó 2004). In the higher parts of the alluvial cones of medium and fine-grained sands (called 'blue sands' by Sümeghy 1944) deposited in the last Pleistocene, the formation of quicksand started in the higher parts of the alluvial cones due to strong northerly winds, while in the lower parts of the floodplain, the formation of infusional loess continued (Borsy et al. 1989).

A major change in the surface appearance was caused by the sudden change in the erosion of rivers and the resulting change in the composition of the alluvium, probably due to a combination of climatic and tectonic events at the Holocene-Pleistocene boundary (Sümeghy 1944, Borsy 1969). As a consequence, the sand transported by lateral erosion was replaced by layers of much finer grained, mainly silty, clayey sediment with several metres width (Borsy 1953, 1954, 1959). The present course of the Tisza, which emerged on the Beregi plain, was occupied by continuous lateral erosion and small, abrupt changes of direction in the subboreal phase from the foot of the Beregszász hill in a north-easterly direction (Borsy 1969, 1995).

Some of the very large number of paleo-channels of varying widths in the area may have been left behind by the Tisza and Szamos, but also by rivers with much lower flow rates, such as the Borzsa (Gábris 1986). According to Borsy (1959), the oldest surface dead-beds date from the end of the Boreal phase and the beginning of the Atlantic phase, as the older ones were either eroded or completely covered by clayey-silty sediments deposited during the Neo-Holocene.

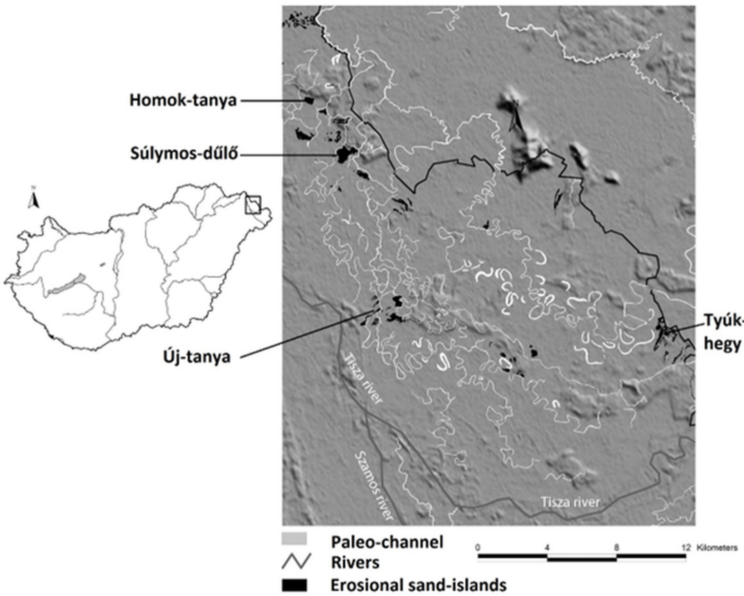

Fig. 1. DEM of the Beregi Plain and location of erosion islands

In some of the abandoned basins, Pleistocene sand surfaces of a few metres high are exposed from the cycle-closing clayey sediments, which Borsy believes may have been much larger in extent before the Holocene. The fact that the moulds avoided being eroded can be explained by the avulsion of the riverbeds (Borsy 1969).

In the present work, we identify and classify previously unexplored sandforms by microscopic alactic analysis of DEM and quartz grains of 0.63-1 mm diameter.

In the present work, we are identifying and classifying sand forms that have not yet been discovered, in order to find out the genetic origin of each sand island. The part of the former single alluvial fun that emerged from the Nyirség was strongly influenced by the aeolian, while in the sunk areas, such as the Bereg Plain, this influence may have been much less pronounced. Formation identification is carried out by DEM, and reconstruction of the evolution of the formations by microscopic alactic analysis of quartz grains 0.63-1 mm in diameter.

2. Materials and Methods

The visual identification of the sand forms was conducted with using a digital elevation model (DEM) generated from the contour lines of the topographic maps. The sand island sediments of the Homok-tanya (three sampling points), the Súlymos-dűlő (one sampling point), the Új-tanya (one sampling point) and the Tyúk-hegy (one sampling point) were investigated. The samples were taken in layers and every 10 cm, 189 samples in total. The most detailed investigations were carried out on an erosion island called Homok-Tanya (Fig. 1, 2), which covers an area of about 400 × 600 m and is located on the eastern border of Mátyus village. A borehole was drilled along a transect from the highest point to the west, about 200 m from the dead-bed, at each of the three elevation levels.The grain size distribution of samples below 0.1 mm diameter was determined by Köhn pipette slurry, while samples above 0.1 mm diameter were determined by dry sieving. The $CaCO_3$ content was determined using a Scheibler apparatus.

To determine the transport medium of the sediment, the surface characteristics of the

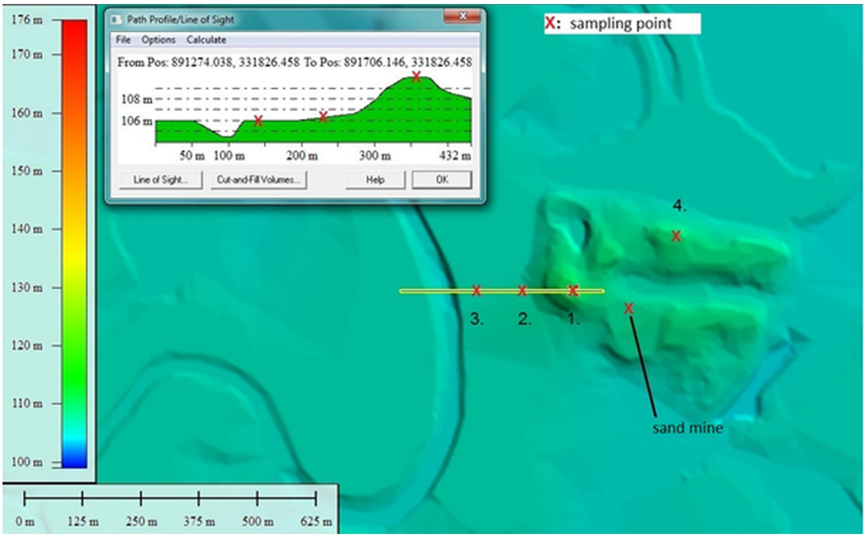

Fig. 2. Location of the Mátyus erosion island with sampling points

most suitable quartz grains for this purpose, 0,63-1 mm in diameter, were examined. The grains were prepared by boiling in 65 % nitric acid, hydrochloric tin chloride, sodium bicarbonate solution and distilled water for 30-30 minutes. To facilitate the analysis, an SLR camera was attached to the microscope and images of the particles were taken at different magnifications.

3. Results

Based on their morphology, floodplain islands can be divided into three groups:

- Irregularly shaped erosion islands, 0.5-4 m high, bounded by dead-beds. Their extent varies from a few tens to hundreds of metres (Fig. 3/A).
- They include former belt reef arcs ranging from several hundred metres up to 2 km in length, rising 0.5-3 m above their surroundings and 20-100 m wide (Fig. 3/B).
- The third type is the coastal dune (Fig. 3/C), which is 600-1500 m long and 100-200 m wide with a relative height of 2.5-4 m.

The distribution of the different types of trains within the area does not show any regularity. The orientation of the longitudinal islands is not uniform either, and in many cases they are perpendicular to each other within a small distance. In addition, I have identified 10 floodplain islands that have not been mentioned in the literature. Of the 10 tidal islands, 5 are belt reefs, 3 are erosion islands and 2 are coastal dunes.

A; Homok-Tanya erosion island sediments

The top 30 cm layer taken from the roof level of the erosion island at borehole #1 (110 m Bf) contains 62 % sand, 13 % rock flour and 25 % grains below 0.02 mm. The grain composition of the sediment becomes steadily coarser as it descends. In the average sample from a depth of 16-17 m, coarse-grained sand accounts for 16,6 %, medium-grained sand for 64,2 % and fine and fine-grained sand for 15 %. The finer-grained sediments together account for only 4 %. Such a grain composition of recent sediments is only found in the Tisza alluvium above Gulács (Károlyi 1960, Konecsny 2002).

The proportion of sand, mainly fine-grained, exceeds 30 % only between 500 and 290 cm in the 500 cm section of borehole #2, which is about 3 m lower than the roof level. Fine medium-grained sand (0,32-0,2 mm) is present in a maximum of 1 %. The upper layer, 0-290 cm, contains on average 50-70 % silt and clay (Fig. 4).

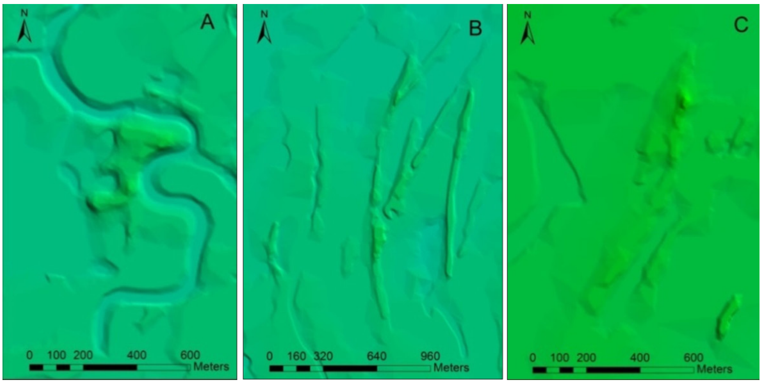

Fig. 3. A Beregi-sík ártéri szigetei: erosion island „A", point-bars „B", coastal dune

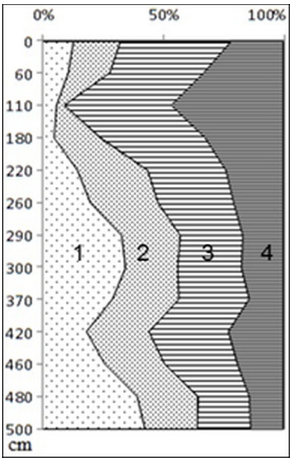

Fig. 4. Grain composition in % by weight of the erosion hole No 2 of the Sand-Farm erosion island.
1: sand. 2: very fine sand, 3: silt, 4: clay

In the entire 400 cm length of borehole #3 along the shore of the bed, clay and silt dominate, with the proportion of fine-grained sand never reaching 20 %.

Borehole #4 was drilled in the lower part (108.5 m) of the northern edge of the erosion island (Fig. 3). The 620 cm deep section can be divided into 5 distinct sediment accumulation cycles (Fig. 5). The high proportion of fine-grained sand (65-71 %) in the lower layer between 620-560 cm suggests a quicksand origin. Z. Borsy, on the basis of decades of research in quicksand areas, found that in well-graded quicksands, fine-grained sand is present in 60-90 w %, while the proportion of grains below 0.05 mm is generally below 4% (Borsy 1961, 1974, Borsy et al. 1982a, 1982b). In the present case, the proportion of <0.05 mm grains ranges from 8 to 13%. This high proportion of finer fractions can be explained by the shortness of the sand movement period, during which the sediment could not be adequately sorted. Recent wind erosion studies in the Nyírség have identified several quicksand layers with similar grain size distributions (Négyesi 2009).

In order to be absolutely sure of the river water or aelolian origin of the layer, about 20 quartz grains of 0.63-1 mm were examined with a binocular microscope, since the surface characteristics of the grains in this size range allow us to infer with great certainty their transport medium (Borsy 1974). Only about a quarter of the grains show traces of elic transport (Fig. 6), so the origin of the quicksand layer cannot be

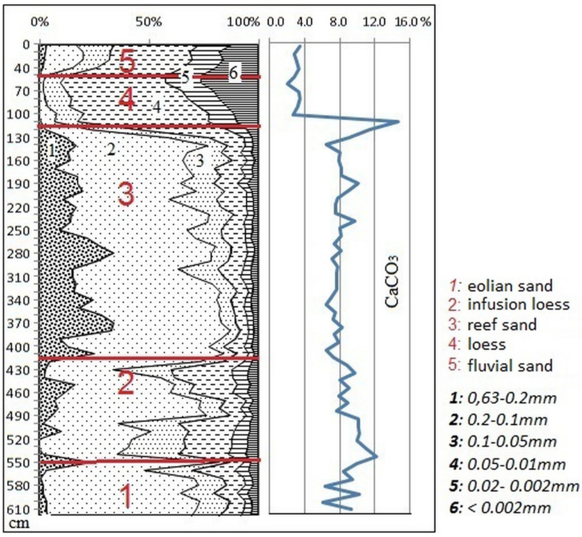

Fig. 5. Grain composition in % by weight of the erosion hole No 2 of the Sand-Farm erosion island. 1: sand. 2: very fine sand, 3: silt, 4: clay

Fig. 6. Light microscopy image of 0.63-1 mm diameter quartz grains from the 620-560 cm layer of the Homok-tanyaerosion island borehole 4

stated with certainty. It is conceivable that the former surface may have been subject to sand movement for a short period, but it cannot be excluded that the river may have redeposited material from a quicksand area.

Samples from the 560-420 cm variable grain size class 530-500 cm and 440-420 cm have a 29-31 % loess fraction and 10-12 % $CaCO_3$. According to the classification system of loess and loess-like sediments of the Solids, they cannot be considered as true loess, but the 0.05-0.01 mm grain size and $CaCO_3$ content suggest a falling powder origin. As the proportion of 0,05-0,01 mm grains is relatively low, it is possible that they were transported as suspended sediment by rivers, while the relatively high lime content was formed under stagnant water conditions.

The samples between 420 and 110 cm are of a high medium-grained sand content, with the strong serration of the grain size distribution diagram indicating a rapidly accumulating floating dust-free belt reef material. A 60 cm thick layer of 53-60 % silt fraction with 15 % lime content is deposited on the reef material in a sharp change. According to the Solid classification system, the layer is clearly loess (more precisely, it is a slightly silty, sandy, clayey loess with a 40-50 % loess fraction by weight, with a medium calcium carbonate content and the designation). The accumulation of the loess layer indicates a new break in the construction of this part of the alluvial cone.

Typical and infusional (floodplain) loesses, which occur in the Great Plain and are mainly of falling dust origin, rarely exceed 4-5 m in thickness, but are usually deposited in layers of only a few decimetres on river sediments or quicksand (Rónai 1985, Lóki 2003). In the present case, the high CaCO3 content of the loess and loess-like sediments is presumably caused by calcite and dolomite crystals precipitated with other particles, which is why this mineral content is called primary or primary carbonate (Pécsi 1993). Pécsi (1993) puts the formation of infusional loesses accumulating in areas of persistent waterlogging or marshland, such as the Mátyus, in the middle of the Upper Pleniglacial. According to recent research on the fauna of Mollusca, the formation of loess in the lowland floodplains started from the first cold maximum of the Upper Wurm (25000 years BP) and lasted until the end of the Late Glacial (12 000 years BP) (Sümegi and Korlopp 1995). A fossil soil layer of the Bölling age (C14 12 900 ± 360 years BP) was excavated on a 200-300 cm thick loess layer (Borsy et al. 1982c, Borsy 1987), covered with quicksand. According to Borsy, the formation of the loess layer may have started in the milder, wetter climate of the Ságvár-Lascaux interstadial (18000-16000 years BP) following the last glacial maximum. At this time, vegetation occupying the lower-lying floodplain areas ensured the uninterrupted accumulation of fallen dust blown out of the prominent alluvial cones.

The 110-50 cm layer of section 4 accumulated at the same age and under the same conditions as the Aranyosapáti's loess layer, based on their close geographical distance and the similarity of the sections. The significant difference in thickness may be due to the different geomorphological position of the areas. Whereas the Aranyosapáti-type loess accumulated on the prominent flood-free quicksand surface of the Nyírség, the Mátyus type loess accumulated in an area that is intermittently subsiding and only becomes flood-free for longer or shorter periods. The upper layer of the section (50-0 cm), deposited on loess, is the result of a recent fluvial accumulation cycle, but due to its coarser composition it is not identical to the Neo-Holocene high clay and silt cycle-closing sediments of boreholes 2 and 3.

The 380 cm thick aggregate of the open pit on the south-eastern part of the sand island has a very similar grain composition to the top two metres of borehole 4, which is about 1.5 metres higher (Fig. 7). The layer at a depth of 380-220 cm can be considered as a belt reef material based on the serration and cross-stratification of the grain composition diagram observed in the field (Fig. 7/A). The images of the quartz grains in the layer clearly show that they were not subject to significant aeolian influence based on their bright surface and siliceous shape (Fig. 8/A). The differences with the grains of the quicksand area of Nyírség (Gégény), prepared by the same process, are clearly visible, with rounded edges and a matt surface due to the impact with the other grains (Fig. 8/B).

Above the point-bars (220-40 cm), there is also a high layer of 26-40 % wind-blown dust fraction, presumably of flaked dust origin, with reddish brown limonite concretions of several mm thickness between 220 and 140 cm, which gradually thins out to a very compact layer between 140 and 40 cm (Fig. 8/B). The high number of concretions can be explained by the very high iron (25068-32500 mg/kg) and manganese (1234 mg/kg) content of the Quaternary sediments of the Beregi Plain (Sümegi 1999, Gosztonyi and Braun 2009, Gosztonyi et al. 2011).

The water of the Bereg artesian wells shallower than 100 m contains significant amounts of dissolved iron (3 mg/l) compared to the lowland (Urbancsek 1965, Rónai 1985). Compared to the average pH of 7.5 H_2O of the section, the pH of 5.95 was slightly acidic, which explains the CaCO3 content of less than 5 %. The layer is a slightly silty, clayey, sandy, moderately leached loess with 30-40 % loess fraction. At the time of accumulation, the area may have been a floodplain relatively remote from watercourses, where conditions

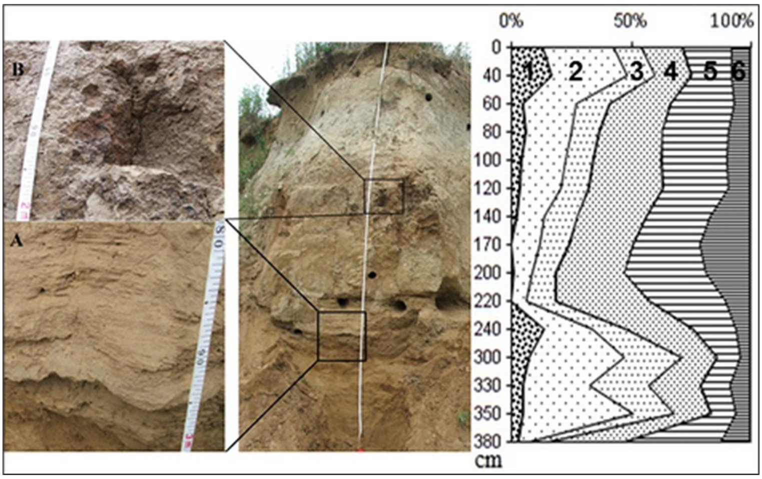

Fig. 7. Reconnaissance of the sand mine wall and grain size distribution of sediments in weight %, A: 380-220 cm cross-bedded belt reef material, B: 220-140 cm reddish brown limonite concretionary level. 1: coarse sand, 2: medium sand, 3: fine sand, 4: very find sand, 5: silt, 6: clay

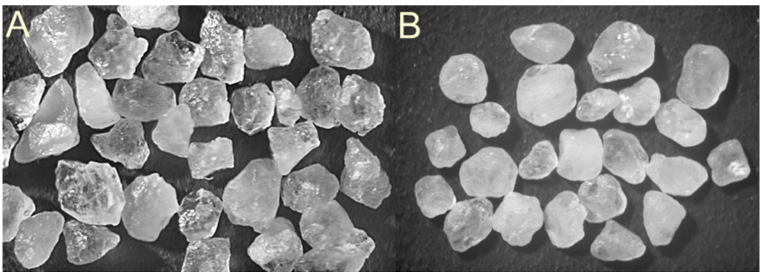

Fig. 8. Photograph of quartz grains of the erosion island belt reef (A) and the quartz grains of the quartz sands of the Gegean quicksand (B)

were favourable for the accumulation of water-soluble metals and the deposition of significant amounts of dead dust. The reddish colour gradually fades from 140 cm onwards and is followed by a brownish grey loamy sand with 26-30 % rock flour content. The final sand layer is 40 cm thick, as in section 4, but slightly coarser. The significant difference between the 180 cm limonitic loess sand layer of the mine wall and the 50 cm thick loess layer of apparently the same age of borehole 4, which is only 200 m away, may be due to the difference in height of the two layers, which is even greater than the surface, at almost 260 cm. As a consequence, the fluvial dust deposited on the deeper reef of the mine was mixed with a significant amount of river sediment of varying grain size, while most of the material accumulating on the mostly trench-free surface of section 4 was fluvial dust, which later turned into lochs.

The upper sandy layer may be the result of a new cycle of sediment accumulation with violent flooding, probably triggered by the rapid melting of snow and ice accumulated in the Upper Tisza catchment during the last glacial maximum (17-21 thousand years uncalibrated C14 BP).

B; Sediments from the erosion islands of the Sulymos-dűlő

The upper 0-480 cm stratigraphic sequence of the Sulymos-dűlő sand line, which is bounded by paleo-medians 2.5 km south-east of the Mátyus erosion island on the border of Tiszakerecseny, was investigated (Fig. 9/B). The grain composition of the samples shows a high similarity with the sediments of the Mátyus sand mine (Fig. 9/A.)

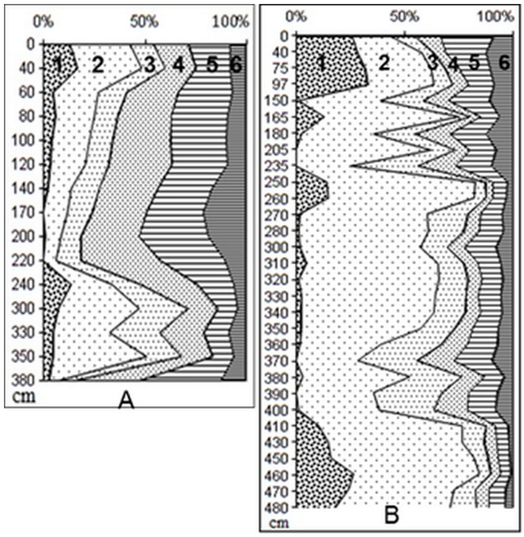

Fig. 9. Grain composition in weight % of the excavations of the Homok-Tanya (A) and Súlymos-dülő (B) erosion islands. 1: coarse sand, 2: medium sand, 3: fine sand, 4: very find sand, 5: silt, 6: clay

The only exceptions between the two series are the absence of loess-like deposits and the slightly coarser grain size composition of the whole sedimentary series and the thicker development of parallelizable layers.

The complete absence of loess-like layers here is due to the more active fluvial processes resulting from the 2 m deeper surface, whereby the settling of the fallen dust could not form a homogeneous layer due to repeated flooding, as it was mixed with fluvial samples. The cyclose sand layer, also observed at Mátyus, reaches a thickness of almost 100 cm and has a much coarser grain size composition. The coarser mechanical composition for the whole section, the thicker development can also be explained by the deeper location and the proximity of the river branch that fills the section.

C; Sediments of the Új-tanya point-bar

In the Új-tanya area on the eastern boundary of Tiszaszalka, a 0-470 cm thick sequence of a belt reef of a multi-member series was investigated (Fig. 10). The assemblage, representing three accumulation cycles, contains sand material cross-stratified between 470-130 cm. In this, similar to drill section 4 at Matyus, thin loess sand layers with a loess fraction of 29-38 % and a CaCO3 content of 10-15 % are deposited between 390-400, 350-360 and 230-220 cm (Figure 10). According to the classification of Szilárd (1983), the deposits, although, not periglacial loess, are indicative of a fluvial dust accumulation, with a relatively high proportion of 0.05-0.01 mm grains and calcareous content (Fig. 10). The 100-50 cm layer also shows almost complete identity with the uppermost loess layer of Section 4 at Mátyus. In the accumulation, the fraction of loess is 45 % and calcium carbonate 18 %. The presence of silty, silty clay of 0-50 cm near the surface is related to the upper layers of the lower drilling point 2 of the erosion island of Matyus. During its accumulation, the lineage was deep enough to allow the accumulation of fine-grained casts, if only a few decimetres thick, to reach several metres thick in the lower parts of the Bereg Plain.

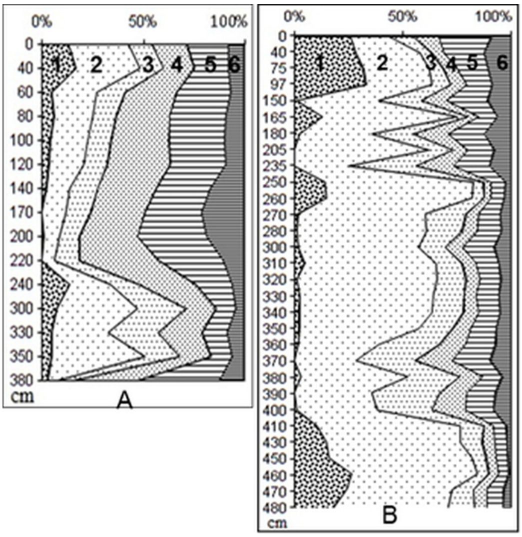

Fig. 10. Grain composition in weight % and $CaCO_3$ content of the New Farm (B) layers of the belt reef.1: coarse sand, 2: medium sand, 3: fine sand, 4: very find sand, 5: silt, 6: clay

D; Sediment of the Tyúk-hegy coastal dune

Between Beregsurány and the border, the coastal dune of Tyúk-hegy, 2-4 m high, about 1.5 km long and 150 m wide, lies closest to the Carpathian mountain-mountainous plain (Fig. 11).

A 340 cm deep borehole was made in the highest point of the line at 115 m. The grain size composition of the samples is the coarsest of all the sections studied so far, with the proportion of coarse medium-grained sand (0.63-0.32 mm) exceeding 30 % in some layers (Fig. 11). The lowest layer, between 340-170 cm, shows a strong variation in the proportion of medium and fine-grained sand, and from 170 cm to the surface a very uniform layer sequence, free of loess deposits, with a slight but steady upward fining. In terms of its origin, its shape, its height and the uniform

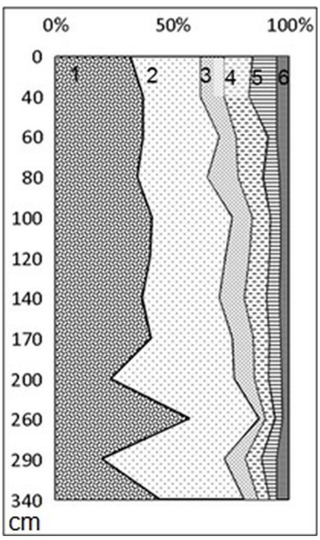

Fig. 11. Grain composition of the Tyúk-hegy coastal dune in weight %. 1: coarse sand, 2: medium sand, 3: fine sand, 4: very find sand, 5: silt, 6: clay

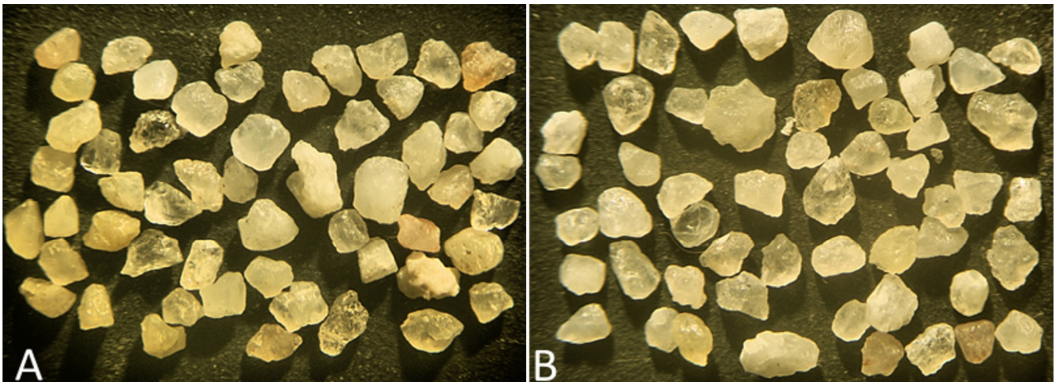

Fig. 12. Grain composition in weight % and $CaCO_3$ content of the New Farm (B) layers of the belt reef.
1: coarse sand, 2: medium sand, 3: fine sand, 4: very find sand, 5: silt, 6: clay

composition of its sediments suggest that it is a relatively rapidly accumulating coastal dune. Microscopic analyses revealed that a significant proportion of the quartz grains in three of the 14 samples examined (0-20 cm and 20-40 cm and the lowest 290-340 cm) show some evidence of eolian influence, which also supports the origin of a coastal dune (Fig. 12 A-B). The high proportion of coarse medium-grained sand in the sedimentary sequence can be explained by the higher gradient of the sediment due to the proximity of the accumulating watercourses to the upland. The total absence of surficial clay layers observed in the deeper sand deposits indicates the inactivation of the form before the Holocene and its prominent, flood-free position during the Holocene.

4. Discussion

The scattered sandstones in the Beregi Plain can be divided into three groups according to their morphology. These are erosional islands, reefs and former coastal dunes bounded by paleo-channels. Despite their different genetics, several characteristic layers can be identified in the sand dunes of Mátyus and the Új-Tanya of Tiszaszalka. Thin sandy-loess strips of presumably pond-dust origin are intercalated between the fluvial sandy material of the lower levels. Their accumulation may have taken place during longer or shorter breaks in the building of the sand layers. The high sand content of the layers indicates that the surface was not permanently free of flooding, because the eolian loess was mixed with a significant amount of fluvial sediment. The type loess found between 110-50 cm in Homok-Tanya 4 and 100-50 cm in Új-Tanya is probably of the same age as the fossil subsoil loess of Bölling age (C14 12900 ± 360 years, Borsy 1987) found in Aranyosapáti. The accumulation of the layer can be dated to the last Gaelic maximum, as the cold dry climate of that period produced a large amount of fallen dust due to frost heaving and the floodplain, which became permanently dry over large areas due to the low water flow of the rivers, provided a suitable surface for its uninterrupted accumulation. The sediments of the Sulymos-Dűlő erosion island, located only 2,5 km from the Homok-Tanya erosion island, do not contain loess or other loess-like sediments. This is due to the more active fluvial activity resulting from the deeper location, which has not created the right conditions for the accumulation of loess and loess-like sediments.

The alluvial alluvial part of the plain, with its several metres thick cyclonic silt-silt loam assemblage, is deposited in sharp shifts on the previously accumulated sandy loess levels. The only exception to this is the highest roof levels of the sand drifts, which currently rise 2-4 m above their surroundings and have been flood-free throughout the Holocene.

The upper 50 cm layer of the only 1 m high belt reef in the Új-Tanya area, with a silt and clay content of 65-70 %, can be considered as a clear Holocene formation.

According to palynological studies, silty, clayey sediments accumulated in the Bereg Plain dead basins as early as the end of the Bølling-Allerød interstadial and the early Atlantic phase (Sümegi 1999, Magyari 2002). In the Nyírség area, several wind-blow sand movements have been described from this Bölling phase until the 18th century (Buró et al. 2018). These occurred during the Late Glacial, Boreal phase, Early Holocene, Subatlantic phase, Late Holocene. Thus, it is conceivable that sand movement in the Bereg Plain sand areas may have occurred during these periods.

A change in the nature surface development occurred between the Pleistocene and the Holocene. Much of the previously deposited sandy sediments eroded away and the newer accumulation cycle deposited mainly silt and clay. This change was probably triggered by tectonic events, but the specific timing of the change is not yet clear. By identifying and studying the sand islands, it became clear that they were formed by fluvial surface formation. During the breaks in the fluvial flow, loess formation and, to a limited extent, eolian processes were involved. The grain analysis clearly shows that the former uniform alluvial fun was still dominated by eolian processes. They became so only later in the already uplifted Nyírség area.

5. Conclusions

Our aim was to classify the sand islands of the Bereg Plain on the basis of morphology using a DEM. Based on morphology, we distinguished coastal dunes, point-bars and erosion islands. Microscopic shape analysis of the quartz grains with diameters of 0.63-1.0 mm revealed traces of aeolian transport only in a very small part of the grains. The sand trains are clearly the remains of a former uniform alluvial fun, which, due to their relative height of a few metres, were left out of the denudation work of the Tisza River. The sand islands were formed by fluvial surface formation. The formations have only minor fluvial influences, so it is likely that the former alluvial fun was not yet dominated by aeolian processes. They became so only later in the already prominent Nyirség area.

6. References

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