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MEANDER CORES ON THE FLOODPLAIN – THE EARLY HOLOCENE DEVELOPMENT OF THE LOW-FLOODPLAIN ALONG THE LOWER TISZA REGION, HUNGARY

Tímea Kiss*, Péter Hernesz, György Sipos

Department of Physical Geography and Geoinformatics, University of Szeged, Egyetem u. 2-6, H-6722 Szeged, Hungary
*Corresponding author, e-mail: kisstimi@gmail.com

Abstract

The aim of the present study is to analyse the morphology, sedimentary structure and age of flood-free islands on the low-floodplain of the Lower Tisza in order to determine the date and causes of river incision. On the study area the identified 16 elevated surfaces were divided into two groups. The real or meander core floodplain islands appear in the northern and central units of the study area. They are characterized by steep slopes, elevated surface and small territory (2.1 km^2 in average). The second type consists of elevated surfaces of point-bar systems and natural levees of paleo-channels, and they mostly appear in the southern unit. They have gentle slopes, smaller relative height and greater area (4.1 km^2 in average). The spatial distribution of the two types refers to slow and slight tectonic uplift in the northern part of the study area, though in the south they refer only to the lack of sinking.
The results of the sedimentological analysis on the meander core at Szegvár show that it originally belonged to the high-floodplain. Due to the slight tectonic uplift the meandering channel incised into the soft sediments, and as lateral erosion was possible, an ingrown-type meander developed, which later as a result of cut-off has become a meander core (or umlaufberg). Based on the OSL data the incision started at least 20.1±2.1 ka ago, and it terminated ca. 8-9 ka ago. The calculated bankfull discharge of the Szegvár paleo-meander is estimated to be 4000-7500 m^3/s, referring to a considerably higher discharge than that of the present-day Tisza (800 m^3/s). Similar planimetric meander parameters of paleo-channels on the high and low-floodplain suggest that the incision was not driven by climate, i.e. discharge change but primarily by tectonic movement. This is also supported by the height condition of the islands, as their surface is almost at the level of the high-floodplain.

Keywords: floodplain formation, incision, ingrown meander, floodplain island, OSL dating

INTRODUCTION

The floodplain of the Tisza River south of Csongrád (Hungary) was formed at the Late Pleistocene and Holocene through the alteration of erosional and aggradational activities along the river. The most important event in its development history was an incision, which resulted in the differentiation of the low and high-floodplain. According to Láng (1960) and Mezősi (1983) this can be dated to the beginning of the Holocene, approximately 12 ka ago, when the Tisza and Maros Rivers incised into the former floodplain by ca. 10-12 m. They explained the process by an increased erosional activity, however the causes of intensified fluvial activity were not resolved. According to Mátyus (1968) the incision occurred later, in the Boreal Phase and it resulted in the development of a 3-5 km wide floodplain. However, Lovász (2002) contested this idea as he claimed that the amount of precipitation had decreased in the Boreal Phase, consequently run-off and fluvial processes became limited. Based on the paleo-discharge data of Gábris (1985, 1986) the discharge of the rivers was mush higher (up to 10 times) in the Preboreal and Atlantic Phases, which could also explain the intensive incision. According to Gábris (1995), the development of the low-floodplain is a rather new process (ca. 4000-5000 y), and overbank accumulation had also started recently, ca. 2.5 ka ago.

The explanation of the incision and subsequent aggradation just by climatic causes has several week points. The area is quite active tectonically: the area of Szeged is the most intensively subsiding area of the great Hungarian Plain since the beginning of the Neogene (Borsy, 1990). Based on the lack of overbank aggradation, however, Somogyi (1967) supposed the termination of sinking since the end of the Pleistocene, or even since the beginning of the Riss-Würm Interglacial. Nevertheless, present-day measurements (Joó, 1998) on vertical tectonic movements indicate intensive subsidence (3-4 mm/y) in the southern part of the Lower Tisza Region, especially at the city of Szeged, at the confluence of the Tisza and Maros Rivers. Another centre of the sinking is at the Middle Tisza Region, where the rate of subsidence is similar to that experienced along the Lower Tisza. In between the two sinking areas, in the northern part of the Lower Tisza Region tectonic movements have a lower rate, and thus the area is relatively up-lifted. However, Timár (2003) emphasizes, that the intensive exploitation of subsurface waters, natural gas and oil might also cause surface subsidence, thus the present-day rate of tectonic movements should not projected to longer periods.

Consequently, no precise data exist on Quaternary vertical movements, but the tectonic activity is clearly indicated by the fluvial forms on the low-floodplain. In case of subsidence overbank aggradation becomes dominant, which can also hide previous forms (Twidale, 1964). In case of uplifting fluvial erosion intensifies, causing incision and subsequent lateral erosion on the former floodplain. Hence, meander cores can develop on the low-floodplain as the result of (ingrown) incised meander development (Fairbridge, 1968), and the process can also separate the low and high floodplains (Gábris, 1995). Incised meanders have two types: ingrown and entrenched (Morisawa, 1985), both developing as a result of tectonic uplift (Twidale, 1964). In case of entrenched meanders incision is quick and meander development usually reaches the solid rock bed, while ingrown meanders develop usually at a slower incision rate when lateral and vertical erosion can coexist. As the result of lateral erosion the meanders can be cut off, which results in the development of meander cores being much higher than the alluvium. Meander cores are cited in different ways in the literature: pembina (Fairbridge, 1968), bedrock spur or natural arch (Summerfield, 1991; Hugett, 2007), umlaufberg (Mahaney, 1984). As incision and lateral erosion coexist, the cross-section of the valley is asymmetric: the convex side of the meander has gentler slope and on the slip-off face indications of point-bars might appear (Fairbridge, 1968).

Meander cores of ingrown meanders appear on the low-floodplain of the Lower Tisza Region. Until the 19th century river regulation works they were flood-free surfaces surrounded by marshlands, therefore in earlier researches these elevated surfaces were cited as floodplain islands, flood-free islands, terrace-islands or Pleistocene remnant surfaces (Mátyus, 1968; Andó, 1969; Mezősi, 1983). The meander cores can be the key to the reconstruction of the first stages of the development of the Lower Tisza Region. The aim of the present study is to identify and classify the flood-free islands of the low-floodplain, to determinate the date of incision and its causes in the Lower Tisza Region by studying the morphology, sedimentary structure and OSL age of meander cores.

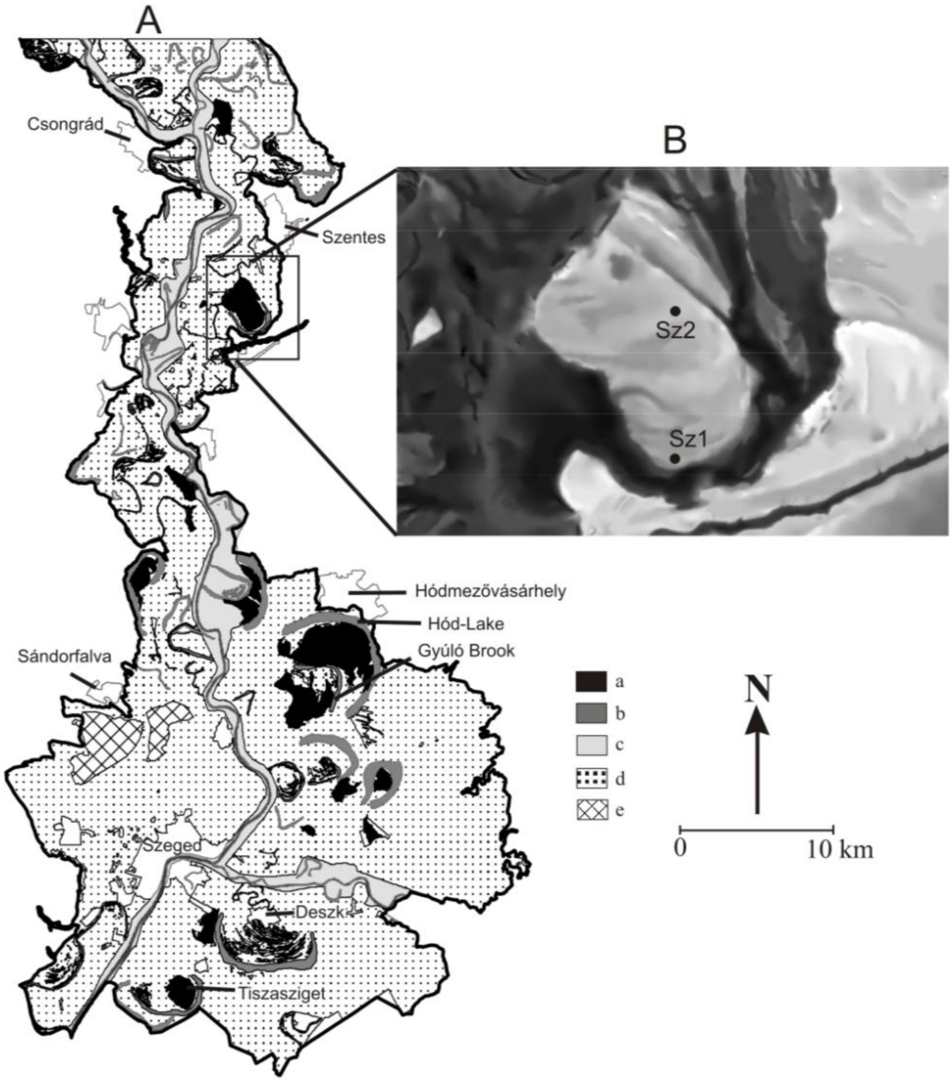

Fig. 1 Main geomorphic features of the Lower Tisza Region (A) the meander cores near Szegvár were studied in detail (B) a) elevated surface, b) paleo-channel, c) artificial floodplain, d) alluvium, e) lake, SZ1-2 sampling sites

STUDY AREA

The research was carried out on the low-floodplain of the Lower Tisza Region (territory: 1214 km^2) between Csongrád and the Hungarian state border (*Fig. 1A*). The border between the low and high-floodplain is quite pronounced (1-5 m) on the northern part of the study area (north of the line between Hódmezővásárhely and Dóc), though on the southern part it is less striking (0.5-2 m) (Kiss and Hernesz, 2011).

Most of the low-floodplain was annually flooded until the 19th century river regulation works (Kiss et al., 2011) therefore it is covered by young overbank sediments (Marosi and Somogyi, 1990). Based on the geomorphic features of the low-floodplain, the study area could be divided into three units (Kiss and Hernesz, 2011). The northern unit (north of the Csongrád-Szentes line) has an elevated edge (3-5 m), it gets narrower towards the south (average width: 13.3 km) and paleo-channels and point-bar systems cover its surface. The central unit (north of the Hódmezővásárhely-Sándorfalva line) is the narrowest (average width: 8.1 km), though its edge is quite sharp (3-5 m). In the central unit scour channels (breaches) and back-swamps are the dominant fluvial forms, indicating limited lateral migration. The southern unit is the widest (average width 24.8 km) and least marked (1-1,5 m in the east and 1-3 m in the west). Its eastern part is covered by paleo-channels and well-developed point-bar systems, however its rim is not well defined as the alluvial fan of the Maros stretches into it. The western part of the southern unit is poor in fluvial forms, as its surface is covered by 3-5 m thick Pleistocene loess (Miháltz, 1967; Mátyus, 1968). Therefore, mostly based on bio-geographical evidences Deák (2010) excluded this part of the low-floodplain. In this case the average width of the southern unit is only 10-15 km, and its western edge is only 1-2.5 m high.

METHODS

A digital terrain model (DTM) was created based on topographical maps (scale 1:10.000), using ArcGIS 10. On the DTM the floodplain islands were identified, their rims and forms, and the neighbouring paleo-channels were localised. The morphomertric parameters of the islands were calculated (area, maximum width and length, mean relative height over the low-floodplain and mean height difference from the closest high-floodplain), and also the mean height of the low and high-floodplain in the vicinity of the floodplain islands were determined. The radius of curvature, width and meander length of the paleo-channels embracing the islands were also measured, and based on these horizontal parameters the paleo-discharge of the channels were determined using the equations of Timár and Gábris (2008).

On the meander core near Szegvár (*Fig. 1B*) two corings (400 cm deep) were made. The SZ1 coring was established on the bank of the paleo-channel, the SZ2 coring was made on the slip-off surface of the island, on the remnants of its former point-bar (*Fig. 5a*). The grain-size distribution of the samples was determined by Fritsch Analysette 22 laser equipment with a measurement range of 0.08-2000 μm. Samples underwent ultrasonic homogenisation and all measurements were repeated three times to check if there is further disintegration. Grain-size classes were determined using the Udden scale.

The age of samples was determined by optically stimulated luminescence (OSL). From the SZ1 and SZ2 corings four and three OSL samples were collected, respectively. Due to the inadequate amount of medium sand in the samples fine grains (4-11 μm) were separated and dated. Although fluvial sediments are examined usually by using the coarse grain method (Rittenour, 2008), we found earlier that in a medium energy environment fine grain mean and coarse grain minimum ages are fairly well corresponding (Sipos et al., 2010) in the area. Nevertheless, based on the measurement of fresh, known age point bar sediments along the Tisza River, ages derived from silty deposits may overestimate the true age by 0.5-1.0 ka (Kovács, 2011), which has to be considered.

The carbonate and organic content of the samples were removed by HCl and H_2O_2. Finally samples were treated in hexafluoro-silicic acid to remove feldspars and to receive the quartz fraction of the sample. Samples were settled on aluminium discs from an acetone suspension. Measurements were made on a RISØ TL/OSL DA-15 automated luminescence reader using the Single Aliquot Regeneration (SAR) protocol (Wintle and Murray, 2006). Presence of residual feldspar was monitored using the OSL/IR depletion ratio (Duller, 2003). Pre-heat tests were carried out in the 190-280 °C range, all samples yielded 220 °C as the suitable preheat temperature for the OSL measurements. In situ gamma and cosmic dose rate was measured by a Canberra Inspector 1000 portable NaI gamma spectrometer during sampling. Alpha and beta dose rates were determined on the basis of U, Th and K contents measured by a Canberra-type laboratory gamma spectrometer equipped with a low background coaxial Ge detector. Alpha efficiency was taken 0.1, wet dose rates were calculated on the basis of in situ water contents.

RESULTS AND DISCUSSION

Morphometry of the floodplain islands

On the study area altogether 16 elevated surfaces were identified on the low-floodplain. These floodplain islands were divided into two groups based on their morphology and origin: (1) meander cores and (2) the high point-bars and natural levees of the paleo-meanders.

The first group of islands have sharp rims and were eroded on some sides by paleo-channels. The mean territory of these islands is 2.1 km^2. The largest (6.3 km^2) is located near Szegvár (No.3), and was studied in detail, whilst the smallest (0.1 km^2) is in its close vicinity (No.2). These islands are slightly elongated, as their average length/width ratio is 2.4. On their slip-off slope point-bars remnants of could be identified. Their edge is well-defined (*Fig. 2*), since they are laterally eroded by subsequent paleo-channels. The size of these paleo-channels (mean Rb= 996 m) is much greater than that of the present-day Tisza (mean Rb= 600 m).

The average height of meander cores is 81.3 m asl, the highest (83.6 m asl) is the northernmost one near Magyartés (No.1), and the lowest (79.2 m asl) can be found in the southern unit, near Maroslele (No.13). The relative height of the islands compared to the low-floodplain is 2-4 m. The highest ones (No.1 and 15) has a relative height of 4.1 and 4.0 m, though the lowest (No.13) is also 2.2 m above the low-floodplain level. Their height reaches or in some cases exceeds the height of the neighbouring high-floodplain. For example the island at Szőreg (No.15) is inhabited since the Neolithic period (since ca. 6500 BP) as the flood-free are provided good circumstances for settlement, and also a 12-13th c. monastery was built on it (Trogmayer, 1977). Thus the surface of the meander cores could be further elevated as a consequence of human activity.

These meander core islands appear mostly in the northern and central units of the Lower Tisza Region, and only two of them (No.15 and 16.) are located in the southern unit.

The second type of floodplain islands consist of elevated point-bars and natural levees of the paleo-channels, thus their rims are not well-defined. The average area of these islands is 4.1 km^2, the largest (16.2 km^2) is the extensive point-bar system of the Hód-tó paleo-channel (No.9), and the smallest (0.4 km^2) is island No.14. Their form is elongated, the greatest length/width ratio is 4.5 (No.7), which is connection with their fluvial origin. On their surface 1-2 m height differences appear, showing the location of point-bar ridges and swales (*Fig. 3*).

The highest (80.6 m asl) of them is near Dóc (No.6), while the smallest (78.9 m asl) is near the Gyuló paleo-channel (No.10). Their height compared to the level of the low-floodplain is smaller than of the first island group, as the highest (No.6) and lowest (No.8) representatives are 3.2 m and 1.3 m high, respectively. Their surface is much lower (79-80.5 m) than the level

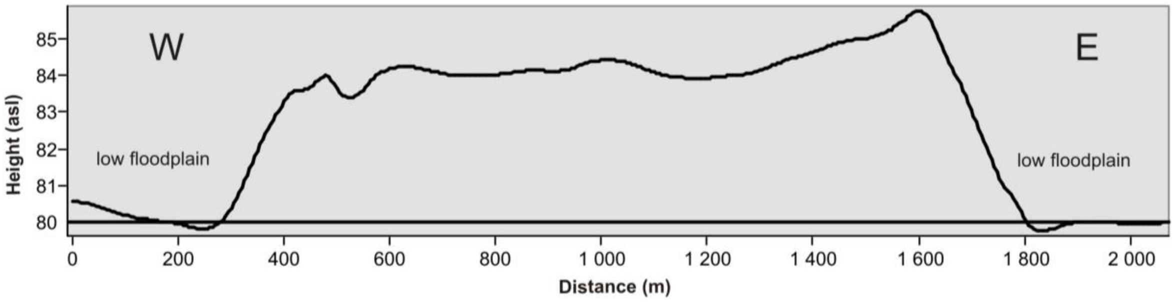

Fig. 2 The cross-sectional profile of island No.1 showing the eroded rims and slip-off face with the remnants of point-bars

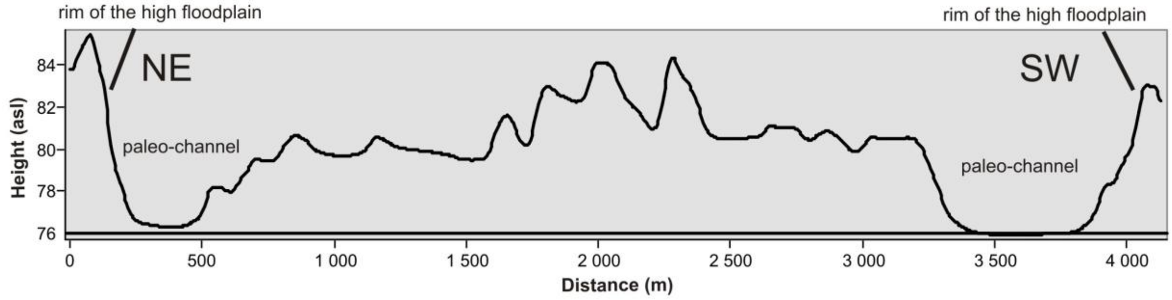

Fig. 3 The cross-section of island No.6, representing an elevated (2-4 m) point-bar system, where the brink-line of the point-bars is almost as high as the high-floodplain of the high-floodplain. They appear along those paleo-channels (e.g. Hód-tó, Gyúló-ér, Deszk, Tiszasziget), which had quite high bankfull discharges. Their radius of curvature (570-3200 m) is 2.5 times greater than of the present-day Tisza (Fiala and Kiss, 2006). They mostly appear in the southern unit of the study area, where these paleo-channels remained

The two island types have characteristic spatial distribution (*Fig. 4A*). In the northern and central units of the study area islands are much higher than the low-floodplain and their surface is almost at the same level as of the high-floodplain. Their steep rims are well defined. Their similar height to the high-floodplain indicates that they can be defined as meander cores, and they are relatively young features as they were not eroded (Andó, 1969). In contrary, the point-bar and natural levee islands appear along the paleo-channels in the southern unit of the study area. These elevated surfaces have smaller relative height and gentle slopes.

The spatial distribution of these two island types explains some details of the development history of the region. The meander cores refer to slow incision, whilst the point-bar and natural levee islands indicate lateral floodplain aggradation, where the subsequent overbank accumulation terminated or became very slow, as the forms are not buried by fluvial deposits, and the surface is not evened out.

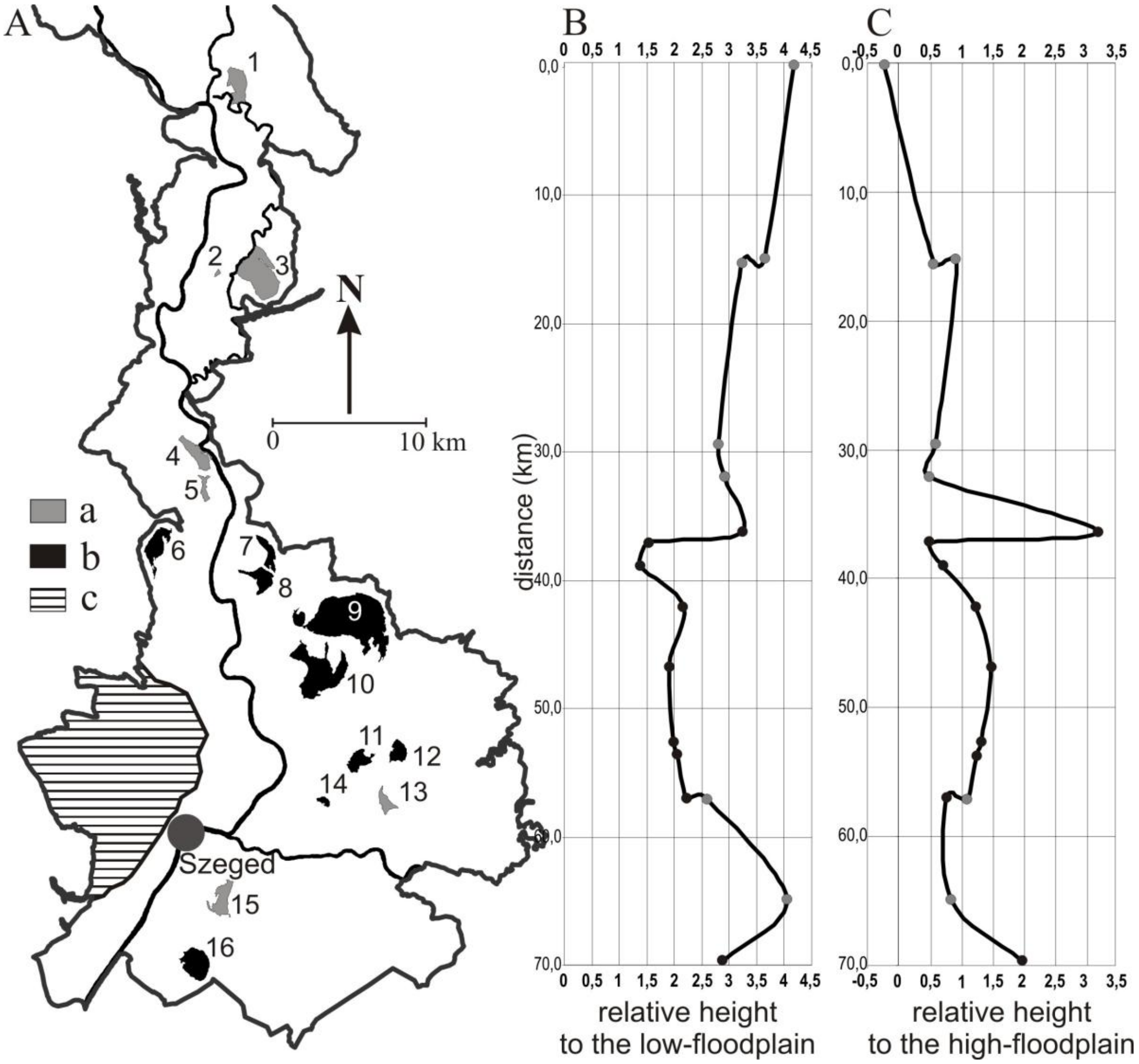

Fig. 4 Location and type of floodplain islands and their relative height

A) Location of floodplain islands: a) meander cores, b) elevated point-bars and natural levees of paleo-channels, c) Pleistocene loess blanket, No.1: Magyartés; No.2: Tétel-hát, No.3: Szegvár, No.4: Ányás I., No.5: Ányás II., No.6: Dóc, No.7: Körtvélyes, No.8: Solt, No.9: Hód-tó, No.10: Gyúló-ér, No.11: Nagyfa, No.12: Batida, No.13: Maroslele, No.14: Lebő-halom, No.15: Szőreg, No.16: Tiszasziget; B) Relative height of islands compared to the low-floodplain.; C) and to the high-floodplain

The spatial distribution of the height condition of floodplain islands

The relative height of island surfaces compared to the high and low floodplains reflects the tectonic activity during and after their development. The height conditions of the western and eastern high-floodplain surfaces are not similar, thus the height of the floodplain islands was compared to the closest high-floodplain surface.

The relative height of the floodplain islands (calculated from the level of the lower floodplain) decreases towards the south (*Fig. 4B*), though this tendency is broken by some islands, as islands No.6 and No.15 are slightly higher and No.7 and 8 are lower. In case of island No.6 this can be explained by the surrounding deeper-lying paleo-channels, resulting a relatively greater height value, whilst in case of island No.15 (at Szőreg) this can be explained by anthropogenic activity (Trogmayer, 1977). The smallest height difference between the lower floodplain and floodplain islands was found in case of the islands No.7 and 8 (at Körtvélyes and Dóc), which are higher than the lower floodplain only by 1.3 and 1.5 m, respectively.

The highest islands (over 3.0 m) mostly appear in the northern and central units of the study area, whilst the smallest ones (under 2.5 m) are located in the southern unit, south of the line between Hódmezővásárhely and Dóc.

The height of islands compared to the closest high-floodplain surface refers to their evolution: supposing that the present-day high-floodplain was the former floodplain of the Tisza (Mezősi, 1983), the surface of islands represents the same level. These forms were formed during the incision of the river into the high-floodplain and simultaneous development of the low-floodplain The mean height of the islands was extracted from the mean height of the high-floodplain (*Fig. 4C*). Only one negative data was measured (No.1, Magyartés): here the island is higher than the high-floodplain by 0.25 m. Towards the south the islands No.1-8 are almost as high as the high-floodplain (they are lower only by 0.5-0.9 m). The next island (No.6) is unique, considering its height conditions, as it is much higher than the low-floodplain (3.2 m) despite of its great difference (3.1 m) from the neighbouring high-floodplain (reason I explained earlier).

Going south the height difference between the high-floodplain and islands surfaces increases (1.0-1.5 m) which can be explained by the different origin of the islands (point-bar systems and natural levees). Island No.13 (at Maroslele) and island No.15. (Szőreg) are the only exceptions being only 0.7-0.8 m lower than the high-floodplain.

Based on relative height conditions, islands in the northern and central parts are much higher, and are at the same level as the high-floodplain. Meander cores in the northern unit imply an uplift process resulting incision and the development of ingrown meanders. On the contrary, islands in the southern part of the study area are less elevated, and the southern unit is a low lying alluvium, however, sinking could not be characteristic or could not last long, as overbank sedimentation did not cover the floodplain forms. All these suggest that the southern part of the study area developed in a different way than the northern and central parts.

Detailed analysis of the No.3 meander core near Szegvár

The area of this meander core is 6.3 km^2, its greatest width is 2.0 km and greatest length is 3.2 km (*Fig 5a*), its mean height is 81.9 m asl, its highest point is at 85 m asl. Its north-eastern rim is quite steep, it was laterally eroded by the Kurca Brook. On the other sides of the form rim is well defined, though it has more gentle slopes. The surface of the studied meander core is not uniform, as the rims are dissected by gullies and on its slip-off surface the fragments of point-bars left behind by incising paleo-meander can be identified (*Fig. 5b*). The paleo-channel dividing the high-floodplain and the surface of the meander core is wide (300-500 m), the length of the palaeo-meander is ca. 5-7 km. Based on its morphometric parameters, paleo-discharge (4000-7500 m^3/s) was much higher than that of the present-day Tisza (800 m^3/s). In this paleo-meander a smaller misfit channel of the Kurca Brook can be identified.

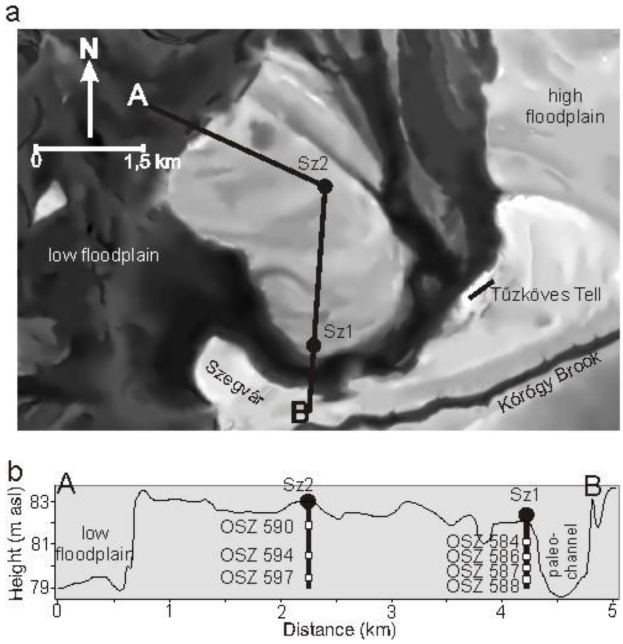

Fig 5 The digital elevation model of floodplain island No.3 at Szegvár, the location of corings (a) and the cross-section of the meander core (b)

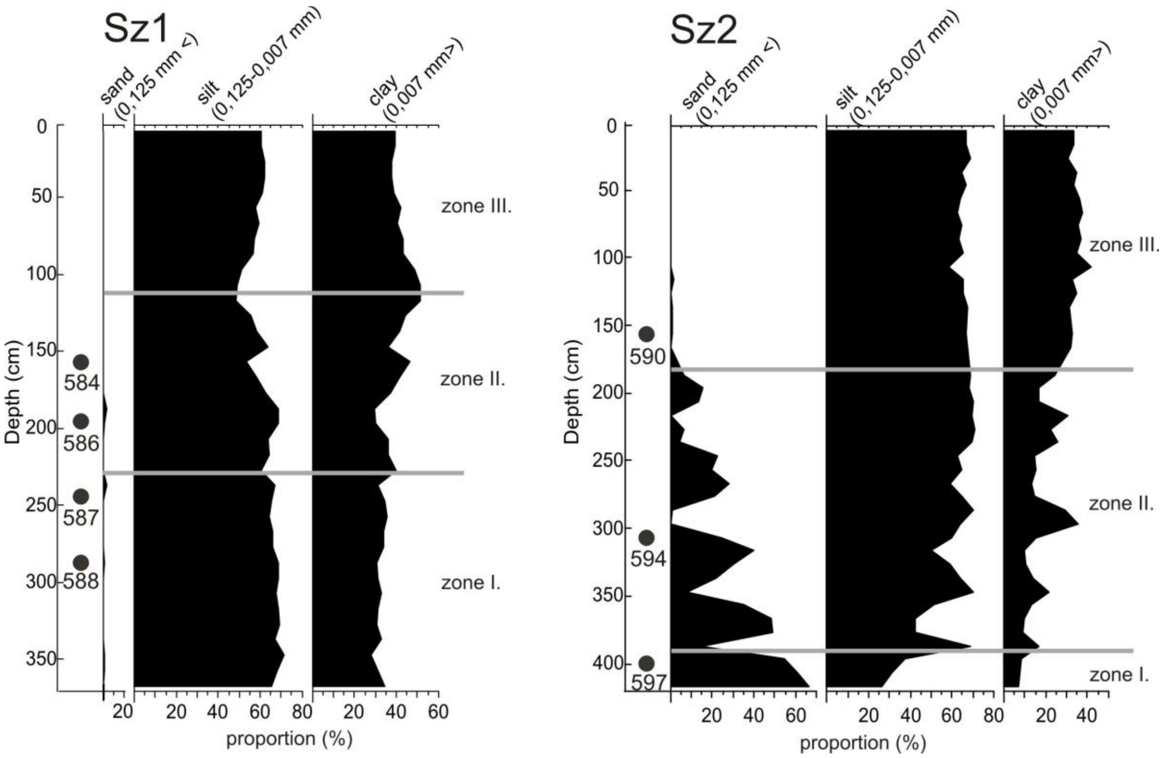

Fig. 6 Grain size distribution of the two corings (Sz1 and Sz2) and the depth of OSL samples

The neighbouring high-floodplain (82.9 m asl) is ca. 4 m higher than the low-floodplain (78.7 m asl), the arched rim in between is well defined as it was laterally eroded by the paleo-channel. The surface of the high-floodplain is dissected by the headward erosion of some channels (i.e. Kórógy Brook).

The high-floodplain probably has not been reached by floods as early as the beginning of the Holocene, thus in the Neolithic Period a continuous settlement could be established on the top of the rim, as it is indicated by the Neolith tell of Szegvár-Tűzköves dated back to 6.8-7.1 ka (Korek, 1987). But the paleo-channel beside the tell and around the meander core remained a swampy area until the late 19th c. river regulation works (on old maps it was indicated as Kontra Lake).

Two corings were made in order to analyze the meander core from a sedimentological aspect. The Sz1 coring was made on the bank of the paleo-channel, approx. 100 m far from the rim of the meander core. In the whole profile clay and silt are dominant. In the lower zone (230-370 cm) clay content (ca. 60 %) overwhelms the silt content (ca. 30 %) (*Fig. 6*). In the middle zone (110-230 cm) the clay content increases further with three well-defined peaks. In the uppermost zone (0-110 cm) the silt becomes dominant (over 60 %). Fine sand (under 0.06-0.125 mm) appear only occasionally (at 180-190 and 230-240 cm), but its proportion is never over 2 %. Results suggest, that these sediments were deposited at low energy conditions: probably the profile represents the loessy overbank deposits (or channel infill) of the paleo-channel.

From Sz1 zone I. and II. four OSL samples were taken (*Table 1*). The oldest sample (190-200 cm) is 16.9±1.7 ka, while the youngest (150-160 cm) is 15.7±1.5 ka old. Thus, the overbank or channel-infill sediments of the lower part of the profile were deposited around 15-17 ka ago at the end of the Ságvár-Lascaux Interstadial or at the beginning of the Oldest Dryas (The geological times scale compiled by Gábris (2003) was applied).

The Sz2 coring was made on the slip-off face of the meander core on the top of a remnant point-bar. In the lower zone of the profile (390-420 cm) sand fraction is dominant (55-60 %), the proportion of silt (26-37 %) and clay (6-7 %) is smaller. In the middle zone (180-390 cm) four peaks of the sand fraction appear (at the depth of 350-380, 300-340, 240-280 and 180-210 cm), but the proportion of sand in the peaks is continuously decreasing from 48.8 % to 15.5 %. At the same time the amount of silt is increasing (from 26.4 % to 70.2 %). In the upper zone (0-180 cm) the sand almost disappears and clay becomes dominant (over 60 %) overtaking silt (ca. 30 %), similarly to coring Sz2. In the lower and middle zones the sand peaks refer to

Table 1 Dosimetry, equivalent dose and OSL age data of the investigated silt samples

site	sample	depth (cm)	water content (%)	U-nat (ppm)	^{232}Th (ppm)	K (%)	$D'_{\alpha+\beta}$ (Gy/ka)	$D'_{in\ situ}$ (Gy/ka)	D'_{total} (Gy/ka)	D_e (Gy)	OSL age (ka)
Sz1	OSZ584	150-160	18 ± 1.8	1.79	6.78	1.31	1.83±0.24	0.89±0.04	2.00±0.24	36.99±1.44	**15.7±1.5**
	OSZ586	190-200	24 ± 2.4	1.64	7.28	1.36	1.74±0.22	0.89±0.04	1.91±0.23	38.57±2.06	**16.9±1.7**
	OSZ587	240-250	24 ± 2.4	1.94	7.25	1.49	1.90±0.25	0.78±0.03	2.07±0.25	37.66±2.10	**16.2±1.8**
	OSZ588	280-290	25 ± 2.5	1.91	7.67	1.42	1.86±0.24	0.78±0.03	2.03±0.24	36.61±1.90	**16.0±1.7**
Sz2	OSZ590	150-160	13 ± 1.3	1.72	6.1	1.07	1.70±0.22	0.84±0.04	1.87±0.22	31.73±0.83	**14.4±1.3**
	OSZ594	310-320	15 ± 1.5	1.55	5.75	0.92	1.49±0.19	0.74±0.03	1.66±0.19	35.13±3.37	**18.1±2.4**
	OSZ597	400-410	17 ± 1.7	1.2	4.2	0.78	1.15±0.15	0.57±0.02	1.32±0.15	30.21±2.36	**20.1±2.4**

near-bank deposits, which were deposited during high energy conditions. These were covered by suspended sediments at falling stage or at smaller floods. The samples of the upper zone represent overbank floodplain sediments.

OSL dating was carried out on three samples of coring Sz2. The lowest sample (400-410 cm) probably represents the active point-bar, the sandy samples at 310-320 cm stand for near-bank deposits, whilst the fine grain dominated zone at 150-160 cm correspond to overbank floodplain sediments (*Fig. 6, Table 1*). The age of the active point-bar, 20.1±2.1 ka, dates back to the Late Glacial Maximum. The accumulation of the near-bank deposits took place at 18.1±2.1 ka, in the Ságvár-Lascaux Interstadial. The clayey-silty overbank sediments accumulated 14.4±1.3 ka ago, thus it was deposited simultaneously with the youngest samples of coring Sz1 – considering their error intervals.

Based on the morphological, sedimentological and OSL data of meander core No.3 at Szegvár the incision of the paleo-meander was already in progress in the Late Pleniglacial. The river laterally eroded the present-day edge the high-floodplain slowly and deposited its sandy point-bar on the slip-off surface of the meander core. This result fits to the findings of Domokos and Krolopp (1997), who made a sedimentological and paleontological study on a sandy deposit on the high-floodplain. They found fluvial sandy deposits covered by 16-18 ka old loess. This reinforces our data, as the point-bar and near-bank sandy layers of the studied paleo-channel are 18.1-20.1 ka old, thus this meander probably indicates the very beginning of the incision process. The over-bank (or channel infill) loessy-silty sediments of the corings date back to 14.4±1.3 and 16.9±1.7 ka, thus by this time incision was significant, and only overbank sediments were deposited on the surface of the meander core. The age of these sediments correlates well to the results of Krolopp et al. (1995), studying the loess blanket west of Szeged, and finding that the loessy cover over the fluvial sediments was deposited ca. 13-25 ka ago.

CONCLUSIONS

Two types of floodplain islands were identified in the Lower Tisza Region. The real or meander core floodplain islands are characterized by steep slopes, elevated surface (higher than 80.5 m) and small territory (2.1 km^2 in average), and they appear in the northern and central units of the study area. They were identified as meander cores of earlier paleo-channels. The second type consists of elevated surfaces related to point-bar systems and natural levees of paleo-channels. They are characterized by gentle slopes, smaller relative height (under 2.5 m) compared to the low-floodplain and greater area (4.1 km^2 in average), and they mostly appear in the southern unit.

The spatial distribution of the two types of floodplain islands can be explained by the different evolution of the floodplain. The development of meander cores in the northern and central units refer to slow and slight tectonic uplift, though in the southern unit the existence of higher fluvial forms of old paleo-channels refer to the lack of sinking, otherwise they would be covered by overbank sediments. This result is in contradiction with the present-day rate of sinking (Joó, 1998), but this disagreement could be explained by the intensive subsurface natural oil, gas and thermal water extraction causing subsidence (Timár, 2003).

The results at the meander core at Szegvár are corresponding well to the data of earlier sedimentological analyses carried out on the high-floodplain (Domokos and Krolopp1997), and prove that the meanader cores are remnant surfaces of the high-floodplain. The age (14.4±1.3 ka to 16.9±1.7 ka) of the loessy overbank sediments covering the meander core date back to the Oldest Dryas, when fluvial loess deposited intensively in the area (Sümegi and Krolopp, 1995; Szöőr et al., 1991).

Due to the slight tectonic uplift the meandering channel incised into the soft sediments, and as lateral erosion was possible, an ingrown meander developed, which turned to be a meander core following a cut-off event. The OSL age of the uppermost point-bar of the ingrown paleo-channel indicates that the incision started at least 20.1±2.1 ka ago. However, the last activity phase of a paleo-channel (at Kenyere Brook) on the high-floodplain was dated back to only 11.5±0.8 ka (Sipos et al., 2010). The incision terminated at 8-9 ka ago, as a huge paleo-meander near Deszk remained well preserved on the low-floodplain, and it was forming its youngest point bars at 8.9±0.6 ka ago (Sipos et al., 2010).

The incision was probably a rapid process. It lasted only for 1-2 ka, as the radius of curvature of paleo-channels on the high-floodplain and at the feet of the meander cores is similar. The rapid incision is also supported by the similar OSL ages of point-bars of the paleo-channels on the high- and low-floodplain (Sipos et al., 2010).

The calculated bankfull discharge of the paleo-meander at Szegvár was 4000-7500 m^3/s, referring to a considerably higher discharge than that of the present-day Tisza (800 m^3/s). This discharge is similar to the discharge of the paleo-meander on the low-floodplain near Deszk (7000 m^3/s) but lower than the paleo-channel (12.700 m^3/s) along the Kenyere Brook on the high-floodplain (Sipos et al., 2010). The similarity in the horizontal morphometric meander parameters of paleo-channels on the high and low-floodplain suggest that the incision was not driven by climate change but primarily by tectonic movement. It is also supported by the height condition of the meander cores, as their surface is almost at the level of the high-floodplain.

Consequently, the northern and central units of the study area were characterized by slight tectonic uplift in the Late Glacial or early Holocene periods, resulting slow incision. In contrary the southern unit was lower lying, less active tectonically, and subsidence was probably not characteristic until nowadays.

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