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EXAMINATION OF FLUVIAL DEVELOPMENT ON STUDY AREAS OF UPPER-TISZA REGION

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Abstract: Purpose of recent study is to show the fluvial evolution of the Upper-Tisza region on two study areas. In the *Bereg Plain* (from the border to the mouth of the Szamos) studying the deeply cut shore wall of the Tisza – partly due to meander cuts – together with the morphometric analyses of floodplain deposits and abandoned river beds yield information on the characteristics and pattern of natural accumulation. These indicate that the characteristics and pattern of recent sedimentation are determined primarily by the distance from active river beds. Characteristic feature of the youngest period is the accelerated accumulation rates (0.2-1cm/year) on the floodplains bordered by dams. These rates were determined by digital elevation models (DEMs); shallow boreholes and geodesical measurements. The part of the Tisza floodplain directly above the Tokaj gate (*Bodrogzug*) is special primarily because no flood preventing dams were constructed between the Tisza and the Bodrog thus the area remained a quasi natural fluvial development area free of intense cultivation up to now. The area is especially rich in forms characteristic for floodplains of the Great Hungarian Plain (abandoned river beds, levees, point bars, crescent beds, floodplain flats, etc.) annual (or even more frequent) flooding of which enable fluvial accumulation even today. Sedimentary analyses carried out with the help of drillings and in situ sediment traps show that accumulated sediments become finer gradually. Grain-size distribution of the sediment is depends on the distance of present (active) and abandoned river beds. Sediments from active beds and levees are coarse grained, while on floodplain flats are fine grained.

Keywords: erosion sand islands, river regulation, floodplain deposition, geoinformatical methods, sediment trap

1. GENERAL GEOMORPHOLOGICAL DEVELOPMENT OF THE NE PART OF THE GREAT HUNGARIAN PLAIN AT THE END OF THE PLEISTOCENE

At the end of the Tertiary the Pannonian Sea covering the central depression of the Carpathian Basin was filled completely by the activity of the rivers running from the Carpathians and forming large deltas in the basin. In this way the most important surface forming elements at the former sea bottom that turned to be a dry terrain at the beginning of the Pleistocene were the erosion and accumulation work of rivers.

In the NE part of the basin the rivers (Tisza, Szamos, Bodrog and their tributaries) leaving the mountains carried out significant accumulation. As a result 100-150 m thick Pleistocene fluvial sediment series were accumulated in the area of the Bodrogköz, Rétköz and the Bereg-Szatmár Plain (Urbancsek, 1965).

On the alluvial fans that are composed of gravel in the upper sections and sand in the lower sections orientation changes of the rivers were caused fundamentally by structural movements apart from the natural shifting of the riverbeds.

A significant change in the morphological development of the NE Great Hungarian Plain was caused by the shift of the Tisza and the Szamos – presumably mainly due to tectonic subsidence – onto the SE part of their alluvial fan into the present Ér valley. Later at the boundary of the Pleistocene-Holocene (Borsy & Félegyházi 1983, Borsy 1995) with the subsidence of further smaller depressions

(Szatmár Plain, Bereg Plain, Rétköz, Bodrogköz, Taktaköz) on the northern part of the alluvial fan the Tisza forming the spine of the river network of the area. In these areas an average subsidence of 50 m in the Holocene was indicated by boreholes and geophysical measurements (Sümeghy 1953). The Tisza shifted from the Ér Valley into these depressions and ran towards the centre of the Great Hungarian Plain rounding the Nyírség from the north through the narrow pass between the Tokaj Hill and the Nyírség (Tokaj Gate) (Borsy 1995). In these gentle sloping floodplain areas the strongly meandering Holocene rivers carried out significant erosion (Fig. 1).

They denuded almost the entire Pleistocene sand area in the Bereg Plain leaving behind small sand islands hardly known till recently. In the Bordogköz such alluvial fan islands remain in larger extent (e.g. wind-blown sand area enclosed by Viss, Zalkod and Kenézlő settlements). Bed of the Tisza and its tributaries crossing the depressions shifted several times also in the Holocene forming an entangled network of abandoned river beds and floodplain landforms with their meanders variable in discharge, size and character due to the variable climate. Among floodplain forms the most significant ones are the series of point bars and crescent beds in the inner closet of abandoned beds, natural levees escorting current and former shorelines, sluice gates cutting through them and feeding floodplain lows via larger-or-smaller creeks. Such forms remained most intact and develop even today in areas where natural fluvial development was not interrupted by anthropogenic activities. One of the finest examples for this is the SW edge of the Bodrogköz, the Bodrogzug. Elsewhere (e.g. in the Bereg Plain cross cut densest by abandoned river bed remnants) river regulation and flood prevention works started at the beginning of the 19th century blocked out the effects of rivers from the major parts of floodplains thus the character of river activity in the narrow active floodplain between the levees changed fundamentally.

2. MOST IMPORTANT RESEARCH METHODS

In order to recognize current and past floodplain processes accurately, apart from recent topographic maps with the scale of 1:10 000 aerial photos and space images of large resolution were used including the photo information of Google Earth. This provided completely new dimensions in the research as such sources were not available or in only a very limited extent.

In order to study the grade, rate and character of floodplain accumulation numerous shallow depth (max. 13 m) boreholes were drilled in both the Bereg Plain and the Bodrogzug. Mechanical composition of the sediment samples taken from every 10 cm by an Eijkelkamp type soil driller was determined by the Köhn pipette. Carbonate and humus content together with the pH of the samples were also measured. For age determination and climate reconstruction purposes pollen analyses were performed in both study areas.

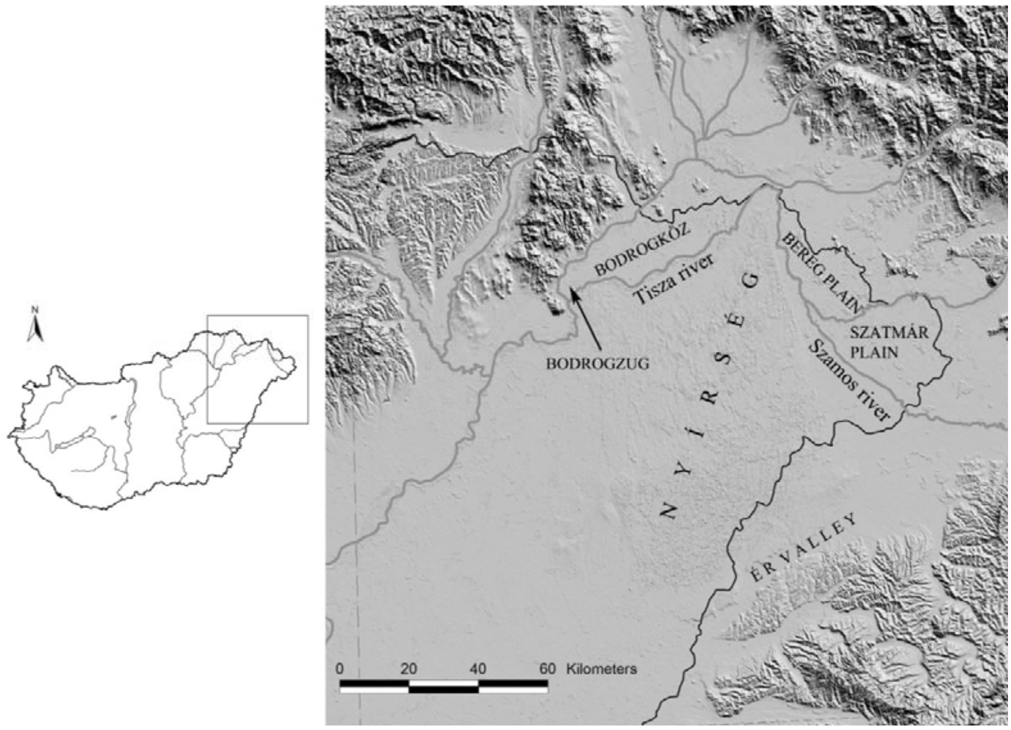


Figure 1. North-eastern part of the Great Hungarian Plain.

In six points of the Bodrogzug, all with specific geomorphological position (in point bars, in crescent beds in between them and in unrelieved floodplain areas relatively distant from abandoned beds) information was gained by own-developed sediment traps related to the quantity and grain-size distribution of sediments carried by floods. Sediment traps were set in pairs in four areas taking samples from the deepest points of the given area in a crescent bed and from the top of the point bar rising around 20 m from the crescent bed. Further two sediment traps were placed on the sores of selected floodplain lows. The sediment traps were 10 cm thick plastic boxes with a total area of 20 x 30 cm placed at two levels, one directly on the soil level and one 40 cm above. Following the collection of the samples that depended on flood events, the samples were dried, their organic matter content was disintegrated by hydrogen peroxide and their grain-size distribution was determined by Köhn pipette.

3. DISCUSSION AND RESULTS, BEREG PLAIN

Erosion islands in the Bereg Plain. The sub-basin of the Bereg Plain is the first major sedimentary depression of the Tisza and many of its tributaries (primarily the Szamos, the Túr, the Borsava and the Bodrog) entering the Pannonian Great Plain from the Carpathians. Thickness of the Pleistocene series containing mostly gravel is around 50-100 meter here. In the last third of the Pleistocene much finer middle and fine grained sand was deposited on the gravel. In the background of such fining of the basin filling sediments climate change can be assumed apart from tectonic processes as its effects are much faster. At this time the character of the Bereg Plain was very similar to the neighbouring areas (the Nyírség that is much higher today – 120-180 m – and covered by wind-blown sand on top, to certain parts of the Bodrogköz that has similar elevation above sea level – 95-110 m – and to the Szatmár Plain). Following this surface development of the Nyírség and the Bereg Plain was separated as a result of the significant elevation of the former. Due to new tectonic activity or climate change unclear today the rivers with primarily accumulating activity until that time denuded the majority of the former sediments in the sand surfaces in the Bereg and the Bodrogköz by significant (primarily lateral) erosion. Although in the Bodrogköz extended continuous sand islands (covered by wind-blown sand currently) were left, in the Bereg plain such forms were mentioned only in passing and with uncertainty in former research. Our remote sensing, field research and analysis of local geographical names carried out in recent years more than half a dozen small sized (with a few hundred metres of diameter at the most) erosion islands elevating 2-4 m from their environment, composed of fluvial sand and covered by loess material at places were identified on topographic maps with the scale of 1:10000 (Fig. 2). (One part of these were used as sand quarries and their part rising above the surrounding area were mostly removed.)
Several m thick fine silty (containing significant amount of clay fraction as well) fluvial sediments of the surroundings of these sand islands – like a sort of "buttes" – indicates that accumulation started again following the erosion of the former surface. This accumulation lasted practically until the river regulation works and reduced gradually the relative height of the islands that "survived" the former erosion (Fig. 2, Fig. 3).

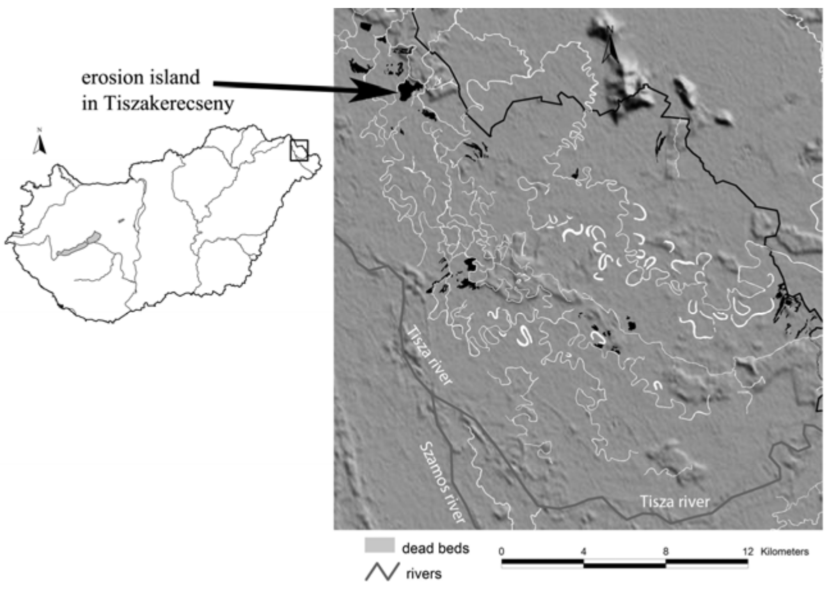


Figure 2. Channel network of the Bereg Plain.

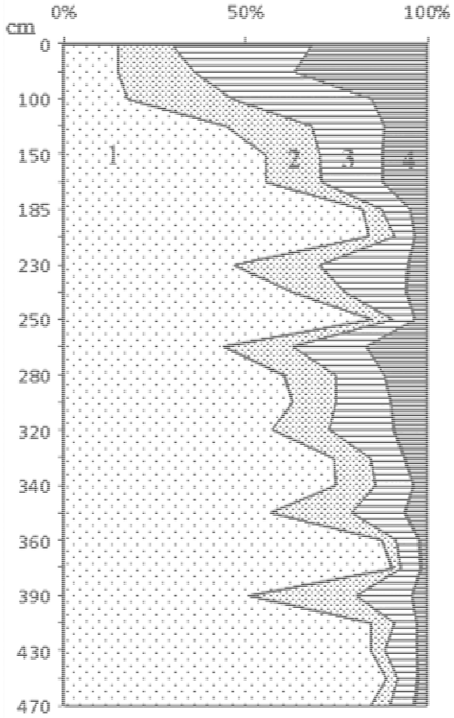


Figure 3. The granulometric composition of the erosion island in Tiszakerecseny. 1: sand, 2: loess, 3: silt, 4: clay.

With the identification of the sand islands the change in surface development at the end of the Pleistocene became apparent, however its particular causes (tectonic or climatic) and time cannot be determined clearly today.

Bed generations in the Bereg Plain. Small scattered sand islands remained from the fluvial denudation of the Bereg Plain suggest that the bed shifts of the ancient Tisza and its tributaries happened not only via bed shifts joined by lateral erosion denuding the entire surface but via the relatively sudden change of flow direction as well. This hypothesis is supported by the bed remnants with SE-NW orientation clearly identifiable on both sides of the current Tisza (in Szatmár and in Bereg as well) on space images. These meander remnants indicate the former flow direction of rivers with much smaller discharge than that of the current Tisza. These meanders accompany marked natural levees higher than their surroundings. On the Bereg side a relatively narrow, only 10-30 m wide but well developed meander remnant series accompanied by natural levees can be recognised especially well (Fig. 2). The lower areas on the outer sides of the natural levees are characterised by an entangled network of abandoned meander torsos of various size and degree of destruction. Four groups of beds can be separated in the Bereg based on their shape characteristics regarding different size and destruction degree. Differences in the shape of beds indicate different ages as well as proved by the palynological analysis of the borehole samples. The oldest bed group hardly visible on the surface, only detectable by remote sensing methods at places indicates rivers cross-cutting the Bereg Plain has been absent from certain areas for a long time during their changes of orientation. Cut off these old beds took place about 25-37 thousand years ago according to the palynological and sedimentological evidence. The age of the young meander series with natural levees is only around 4000 years based on similar analyses and as the bed filling sediments show a filling rate of only 0.3 mm/year their relatively "fresh" appearance is understandable. In our opinion the Tisza got from this young meander series to its current bed by a sudden change of orientation. Starting place of the orientation change could have been near the current Hungarian-Ukrainian border based on the morphological characters.

Specific connection of bed remnants in the Bereg Plain. Reconstruction of the development of the abandoned bed network in the Bereg Plain is made difficult mainly by its entangled figure. During studying the connection of certain river bend remnant or bed remnant groups on very detailed new space images and topographic maps it was revealed that the multiple connection of them is given frequently by the bed remnants branching off at the peak of the abandoned bends. As can be seen on the maps place of these branching offs draws a "Y" (Fig. 4). Sometimes these are the traces of short beds loosing way in the floodplain low but they are longer elsewhere and reach the neighbouring bed remnant as well. In our opinion these are the routes of floods flowing and retreating through the natural levees developing along the still active beds and with their gradual increase they became connected to the similar branching offs of neighbouring meanders. Such interpretation of branching offs helps to understand the entangled bed network and gives a sound basis for recognising the once separate meander series.

4. MORPHOLOGICAL EFFECTS OF RIVER REGULATION IN THE BEREG PLAIN

Major part of the Bereg Plain was covered periodically by water until the organized regulation works started at the middle of the 19th century. This is proved clearly by the location and structure of settlements on the higher natural levees. The right levee of the Tisza running in the Bereg Plain was completed by 1856 (Ihrig, 1973). With creating the levee, conditions of free fluvial surface development ceased by the end of the 19th century despite frequent levee rupture. In order to discharge floods quickly 29 bends were cut by the beginning of the 20th century beside the construction of the levee.

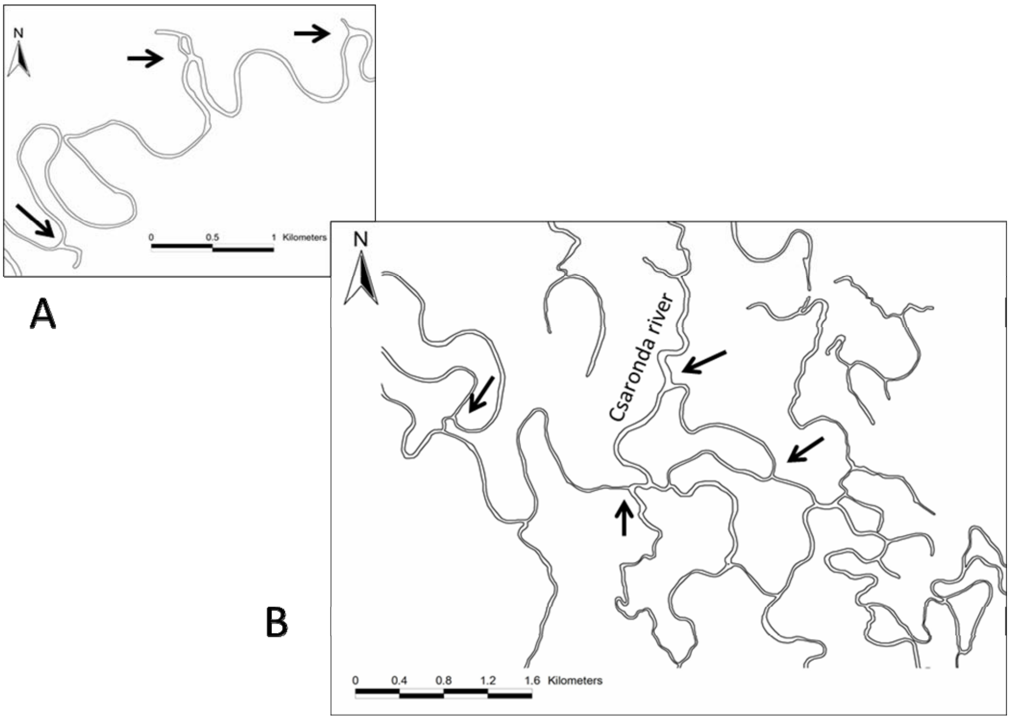
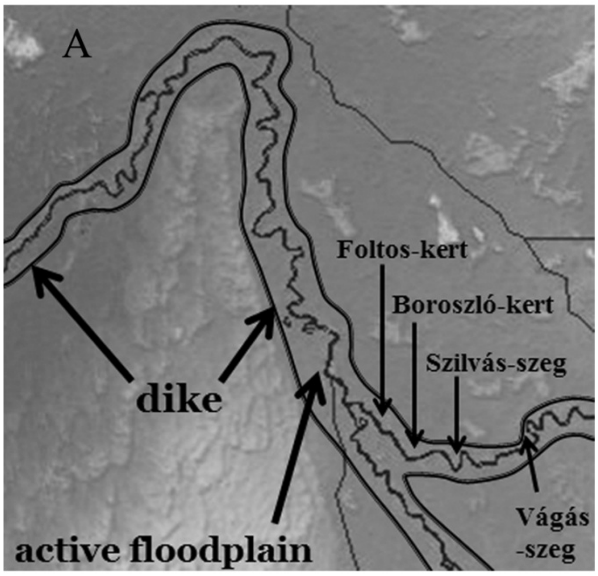


Figure 4: "Y" draws branching offs in the Bereg-plain.

Around 80% of the cuts developed into main river bed. Since the construction of the levee the Tisza is forced to carry out its accumulation activity over a narrow, only 400-2000 metre wide "corridor" (active floodplain) the area of which is only 5-6% of that of the former open floodplain (Fig. 5, A). Several authors discuss floodplain development of middle course rivers (within 250 m of the river), but only a few of them discuss accumulation of the far region of these geomorphological units (Walling & He 1998, Walling et al., 1998, Steiger & Gurnell 2002). Water management experts called attention to higher and higher water levels accompanying the same amount of discharge in the case of floods in the last decades (Schweitzer et al., 2002). This can be explained apparently the tightening of the through flow cross-section. This tightening is the result of the rising of the bottom level due to siltation as the width of the active floodplain is stable. This problem of the active floodplains along the Tisza was studied in the framework of numerous research projects in other sections of the Tisza in the last decade (Gábris et al., 2002; Kiss et al., 2002; Babák, 2006; Sándor & Kiss, 2007; Vass, 2007; Dezső et al., 2009; Vass et al., 2010; Gosztonyi et al., 2011). In the course of the active floodplain research carried out in the Bereg Plain, rate of accumulation was determined by several methods. Most striking change was experienced in the case of the cut abandoned beds – as marked negative forms. In certain cases the cut bed sections may have a distance of 1-1.5 km from the new beds that developed to be part of the main bed. Therefore active bed hydrology caused sediment accumulation mechanisms in the abandoned beds terminated abruptly and the bed material composed mainly of middle sized sand (0.2-0.63 mm) is covered by silt and clay (<0,02 mm) brought by floods from the distant new beds. The reverse can be observed in the vicinity of the new bed. In this area formerly only fine particles were deposited by floods from the distant active bed. Since the bed change, however, much coarser sandy sediments are deposited from the much closer new bed (Fig. 5, B). Gives fine examples on the profiles of a borehole series drilled between the old and the new beds (Foltos-kert).

During the interpretation of borehole F1 drilled in the oxbow lake a 90-100 cm thick accumulation composed of 40-60 % silt was measured on top of the bed material suggesting a filling rate of 0.9-1 cm/year (Fig. 6). The upper 70-80 cm of the borehole F7 drilled in the new bed is sandy silt much coarser in mechanical composition than the finer formations below (Fig. 6). In the case of the neighbouring meander cut in 1860 (Boroszló-kert) similar rate of accumulation was measured (130 cm over 150 years corresponding to 0.87 cm/year).

Rate of accumulation in the active floodplain was investigated by other methods as well. As the height of the present active floodplain and that of the immediately neighbouring areas that are reclaimed areas today were generally the same prior to the construction of the levees the current average height of the areas within the levees and that of their neighbouring outer areas was determined at three study locations.



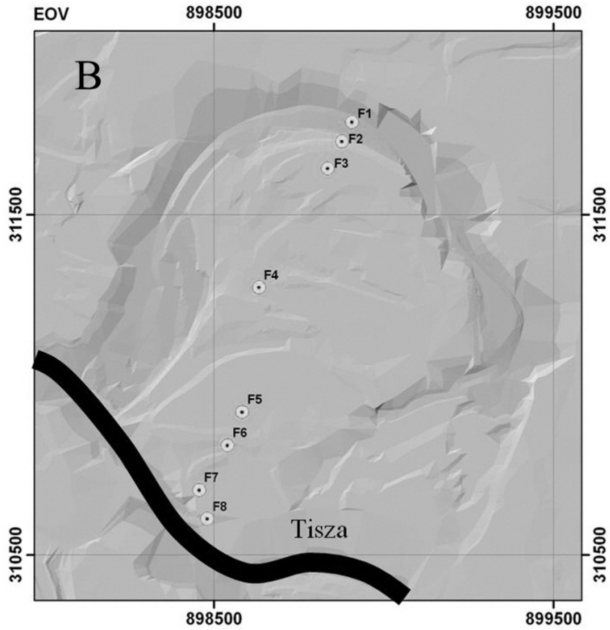


Figure 5. A: Sample areas of active floodplains in the Bereg Plain. B: DEM model of Foltos-kert with drillholes (F1-F8).

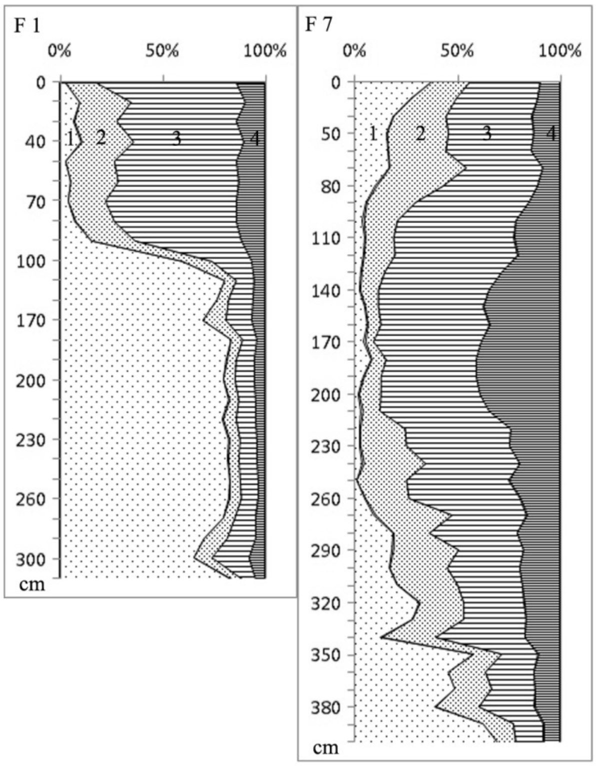


Figure 6. The granulometric composition in Foltos-kert. 1: sand, 2: loess, 3: silt, 4: clay

For determining the average height a digital elevation model was prepared from the study areas. For this all contour lines of the topographic maps with the scale of 1:10000 prepared between 1968 and 1971 and reworked in the United National Area System (EOTR) were digitized using the software ArcMAP 9.0. Using the contour lines a TIN model was prepared by ArcMAP 9.0. The TIN model was transformed into a raster file (with the resolution of 1 pixel is 10 m). Following this 300-400 points were taken randomly in the area of the selected patches. Interpretation of the data was performed by the software SPSS-13 (Fig. 7).

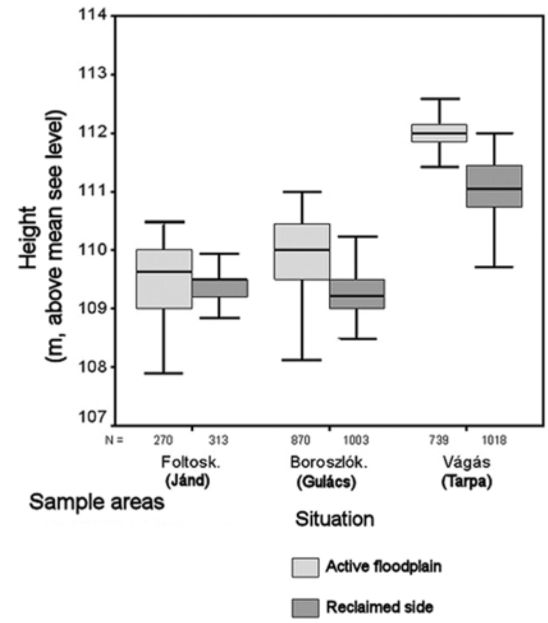


Figure 7. The points of the sample areas illustrated with boxplots.

For comparison in one of the study areas (*Szilvás-szeg*) height of the active floodplain and that of the reclaimed floodplain were determined by an optical leveller with cm accuracy along a 2.3 km long cross-section. Results from both analyses show greater height for the level of the active floodplain. Height difference between the active floodplain and the reclaimed floodplain decreases in the direction of flow. This can be explained by the significant gradient decrease of the river (from 21.2 cm/km to 13.2 cm/km), table 1.

Height differences between the active floodplain and the neighbouring reclaimed floodplain in the case of the three studied meanders (based on the data of.

In conclusion we can state that all applied methods prove the accumulation of the inside section of the active floodplain. Greatest accumulation was experience naturally in the lowest lying oxbow lakes as 0.87-1 cm/year. In the case of average heights of neighbouring active floodplain and reclaimed floodplain areas with similar heights decreasing difference was detected in the direction of flow (Vágás-szeg 1 cm/year, Boroszló-kert 0.56 cm/ year, Foltos-kert 0.2 cm/ year). It is interesting that accumulation rate in the case of beds in the active floodplain is around 1 cm/year while this value can be only 0.33 mm/year in the case of open floodplain beds (Félegyházi et al., 2004) that might be even 5-10 km from the river. This difference is more than 30 times.

5. DISCUSSION AND RESULTS, BODROGZUG

Characteristics of natural geomorphological development in the Bodrogzug.

The Bodrogzug is the SW corner of the area between the Tisza and the Bodrog (Bodrogköz) extending to the mouth of the Bodrog below the Tokaj Hill extending over 40 km^2 (Fig. 8). Its area is the joint floodplain of the two rivers flooded regularly even today as no significant levees were constructed or the major ones were pulled down. No settlements can be found in the area, lands have never been ploughed, main land-use was meadow and pastoral land management with some extensive cattle keeping. Therefore the area retained its natural character. Its vegetation is composed of the seaweed of the abandoned river beds (oxbow-lakes), swamps, reeds, wetland hayfields, willow groves that are rich in animals as well. Therefore the area became a nature reserve. The Bodrogzug belongs to the Tokaj Bodrogzug Landscape Protection District established in 1986 and it has been a RAMSAR area since 1989. Protection is ensured by the minimum land-use in the area managed by the Aggtelek National Park in the form of hayfields, pastoral lands and some forestry.

Most of the floods enter the Bodrogzug from the direction of the Bodrog and 80 % of its area is submerged already at water levels equalling the first flood alert level (this is 600 cm at Tokaj) (Szabó et al., 2004) and more than half of the area lies below floods 50 cm lower than that level. Water level of the Tisza at Tokaj has exceeded the first flood aler level 124 times since 1901 and their total duration equals 1230 days.

During the three years of our detailed research (2008-2011) water level exceeded 550 cm on 18 occasions with the total duration of 156 days (Table 2). As the two rivers ran all across the entire area in the Early and Late Holocene the near surface layers are composed of various alluvial formations (alluvial clay, alluvial silt).

The Bodrogzug is a basically accumulation river floodplain, a special “treasury” rich in geomorphological landforms characteristic for river floodplains (Fig. 9). As floods occur repeatedly even today its forms are not relict forms, their development is not over and their evolvement can be observed with appropriate methods. Abandoned beds of various size and age are especially abundant, most of them are meanders. Based on their size and measureable meander parameters, they are originated from different rivers or reflect discharge changes from different time periods of the same river (the Tisza or the Bodrog) (Fig. 9). Although today – similarly to other natural floodplains – water runs in them only at the time of floods causing no real change in shape, this frequent supply of water sustains special conditions for the flora and fauna contrary to the oxbow-lakes outside the levees in other sections of the Tisza.

Table 1. Height differences between the active floodplain and the neighbouring reclaimed floodplain

		Average m. (m)	Median	Standard deviation	Interkvartile mid-range
Foltos-kert	inside levee	109.5	109.6	0.64	1
	outside levee	109.3	109.5	0.3	0.3
Boroszló-kert	inside levee	109.9	110	0.56	0.93
	outside levee	109.3	109.2	0.43	0.5
Vágás-szeg	inside levee	112.1	112	0.4	0.34
	outside levee	111.0	111	0.48	0.71
Szilvás-szeg *	inside levee	109.7	-	-	-
	outside levee	108.6	-	-	-

* result of the optical measurement

Figure 8. Area of Bodrogzug on GoogleEarth image.

Table 2. Floods and water levels (Tokaj, 2008-2011)

Water level / Year	above 550 cm		above 600 cm		above 700 cm		above 800 cm	
	occasions	day	occasions	day	occasions	day	occasions	day
from 15/06/2008	2	11+6=17	1	9	1	4	0	0
2009	5	4+4+4+4+5=21	1	4	0	0	0	0
2010	8	17+8+2+3+32 +4+1+28=96	4	78	3	44	2	13
until 15/05/2011	3	6+11+5=22	2	7	1	1	0	0

As bed remnants do not form a completely continuous network channels were formed at several places to connect them and help water flow, some of the channels continue even in the beds. In the inner areas of the Bodrogzug there are no other signs of anthropogenic surface forming than the channels.

Striking features of fluvial surface formation are the series of characteristic floodplain lows, natural levees along current and former shorelines and sluice gates (kept open artificially at places) cutting the natural levees and still operating today apart from bed remnants. Besides point bars and curved “crescent lows” or “crescent beds” are especially spectacular fluvial forms (Fig. 9).

Although height difference among these is only a few dm their vegetation differs significantly due to differences in the duration of water cover (and in moisture conditions in general) thus point bar areas – at 4-5 places at least in the Bodrogzug – stand out markedly from their surroundings. As these are somewhat distant from the active beds the question arises, what effect sediments deposited from recent floods has on the development of their forms. Although active beds shifted away from them hundreds of years (even thousands at several places) small height difference between point bars and crescent beds reflected by vegetation has not disappeared.

According to the palynological interpretation of the borehole in the Nagytökös lake – at places 18 and 19 (Table 3), (Félegyházi 2010), the lowest silty sediments between 400 and 550 cm were deposited as floodplain sediments already in the second half of the

Figure 9. Geomorphological map of Bodrogzug. The numbers show the place of sediment traps.

Atlantic phase and the layers above them are not from a river bed but rather suggest an accumulation floodplain distant from the bed. Most beds in the Bodrogzug were not active in the second half of the Holocene and their filling sediments have floodplain characteristics. Presence of accumulation today, however, in theory causes the height difference to be levelled. In order to see the form evolvement tendency of point bar areas field measurements were started in 2008 with installing load traps in several beds and on reefs in between them. The load traps collected sediments at two levels, 40 cm above the soil and directly above the soil (at 10 cm high due to technical reasons). Character and trends in accumulation were studied with the help of more than a dozen shallow (max. 6 cm) boreholes.

In the Bodrogzug the character of the sediments deposited today is virtually the same as the material of the near surface layers. In the sediment traps (20 traps in total at 10 places) apart from the dominant organic matter almost exclusively silt and clay were found (Table 3, Fig. 9). Significant amount of sand was found only in the trap located less than 100 m from the current Bodrog bed where water flows through the channel like open sluice gates already at water levels of 550 cm and not only floated material is carried there. Boreholes in the point bar areas, in the floodplain lows and in the completely unrelieved areas reveal that below the upper 80-120 cm thick strongly clayey-silty (joint ratio of clay and silt is around 60-80%) covering layers the material becomes gradually – suddenly at places – coarser (Fig. 10). Ratio of the sand fraction increases from around 10% to two or three times that value and may reach up to 50% at places.

Fining of the sediments towards the surface – even though fluctuations can be detected – reflects change in fluvial development. Outer causes and the duration of this change (e.g. change in the discharge or in the gradient) are not known yet but it is clear that fining of the load in the uppermost zone does not continue today and this might be related to the severe and frequently repeated floods of the last one and a half decades.

Accumulation of the Bodrogzug as a floodplain is flood dependent. Therefore filling has a rhythm. Without floods accumulation may pauses for years at the time of floods, however, the quantity of deposited material is influenced strongly by the time of the floods. More sediment is carried distant from the active beds from late winter – early spring floods because less vegetation at this time of the year presents less blocking effect against water flow. In 2009 for example, no sediments were taken by the summer floods into the traps 1000 m away from the bed. In the spring and summer of 2010, however, significant amount of material was deposited in the traps from repeated floods. Greatest load quantity was deposited from the floods of 2010 repeated numerous times, however, with a relatively low water level indicating that the quantity of load getting into the floodplain depends primarily not on the height of the water level during the flood but on the frequent repeat of the floods. (In the traps close to the Bodrog bed the material was almost tenfold.).

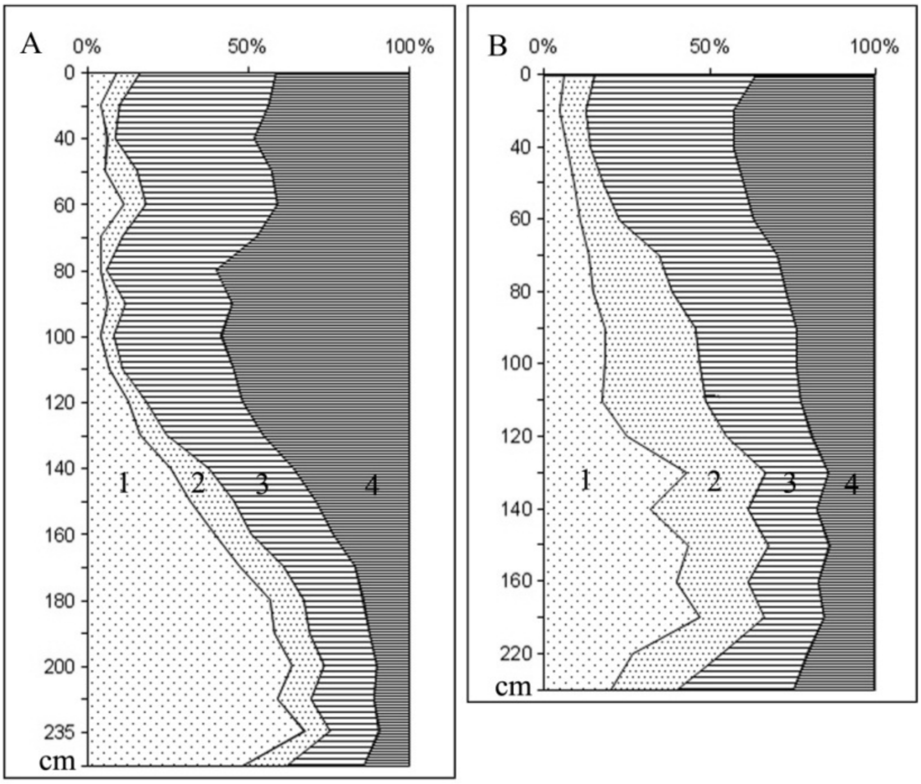


Figure 10. The granulometric composition of a backswamp (A) and a point bar (B) in Bodrogzug.
1: sand, 2: loess, 3: silt, 4: clay.

Table 3. Grain-size distribution of the material of a few load traps (measured by Köhn pipette)

Trap No.	Trap location	Sand 0.1-0.2 mm	Dust 0.02-0.05 mm	Silt 0.002-0.005 mm	Clay <0,002 mm
1	Lebuj - bed - 10 cm	1.2	8.5	47.8	42.5
2	Lebuj - bed - 40 cm				
3	Kerektó - bed - 10 cm	7.2	7.2	36.2	49.4
6	Holt-Bodrog - bed - 40 cm	0	8.2	48	33.8
11	Horgony - reef - 10 cm	0.8	7.4	54.5	37.3
12	Horgony - reef - 40 cm	0.4	9.2	55.7	34.7
13	Fekete-tó - reef - 10 cm	1.8	8.6	60.6	29
18	Nagytökös - reef - 40 cm	0	0	47.8	52.2
19	Nagytökös - reef - 10 cm	0	1.8	60.2	38

Table 4. Load trap data in the Bodrogzug (quantity of samples recalculated to mm on the basis of density $d=2g/cm^3$)

„lower" = trap placed 10 cm above the ground, „upper" = trap placed 40 cm above the ground

	Placing the trap	First collection 10/200805/2009	Layer (mm)	Second collection 10/2010	Layer (mm)	Third collection 04/2011	Layer (mm)
1	2	3	4	5	6	7	8
Lebúj - low - lower lower	06/2008	-		16.1g	0.14	15.78	0.13
Lebúj – low - upper	06/2008	-		11.3g	0.10	6.28	0.05
Kerektó – low – lower	06/2008	-		38.8g	0.33	5.3	0.04
Kerektó – low – upper	06/2008	-		26.8g	0.22	3.78	0.03
Holt-Bodrog low – lower	06/2008	-		68.4g	0.57		
Holt-Bodrog low – upper	06/2008	-		22.5g	0.19	8.32	0.07
Holt-Bodrog reef lower	06/2008	-		40.9g	0.34		
Holt-Bodrog reef	06/2008	-		13.8g	0.11	3.47	0.03
Horgony low lower	06/2008	80.7g	0.67				
Horgony low upper	06/2008	87.5g	0.73				
Horgony reef lower	2008. 10.	34.9g	0.29	296.4g	2.48	40.84	0.34
Horgony reef upper	2008. 10.	17g	0.14	172.8g	1.44	38.97	0.32
Fekete-tó low- lower	2008. 10.	-				5.12	0.04
Fekete-tó low – upper	2008. 10.	-				3.02	0.02
Fekete-tó reef lower	2008. 10.	-		39.3g	0.33		
Fekete-tó reef upper	2008. 10.	-		7.8g	0.07	2.78	0.02
Nagy-Tökös lake – low lower	2009. 04.			-			
Nagy-Tökös lake – low upper	2009. 04.			-		8.68	0.07
Nagy-Tökös lake – reef lower	2009. 04.			-		11.55	0.10
Nagy-Tökös lake – reef upper	2009. 04.			-		8.88	0.07

[1]sampler damaged severly, [2]calculated value due to the disappearance of one part of the samplers, [3]sampling was not successful due to various reasons

Based on the data of the load traps (Table 4) estimated accumulation is 2-3 mm near the bed in years with severe floods and 0.1-0.6 mm/year in the inner areas. Between the autumn of 2010 and May 2011 a very high flood appeared the load quantity related to it is much less than that of the smaller but more frequent floods of the year before (mass of the material in the trap was one order of magnitude less).

Collection of sediments was not always possible in areas inaccessible as a result of the floods. Damaged or disappeared traps due to icy floods also caused missing data in the data series, however, results show clearly that significantly more sediment is deposited in crescent lows than in reefs. In point bar areas not affected by recent bed shifts therefore the gradual disappearance of the forms spectacular today and thus the change of the vegetation can be expected.

The geomorphological picture of the quasi natural floodplain of the Bodrogzug is formed even today by floods. Determination of the character and grade of this change helps the reconstruction of the development of not only this particular area but also contributes to the understanding of the development of neighbouring landscapes accumulated by the Tisza and its tributaries.

6. CONCLUSIONS

Based on the recent research in the NE part of the Great Hungarian Plain using more informative instruments, maps and space images more detailed than before and traditional field research methods several elements of land development were identified not known or ignored before. Members of the entangled bed network of the Bereg Plain recognized so far lost their connection to the active river beds at least 25000-37000 years ago. Following this, the beds and their surroundings were filled by the deposition of fine (mostly silty) sediments. The erosional islands, however, rising from the general level of the plain, composed of coarser fluvial strata and covered by loassy material at places reflect significant erosion in the past.

Accurate time and reasons of this process are not known today. The directions observable in the bed network of the plain suggest sudden bed shifts in the case of the main river (Tisza). Explanation of the development of the entangled bet network might be obtained from studying the "Y" shaped embranchments detected near the tips of abandoned bends. These can be the result of water flowing through the former natural levees into the surrounding areas or back.

General accumulation in the Bereg Plain ceased following the river regulation works and appeared only in the active floodplain areas in the last one and a half centuries, however, in intensified form. In the meantime the Tisza was shortened significantly by bed cuts and its main bed cut in significantly while its floods in the active floodplain cause accumulation that endangers successful flood prevention as the cross-section of the active floodplain is reduced continuously. Our measurements provided data behind the character and rate of accumulation in the active floodplain. Where regulation works did not affect the Tisza and the Bodrog, its main tributary (e.g. in the Bodrogzug) accumulation is still active even today. Character and rate of this accumulation were studied with the help of boreholes and sediment traps. Based on all these it can be stated that the free geomorphological development of such free floodplain parts is still continuing, its forms are changing thus they are special "laboratories" of natural fluvial development worth conservation in the Great Hungarian Plain that has been otherwise transformed strongly by man.

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